

Abstracts of AAPG International Convention - Cairo, Egypt; October 27-30, 2002

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Impact of Transfer Faults on Basin Evolution, Sedimentation and Hydrocarbon Accumulation, by Abraham Zelilidis¹, A. Barkooky¹, M. Darwish¹, N. Tewfik¹, J. Vakalas¹

Comparison between Fan Deltas Formed in the Gulf of Suez in Egypt and in the Gulf of Corinth in Greece, by Abraham Zelilidis¹, A. Barkooky¹, M. Darwish¹, N. Tewfik¹, J. Vakalas¹

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Image Enhancement Below the pre-Khuff Unconformity Using Pre and Post-Stack Multiple Attenuation,
by Michael A. Zinger¹, Khalid I. Hassan¹, Richard G. Jerskey¹

Moustafa E. Oraby and Ahmed El-Seginy

Collaborative New Technology in Well Construction. A New Avenue towards Lowering the Overall Well Cost

It is critical to any operating company to minimize the cost of well construction in both exploration and development especially in deep-water operations. The challenges in drilling environment require the state-of-the-art new technology. The new technology is costly on the service companies to develop and at the same time costly on the operating companies to apply. These two conflicting factors require more collaborative efforts between the operating companies and the service companies to properly apply the appropriate new technology to reduce the overall AFE well cost. This approach, in turn, enables the operating companies to cover the extra cost of the new technology.

In this paper, different types of integrated solutions using new technology in both drilling and formation evaluation are discussed to show the applicability of the concept. The faster drilling rate using the slickbore technology, the higher Rate Of Penetration using the X-series bits and the proper mud design to control the losses and enhance the drilling performance are illustrated.

On the formation evaluation side, proposed combinations of the LWD, Logging While Drilling, and Wireline logging to eliminate the repeatability of information but still provide the essential data is discussed. The combined LWD Acoustic, Magnetic Resonance (MRIL-WD), the gamma ray and resistivity represent an attractive replacement of the conventional radioactive combination. The wireline logging will be optimized depending on the need of the formation evaluation.

All the above will not be complete without the capabilities of real time operation. Sharing the data between the rig and the experts in their offices is very vital technology in reducing cost, saving operation and speeding the operation decisions.

More ideas and technical combinations are discussed in the paper that aimed to show that using such approach will reduce the well cost and at the same time applies the up-to-date technology for better well construction and evaluation.

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Integrated Optimisation of Lease Development Strategy and Reservoir Management Through Use of Simulation Tools

North Port Said is an offshore concession located in the Mediterranean Sea about 30 km off the Northern Egyptian coast. More than 25 gas fields have been identified based on seismic interpretation. These accumulations are often characterized by several hydraulically independent reservoirs. Two gas-condensate fields were discovered by two discovery wells in 1982/1983, and these wells showed several gas bearing intervals inside the Wakar formation of Miocene age. Following that discovery, 6 additional gas fields have been discovered through 6 additional exploration wells in which all wells found several normal-pressure dry gas bearing intervals inside the Kafr El-Sheikh formation of Pliocene age. The remainder of the identified gas fields belongs to Pliocene age. Production started in 1996 and there are currently three gas fields producing through 16 wells with daily production of 10,500,000 Sm³ of gas & 1,750 Sm³ of condensate as of 1999.

A 3-D simulation model has been built for each independent reservoir. The independent simulation models have been coupled to account for constraints on overall production rates and sharing of a common surface network.

Coupling independent reservoirs also allows accounting for constraints on overall surface production rates, including the physical impact of a surface pipeline network. Individual simulation models are thus run simultaneously as separate processes honoring all common surface constraints.

The current field(s) development plan is to produce the gas fields into a common surface facilities network. The optimization of the facilities and surface network includes up to a maximum gas production rate of 14,000,000 Sm³/day.

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Longitudinal Variations in Rift Architecture and Sedimentation - Case Study from the Eastern Blocks of the Gulf of Suez, Egypt

The Gulf of Suez represents unique exposures for studying architecture and sedimentation in rift systems. The central - east rift-blocks are selected for detailed mapping and analysis aiming at reaching a model for rift development and sedimentation in time and space.

The northern rift-border (Baba) fault-system reflects listric-geometry through linkage of several fault-segments. Linkage areas represent deficit-nodes for ruptures. Generally, displacement cessates due south where the northern major displacement exceeded the rate of deposition and shows extensive drags and thrusts. Baba fault-system merges at depth and along-strike with major rift-coastal fault, which forms an intra-basinal ridge separating two different basinal-segments. These two fault-systems cessate southward and synthetic approached with a master Miocene-bounding (Sidri) collateral faults. The linkage area represents low-stand zone overlapped by syn-rifting sediments. Younger channel-clastics charged the rift through this low-stand entry point.

8.5 km wide flexure-zone represents the entrapped block between Sidri fault-system and the basement-border fault. This flexure-zone is crossed by two longitudinal, conjugately dipping fault-systems with intervening transfer zones. Sidri fault-system terminates due south across a hard-linkage transfer fault. South of the latter, the rift is bounded by a master fault showing along-strike displacement variation and transverse folds.

The above represents drastic longitudinal variations in rift-width and blocks architecture reflecting rift development through several rift-centers that propagated and linked during three rift-phases. The linkage areas and differential fault associated subsidence controlled the Miocene basin-morphology and related sedimentation.

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Miocene Synrift Paleokarst and Related Sulphur Deposit in Gemsa Area, Red Sea Coastal Zone, Egypt

Two paleokarst profiles developed within the Miocene sediments of Gemsa area, Red Sea, Egypt. These two-karst systems are separated by erosion surface. The lower is Endo-paleokarst of Upper Miocene, developed mainly in the Miocene gypsum, anhydrite and carbonate of Gemsa Formation. The upper surficial paleokarst is subsequently developed on the overlying carbonate rocks. The erosional contact between the recognized paleokarst profiles is dominated by rhizocretional horizon consists of argillaceous debris and residual organic materials accumulated pedogenetically on the surface and converted onto kaolinite.

The lower paleokarst is resulted from ascending hot spring water that intrude the fracture system prevailing during the late Miocene synrift activity of the Red Sea, and may be associated with the processes of oil migration during release of the associated water under relatively phreatic conditions. The upper surficial karst profile is related mainly to a humid paleoclimate of the Quaternary age. Abundant cavities detected in the vicinity of sulfur deposits can be formed by thermal karstification, which is one of the most important processes controlling the formation and redistribution of the sulfur deposits in Gemsa area. The occasional presence of silicification is a rather good indication for thermal karstification processes.

A new karst model for the formation of sulfur deposits is suggested. It agrees with the hydrogeological features of the Miocene sequence and its tectonic instability and the numerous intervening unconformity surfaces with the biogeochemical mechanisms of sulfur origin in moderate temperature diagenetic environments.

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Cycle Time Reduction and Quality Enhancement Through Knowledge Management: An Example from the Nile Delta, Egypt

Use of Landmark's Knowledge Management System software, coupled with ARCVIEW GIS, has resulted in at least a six-month gain in productivity for BP-Egypt's Gas Business Unit Nile Regional Team. The quality of the interpretations has been increased and the regional mapping products have become "living documents". Other staff can now routinely access these files and interactively improve or modify the interpretations with more data. A true "learning organization" which can shift quickly from regional to reservoir scale assessment has become a reality.

The system used allowed the team to iteratively integrate multiple disciplines, datasets and other software applications. Data included geophysical & geological grids and contours, geochemical, log and core analysis, pressure data, land sat imagery, paleobathymetry, geotiffs and access to scanned images and reports.

We believe this project demonstrates a significant financial "prize" in value added team integration, data access, report and image file archiving. Key learnings presented in this paper will also show steps that can be taken in the future to provide even more powerful learning systems, including integration of tops databases with all other depth-related data, especially production and pressure data.

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Characteristics of Asl and Hawara (Sequence 30) in Central Gulf of Suez

Asl and Hawara sequences (S30)

are among the important Miocene reservoirs in the Gulf of Suez.

Gupco has currently produced lot amount of oil from this reservoir. This sequence (S30) represents a model for developing a prolific reservoir in tectonically active basin. Facies analysis produced from studying cores and ditch cuttings from different wells is done including sedimentological, petrological, and paleoecological interpretations.

The study indicated

that the clastic supply originally was derived from mountainous ranges bordering the western side of the Gulf of Suez. The tectonic movements as well as the relative stand of sea level played an important role in the sand distribution, where series of unconformities appeared from the uplifting blocks led to produce accommodation zones for reservoir sand accumulated. A depositional environment model for such S30 reservoir is constructed.

Implementing the above-mentioned factors helped in mapping reservoir Asl & Hawara reservoir sands and enhance future exploration activities.

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Interpretation of Seismic Borehole Data of Rourd Chegga Field, Sahara, Algeria

Recently, a seismic bore survey (Walk-away) has been realized in Algeria. The aim of this operation is to a geological problem met in the production field of Rhoudé chegga (RDC).

Although the RDC-6 well, has reached the top of structure and is situated 888 meters at the east of the RDC-1 well, which produces oil, the results were unfortunately negative. The RDC-6 well has been drilled in order to develop the Rhoudé chegga field.

Structural and stratigraphic interpretation of the walk-away, recorded at the RDC-6 well, have given two hypotheses for understanding the negative results.

Seismic interpretation has shown two geological faults between the wells RDC-6 and RDC-1. Probably, these faults act as obstacles for hydrocarbons migration.

Seismic attributes show a facies variation of the clayey sandstones formation from RDC-1 to RDC-6 (increase of clay).

At the RDC-1 well, the reservoir (lower triassic) is 3555 meters deep and 20 meters thick.

We can say that it can't be imaged by seismic conventional methods.

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Amplitude Analysis and Inversion for Prediction of Lithology and Hydrocarbon

Information about the subsurface lithology and rock properties is encoded in the amplitudes of the seismic reflection data. This information can be decoded by using the appropriate technology. Reflection amplitude analysis and inversion techniques are advanced investigation tools that aim to provide rock physical properties from pre- and post-stack seismic data, which conceal valuable information about amplitude variations, and represent an ideal complementary use to the conventional subsurface structural imaging through the identification of different lithologies and fluid saturation.

It is known that, the amplitude of a seismic reflection is an angle- dependent function. Consequently, it varies with the offset distance between the source and the receiver. In certain depositional and reservoir settings, the variations of amplitudes with offset or with angle can provide useful clues to the presence or to the extent of a hydrocarbon zone. On the other hand, although the reservoir structure can be mapped from conventional stacked data, the post stack seismic inversion techniques are useful in the estimation of the acoustic impedance from reflection amplitudes. The estimated impedance can be further used to predict lithology and petrophysical properties away from well control.

Success of any of these techniques depends, mainly, on data quality and signal to noise ratio. With good 3D data quality that characterized by high signal to noise ratio and broad frequency spectrum, testing of these techniques can be proposed. Khalda had considered a study of the inversion technique, and in phase to consider testing amplitude variations with offset and angle techniques.

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Implementation of Environmental Impact Assessment into Exploration and Production Activities

Recent environmental regulations as well as the Egyptian environmental law aim to protect the environment from impacts resulting from industrial and development activities and, in the mean while, prohibit disposing wastes without necessary treatment. The Egyptian current environmental law (Number 4, of 1994) states that " New establishments or projects, expansions or renovations of existing establishments must be subjected to an environmental impact assessment before a permit is issued."

The main objective of the environmental impact assessment (EIA) is to examine the environmental effects of new projects and to ensure that these effects are taken into account in an appropriate manner at all stages of a project cycle. It is mandatory to ensure the protection and conservation of the environment and natural resources, including human health, aspects against uncontrolled development.

EIA is being presented in compliance with the Egyptian environmental law and regulations as well as Khalda's conscious HSE policy.

Khalda is committed to the exploration and production of oil and gas, fully respecting the natural environment of each work site and the surrounding population. It is therefore responsible for the environmental impacts of its operations.

This paper highlights the importance and characteristics of the EIA and its implementation into E&P projects.

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A Well Driven Processing Approach for Seismic Imaging of Subtle Traps

At present the choice of both processing sequence and seismic processing parameters relies on the skills and experience on the part of the processing analyst. Typically, processing parameters selection is performed by inspection and subjective judgment of seismic data processed through a variety of processing steps and parameters. However, examination of this conventional processing technique shows that it fails in many cases to provide a good tie with borehole seismic data, which in turn does not allow reliable interpretation of the seismic data. This paper demonstrates an alternative processing technique for integrating borehole data into the processing parameters selection from the earliest stage of the processing. The present processing technique is based upon (1) proper editing of the well acoustic data (sonic and density). The log editing is based on multi-log approach and is carried out interactively and by direct interaction between borehole and seismic data, and (2) quantitative and objective evaluation of the processing parameters selection obtained from the integration of borehole and seismic data by means of statistical attributes calculation of the extracted wavelets. These attributes values define both the best correlation between the well trace and the corresponding seismic trace and the complexity of the extracted wavelet. The present processing technique is illustrated with data from an oil field from the Egyptian Western Desert. Benchmark results have proven the superiority of seismic imaging results obtained by the present processing technique with respect to that obtained by the conventional processing. The present methodology offers two major advantages over the conventional processing approach. First, seismic data shows a better focusing of the fault shadows and more certainty of the fault pattern alignments. Second, it provided an improvement in the tie between the surface and the borehole seismic data so that events on the processed seismic data can be easily identified in terms of polarity and time.

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Seismic Reprocessing as a Powerful Tool in Hydrocarbon Exploration

Old seismic data carry subsurface information more than what has been produced during the original processing. The most important objective of seismic data processing is to produce seismic sections that allow the interpreter to better define a prospect, while at the same time reflecting the subsurface geology. However, in order to achieve this objective, approximations of processing parameters took place to produce compromised data which can be used to interpret both shallow and deep horizons (reflectors). On the other hand, we would like to produce true and accurate geologic models in the three dimensions, but because of the complex nature of the subsurface and limitations of measuring techniques, we have to change from compromising processing into objective processing.

In many areas where the old seismic data represent the majority of the data set, seismic reprocessing becomes a very important and a relative cheap alternative to the acquisition of new seismic data.

Effective reprocessing of old seismic data are based on :-

- Specific objectives
- Latest processing techniques
- Minimizing approximations

Can significantly improve the final results which accurately depict the location and the real extent of hydrocarbon traps.

Applications of normal move out (NMO), reverse NMO, F-K filtering, surface consistent deconvolution, multiple attenuation processes and effective residual statics before and after stack have resulted in dramatic improvements of old seismic data and consequently enabled the interpreter in defining new prospects, which were not observed as a result of the original processing.

Khalda Petroleum Company has experienced data reprocessing in several areas which resulted in discovering hydrocarbons that added large amounts of reserves to the company.

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Fault and Fractures within Jurassic Petroleum System in Kuwait, with Special Reference to Hydrocarbon Habitat

This paper is representing an ongoing study for fault and fracture systems within Jurassic Petroleum System in Kuwait. The study aims at detailed description of faults and fracture systems and discusses the specific characteristics of these. So far the Structural elements of Jurassic Formations were inferred on the basis of gravity, magnetic and old vintage regional 2D seismic data.

The newly acquired high quality seismic data (2D and 3D) coupled with wealth of information in the form of core, thin section, image log and specially designed VSP data from drilled wells form the basic ingredients for this study. These have been integrated with regional stress regime. This has resulted in the understanding of fault and fracture systems from regional to microscopic scale. The key controls for faults and fractures were established. The faults have been categorized on the basis of genesis, age, reactivation history, trends, extent and throw etc. Image log data and seismic attribute (coherency, Edge detection, etc) have been used to decipher sub seismic faults and associated fracture systems.

An attempt has been made to see the relationship with oil habitat. The fracture systems associated with certain fault trends have facilitated the flow of Jurassic reservoirs while the others played a key role in compartmentalization of these reservoirs. The reactivation of Jurassic faults affected the seal integrity of Gotnia Formation at few places, laterally as well as vertically. The positive influence of reactivation had been on fracturing, which is key for Najmah/Sargelu reservoir productivity. While Fault related diagenesis have adversely affected the reservoir properties of nearby wells.

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Reservoir Control and Oil Geochemistry

Doesn't doubt the power of geochemical information. This data mainly use for genetic conclusions. However, geochemical application for exploration and special for production is still limited. We believe the oil is complex hydrocarbon solution, making interconnected system with rock matrix and contacting water solutions. Oil samples from some West Siberian lithologically screened accumulation fields have been analysed. The ash value flow, capacitor properties and types of cement is observed. Different zones are focused in parallel lines reservoirs pinchout line. In change of structure oils the following is revealed based on bulk data and individual hydrocarbons (HC) distribution. The most appreciable changes are observed in distribution of gasoline HC's and some other HC's. The gradient of change on kilometre to the screen (G) was calculated. To clay screen the ratio alkanes/iso-alkanes (G - 0.09) and alkanes/ Cycloalkanes (G - 0.17) decreases. These gradients are well correlated with zones of identical reservoirs distribution. Hexane/iso-hexane quickly varies at the screen (up to 5 km) and further becomes gently sloping. Uniform reduction of benzene concentration is observed to the screen (G - 0.05). The basic features of oil composition change are connected with natural chromatography by effect of reservoir diverse. Various HC's are subject to various influence of sorption forces on phases border of the rock - fluid. Thus fluids too are not homogeneous at contact with water, each HC thus are dissolved differently. The received results testify that the data of oil composition can be use for of reservoir distribution and optimisation of exploration processes.

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Inversion of Electrical and Shallow Seismic Data for Detecting the Groundwater Sources Affecting El-Ashmunein Archeological Site

The site of the ancient Egyptian city of Khmunu, later the Graeco-Roman Hermopolis Magna, has long been known, situated on the west bank of the Nile in south of El-Minia, Egypt. The modern name of this site is El-Ashmunein. This archaeological site is suffering from the rising of the subsoil water level. As result most of the temples were subjected to detritions process or completely destroyed. There is no studies for managing the groundwater sources in this area.

In this study twenty vertical electrical sounding distributed in six profiles and ten shallow refraction seismic profiles were measured. These data were processed and interpreted. By using all available geologic information and the result of interpreted data the subsurface succession and the depth to the water table were detected. This succession is formed from four layers. The first and second ones consists from Nile silt and the second layer is characterized by low resistivity ranging from 5 to 13 Ohm. m and depth ranging from 1.2 to 10 m. The third and forth layer consists mainly of sand and gravels. The expected depth to the water table is ranged between 0.7 and 3.4 m. The main reason for the ground water table rising is the second layer, which prevent the passing of the groundwater percolated from the near by cultivated land to third and forth layer. It is necessary to drill number of wells around the study area and pumping from it trying to decrease the water table level.

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Growth History and Gas Potential of the Saudi Arabian Petroleum Systems

Integration of structural growth history with basin modeling provided possible migration scenarios of the different hydrocarbon systems. Peak oil generation for the Paleozoic has started since the early Jurassic, and peak gas generation since the early Cretaceous. Gas generation for the Mesozoic, however, has commenced since the Eocene.

Silurian source rock maturity shows a progressive increase in gas generation north of Ghawar and in the Rub' Al Khali. Jurassic source rock maturity indicates oil potential in east Arabia and gas in the Rub' Al-Khali.

Jurassic isopach shows basin tilt to the west due to the accumulation of thicker sedimentary packages during the late Jurassic. Since the Tertiary, however, reversal tilting of the Arabian Plate to the east could have influenced gas migration.

Hercynian structures terminating growth at the Jurassic could have been filled with Paleozoic oil over the greater Ghawar area. Paleozoic gas from the south of Ghawar source area would have flushed oil up dip towards Central Arabia, confirming the existing hydrocarbon finds, and filled south and west of Ghawar with gas. Paleozoic gas from the more mature east of Ghawar source area would have filled north Ghawar with more mature gas. Gas maturity over Ghawar increases from south to north. Any oil filled structures over Ghawar could have been cracked to gas.

In contrast, structures continuing growth to the present would have a higher chance capturing the later migrating gas. Determining timing of both structural growth and gas and oil migration would, therefore, significantly reduce the exploration risk for gas in Saudi Arabia.

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3D Petroleum Systems Modeling of Eastern and Central Saudi Arabia

3 Dimensional Petroleum Systems Modeling (3D PSM) is an integral process that describes and models petroleum migration, dynamically and through geologic time, from source to trap. It considers all petroleum system elements such as source, reservoir, seal, trap, migration and timing of all key processes. In contrast, conventional basin modeling is mainly concerned with hydrocarbon generation within the source rock.

A 3D model was constructed for Eastern and Central Arabia that described thermal and maturation histories of the Paleozoic geologic successions. This model emphasized hydrocarbon generation and migration histories from the Silurian Base Qusaiba source rock to the Devonian Jauf and Permo-Carboniferous Unayzah reservoirs. Migration of different hydrocarbon compound classes was modeled using a compositional generation scheme for the Silurian Qusaiba source rock.

Results show that Tertiary tilting of the basin has affected present-day drainage areas. Several sensitivity runs were performed to test the influence of certain petroleum systems elements such as reservoir, seal, source and migration properties on the distribution and composition of hydrocarbons within the study area. A 3D hybrid Darcy/Flowpath simulator was used to test different migration scenarios taking into account open and/or closed fault systems. Present-day accumulations were compared with the simulation results to validate their sensitivities.

The results demonstrate that 3D petroleum systems modeling technology, if well calibrated, provides an excellent exploration tool to predict distribution and type of petroleum occurrences. Once reservoir hydrocarbon compositions are reasonably predicted, the application of such a tool will witness a new era in petroleum exploration and development.

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Hydrocarbon Characterization and Gas Potential of the Saudi Arabian Mesozoic and Paleozoic Petroleum Systems

Saudi Arabia's Paleozoic and Mesozoic petroleum systems are discussed with respect to source rock generation potential and hydrocarbon geochemistry. Hydrocarbons found in both systems are extraordinarily distinct, suggesting the presence of an efficient seal separating the two systems. Carbon isotopes provided an excellent hydrocarbon-source rock correlation tool.

The Paleozoic petroleum system consists of the Early Silurian "hot" basal Qusaiba shales as the principal source rock. The main reservoirs are the Devonian and PermoCarboniferous sands and carbonates. The basal Khuff clastics are the regional seal for the Permian Khuff and Unayzah reservoirs, and interbedded shales for the Devonian Jauf reservoir. Hydrocarbons found in this system include non-associated gas in Eastern Arabia and extra light oil in Central Arabia.

The Mesozoic petroleum system is made up of the Jurassic and Cretaceous sub-systems. Argillaceous carbonates of the Tuwaiq Mountain and Hanifa formations are the source rocks for the Jurassic system. Carbonates of the Arab, Manifa, Hanifa, Hadriyah and Fadhili are the main reservoirs. The pervasive Hith anhydrites are the major regional seal for the Jurassic system. Hydrocarbons found in this system are typically medium to light oil and associated gas. The Cretaceous system contains mainly two groups: light oil in the Shu'aiba carbonate reservoir of the Shaybah field, and heavy to medium oil in the Wasia clastic reservoirs of the offshore fields.

Based on basin modeling of the respective source rocks, Paleozoic hydrocarbon potential indicates gas in the east and south, and oil in Central Arabia, confirming the existing hydrocarbon finds. The Jurassic potential is oil for most of eastern Arabia and gas for southern Arabia. The potential for the Cretaceous section is mainly oil. Reconstruction of the basin's history along with hydrocarbon generation provided a regional interpretation of the oil and gas migration histories.

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Structural Architecture and The Evolution History of Sarbut El Gamal-Abu Ideimat Area, Gulf Of Suez Rift, Sinai, Egypt

The study area lies in the central dip-province of the Gulf of Suez. Excellent three-dimensional exposures enabled detailed analysis of the style and mechanics of this part of the Suez rift.

The Miocene sequences are bounded by a linked fault system: the Miocene Bounding Fault. This fault behaves as a Rift Bounding Fault in the southern part and extends northwest as an interbasin master fault.

The area between Wadi El Hommur and Wadi Thal provides three comprehensively variable structural sectors. The southern sector of Gabal Sarbut El Gamal is characterized by thick Miocene hanging wall sequences and flat Paleozoic-Lower Cretaceous footwall sequences. The central sector of Gabal Abu Ideimat provides two different Miocene Bounding Fault and Rift Bounding Fault with intervening rollover anticline. The Miocene sequence in this part is thinner than its equivalent in the northern and the southern parts. The northern sector of Wadi Thal reveals Miocene Bounding Fault and a diffuse rift shoulder. This shoulder shows a master interbasin ridge and the whole block is totally rotated to the west making a twist zone of mixed dip regime with the central sector.

The development of the Rift Bounding Fault in Gabal Abu Ideimat area and the eastern flanking fault of the inter-basin ridge in the northern part represents younger stage of tectonics after the achievement of the Miocene Bounding Fault. This provides an evidence of piggy-back rift propagation where the rift was getting wider with fault propagation in the footwall of the older Miocene Bounding Fault.

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The Contribution of Potential Field Data Transformations for Enhancing and Interpreting the Structural-Tectonic Setting of the West of Cairo Area, Western Desert, Egypt

Transformations and interpretation tools for the potential field data of West Cairo area, have been carried out, to enhance the configuration of the sedimentary basins, basement and shallower structures. Total intensity aeromagnetic data have been reduced to the magnetic north. Both gravity and magnetic data were edge-enhanced.

The directional features of the potential field were enhanced utilizing the sun-shading technique. The particular elevation and azimuth of the sun-shading are very powerful parameters in this filter, where the features laying normal to the sun azimuth are enhanced and the feature parallel are reduced. The geological noises created from dyke anomalies cutting feature of interest have been removed by using the strike filtering transform through the effective steps (enhancement and suppression) and to filter parameters (direction 60° clockwise from the north and 3 severity levels: 1, 3 & 5 km).

The gradient components and the analytical signal transform option have the optimum impact in the processing of the available data. Two-dimensional power spectrum was done to determine the depths to causative magnetic bodies. The magnetic bodies are delineated at two interfaces of 1.2 and 2.9 km depth. Horizontal and total phase angles are calculated on the RTP map at these interfaces to inspect the locations of fault zones and the extension of bodies. Euler deconvolution was applied for the automatic definition of the positions, depths and shapes of the effective bodies, and the structural trends according to the model used (step fault, dyke, sill or contact).

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Sedimentological Models and Hydrocarbon Potentialities of the Khatatba Formation (Jurassic), North Western Desert, Egypt

The Khatatba sandstone with proven gas potential has gained much interest during the past few years after many discoveries in the Khalda concession, north Western Desert, namely, Shams, Tut, Amoun, Falak and Salam fields. These sandstone reservoirs are sourced mainly from the coal / shale sequence of the Khatatba formation, Jurassic age, which is the proven primary potential source in the Western Desert.

The Khatatba sandstones are complex, meandering channels of variable thickness. These types of sandstone reservoirs need great effort to predict and delineate after their discovery.

The study of the distribution and geometry of Mesozoic rock units (Khatatba formation) in the area of study indicated the influence of two tectonic trends of deposition at this time. These are NNE "Shushan basin" trend and the WNW "Tethyan" trend.

The main objective of this paper is to construct the sedimentological model of the Khatatba sandstone reservoirs to help in predicting the channels axis. Hence, determining the next location in the future exploration. Therefore, the integration of the sedimentological and petrophysical data, as well as detailed structure mapping are all important tools to achieve this objective.

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Mesozoic and Cenozoic Petroleum Systems of Tunisia, North Africa

The North Africa and Tunisia are best known for their Paleozoic petroleum systems and yet, the greatest production in Tunisia derives from Mesozoic and Cenozoic petroleum systems.

Most of these petroleum systems originate from Albian-Turonian and Eocene widespread source rocks. Mesozoic and Cenozoic prospectivity extends over all the onshore and offshore areas, northern of the Ghadames Basin which represents the Paleozoic province. However, the Gulf of Gabes contributes the vast majority of the oil and gas reserves (e.g.: Ashtart field; 1Bb of oil and Miskar field; 2TCFG). Stratigraphically, Mesozoic and Cenozoic reserves are spread over a wide range of reservoirs, predominantly carbonate, the most productive reservoirs lie in the Upper Cretaceous-Eocene levels. Jurassic and Lower Cretaceous petroleum systems apparently of limited extension, rely on Mid-Jurassic source rocks and probable Triassic organic rich intervals. Further potential petroleum systems are predicted in the unexplored Northern thrust belt area. Recent geochemical investigations have confirmed the potential of conventional Upper Cretaceous-Eocene source beds and have particularly revealed the presence of an overlooked mature Oligocene-Miocene source rock.

Success of exploration within Mesozoic and Cenozoic basins is controlled by several factors including maturity of source rocks, migration pathways, preservation, fracturing of reservoirs and early trap development. With the exception of the Gulf of Gabes, vast areas of Mesozoic and Cenozoic provinces remained underevaluated and still undrilled or lightly drilled. Moreover, drilling has generally focused on relatively shallow targets.

Remaining potential appears to be still significant. Exploration needs to be driven by new technologies, new forms of analysis and new data in the mature areas. In the less mature basins and in frontier exploration areas, application of petroleum system approach would help to reduce exploration risks.

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Characterizing the World's Largest Reservoirs: From Youth to Maturity

No abstract required

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Modern and Fossil Bathymetric Data: Application to Exploration in the Nile Delta, Egypt

Understanding depositional environment and paleobathymetric relationships of Miocene to Pleistocene sediments in the Nile Delta, Egypt is vitally important in constructing a sequence stratigraphic framework for the basin, and predicting seal and reservoir fairways. Paleobathymetric interpretations routinely use benthic foraminiferal distributional data and planktonic-to-benthic ratios as proxies for water depth. Foraminiferal (benthic and planktonic) distributional data are largely correlated to water depth and to some degree other factors (e.g., freshwater supply). Understanding the distribution of present day faunas and linking them to their fossil counterparts is the most direct method to model environmental relationships in the fossil record. A recent study of 112 piston cores collected in water depths ranging from 70 to 2863 meters in the off shore modern Nile Delta has provided local ground truth data needed to interpret water depth changes for the Miocene/Pleistocene Nile Delta.

With these modern benthic foraminiferal data as a reference the Integrated Paleontological Systems (IPS) software was used to calculate the most likely paleowater depth, and the minimum and maximum water depths for each sample. IPS produced log format output that was particularly beneficial in its ease of integration with other geoscience data - petrophysical and geophysical. Trends (shallowing and deepening) in the paleobathymetry curve indicate significant changes in the depositional environment and enabled us to better understand the development of parasequence sets.

In addition to estimates of paleowater depth, IPS allowed analysis of faunal discontinuities (dramatic excursions) using a cosine-theta calculation that detected and helped to define stratigraphic boundaries. Discontinuities could further be classified as local or regional events or sampling artifacts by calculating separately for the benthic and planktonic components.

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Hamra Quartzites (Ordovician) Reservoir Properties Prediction Enhanced by a Combination of Compressional and Shear Slowness

The prediction of the reservoir properties for the Cambrian and the Ordovician producing in the Hassi-Messaoud area, is still one of the most important task that needs a big exploration effort to discover new oil accumulations as a satellite of the supergiant Hassi-Messaoud oilfield. In this work, the focus is on the combination of compressional and shear velocities data, as reservoir prediction tool. The most common velocity used in seismic is V_p , the compressional wave velocity (P - Wave).

A succession of well logs was obtained during a recent discoveries wells, drilled in Hassi-Dzabat, in the Southern part of Hassi-Messaoud field, where the Ordovician reservoir (Hamra Quartzites) was found to be relatively very thick (330 feet). Well logs analysis indicate the presence of an interesting high resistivity pay of 167 feet. The estimated porosities from logs range from 5 to 7 %. No significant shows were recorded during the drilling due to the utilisation of the mud oil for drilling. This interval was tested with an average flow rate of 1600 BOPD.

A full waveform sonic was recorded in the HDZ-2 well. The compressional and shear velocities are, therefore, extracted and used to calculate the different elastic properties of the formation (Poisson, Bulk Modulus, Compressibility, Sigma Function, Acoustic / Elastic Impedance, Stonely attenuation...). The preliminary results indicated that the Hamra Quartzites formation can be, at least, subdivided into three (03) individual units that have the same « mechanical facies », which is different from the usual lithofacies description; the medium unit is considered to be the main producing one; the upper unit, characterized by low porosity values, it appears to be more fractured with high permeability values, and shows some interesting correlations when compared with the calculated elastic parameters (Poisson Ration Vs Fractures, Acoustic Impedance Vs High Resistivity Zones...).

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Geologic Insights Gained from Studying the Total Petroleum Systems of the World

Challenging insights were gained by analyzing the 149 Total Petroleum Systems and their constituent 246 Assessment Units that contain more than 95 percent of the known conventional hydrocarbon resources during the recent USGS World Petroleum Assessment 2000. Ten significant insights related to the elements of the petroleum systems are: 1) Petroleum is trapped in many ways, less than half of known petroleum occurs in exclusively structural traps. 2) Type II source rocks are by far the dominant source rock type and source rocks occur throughout the sedimentary rock record. 3) Mesozoic source rocks (particularly Jurassic- Cretaceous) are the most important volumetrically. 4) Young Cenozoic petroleum systems are volumetrically dominant, and much petroleum has clearly been lost from older petroleum systems. 5) The key elements of petroleum systems are cyclic. 6) Despite enormous recent success with deepwater reservoirs, volumetrically they are currently the least significant of those considered; continental reservoirs are dominant. 7) Future discoveries will be dominantly from clastic reservoirs. 8) Salt is a very effective long-term seal, and salt seals are a critical preservational component of older Paleozoic petroleum systems. 9) Most of the petroleum systems in the world are dominated by vertical migration or limited lateral migration (less than 20 kilometers) from the mature source rock area. 10) Many major conventional natural gas systems are closely linked to large unconventional (continuous) resources.

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Rift Border Fault System Evolution and Impact on Sedimentation, Southwestern Gulf of Suez, Egypt

The Gulf of Suez is a major petroliferous basin in Egypt. Poor seismic attributes of sequences underlying thick Miocene salts gave importance in studying the surface structural architecture and rift-sedimentation aiming at reaching better subsurface image. The Southwestern rift-segment is selected in this study where numerous hydrocarbon fields exist in vicinity and few works are published. Detailed field analysis and mapping revealed multi-storied fault developments in time and space with variable impact on sedimentation.

Two major interbasinal accommodation zones are delineated with extension in basement rocks of the rift shoulder as Precambrian shear zones and imbricate-thrust system. The rift border fault system bounds the rift and is represented by linked short segments of 4-7 km long. Several fault-segments propagated in one direction showing maximum displacement at one fault tip. Hard-linkage transfer faults connect fault tips of variable magnitudes.

Differential evolution of fault-segments had a great impact on rift-sedimentation. Entrapment of early-rift sediments adjacent to some faults indicates early-rift fault development whereas divergent sedimentary-wedging away from other faults refers to deposition on flexure-zone above a blind fault. Deposition of younger sequences adjacent to fault planes prove later fault-ruptures.

The differential fault development and along-strike displacement variations are reflected on the rift shoulder paleoslopes. Channel reservoir clastics derived from the shoulder into the rift basin across trap-door transfer faults.

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Hydrocarbon Systems of Central, Eastern and Southern Saudi Arabia

Hydrocarbons from Paleozoic and Mesozoic petroleum systems are assessed with respect to their source rocks potential and genetic relationships. Paleozoic petroleum system source rocks principally include Early Silurian basal Qusaiba hot shales. Mesozoic petroleum systems consist of Jurassic and Cretaceous systems. Argillaceous carbonates of Tuwaiq/Hanifa formations are the principal Upper Jurassic source rocks in eastern and southern Arabia. Middle to Upper Jurassic source units are confined to northern Arabia area. Cretaceous source system comprises of Wasia formation in southern Arabia and both Wasia and Sulaiy for offshore Arabia.

Paleozoic source rock potential indicates gas in the east and south, and oil in central Arabia, confirming the existing hydrocarbon finds. Hydrocarbons found in this system include non-associated gas in eastern Arabia and extra light oil in central Arabia. The Jurassic source potential is oil for most of eastern Arabia and gas for southern Arabia. Hydrocarbons found in this system are medium to light oil and associated gas. The source rock potential for the Cretaceous section is mainly oil. Hydrocarbons include light oil in southern Arabia and medium to light oil in the offshore areas.

Diamondoids, biomarkers and isotope data suggest that the Paleozoic oils are uncracked to lightly cracked in central area and southern Ghawar accumulations but are extensively cracked in north Ghawar field. In addition, some of the analyzed Paleozoic hydrocarbons show mixed origin as indicated by the presence of biomarkers and diamondoids. The possible hydrocarbon mixing from both Mesozoic and Paleozoic systems demonstrates migration complexity despite assumed effective seals.

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Data Management Strategy for an E&P Data Ready Center

A comprehensive and practical data management strategy based on a data centric approach will be presented. The practicality of this strategy comes from its development through an extensive review and study of E&P organization business processes and data/work flow to identify major issues. Extensive analyses of the resulting dataflow with the identified issues lead to a proposed strategic solution where the data is the core of the solution. The solution marries both technology and solid business practices to ensure safeguarding of data and knowledge, archiving resultant data, delivering quality data fast to the users and improving communications between data producers and consumers.

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Integrating Seismic Inversion and Waterflood Pattern Management Planning, Upper Cretaceous Maaddud Formation Reservoir, Raudhatain Field, North Kuwait

have been drilled to complete the Sea Water Injection Phase 1 area. Each pattern is an inverted 9-spot of 250 acre spacing. Peripheral wells are typically less productive than crestal wells, suggestive of degradation in reservoir quality towards the flanks of the field.

To optimize Sea Water Injection Phase 2 over the flanks of the field, and right-size the patterns, a reservoir quality stratigraphic model was developed using a seismically derived porosity cube with reservoir structure and isochore maps. The porosity cube was derived by inverting the 3D seismic data using a constrained sparse spike inversion method, developing an AI to PHIE function from well control, then transforming the AI volume to a PHIE volume.

The PHIE volume clearly shows reservoir quality trends related depositional setting and faulting. Average porosity derived from the wells matches the average PHIE volume. A critical concern in the inversion was accuracy on the flanks of the structural high beyond well control where reservoir quality begins to deteriorate. An innovation technique incorporating structure into the interpolation of the low frequency earth model has proved successful. Efforts are underway to optimize pattern size to the reduced porosity volumes mapped on the flanks.

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Challenges of Reservoir Characterization in Mauddud Carbonates: North Kuwait

The Mauddud Formation in North Kuwait consists of Early Aptian carbonates deposited in a low angle ramp setting. The reservoir holds more than 6 billion barrels of in place oil in two adjacent doubly plunging anticlines of Raudhatain and Sabiriya structures. Initial reservoir characterization of the field was based on primary depositional characteristics. Static data from a relatively dense well controls but limited dynamic data were available and made use of. Availability of more dynamic data necessitated a modified reservoir characterization to account for the fluid flow.

Mauddud formation is under production for last 40 years from 18 wells in Raudhatain field. Only two wells have cumulative production over 20 million barrels each while the rest wells have produced less than 1 million barrels. There is very little aquifer support and the reservoir pressure had dropped by 1400 psi for a cumulative production of 4% of initial oil in place. An inverted 5 spot water injection pilot was designed and implemented in an unfaulted area of the field to guide pattern injection for the reservoir. Water break through was observed in the producers within a time range of 2 to 14 months.

Analysis of static and dynamic data from the pilot study broadly associated primary depositional rock fabric as being the main control over fluid movement. Rudistic floatstones, deposited in inner-ramp/restricted lagoonal settings was found to be acting as thief zones. Core recovery across such facies is very poor. Zones with such lithofacies were identified from cores and electrologs. The reservoir was developed with inverted nine spot with 59 producers and 23 injectors. Zones having Rudistic floatstone facies were not perforated in the injectors.

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Hydrocarbon Systems of the Ghadamis and Murzuk Basins, West Libya and Their Relation to Al Qarqaf Arch

The Ghadamis and Murzuq Basins, west Libya, located within the African Shield, are major producers of hydrocarbon in the western part of Libya. Since 1958 more than seventy oil and gas fields have been discovered in the two Palaeozoic basins which are separated from each other by the east-west running Al Qarqaf Arch. The Murzuq Basin is the lesser explored of the two.

In this paper, the hydrocarbon accumulations of the Ghadamis and Murzuq Basins are investigated and grouped based on data collected from about seventy oil and gas fields. The work includes classification of different reservoirs and their relation to the geographic distribution of oil and gas fields. The reservoir characteristics indicate that the Ghadamis Basin hydrocarbons have accumulated mainly in combination and stratigraphic traps in areas close to Al Qarqaf arch, and in structural anticline traps in areas close to the centre of the basin. In the Murzuq Basin, hydrocarbons are trapped mainly in structural faulted anticline traps. The lithology of all reservoirs is mainly sandstone. In the Ghadamis Basin the depositional environment ranges from shoreline in areas close to Al Qarqaf to shallow marine in the centre of the Libyan part of the basin. The depositional environment for discovered Murzuq Basin oil fields is mainly shallow marine.

The distribution of oil fields in the Ghadamis and Murzuq Basins appears to be confined to a regional trend, which reflects a close relationship between tectonics, sedimentation, oil migration and accumulation.

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Arch Structures and Hydrocarbon Exploration

Arch structures are areas of broad, uplifts on a regional scale. They developed throughout the geologic history of the Earth. It is usually a basement doming. Basement structures such as arches are common features in many fore-land basins. They are as important as basins in the tectonic history of the cratons and occupy similar surface areas, and are one of the most important producers of second order basins. In many continents the records indicate that arching was a dominant structural style during Early Paleozoic time. The palaeogeographic effect of arch development in adjacent sedimentary basins is clearly observed in many in many areas. Hydrocarbons are present around many of these arches in both structural and stratigraphic traps. It is recorded that arches or uplifts produce reefal belts in carbonate basins as in the Peace River Arch, Western Canada and will produce pinchouts in the case of clastic sedimentary areas as in Hassi Maessoud, Algeria. These structures are significant controls on the distribution of reservoirs and become focal point for hydrocarbon migration and accumulation. Several structural processes such as faulting and folding characterize areas of arches. This will keep the area of arches higher than the adjacent basins and erosional activity in areas of arches or uplifts than surrounding areas. The analysis includes characteristics of arch structures, occurrences of arches around the world, examples of arches located within different Paleozoic hydrocarbon producing sedimentary basins, and characteristics of oil fields associated with these structures. Al Qarqaf Arch separating west Libya the Ghadamis and Murzuq Basins were used as an example for the influence of arches on hydrocarbon migration and accumulations.

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Using The Other End of the Capillary Pressure Curve - Discriminating Permeability Based Rock Types With Well Logs When the Permeability Mechanism is Related to Displacement Pressure and not Porosity

A large Lower Cretaceous age carbonate reservoir in Saudi Arabia contains reservoir rocks with permeabilities that vary from 0.2 to 2000 md. Characterization efforts to model the reservoir proceed from the very important highest permeability rock types that dominate well and inflow behavior to the lower quality storage and dispersed delivery rock types.

Investigations of capillary pressure data suggested three petrophysical rock types (PRT's), one petrophysical rock type with permeability related to porosity and two PRT's with permeability unrelated to porosity but strongly related to the systematic decrease of the entry or displacement pressure, P_d , or the increase in the largest pore throats.

Well logs that are sensitive to porosity are well known and recognized. Our reservoir, however, needed to use well log responses related to the P_d (displacement pressure) end of the capillary pressure curve. This rock property is usually assessed with invasion related well log responses. A range of potential well log candidates were investigated, robust discrimination of order of magnitude changes in permeability caused by increases in large pore throat sizes were successfully discriminated by the judicious use of the combination of porosity, SP and sonic well logs.

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A Geographic Information System Application in Fracture Prediction for Jurassic Carbonate Reservoirs in Kuwait

The aim of the study was to develop a process for analyzing and integrating fractured reservoir datasets in order to make predictive estimates of fracture density, and to develop it in sufficient detail to allow others to apply the techniques. Geographic Information System (GIS) software applications store, analyze, and display multiple layers of geographic information. GIS is made up from several interrelated and linked components with different functions. GIS have functional capabilities for data capture, input, manipulation, transformation, visualization, spatial query, combination, modeling, and output.

Fractures are the key component for hydrocarbon flow in low-porosity Jurassic carbonate reservoirs in Kuwait, and fracture prediction is therefore a very important process. Rock deformation, such as folding and faulting, are the main causes of fracturing in carbonates. This presentation will explain the process for the prediction of the spatial distribution of fractured reservoirs using GIS tools. The Model of the fracture prediction process was built by assigning the fault system to a fault classification and integrating with the structure map analysis (slope, curvature etc...). The technique has been used for predicting fracture-prone areas in low-matrix porosity Jurassic carbonate reservoirs.

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Advance Formation Evaluation of Kerogen Rich Reservoir - A Case Study from Kuwait

Standard approach of determining porosity from cross-plots of Neutron, Density and Sonic does not provide acceptable porosity in reservoirs having high kerogen content due to extremely high kerogen responses. Moreover, reasonably accurate estimation of Kerogen content in such reservoirs by conventional log analysis models is not possible as kerogen parameters are not precisely known.

Use of Nuclear Magnetic Resonance (NMR) derived porosity that is not affected by kerogen/immobile hydrocarbons has made it possible to evaluate such reservoirs quite accurately. Accuracy of these results has been verified by comparison with the core porosity corrected for reservoir conditions.

The difference in the cross-plots derived porosities and those from NMR reflect the kerogen content fairly well. A reasonable correlation has been observed between Uranium component of the radioactivity determined from Gamma Ray Spectrometry and the kerogen content in most parts of reservoir.

By comparison of NMR porosities integrated across different ranges of pore sizes were done with the core data and a reasonable match has been achieved. These porosities have been used in the final log interpretation.

Effective porosity of the reservoir is very low therefore the production depends mainly on fractures. Sonic Borehole Imager has been used as principle fracture indicating tool because of oil base mud. Comparison of fractures detected from Sonic Borehole Imager with NMR permeability and the results of Stoneley analysis enabled to identify open fractures, select perforations intervals precisely for successful completion of the wells.

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Natih Unconventional Play: Reviving a Dormant Play

Stratigraphic opportunities of the Late Albian to Early Turonian Natih Formation of North Oman have been recognized since the early 1960s. However, throughout the years, the Natih unconventional play has remained risky. The risks were mainly attributed to limited 2D seismic data and a poor understanding of the charge system.

The potential for stratigraphic trapping within the Natih has been re-assessed through:

1. the utilization of 2D and 3D seismic data,
2. the construction of common risk segment maps,
3. the evaluation of recorded hydrocarbon shows,
4. fieldwork.

The following stratigraphic exploration opportunities have been addressed:

1. Combined 2D and 3D seismic data from North Oman display a complex system of channels at the top of the Natih A. The channels range from wide, fairly straight and slightly sinuous to narrow, highly sinuous channels that show meander loops and cutoffs. The stratigraphic traps are largely dependent on the infilling of these channels, incised into the Natih A and running perpendicular to the regional dip, with mud and shales.
2. Reefal buildups and mounds along the prograding platform edges of a Natih E intra-shelf basin, occurring in the area between the Fahud and Ghaba Salt Basins. These structures are fully surrounded by intra-shelf basinal facies, which provide top and lateral seals.
3. Truncated Natih intervals are recognised in NW Oman. Reservoir intervals occur as truncated carbonate wedges with intra-formational lime mudstone and shales acting as seat seals and the base Tertiary Shammar shale as top seal.

The availability of 3D seismic data coupled with a better understanding of the charge system is expected to revive the Natih unconventional play.

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Effective Use of Depositional and Diagenetic Tools to Predict Good Reservoir Quality of Khuff Formation in Eastern Saudi Arabia, and the Gulf Countries

The late Permian Khuff Formation, represent a part of the Tethys sea deposition over the Arabian Plate, located, paleogeographically, in southern hemisphere at the same latitude as it is now. The Formation in Saudi Arabia consists of several packages of cyclic sediments. There are five major units, the Khuff-E, D, C, B, and A members from bottom to top. The Khuff-E is mostly very shallow marine deltaic clastics, with some lenses of dolomudstones and shales in the east and with incised valley-fill clastics in central Arabia to the west. The Khuff -D is mostly dolomudstones, with lenses of anhydrites and shales. In this unit, there are two layers of nodular anhydrite that are very prominent markers called the Khuff-D markers; they can be correlated regionally in almost all of Saudi Arabia, the Gulf countries and Iran. The Khuff-C, B and A contain the reservoir facies in Saudi Arabia, the grainier reservoir facies, subtidally deposited, are usually interbedded with mudstones and anhydrites that deposited in intertidal and supratidal environment.

Because of the importance of the Khuff as a major source of gas in Saudi Arabia, it was studied in detail. Regionally, the depositional setting was defined, the Khuff Formation isopach was mapped, lithostratigraphic units were correlated, major facies were recognized, anhydrite footage and average porosity were mapped. These tools combined were used to interpret the shelf edge and shelf break locations. Then areas of good reservoir potential with cleaner facies and less anhydrite were predicted near the shelf edges and shelf breaks. Sour gas areas were explained, in areas with more anhydrite concentration and less grainy facies. Poorer areas of reservoir facies were predicted and explained.

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Mega-Pressure Systems in the Arabian Basin

The Arabian Basin is divided into three Mega-Pressure systems, based on detailed geologic and engineering data collected from oil and gas fields in Saudi Arabia. These pressure systems are named the Post-Jilh normally pressured system, the Pre-Jilh normally pressured system, and the Pre-Jilh over-pressured system. This work represents the first attempt to identify the pressure systems in the Arabian Basin.

The Post-Jilh normally pressured system extends from the Mesozoic outcrops in the west into the basin center at the Arabian Gulf in the east. The Pre-Jilh normally pressured system extends from the Paleozoic outcrops in the west to approximately mid-way between the outcrops and the Arabian Gulf. The Pre-Jilh over-pressured system occupies all areas to the east of the Pre-Jilh normally pressured system. Source rock studies and mud weight records suggest that the Jilh Dolomite separates the Post-Jilh system from the two Pre-Jilh systems throughout the whole basin. The Jilh Dolomite is an extensive 150-foot thick competent dolomite that is present near the top of the Triassic Jilh Formation. Deep sealing faults likely form the boundary between the two Pre-Jilh systems.

Smaller scale pressure systems are believed to exist within the three mega-pressure systems as indicated by the variations in pressures of the Permian Unayzah reservoir. A detailed mapping of such smaller systems and studying the causes of overpressures are necessary to understand the history of hydrocarbon migration and trap charging in the Arabian Basin.

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Factors Concerning the Development, Distribution and Preservation of Reservoir Facies in Jurassic Carbonates and their Impact on Petroleum Systems in Eastern and Northeastern Saudi Arabia

The Rimthan Arch is a positive feature, which existed from Bajocian until Portlandian time separating the Gotnia and Arabian intra-shelf basins throughout this period. This feature, whose lateral extent has varied considerably throughout time, significantly controls development of Jurassic reservoir facies. The distribution and quality of the most important carbonate reservoirs in the Eastern Province of Saudi Arabia appear to be controlled by a system of positive elements; tectonic and/or depositional highs. Water depth, energy and primary depositional environment created and/or modified the sediments into reservoir rocks in the vicinity of these highs.

Analysis of petrography, paleontology, core description work, core porosity/permeability analysis and integration with well logs and seismic interpretation permit a reasonable description of the Upper Jurassic Arab carbonate facies throughout the area, and are summarized into regional facies and net pore volume maps. Similarly, reservoir distribution maps for the other reservoir units from this time are presented.

An attempt is made to use sequence stratigraphy and seismic stratigraphy to describe the systems, and to predict facies variation as it pertains to the development of petroleum systems and prediction of various potential stratigraphic play types such as; dolomitization as a sealing mechanism, facies variations, biohermal buildups and updip reservoir pinchouts. Recent reprocessing of seismic data indicates that such facies variations may be seismically detectable.

Saudi Aramco oil typing work indicates a distinct separation of oil families into Gotnia and Northeastern Arabian Families and enhances the prospectivity of the Rimthan Arch trend.

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Diagenesis of Jauf Sandstone in Hawiyah Area, Saudi Arabia

Jauf Formation of Lower Devonian age is an important hydrocarbon reservoir in Saudi Arabia. The sandstone reservoirs of Jauf Formation are mostly fine to medium-grained, moderately to well-sorted and texturally mature quartz arenites. Average composition of the framework grains of the sandstone reservoirs of Jauf Formation is 77% quartz, 2% feldspar and 0.1% rock fragments. Major authigenic cements include calcite; chlorite, illite and quartz while minor amount of pyrite and illite/smectite clay are present.

The diagenetic processes include compaction, cementation and dissolution. The degree of compaction is evidenced by long, concavo-convex and sutured contacts. Cementations include an early calcite cementation phase followed by clay coatings (chlorite and illite), quartz overgrowths cementation and late calcite cementation. In addition, some minor pyrite cementation has occurred in early stage of burial. Early-calcite cement is poikilotopic and has occupied most of the pore spaces in some samples reducing the primary porosity. Chlorite pore fillings and grain coatings have reduced both the porosity and permeability to some extent but also have helped to retain initial porosity at depths by retarding the development of quartz overgrowths. Illite cement is most commonly found as hair-like growth coating the grains and bridging pore throats. This reduces the permeability dramatically. Quartz overgrowths have reduced the porosity and permeability significantly. The late-calcite cement does not have a profound effect on the samples. The invasions of acidic fluids have resulted in partial dissolution of calcite cements and feldspar grains creating secondary porosity in many samples.

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Pre-stack Depth Imaging as a Tool of Accurate Structure Delineation in Presence of Complex Surface Topography

In Saudi Arabia, complex surface topography features and in particular sand dunes, lead to distortion of target horizons on seismic time images. These distortions can lead to incorrect time and final depth maps unless corrections are made during processing.

In this paper we show benefits of pre-stack depth imaging workflow that includes tomographic iterative velocity modelling procedure. The workflow is presented for 2D data, but it can be applied with minor modifications to 3D data as well.

Initial velocity modelling uses CMP gathers on floating datum to derive layer velocities using ray tracing based approach - coherency inversion. Ray tracing is performed from floating datum representing a smoothed version of the topography. An initial velocity-depth model is used for the first pass of pre-stack depth migration. This process generates a depth section and depth image gathers in each bin location. Residual moveout on depth image gathers is analysed along the model horizons and the initial interval velocity - depth model is used in tomographic model update procedure. Low effective offset for shallow reflectors does not allow direct update of the shallow velocity model. We introduce a tomographic procedure that uses better quality deeper reflections along with shallow reflections to update the shallow velocity model. The updated velocity model is used for the next iteration of pre-stack depth migration and at this stage tomography is used to update velocity in deeper layers of the model. This way we generate a final velocity model and final depth image free of artificial distortions observed on time images.

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Tectonic Fractures Analysis of the South Fuwaris Field in the Kuwait-Saudi Arabia Partitioned Neutral Zone

The South Fuwaris Field anticlinal structure is located in the southwestern part of the Partitioned Neutral Zone between Kuwait and Saudi Arabia. An oriented core fracture analysis integrated 3-D seismic attribute maps with geology, rock properties, pressure, and production data were used to investigate the nature, orientation, and geometry of the reservoir fractures. The study showed the presence of open fractures in the Lower Cretaceous carbonate reservoir. The FMI analyses of vertical and horizontal wells were used to verify the open fracture orientation. The in-situ stress was confirmed from the induced fracture orientation.

The kinematic analysis of the South Fuwaris structure indicated that compressional stress was responsible for creating the main axis of the structural culmination and the induced fractures, whereas an extensional stress created the open fractures. The dynamic analysis indicated that the main axis of the anticlinorium, together with the induced and the extensional fractures are caused by a right-lateral shear couple. This simple shear tectonic model with compressional and extensional components was responsible for producing similar Cretaceous tectonic trends elsewhere in the region. Structural deformation probably occurred throughout the Early Cretaceous.

By using this model, a better understanding of the fracture system of the South Fuwaris was obtained. The new information was in turn used to design the horizontal trajectory of two South Fuwaris wells. Encouraging results were obtained for both wells. The field is currently undergoing a reservoir evaluation aimed at designing an optimum depletion strategy. It is expected that the exploitation and development plan will include the drilling of several horizontal wells. The application of the tectonic model described here will have a direct impact on the design of the horizontal well trajectories.

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Connectivity Between the Ghazal and Mazalij Fields

The target reservoir of the Ghazal and Mazalij Fields is the Paleozoic Unayzah Formation. The Mazalij reservoir was discovered in 2000, on the down-thrown block of a succession of faults that separate it from the crestal area of the field, where the reservoir was missing. The Ghazal Field was also discovered in 2000, where it encountered a thick Unayzah with excellent sand quality. The two fields were initially thought to be disconnected. Several pieces of evidence (including depositional growth, structural depth, pressure regimes, geochemical analysis, and 3D seismic data acquired later) indicated that the fields may be connected. A delineation well was proposed to test the connectivity between the two fields. In order to select the optimal location for the well, accurate depth maps of the entire Ghazal/Mazalij region were produced. The goal was to generate not only a map of the depth structure of the Unayzah, but also maps of the depth and isopach of all key layers in this region, since this is vital to understanding the growth structure of the reservoir and obtaining a good assessment of the depositional environment in this area. The location of the delineation well was selected to be on the apparent saddle between Ghazal and Mazalij in order to directly settle the issue of the connectivity of the two fields with a high degree of confidence and to afford a much more accurate assessment of the reservoir compartmentalization in this region. The results of this well helped confirm the connectivity between the two fields.

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3D Seismic for Exploration, an Integrated Process from Acquisition to Interpretation

The large four way closures have been found. The remaining traps require high quality and densely sampled data to properly explore, evaluate and risk prospects. 3D seismic can be used cost effectively to derive useful information for pure exploration.

This example shows 3D data over an area dominated by large sand dunes alternated with sabkha plains generating static problems, and with severe surface and internal multiples. A careful acquisition design and processing sequence and the involvement of an integrated team of geophysicists and seismic interpreters have lead to excellent results.

'Wide-line' or 'Sparse' 3D seismic data have been acquired with relatively large source- and receiver line spacing, low sweep effort per source point but with long offsets and still reasonable fold, as compared to field-development 3D's. Despite these economised parameters, the final result is very detailed. Structural and stratigraphic features can be highlighted using attribute mapping and 3D visualization tools. Seismic amplitudes relate to reservoir porosity and are a valuable risking tool. The data allow a better geological understanding of the area both in structure and stratigraphy. These good data provide a higher degree of confidence and improve the risk evaluation associated with each of the multiple exploration prospects.

These high quality data are the result of working as an integrated team; a case history showing the importance of such teamwork on optimizing all steps of the geophysical process in a difficult terrain.

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Regional Pressure Study in the Deep Nile Delta

Pressure is a key factor in understanding migration, trapping, reservoir fairways, drilling risks and costs. Pressure data from 80 regionally spaced wells and several basin model lines provides insight on regional Nile Delta pressure trends. A regional velocity pressure cube created from seismic interval velocity data shows a strong correlation with depositional facies, depositional rates and structure. Identification of "pressure regressions", where reservoir pressures are significantly lower than those of the encasing shales, are readily apparent.

Compaction disequilibrium exerts the dominant control on pressure trends in Pliocene strata, with a secondary overprint by facies. The diagenetic conversion of smectite to illite dominated shales with temperature is an important secondary factor in the Lower Pliocene and pre-Miocene.

Pressure regressions to near hydrostatic in Messinian age strata result primarily from pressure release through laterally extensive valley-fill and alluvial plain sandstones that outcrop southward. In shale filled valleys or barren interfluvies, high pressure dominates. Pre-Messinian strata show full regressions in delta plain sandstones subcropping the Messinian unconformity. Partial regressions occur in many deep-water slope-channel fairways. Regressions are largely absent in delta slope facies or other condensed intervals, where "hard pressure" is encountered.

The integrated approach used suggests that regional pressure trends may be predictable to depths of up to 4000 meters below mudline. This provides a powerful predictive tool for understanding plays, prospects and drilling hazards.

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Multi-Scale Multidisciplinary Oilfield Data Integration Using Geographic Information Systems

The integration of oilfield data becomes mandatory especially in applications that require solutions based on multi-disciplinary data. These data normally stored in various formats at different scales are difficult to combine in one package. Geographic Information Systems (GIS) has proved to be very successful in managing and analyzing multi-source data. Today's systems take advantage of the high speed and processing power of computers to process large data sets and use state-of-the-art Object Relational Database Management Systems, (ORDBMS) to store and retrieve information.

GIS are employed to integrate multi-scale multidisciplinary oilfield information. Regional and sub-regional information including remote sensing imagery, geologic and topographic maps, and surface structural maps are integrated with subsurface information e.g. well-data, formation tops, seismic maps as well as high resolution rock-based information (plug and core based description). The system encompasses multi-scale information in one graphic user interface where the user can leap from low-resolution regional or sub-regional to high-resolution plug-based information. The raster processing engine of the GIS enables the creation of the isopachs grids (maps) on the fly from formation top data. This is only one example of many in map topology that GIS can provide for the geologist. This application allows using GIS at all project stages from field mapping and data collection to data management and finally to 3D displays, management, and analysis of data.

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Minimizing the Exploration Risk by Using 3DVSP

Most of the surface seismic data acquired, especially at the pre-Miocene horizons, from Ras El Ush offshore area, Southern Gulf of Suez, can be rated poor. As a result, seismic mapping of the horizons below the Miocene salt is difficult and unreliable. This is due to the masking of the seismic energy by South Gharib Formation salt, generated multiples from Zeit Formation interbeds and geologically and geometrically complex target reservoir horizons.

Two 3 Dimensional Walkaway Vertical Seismic Profiling Surveys (3DWVSP) have been acquired, for the first time in Egypt and Middle East, from two of Ras El Ush Field deviated wells (Ras El Ush#5 & #6). This is where the receivers were emplaced below the Miocene salt. For the first time, the recorded seismic energy, especially of the pre-Miocene horizons, were not attenuated or masked.

The 3 DWVSP depth volume was merged and integrated with post stack depth migration of the surface 3-D seismic data acquired in May 1997 from Ras El Ush Offshore area. This provided a great chance, for the first time, to work with real sub-salt data in 3D volumes. Also this enabled us to conduct serious and valuable trials for interpreting and mapping precisely complex sub-salt pre-Miocene horizons.

For aggressive petroleum exploration in remote areas (e.g. Deep seated targets in the Gulf of Suez, Red Sea, Mediterranean sea...etc.), 3D VSP seismic receivers, can be designed, to be spread, below the salt or above the exploration target, in a highly deviated or horizontal single or multiwell pattern. This is before or at the same time with the surface 3D seismic surveys.

The 3D VSP can be used (e.g. In Modeling) for designing better field parameters for further 3D seismic acquisition, and if combined with surface 3D seismic, seismic coverage will be improved.

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Model Based Deviated VSP Reservoir Imaging Technique in tough field conditions (Case History)

Seismic imaging in tough field conditions is always a challenge for geoscientists. Deviated VSP images with fixed source offset are not quite often acquired due to severe ray paths bending and oblique incident angles. In this paper, we demonstrated that a good quality subsurface image can be obtained in such cases using a geological model and proper field geometry correction for the ray paths.

The data set used in this experiment, was from a well, spud on land and target bottom hole location was deviated around 38 degree towards very shallow marine environment, making it extremely difficult for imaging the reservoir with moving source boat standard procedure, thus, leaving a choice for other alternative methods.

Multiple ray path arrivals from source to receivers positions in the well, were simulated utilizing ray trace model technique, field survey geometry and well deviation data on acquired depth levels. The field measured times were corrected for slant paths and time-frequency dependent spherical divergence. The corrected time based interval velocities were computed and used in the model to generate equi-offset contours for stacking the image along these contours.

Moreover, time based residual normal move out corrections were applied to deviated VSP wave field before making the final CDP image. A comparison of final processed image of deviated VSP was made and integrated with 3D seismic in the existing area, which showed extremely good match with the reservoir image in higher resolution.

This real data example showed that wells deviated up to an angle of 38 deg., can be used with fixed source offset to reliably image the subsurface with lateral coverage as a function of source offset, well deviation, geological dip and velocities.

An additional by product of offset source deviated VSP, in such cases, is mode converted P to S energy, which can be analyzed to provide further useful information about reservoir characterization.

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TAU Migration and Velocity Analysis: Application to Data from Midyan Region of the Red Sea

Imaging the pre-salt reflections for data acquired from the coastal region of the Red Sea is a task that requires prestack migration velocity analysis. Conventional poststack time processing methods lack the lateral-inhomogeneity capability needed for such a problem. Prestack migration velocity analysis in the vertical time domain reduces the velocity-depth ambiguity usually hampering the performance of prestack depth-migration velocity analysis. In prestack TAU migration velocity analysis, we keep the interval velocity model and the output images in time. This allows us to avoid placing reflectors at erroneous depths during the velocity analysis process, and, thus, avoid inaccurately altering the shape of the velocity model, which, in turn, slows down its convergence to the true model. Using a one-dimensional velocity update scheme, the prestack TAU migration velocity analysis produces good images of data from the Midyan region of the Red Sea. For the first seismic line from this region, only three prestack TAU migration velocity analysis iterations were required to focus pre-salt reflections in time. However, the other line, which crosses the first line, is slightly more complicated, and thus, required five iterations to approach the final, reasonably focused, time image. These results compared favorably with images obtained for the same two lines using the Common-focus-point imaging technique, developed recently at Delft University. After mapping both images to depth using the final velocity models, the placement of reflectors in the two 2-D lines were consistent at their crossing point. Some errors occurred due to the influence of out-of-plane reflections on 2-D imaging. However, such errors are identifiable and are generally small.

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Enhanced Sub-Salt Imaging of 2D Seismic from the Northern Red Sea, Egypt

Exploration targets in the recently offered Northern Red Sea license blocks were historically base salt highs in the Miocene. The low success rate for this play was attributable to poor seismic data quality. 2D seismic data has been reprocessed utilizing the key technologies of surface related multiple elimination (SRME), pre-stack Kirchhoff time migration, and pre-stack Kirchhoff depth migration. Dramatic improvements in seismic imaging show that the exploration wells missed the Miocene highs or tested eroded highs where the pre-Miocene reservoir section was absent.

The SRME technique substantially improved the data, suppressing strong free-surface related multiples and allowing for better velocity estimation and imaging. Interbed multiple elimination (IME), with the water bottom as the multiple generator, provided minimal improvement. Radon de-multiple added minor improvements. Remaining multiple energy was deemed to be of a diffracted or 3D nature and could not be removed with 2D techniques.

Pre-stack time migration provided reliable velocities and imaging to top salt and proved a good starting point for the depth migration of base salt and the sub-salt section. Tomography, salt flooding and horizon-based substitutions were used to generate the velocity field. Additional improvements to the seismic image were obtained by vertically stacking a series of migrations where the pre-salt section was migrated with slightly different velocity fields. This vertical stacking process reduced remnants of the diffracted multiples and increased the signal-to-noise of the gently dipping underlying geology.

This reprocessing effort contributed greatly to BP's ability to properly assess the acreage and prepare an appropriate bid application.

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Integrating Kerogen and Bitumen Analyses to Enhance Characterization of Source Rocks in the Northwestern Desert of Egypt

A close examination of the oil and gas potential of the Egyptian Western Desert confirms it as an area with substantial remaining reserves which have yet to be intensively explored.

In the Western Desert, the source rocks are typically shale sequences associated with the transgressive front of the Upper Jurassic and Upper Cretaceous. The organic facies and the thermal maturity of these Mesozoic source rocks still need clarification.

This study aims to integrate the geochemical data, obtained from kerogen and bitumen analyses, in the most effective combinations for evaluating and detecting new horizons as potential petroleum source rocks. This intends to promote and facilitate more exploration and development activities in the study area and its environs.

Core samples and selected cutting samples from Meleiha area were analyzed for total organic carbon, Rock-Eval pyrolysis, visual kerogen analysis, vitrinite reflectance measurements, bitumen analysis, biomarker studies and carbon isotope determinations. Four distinct organic facies are recognized in the well: Organic Facies I consists of the sandy shale sequences of the Bahariya, Kharita and Alam El-Bueib formations; Facies II and Facies III include the organically lean Alamein Dolomite and Masajid formations; and Facies IV comprises the organically rich interval of the Khatatba Formation at the base of the section penetrated. Only the rocks of organic facies IV are organically rich enough to act as principal petroleum source rocks. Maturity levels in the area range from immature to peak oil generation. The oil window is entered at approximately 8000 ft.

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High Resolution Sequence Stratigraphy of the Fahud Natih C & D Reservoir Units: Constraints on Production

Vertical and lateral heterogeneities due to depositional and diagenetic variations are common in the Lower Cretaceous Carbonates of North Oman. This exerts a major constraint on oil-field development schemes such as GOGD versus water-flood development in Natih reservoir units of the Fahud Field.

Facies distributions were studied in six cored wells in Fahud Field. Core descriptions, a regional overview based on outcrop analogues, and a literature survey were used to build a core-log depositional model indicating that sediments were laid down over a low topography deeper shelf.

High Resolution Sequence Stratigraphy established the stratigraphic architecture, dividing the Natih C & D into 3 orders of cyclicity. The 4th order cycles are the highest level of cyclicity that can be correlated easily across the field. The 3rd order regressive-transgressive cycles form the larger units and sequences, roughly equivalent to the existing reservoir subdivisions (Natih A-G).

These results were used to build a 3D static reservoir model for the Natih C & D Reservoir Units.

In Rudist Sands, Wackstone/Packstones and Packstone/Grainstones, where fractures occur in 4th order regressive cycles within 3rd order regressive cycles, it seems doubtful as to whether a connected fracture network exists. The reservoir rock is interpreted as too weak to maintain large-scale fractures, so water-flood development could be successful. More competent and highly permeable Rud/Floatstones, with dissolution of the shell fragments leading to a well-connected vuggy-pore system (transgressive part of a 3rd order sequence), is interpreted as suitable for GOGD development.

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The Effect of Strike-Slip Motion on Hydrocarbon Entrapment in Southern Province of the Gulf of Suez

Geisum and Tawila fields lie in the southern entrance of the Gulf of Suez, south to the Morgan hinge zone, where the fault blocks are commonly tilted to the south - west.

The structure configuration is interpreted from 3-D seismic for both fields as north-west tilted fault blocks, which are dissected and bounded by sets of clysmic faults having various magnitudes of throws.

The structure is segmented by sets of cross-faults showing dextral strike-slip motion in the Geisum field and sinistral in the Tawila.

The major cross-fault in Geisum field divides the structure into two blocks; the southern and the northeastern. The large lateral displacement of this major fault brings the thick preserved pre-Miocene in the northeastern block to juxtapose the fractured granitic basement in the crestal area of the southern block. In both blocks the main reservoirs are the Cretaceous sandstones and the fractured Precambrian basement.

Oil was recently discovered in the well developed Middle Eocene (Thebes Formation), while in the southern block the equivalent section of Middle Eocene was found water-bearing.

In the Tawila field, the major cross fault separates the field into southern and northern blocks. In the southern block, oil was found in the Miocene Kareem and Belayim Formations, while in the northern block which is in a higher structural position, the Miocene sand was water bearing. The geochemical study suggested that Miocene reservoir had been charged from the basin located south of the Tawila field. This reveals the role of strike - slip motion in creating a new oil trap in the study fields, thus encouraging further exploration in the vicinity.

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Pindos Zone Sub-Marine Fans in Greece Related to the Remnant Pindos Ocean Closure in a Trench during Paleocene and Later in a Rift during Miocene Time

The early Tertiary renewed crustal compression initiated eastward subduction of the remnant Pindos ocean basin, where submarine fans were accumulated, from Paleocene to early Eocene. Palaeocurrent data show mainly a south direction that indicates a longitudinal transportation, along trench, that typifies trench sedimentation. Submarine fans are characterized mostly by inner fan deposits. The absence of outer fans could be attributed either to a confinement of sediments within the trench or preferential subduction of outer fan sequences. The presence of high-energy lithofacies, conglomerates and thick coarse-grained sandstones with lithic fragments at their base, are typical of a trench environment due to the steep gradient of the slope. The presence of thick muddy sequences record deposition from large muddy turbidity currents induced by ponding and interaction of the flow with the topographical confinements of the trench (elongate depressions formed by normal faulting along the outer trench wall). Finally, these deposit deformed into close synclines and anticlines that are typical features of an accretionary prism. Dating of the studied deposits show a stratigraphic gap from early Eocene to late Oligocene, that could be related to the closure of the Pindos ocean and the continent to continent collision, with the development of the Pindos foreland. On the other hand, the presence of Miocene deposits could be related with the development of a rift in the Pindos zone, where submarine fans were accumulated due to the migration of the foreland bulge, both westwards in the Pindos foreland and eastwards in the Mesohellenic basin.

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Integrated Crosswell Seismic-Advanced Technology to Improve Reservoir Description in Belayim Field (Egypt)

This paper describes the results achieved applying the Integrated Crosswell Seismic (ICS) technology in Belayim Field (Egypt). ICS is an innovative methodology to improve the de-scription of the internal geometries of the reservoir between two or more wells.

In December 2001, TomoSeis Corporation acquired Crosswell Seismic Data in the Belayim Land field as part of a reservoir characterization project being conducted by AGIP and Belayim Petroleum Company (Petrobel).

Seven wells were prepared by Petrobel, resulting in the acquisition of five complete cross well profiles. The well spacing between these wells varies from 200m and 835m.

The cross well profiles were designed to be able to:

1. Define the structure of the horst in the Belayim formation
2. Provide a high resolution image of the zones IIA through IV
3. The ultimate goal is to help deter-mine why production varies be-tween the different wells by im-aging the pro-posed fault east-west fault zone and the production zones in detail

The interpretation of the final seismic profiles allowed to recognize sub seismic faults not visible on a conventional surface 3D seis-mic survey, and lateral velocity variation attributed to the facies variations.

The new structural features were used to update and verify the current geological model.

A new dynamic model based on the updated geological one, will be built allowing us to define and plan with more confidence and accuracy a new injection pattern and location of new producers.

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Application of GIS and Modelling Tools in the Environmental Management of E&P Activities: The ENGIS Project

The management of the environmental protection in oil exploration and production operations deals with a whole range of activities which are all site or asset geographically related. The range of these activities include, but not limited to, environmental impact assessments, environmental engineering, atmospheric emissions, modelling and forecasts of geodynamic phenomena, environmental geology, biodiversity, acoustic wave and vibration-induced pollution, meteorology and oceanography, site remediation activities, audit and risk assessment, hydrocarbon spills preparedness, HSE management systems, research and development projects and all these activities

The ENGIS (Environmental Geographic Information System) project is designed to use and apply the GIS tools as integrated information system to support environmental operational, management and field activities in E&P operations representing and quering the above data on asset and geographic basis. The result of the project will be the development a pilot case to be used as a reference to enhance and support the management of the environmental data and activities at headquarter level in the overseas subsidiaries.

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Petroleum Potential of the Gemsa Basin, Southern Gulf of Suez, Egypt

The onshore Gemsa Basin is a large northeast-southwest trending half graben in the S. Gulf of Suez. It remains under explored, but could have the same hydrocarbon generative potential of the prolific offshore half-grabens in this part of the Gulf.

The thick sedimentary section consists of Pre-Rift and Syn-Rift rocks of Cretaceous to Recent age, separated by significant unconformities and deposited under varying depositional environments. Five organically rich, fine grained units within both pre- and syn-rift sequences are recognized as potential source rocks, with the main ones being mature for hydrocarbon generation. Expulsion from the Cretaceous source rocks (Sudr & Brown Ls) began 5 to 7 million years ago, and from the Miocene (Kareem & Rudeis fms) between 3 to 5 million years ago.

Thermal and burial history modeling, calibrated to a data base of measured kerogen and maturation parameters, was done on several basinal wells in the area, as well as on hypothetical 'pseudo wells'. The results indicated the amount of hydrocarbon generated exceeds the proven hydrocarbon volume found to date in the vicinity of the areas of maturation. Therefore, significant potential remains for commercial hydrocarbon discoveries in the Gemsa Basin.

Due to a very thick overburden of evaporitic rocks, the present day seismic data are not of adequate quality or resolution to accurately image potential stratigraphic and/or structural traps. Recent advances in seismic acquisition and processing technology is expected to improve the image of the subsurface. Multidisciplinary integration of this new data with other exploration tools should yield a new prospect inventory for this basin.

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**The Ranim Diapir - Active Salt Diapirism and the Relationship of Salt Structures to Sub-Salt Exploration Targets.
Southern Gulf of Suez, Egypt**

Non-piercement salt structures are widely recognized at many localities in the Gulf of Suez, but piercement diapirs have only recently been documented at Ranim Island and SW Gebel el Zeit. Both types of structures may bear a genetic relationship to major petroleum-trapping structures in the sub-salt section; sub-salt traps are otherwise difficult to interpret due to the detrimental effect of the deformed salt on seismic data quality.

Recent drilling confirmed the existence of a diapir adjacent to Ranim Island. Recumbent folds and thrust faults were formed by flow of Belayim Formation salt into the overlying Hamman Faraun Member and the South Gharib Formation salt. This contradicts the previous interpretation, that salt structures were formed by subsidence ("down-building") related to withdrawal or removal of the South Gharib salt.

The spatial relationship between salt structures and sub-salt faults at Ranim suggests a possible genetic relationship between salt structures and sub-salt faults. Such a relationship could be used to develop predictive models of sub-salt structure, and particularly the locations of the edges of tilted fault blocks that are the primary petroleum traps. Current improvements in seismic data processing make it possible to better image sub-salt structures, but the most powerful technology - pre-stack depth migration - requires as input a high-quality structural model to constrain the lateral velocity field.

Continued refinements in seismic data quality and the use of salt structures as indicators of sub-salt faults will help delineate additional exploration opportunities and reduce exploration risk in the established southern Gulf of Suez producing province.

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3D Seismic Depth Imaging As An Approach To Improve Pre-Salt Structures, Ras Garra Area , Gulf Of Suez , Egypt

The Ras Garra Development lease is located on the southern part of the Gulf of Suez,
The exploration activity started in this area by acquiring the first 2D Marine seismic survey in the Gulf of Suez in 1955.

In 1995 , the area of interest was covered by 3D seismic survey (220 sqkm) to optimize field development and exploitation.

The primary target is represented by pre-evaporitic sedimentary Miocene sequence . The impact of the presence of salt bodies on the seismic image in Time domain is relevant, it affects the ray path, producing a deviation of the ray, reduces the penetration of the energy under the salt layer and produces a pull-up effect under the salt. This makes difficult the correct definition of the fault heaves, his position and the dip of the reflectors, increasing the uncertainty about the size and the spatial position of the prospects.

Owing to the structural complexity, due to the presence of an irregular salt body above the target, we followed an approach based on depth imaging: the construction of a Velocity Volume and a full 3D Pre Stack Depth Migration (3D Pre SDM).

The final depth migrated 3D seismic volume showed a general improvement of the image of the subsurface:

- New structural features were indeed highlighted in the Pre-Evaporitic sequence.
- A better definition of the normal faults pattern that created the trap system in the area.

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Additional Wildcat Exploration targets in the Deeper Pre-Cambrian Basement Complex of Gulf of Suez and North Red Sea Region, Egypt

The authors in this paper believe that there is a potential geologic chance, to be highly considered by petroleum explorationists, for petroleum to be migrated and trapped in the unexplored, deeper, (highly fractured, highly altered, possibly layered, faulted and folded) older Precambrian basement complex system. This is likely as a stand-alone petroleum trapping system, apart from the Miocene and pre-Miocene sedimentary system, or combined. There are four main assemblages, which constitute nearly all of the Precambrian basement complex section in the Northeastern Desert. These are (1) Hammamat Formation (2) Dokhan Volcanics (3) Dikes and (4) Plutonic granite and granodiorite. Southward, across a major structural discontinuity trending southwest, the basement is very different and is characterized by the presence of ophilitic ultramafics and banded Fe-formation, and southwest trending shears. The basement masses, in the adjacent surface outcrops (Gebel El Zeit, Ush El Malaha, Araba-Durba etc) and subsurface are generally extensively fractured. The exposed fracture systems are mainly arranged in two perpendicular sets oriented in northeast varying trends. Some fractures are characterized by steep to vertical inclination, others are gently dipping and some are subhorizontal. Petroleum was discovered and produced from the top 300 to 400 meter of the fractured basement complex reservoir system (egs. Zeit Bay, Geisum, Ashrafi, Magaweesh,..... etc Oil Fields). Last, but not least, not all the above mentioned basement complex sequences were reached or drilled, accordingly the authors recommend to drill a parametric well to test the footwall block of one of these mountain range blocks (e.g. Gebel El Zeit, Nazazat - Ekma, Araba-Durba, ... etc).

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Hydrocarbons in the Mediterranean Rim Countries

The poster should give an overview of the Mediterranean littoral countries regarding the hydrocarbon environment, the differences of the energy-deficient Mediterranean Europe and the hydrocarbon-rich North Africa/Near East. As regards hydrocarbon reserves, production and consumption the countries around the Mediterranean Sea belong to an important economic area. Their combined share of world hydrocarbon resources is in the range of 2 % and 4 %, concerning world reserves at about 4 %.

The common reserves of crude oil and condensate of the Mediterranean countries reached nearly 50 billion bbl, the natural gas reserves ca. 8,000 billion m³. In 2001 the Mediterranean countries produced more than 4 million b/d of crude oil and condensate and 131.8 billion m³ of natural gas. Libya, Algeria and Egypt are the dominating oil producers while the main gas producers are Algeria, Italy and Egypt.

The distribution according share of area, population, consumption, production, reserves and resources is different between European and North Africa/Near East countries.

The tectono-sedimentary framework of the Mediterranean region is widely described by different authors

The petroleum systems obtain a wide stratigraphic range from Silurian to Oligocene-Miocene times.

The pipeline network for oil and gas in the European part of the region is well developed, thus the Mediterranean region is connected with sources in the North Sea, Russia, the Middle East and North Africa.

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Impact of Regional 3D Seismic on Understanding Complex Rift-Related Deformation: Southern Gulf of Suez, Egypt

The B-Trend of the southern Gulf of Suez, Egypt, is a prolific structural trend with several moderate sized oil fields and significant additional potential. Our current exploration effort is focused on the pre-rift section in rotated, normal-fault bounded blocks.

Previous 3D interpretation in the area were based on several small field-size post-stack depth-migrated 3D surveys. Data quality was hampered by limited aperture and multiple interference which severely degraded the image beneath the shallow, multiple generating, Miocene evaporite section. Steeply dipping fault blocks were very poorly imaged. The interpretation of these datasets emphasized a NE-SW cross fault trend as the main control on individual hydrocarbon pools within in the larger rift-parallel trend.

We recently acquired a regional 3D survey covering the southern Gulf of Suez, and the entire B-Trend. The new survey was both post-stack and pre-stack depth migrated and showed major improvement in imaging compared to previous data, as well as a significantly expanded view of the structural trends away from the existing fields. The new regional interpretation suggests that a N-S fault orientation has significant control on the major structural traps, with less emphasis on the previously identified cross-fault trend. This later interpretation is supported by outcrop observations on the exposed, western rift margin.

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Mercaptan Iso-Containers a New Substitute to Barrels Filling System for the First Time in Egyptian Gas Plants

For the first time in the Egyptian gas plants, Iso-Containers were used in W.D.G.C. to make-up the Plant Ethyl Mercaptan storage tank

The new filling system is done without any mercaptan contact with the atmosphere, one hose is connected between the plant storage vessel and the Iso-Container and another hose is connected between plant fuel gas and the Iso-Container.

Make-up gas pressure is applied to the Iso-Container, forcing the liquid Ethyl Mercaptan to flow through the liquid hose to the storage vessel.

The barrels system requires more costs for washing every single barrel with soda ash as well as the spilled pump, floor and connections, also cost for dumping the empty barrels (Dumped by burial).

Losses of Ethyl Mercaptan are a common practice during barrel evacuation (1%) due to evaporation, spills and residual amounts in every barrel.

From our previous experience, make-up with 50 bbls from barrels took one working day, meanwhile, make-up with 200 bbls from Iso-Containers lasted for 1/2 working day only. That is about 8 times.

Handling 2 Containers annually is much more easier and more safe than handling 200 barrels.

The closed transfer system caused no fumes evolution to Environment compared to the barrel open transfer system, which irritated both plant personnel and community.

No storage space is needed for Mercaptan barrels, Mercaptan is a flammable material requiring special storage conditions.

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Increasing Exploration Successes Utilizing New Single-Sensor Seismic Towed Streamer Acquisition Technology

Significant improvements have been made over the last two decades in 3D seismic imaging that lead to large oil and gas discoveries in various geologic basins. These improvements have, however, more or less completely focused on increased efficiency of hydrocarbon exploration.

As oil and gas fields become mature in terms of their production life, better understanding of the reservoirs is required to maximize hydrocarbon recovery and optimize the net present value of these fields. This paper presents seismic data from well known fields in the Gulf of Mexico and North Sea, where revolutionary new seismic technology has been applied to significantly improve the seismic resolution, amplitude accuracy and imaging quality of the reservoirs.

Seismic has not only revealed the subsurface in exploration but also has become a useful tool for reservoir management to map detailed, complex reservoir features like thin-bed and fault resolution, fluid saturation and lithology discrimination. This will require true amplitudes preservation, spatial as well as the temporal sampling of the data, and development of new data processing and analysis algorithms with sufficient confidence to influence decision making in exploration and reservoir management.

Several case studies will be presented and are based on careful analysis of earlier seismic from the fields, which enabled us to set appropriate quality requirements and specifications for the seismic imaging.

The data acquisition was performed using a new revolutionary seismic system. This system has the capacity to receive and record seismic data from each individual hydrophone, to actively steer the seismic streamers laterally to keep the cross-line spatial sampling close and constant even under the influence of cross-currents, and to measure and compensate for variations in the seismic source signal from shot to shot.

The new single sensor towed streamer technology provides high quality seismic data required for efficient and optimal drilling and production of a reservoir.

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Technology Applications in E&P

No Abstract

Ali Mohamed Bakr¹, Fred Wehr¹, Sheldon Plahn¹ (1) Apache Egypt, Cairo, Egypt

Application of 3-D Versus 2-D Velocity Model: Implications of Depth Conversion Hayat-Yasser-Kenz Fields (Khalda Concession, Western Desert, Egypt)

Multiplying a simple 2D velocity grid by a time grid to generate a depth grid can result in inaccurate predictions of geological tops, faults, fault patterns, and reservoir volume. This paper addresses the problem and demonstrates the value of 3D depth conversion in the Khalda area.

Apache has acquired approximately 2500 km² of 3D seismic data in the Khalda Concession in the Western Desert of Egypt. Hayat, Yasser and Kenz are major oil fields in the Khalda concession, producing from reservoirs in the Bahariya and AEB Formations (Cretaceous). Three main 3D velocity models were constructed over Hayat-Yasser-Kenz and compared to the 2D estimating method. The three 3D velocity models are: (1) stacking/migration velocity (using only seismic stacking velocities), (2) time-depth velocity (using only time-depth pairs from wells data), and (3) migration velocity calibrated with T-D pairs (using both stacking velocities and well control).

Calibrated models provide more reliable results, including a more accurate tie to wells as well as a more structurally admissible fault pattern. The entire seismic data set, including traces, horizons (time), and faults are converted to the depth domain using the proper velocity model. This enables much tighter integration of seismic interpretation and well data.

The reservoir depth map out of this volume was used for validity check and it shows \pm (10 feet) prediction error. Results confirm more reliable well top prediction and possible additional propectivity using the 3-D calibrated velocity models versus the 2-D average velocity methodology.

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Enhancing Well Data Sets Using PC-based Visualisation Software

Increasingly oil companies store their well data sets on large-scale Unix databases. Often only petrophysical data along with a selected amount of additional well data is stored. This leaves large quantities of valuable well data in original data formats or worse still as paper logs that are inaccessible to E & P personnel.

Some oil companies are now starting to collate and quality control their data from these various sources using a PC-based visualisation software chosen for its flexibility and ease of use. Once the data is displayed and verified it can be saved as industry standard image files for archiving or for use in other applications. In addition the data that has been gathered from alternative sources can be exported to the corporate database to be stored as a more comprehensive well data set or for use in reservoir modelling packages. Fields worth of data can then be presented in a web-enabled interface on CD or on a corporate intranet making data and images readily available to all E & P personnel.

Once complete the oil company has gained in two main areas: firstly, existing well data on the company database has been checked and if necessary repaired and expanded, and secondly, the data is available both electronically as digital data and image files and as new high quality hard copy logs.

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Geochemical Fingerprinting of Oil Seeps in the Southern Part of the Gulf of Suez and its Geological and Archaeological Implications

Molecular geochemical properties of crude oils and surface petroleum seeps from the southern part of the Gulf of Suez were evaluated. The characterizations of individual aliphatic, aromatic, and biomarker compounds were based on gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS) analyses. The results provided a strong evidence for a close genetic association of these samples. The geochemical characteristics suggest an origin from Tertiary source rocks deposited in a normal marine environment that received continental runoff. The molecular signatures of the investigated samples were very similar to those of the Lower Miocene Rudeis Formation source rock in the southern part of the Gulf of Suez. Further, biomarker fingerprints of the investigated oil seeps were compared with those of the Dead Sea asphalt as well as the bitumen from some Egyptian mummies reported in the literature. The results suggest that the oil seeps from the southern end of Gebel El-Zeit may have been used by the ancient Egyptians for embalming.

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Paleo-Oil Migration and Charge Modeling of the Murzuq Basin, Libya

The Murzuq Basin of southwest Libya is a saucer-shaped intracratonic sag bounded on three sides by prominent structural highs, each with a wide Paleozoic outcrop belt at high topographic elevation. Basin fill is predominantly Paleozoic and Mesozoic sandstone and shale, with rare limestone. The main petroleum reservoir is the upper Ordovician Memouniat sandstone. The primary source rock is the Silurian Tanezzuft shale.

Basin modeling indicates that in the various depocentres of the basin, high TOC shales of the Tanezzuft Formation have been oil generative since late Devonian. Oil migration patterns have changed in response to evolving basin structure and patterns of water flow. Since the basin was uplifted above sea level following the Hercynian Orogeny, meteoric water recharge has complicated the pattern of oil migration and introduced the risk of flushing. Given these complexities, hydrodynamic modeling is a useful tool for reducing exploration risk.

By modeling the evolving hydrodynamic framework of the Murzuq Basin, oil migration patterns in the Memouniat reservoir were mapped for four distinct "snap shots" in the basin history:

Present Day

Holocene (10,000 y BP)

End Cretaceous (c. 65 my BP)

End Carboniferous (c.286 my BP)

Reservoir structure, hydraulic head and oil kitchens were mapped for each time step as inputs for Dynamic Oil Migration Modeling. The Dynamic Oil Migration Maps reveal charge fairways and shadow zones (regions of no-charge) for each time step. Despite the symmetrical basin geometry, charge fairways are surprisingly restricted and large parts of the basin never received oil charge.

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From Field Tapes to 3D Depth Volume in 2 Months: A Challenging and Successful Project in The North Bardawil Area

In the North Bardawil Concession area, operated by IEOC, the exploration target is represented by the turbiditic sands beneath the Messinian Evaporitic complex. Their seismic image is heavily affected by the overburden velocity variations and only a correct depth imaging approach can remove these distortions clearly visible in the time volume.

A depth imaging project was then started with the main target of resolving the depth positioning of the seismic reflectors. This objective would have required a careful velocity analysis and a proper depth migration. Another strict constrain was its time schedule: due to exploration obligations the whole depth imaging project was due to be completed in two months. Then a work flow was designed to try to accommodate either the quality requirements and the short time frame. Since the construction of a detailed velocity volume could only be achieved via a velocity analysis in the depth domain, 31 seismic lines were extracted from the relevant 3D survey, processed from field tapes to deconvolved CMP gathers, further improved in the pre-stack depth domain and used to derive a consistent 3D velocity volume. A 3D Post Stack Depth Migration (PoSDM) algorithm was applied to the stack volume producing a depth volume down to 7800 m, over the 800 sqKm of the 3D survey.

The strict cooperation between time processors, depth imagers, geophysicists and geologists coupled with the availability of adequate computer facilities proved to be the winning factor for the successful completion of this challenging project.

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Tomography for Near-Surface and Imaging Velocity Determination – Examples from the Western Desert in Egypt

The accurate determination of the velocity distribution in the subsurface is probably the single most important part in the long sequence of processing steps. In land surveys velocities impact the noise patterns, the amplitude behaviour, the static and dynamic distortions. In general processing attempts to correct for these effects with velocities that are individually tuned.

Noise attenuation and amplitude correction velocities are spatially smooth or even constant. Near-Surface velocities for static corrections require much more detail if their effects on the timing of structures are to be reliably resolved. The velocity model that is used for depth imaging generally undergoes various iterations and is the most difficult yet also the most important part of the velocity puzzle.

This paper will concentrate mainly on the near-surface and depth imaging velocity models and the tomographic approach to derive them. For the near-surface model first-arrival times are raytraced and inverted for slowness updates in a cell-based model. Similarly for the depth imaging case a cell-based model is used to compute slowness updates derived from user-supplied velocity information. This velocity information is much easier to obtain and more readily available in routine processing than reflection time picks from prestack data which requires good data quality and is very time consuming.

Examples of the techniques are shown on data from the Western Desert in Egypt with a discussion of specific issues that were encountered during processing.

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Conditions of Forming Stratigraphical Traps in The Lower Cretaceous Clinoform Complex and Regularities in Their Distribution, Western Siberia

The Lower Cretaceous clinoform complex of Western Siberia is the most prospective oil/gas complex; it contains large and giant hydrocarbon fields in stratigraphical and structural-stratigraphical traps. However, its genesis and structure remain an enigma.

The paleoreconstructions of conditions of forming the clinoform deposits on the basis of interpretation of core data (petrographical, granulometric, petrochemical, paleontological, paleogeomorphological and other researches) and also geophysical data allow definite conclusions:

- Stratigraphical traps are associated with turbidity, avandeltaic, and deltaic deposits;
- The best reservoir rocks are formed by grain streams at the regressive stage of sedimentation followed by the effect of contour currents;
- The most concentration of sorted sandy material is observed on the flanks of paleostructures in the way of grain streams;
- A complex porous-fractured type of reservoirs has the most wide occurrence.

16 sequences of 4 order related to the stages of sedimentary basin starved filling are identified and mapped in the Frolovsky, Kaimyovsky, and Nadym-Pursky oil-gas regions. The maps and schemes of distribution of reservoir characteristics, granulometric coefficients, and the facial environments of sedimentation are constructed. The specificity of forming the Neokomian clinoform deposits in the axial part the sedimentary basin (decrease by 75% of psammitic material entering the basin, absence of continuous areal occurrence of shelf beds; nearly the same amount of clastic material entering both from the east and the west) is shown. The depocenters of arenosity, and the ways of entering grain material are shown. The forecast of forming stratigraphical and structural-stratigraphical traps is given.

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Application of a 3-D Hybrid Seismic Inversion on María Inés Oeste Field, Santa Cruz, Argentina

Application of a 3-D hybrid seismic inversion on María Inés Oeste field, Santa Cruz, Argentina
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Abstract

In this paper, we apply hybrid seismic inversion on a three-dimensional (3D) seismic data set from María Inés Oeste, one of the major oil and gas fields in Argentina. The María Inés sandstones are Paleocene in age, the traps are mainly structural, and the reservoir is about 50 m thick, containing either oil or gas. These oil/gas-bearing sands usually cause anomalously high amplitude bright-spots on the stacked seismic data. These bright-spots were generally used as hydrocarbon indicators for this area. Drilling through these bright-spots has resulted in pay, as well as some dry wells.

Hybrid seismic inversion, a combination of prestack waveform inversion and poststack inversions of some amplitude-variation-with-offset (AVO) attributes, allowed us to demonstrate that the Poisson's ratio, obtained from this hybrid inversion was effective in fluid discrimination and provided successful drilling locations. We also demonstrate that the Poisson's ratio contrast; obtainable from a standard AVO is not as effective in fluid discrimination as the one from hybrid inversion.

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Best Practices for Sub-Salt Imaging

Exploration and development of sub-salt prospects has been a very difficult and risky endeavor because of the difficulty in obtaining a good image of the sub-salt sediments. However, recent advances in computer technology coupled with enhanced and varied depth imaging algorithms have greatly improved the quality of the sub-salt imaging.

To properly image sub-salt sediments, we need to honor the complexities in the propagating wavefield that are generated by the high velocity contrast between the salt and the surrounding sediments. To do so requires building an accurate velocity model that includes: a) the structural details of the top and base salt surfaces, and b) detailed sediment velocities above and below the salt.

Obtaining an accurate and detailed suprasalt velocity model requires sophisticated tools such as tomography. Determination of the salt morphology requires full volume imaging so that small surface undulations are sampled in detail. This imaging method can be either Kirchhoff-based for detecting the existence of very steep or overturned salt flanks or wave equation-based for properly imaging the base salt in the presence of a complex top of salt surface. Such hybrid imaging workflow exploits the best features from each imaging algorithm. Finally, given the poor signal-to-noise ratio beneath the salt, sub-salt sedimentary velocity analysis can only be done in the context of analyzing the seismic image rather than gathers.

The extent to which an interpretable image can be obtained ultimately depends on whether sub-salt reflections have been recorded in the first place. Sophisticated wave equation-based illumination analysis tools can be used to analyze an existing or any planned survey in the context of sub-salt illumination of sedimentary reflectors.

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What is the Benefit of Using Prestack Attributes

It is becoming coming common practice to perform 3-D prestack inversion of iso-offset or iso-angles cubes, in order to estimate elastic parameters such as P- and S- impedances at the reservoir level. In particular , S- attributes should provide information on the reservoir parameters complementary to the information derived from P-attributes.

In the context of prestack attributes, four question arise. (1) What is the amount of non redundant information provided by the S- attributes ? (2) What are the best parameters (such as impedances and Lamé parameters) for interpreting prestack attributes in terms of reservoir properties ? (3) How to define reservoir properties that are significantly related to the P- or S- information ? (4) What is the impact of the limited bandwidth of the prestack seismic attributes on the reservoir property estimation ?

These questions will be examined in this presentation through a deep-water case study. A general workflow has been proposed to quantitatively exploit the pertinent prestack attributes in relation to the reservoir properties, while assessing the uncertainties of such an interpretation. The workflow involved segmentation algorithms and estimation techniques in a probabilistic frame. It allowed for the derivation of maps or cubes of average reservoir properties, such as porosity or shale volume, and their associated uncertainties. It was an efficient tool for quantifying the benefits of prestack attributes.

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Breakthrough Horizontal Well Length in Gulf of Suez, Egypt

As the longest horizontal well drilled to date in Egypt the East Zeit A-19 well in the Gulf of Suez has measured up to expectations of flow rates and sustained production. The well was drilled by Ocean East Zeit Petroleum Company from the East Zeit "A" platform in the central southern Gulf of Suez to exploit the Miocene Kareem Formation, a prolific producer in many fields in the Gulf. The Kareem Formation is characterized by a series of stacked sands deposited as regressive submarine fan deltas that prograded over and downlapped onto the Upper Rudeis. Since only poor quality vintage 2D seismic was available over the East Zeit field during prospect generation the entry and exit points of the horizontal section had to be derived by numerical models using existing well data that integrated geology and reservoir parameters.

A well of this technical complexity required an integrated team effort between geologists, reservoir and drilling engineers and service companies. Successful drilling using eccentric tools that allowed simultaneous reaming and drilling with steerable assembly (SRWD), allowed the 2700 foot horizontal section to be drilled using robust MWD/LWD tools at the most economic cost without sacrificing data gathering. A pre-slotted 5 inch liner was hung uncemented off the 9 5/8 inch casing. Once the well was turned on the field production increased from 7,100 to 14,392 bopd. The A-19 well has produced over 4 million barrels of oil to date making it one of the most prolific wells in the East Zeit lease.

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Prediction of Potential Reservoir Bodies from 3D Palinspastic Restoration

Structural restoration is an established method by which to validate seismic interpretations. In addition, palinspastic reconstruction can help identify potential reservoir depocentres, enable the measurement of catchment areas at the time of hydrocarbon migration and lead to an improved understanding of complex hydrocarbon systems such as those in the deepwater, offshore Nile Delta.

Accurate identification, quantification and risking of prospects set within complex channel systems are challenging tasks. Palinspastic restoration offers a means by which these challenges can be met, as well as revealing the geological evolution of the system. Restoration is achieved by the sequential backstripping of the present day depth model. Upon removal of each successive layer, the remaining surfaces within the model are adjusted to account for faulting, decompaction and isostatic adjustment. Using the complete palinspastic history gives significantly different result than simply using isopachs and palaeoisopachs alone. Lateral variations in sediment thickness will result in non-uniform changes to the surfaces furthermore local variations in sediment porosity can be accounted for by application of attribute maps. Down-dip sediment dispersal on the back-stripped surface delineates the palinspastic accommodation space for a range of spill thicknesses and reveals potential reservoir body locations. Conducting up-dip hydrocarbon migration analysis, prospects can be ranked in order of volume and risk. On correlation with proved fields, this technique can be extrapolated to frontier areas and used in risk reduction in high cost deepwater exploration.

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Opening History and Structural Evolution of the Northern Red Sea Based on Integration of Outcrop, Well and Seismic Data: Implications to Hydrocarbon Exploration

The opening of the Red Sea occurred in three phases: 1) formation of Early Miocene half-graben linked by accommodation zones, strongly influenced by pre-existing basement fabrics. 22-24 Ma old dikes and fault kinematics indicate that the extension direction was N55E (rift orthogonal). 2) development of a triple junction at the southern end of the Gulf of Suez at 12-14 Ma. The new extension direction was N15E (oblique rifting), parallel to the Gulf of Aqaba transform. Massive halite was deposited throughout most of the basin due to closure of the seaway connection to the Mediterranean. 3) Latest Miocene to Recent formation of an axial bathymetric trough underlain by highly extended and magmatized continental crust. The axial trough is segmented by incipient fracture zones that parallel the Gulf of Aqaba, as at Zabargad Island. Individual segments of the axial trough are slightly oblique to the Miocene rift trend in response to the rotation of the regional extension direction. Salt ridges formed along both margins of the Red Sea, trapping post-salt sediments in rim-synclinal basins. This resulted in a starved axial region, where the salt maintained a sub-horizontal upper surface despite extensive faulting at depth. Large areas of both margins are collapsing into the deeper basin via gravity faults that detach within the Miocene salt. The hydrocarbon systems operating in the northern Red Sea are within the Early Miocene section. Hence, a key to exploration lies in separating the effects of phase one deformation from those of the younger events listed above.

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Age of Rifting of the South Caspian Basin: Inference from its Margins in Azerbaijan and Iran

The age of the first deposits in the deep (20 km) central part of the South Caspian basin (SCB) is not known. Moreover, the basin being probably underlain by an oceanic crust, the first steps of the basin's evolution, before opening (i.e. the rifting phase) are not present and not possible to analyse in the central basin. Therefore, in order to characterize the rifting phases and to infer the timing of oceanic opening, the study is focused on some tectonic units surrounding the SCB (in Azerbaijan and especially North Iran) which were formerly margins or prolongations of the SCB. Subsidence analysis is combined with tectonic and geodynamic reconstructions.

A calendar is deduced of the SCB evolution from the analysis of tectonic subsidence on its margins. The data on the Alborz show that the rifting phase on the southern margin of SCB took place in Early? to Middle Jurassic at the same time as the opening of the Great Caucasus Trough which occurred since Sinemurian (?). Its north margin was prolonged into the SCB northern margin, towards the Great Balkhan. The Callovian-Late Jurassic phase of subsidence mainly seen in the basinal area and in the lateral extensions of the SCB seems to indicate the beginning of oceanic opening. This opening worked in the frame of an important back-arc extension of a very long basin behind an arc, supported by the presence of an important Middle Jurassic volcanism going from Pontides to Alborz through the Lesser Caucasus.

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E&P 3D Seismic as a Tool for Shallow Hazards Detection

In deep and ultra-deep water the use of an E&P 3D is a cost saving alternative to a traditional well site survey. Conventionally processed 3D seismic cubes are often inadequate for detecting the features generating hazards and so a special reprocessing is needed for increasing their overall frequency content and consequently the vertical detail; also spatial resolution is improved using bin interpolation. Once achieved the necessary quality in the seismic data, the following 3D cubes are produced:

- 1) Migrated seismic volume: it is used for detailed seismic stratigraphy and shallow layering definition; potentially dangerous levels or objects are here identified as function of amplitude, geometry and structural features. Water bottom bathymetry is also produced.
 - 2) Velocity cube: it is used to for the depth conversion of the previously defined layers and for pore pressure prediction.
 - 3) Pressure cube: it is calculated from the above velocities and gives the pore pressure development along well trajectory
 - 4) Continuity cube: it is necessary for a very detailed geometrical characterisation of the potentially hazardous features. From the continuity cube the geomorphology of the sea bottom is usually extracted.
 - 5) Acoustic inversion cube: it is used for lithology and fluid prediction in the investigated levels
- The final result of the studies performed on a E&P 3D survey is the production of a tophole prognosis chart that identify both the hazard percentage and the pressure development as a function of depth.

. Cai Gang¹, . Qu Zhiyi¹ (1) Geophysical Engineer, LanZhou, GanSu Province, China

Study of Seismic Data Velocity and Mapping Method in Complicated Structure Area and Its Application

At present, seismic data interpretation, velocity analysis, time-depth conversions usually are completed on one interpretative software. As we know, every interpretative software application has its advantages and disadvantages. Only using one kind of interpretative software in complicated structure area can't meet the needs of each work assignment. We analyze the advantages and disadvantages of two mapping modules CPS-3 and Z-Map Plus in GeoQuest and Landmark respectively. The functions of the velocity analysis module InDepth have been perfected and data transmission between CPS-3 and Z-Map Plus was achieved. With in a complicated structure area of inconsistent datum plane between seismic section and velocity spectrum, a new method of time-depth conversion has been used to make the structural map. A 3D velocity field of high accuracy is found and time-depth conversion is completed on a datum plane of velocity spectrum to make the structural map by combining CPS-3 and Z-MAP Plus. Three dimensions visual software Earth Vision is applied to display final structural map. This method was applied and achieved success in the C area.

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Lessons Learned and the Way Forward In DW Drilling as a result of Shell/Bapetco's 1st drilling campaign in NEMED

The Shell Egypt Deepwater Services Well Delivery unit, seconded into JV company Bapetco established a DW drilling record for Egypt when 2 DW vertical exploration wells were drilled in 2001, in 1500 m and 1800 m Water.

The Phase-1 operations resulted in a wealth of lessons learned.

With ample time to address the issues the Bapetco's DW department did not only find the answers to long outstanding operational issues, it also went a step further and worked on new developments, technology and practices.

One of the most important steps in any operation is to learn from the previous operational experiences and to build up the proper learning curve. The learning curve is the methodology to be used in planning for the upcoming activities. This will lead to overcoming the problems faced in the previous operations and to apply the proper technology and solutions. From this understanding, the previous experiences that Bapetco had in the two Deep Water wells, Shorouk Ki-69-1 and Leil Kg-61-1 are discussed.

First a list of Highlights and Low lights are presented. With 80% of the NPT experienced in 2 area's the learnings wrt Hole condition & MDT issues are explained. Latest a series of new developments, technology and practices are discussed.

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Innovative Semi-quantitative AVO Modeling and Analysis to Reliably Predict Hydrocarbon vs. Brine Occurrence In Sand Reservoir

The case concerns an advanced AVO analysis study, carried out in an exploration area in the Mediterranean offshore, where the need of a reliable tool to rank a number of possible prospects was an issue. The request for increased reliability of the AVO method, capable of quantitatively predicting, also in terms of probability figures, the distribution and characteristics of fluids, or even the petrophysical characteristics of the reservoir was then set as a leading development goal.

This has been targeted through a probabilistic inversion of AVO data, based upon a stochastic AVO modelling, that allow "intelligent" extrapolation of known AVO information from the wells to predict reservoir fluids in any exploration scenarios.

This ENI-Agip proprietary "Fluid Inversion" methodology, is focused to estimate the probability that an assigned AVO response can be reliably ascribed to the presence of either brine, gas, oil in a sand reservoir.

The developed software compares the real AVO responses at the several targets with a generalized model, which takes into account the expected variability of all the petrophysical parameters involved into the AVO phenomenon. This model is developed through a statistical analysis of all borehole data in the study area.

The methodology allows an effective and powerful extrapolation of the AVO information, modelled at the well, to any new target belonging to an homogeneous geological-petrophysical scenario, even at different burial depth. The resulted fluid probability maps represent a new way to leverage pre-stack seismic information to benefit the interpretation accuracy and prospect generation process.

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Petrophysical Characterisation of Lower Palaeozoic Reservoirs of Saudi Arabia: An Insight into Factors Controlling Reservoir Quality

There is significant conventional and tight gas potential within the Lower Palaeozoic clastic reservoirs of Saudi Arabia and a number of prospective, sand-prone intervals have been identified in Silurian to Cambrian section. This interval is relatively under explored, but often has encouraging hydrocarbon shows and well tests. Using a very extensive database, the authors have identified the principal factors controlling reservoir quality. This has implications for future exploration in Saudi Arabia.

Sedimentological and petrological data were collected from core, logs, and outcrop in order to identify significant petrophysical trends and relationships and better understand the factors controlling reservoir quality. Core porosity, permeability, and capillary pressure trends have been identified and related to depositional facies and depth of burial.

The variable burial and temperature histories of the sandstones result in significant diagenetic control over porosity and permeability. Key factors detrimentally affecting reservoir quality include at least two phases of quartz cementation and pervasive illite cementation. In deeply buried sandstones (>12,000 feet), illite rich reservoirs are typified by dominant (ineffective) microporosity and low permeabilities (<0.1 md). Much higher permeabilities (locally >1000 md) are recorded in less deeply buried sandstones where pervasive illite cementation is not present. Burial history models and fluid inclusion data have been used to constrain the time of quartz cementation and relate it to time of hydrocarbon generation and migration.

Enhanced reservoir quality is encountered in areas where early diagenetic development of chlorite grain coatings has inhibited subsequent quartz overgrowth cementation, and where intergranular porosity has been supplemented by feldspar grain dissolution.

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Fracture Permeability Evaluation in Bouri Field

Aim of this paper is to describe the methodology applied to the study of fracture permeability in Bouri field (Libyan offshore). In this field, fractures give an important contribution to productivity. This is evident considering well tests interpretations; moreover, dynamic data show how the intensity of the fractures decreases far from the main discontinuities.

In the past these phenomena had been modelled using permeability multipliers near the faults and in correspondence of the wells with high Kh. This approach involved a remarkable uncertainty in the western zones where well data are few; therefore a different methodology has been tuned.

This methodology is based on the interpretation of data coming from different sources: 3D seismic, well tests and core analyses. The first phase was the creation of a database comprising the geometric characteristics of the faults; then they have been analysed to point out homogeneous groups. The next phase was the analysis of the spatial distribution of the faults (seismic and subseismic) and led to the processing of a fracture intensity map (P21). Then P21 average value has been calculated for all the wells on a circular area whose diameter is function of the drainage radius of the well itself. The P21 values obtained have been correlated with permeability from tests and cores. Based on this correlation, permeability maps were drawn and they have been introduced into the dynamic simulator. A satisfactory history match has been obtained in a shorter time through minor changes.

Pietro Cavanna¹ (1) ENI Agip Division, N/A, Italy

ENI's Gas Operations and Strategy in the Mediterranean Area

A brief outlook of the main gas activity, results and goals in the Mediterranean area is presented. Italy's geographical position in the Mediterranean Sea is a natural condition to be a reference point for the development of gas projects along the North African coastline.

Three case histories are then discussed: Italy, Egypt and Libya.

Italy represents the first country where gas has been explored and developed since the 1950s, with significant discoveries, an important storage system and a 29,000 km pipe network.

In Egypt, IEOC made its first gas discovery in Abu Madi onshore field in 1967 and developed the first gas clause. In the 1980s, several discoveries were made in the Egyptian offshore.

In Libya, even though the target was traditionally oil-prone, the first gas discovery occurred in the NC41 area in 1976. However, it was only after negotiations with NOC that an agreement was signed in 1999 with Libya's state-owned company to develop gas resources in NC41 and Wafa fields for an export project by realizing a challenging gas transmission system connecting Libya to Sicily.

Therefore, as the above mentioned activities attest, Eni is one of the major players in the gas operations and strategies in the Mediterranean region.

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Constraining Geostatistical Reservoir Models with Seismic Attributes

Complex seismic trace analysis appeared with the advent of seismic sequence stratigraphy in the mid 1970s. Vail and his colleagues expected that seismic attributes would eventually quantify their seismic facies parameters. Since then we have seen a proliferation in the number (hundreds) and often times an inappropriate use of seismic attributes for reservoir characterization. Efforts to understand the meaning of the plethora of seismic attributes include the use of linear and non-linear techniques, such as Fourier spectral analysis, Principle Components, Discriminate Function, neural networks, and others. The idea was that perhaps combinations of attributes might make sense when individually the attributes lacked clear geological significance, except that they revealed some sort of pattern. Most of the attributes are highly correlated simply because they are derivatives of one another and there is no guarantee that their correlation with a reservoir property is meaningful. Great care must be taken when choosing seismic attributes, because it is not unusual to find spurious or false correlations that do not reflect any physical basis for the relationship and the probability of finding false correlations increases with the number of seismic attributes considered and is inversely proportional to the number of data control points. It is time to return to "first principles" and establish a clear relationship between a reservoir attribute, be it facies, porosity, or lithology, for example, and a seismic attribute(s).

We illustrate the use of seismic attributes following a four step procedure: 1) Calibration phase, 2.) Choice of the seismic attribute, 3) Cross-validation, and 4) Prediction and Uncertainty Analysis using Collocated Cokriging and Collocated Cosimulation.

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The Taranto Gulf (Deep Jonian Sea): A Future Play for Hydrocarbon Exploration

The interest to explore the Jonian Offshore started on 1971 year, when the Luna gas discovery occurred in the Tertiary S. Nicola dell'Alto Formation. Since that time the exploration has been concentrated along the Calabrian coastline, from the Crati river mouth to Squillace Embayment, inside of the 1000 m. isobath, pursuing the Tertiary plays. However, after the Hera Lacinia gas discovery, on the 1975 year, up to the present time, any large success has been carried out. Therefore to continue the exploration activity in this part of the Italian sea, it needs to consider different plays even if located in deep waters.

The future, for the hydrocarbon exploration in the deep Jonian sea, could be represented by some Apulian Platform upthrusts, in the Taranto Gulf, located below the alloctonous accretionary wedge front and the Plio- Pleistocene overburden of the Taranto Valley. A moderate optimism for such a play, results by : 1) the Val D'Agri oil discoveries in the Apulian Platform; 2) its analogy with the, onshore located, Rotondella structure. On this moderate overthrust of the Apulian Platform, four wells have been drilled, in the past, and small oil quantity were found in two of them. Recently, a new analysis carried out in the samples has shown that the Rotondella oil is related to the Val D'Agri oil family.

Therefore, in the Taranto Gulf area, the existing structural, stratigraphic and geochemical conditions get to hope positive exploration results.

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How Much is Oil Worth?; How Much Can We Spend to Find It?

No Abstract Requested

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Integrated Time-Lapse Reservoir Monitoring: The Amelia Field Case

Time-lapse seismic was used to assess the performance of the Amelia gas field (off-shore Italy) producing under strong water drive.

Objective of this work was the characterisation of main producing sand intervals by integrating two "legacy" 3D-seismic surveys and borehole data. A methodology, developed under the European project HUTS, has been proposed to test the integration of time-lapse information into the Amelia history match loop.

The work consists of these steps:

1. Rock Physics Characterization. The main reservoirs physical properties were defined by extensive core measurements/analyses at reservoir condition.
2. Integrated Time-lapse Processing of 3D-volumes to achieve high repeatability. Seismic processing parameters were determined for the two surveys using wells. Spectral equalization of wavelets in the seismic traces was performed to improve repeatability.
3. Integrated Multidimensional Petro-acoustic Calibration of the 3D-volumes. Microscopic properties of the reservoir rocks together with logs were used to estimate clay-content, porosity, saturation and pressure.
4. Simulator Rescaling and Petro-elastic Modelling. To compare dynamic simulation and 4D-data, the depth-migration of AI-volumes and related scaling to simulator cells were required. Seismic response of reservoirs was simulated through a petro-elastic model that enabled to generate synthetic AI from numerically simulated pressure and saturation distributions.
5. History Match using 4D data. Depth-migrated and simulated AI-data were iteratively reconciled by including a 4D-term in the HM loop.

This approach produced good repeatability between seismic volumes while the qualitative time-lapse analysis of the AI-volumes enabled to visualize fluids movement within the main pools.

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This approach produced good repeatability between seismic volumes while the qualitative time-lapse analysis of the AI-volumes enabled to visualize fluids movement within the main pools.

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Fault Propagation Folds and Relay Zones and Their Influence on the Distribution of Syn-Rift Sandbodies: Examples from the West Flank of the Oseberg Field, Norwegian North Sea and the Hammam Faraun Fault Block, Sinai, Egypt

Fault propagation folds and relay zones and their influence on the distribution of syn-rift sandbodies. Examples from the west flank of the Oseberg Field, Norwegian North Sea and the Hammam Faraun fault block, Sinai, Egypt.

Stephen Corfield¹, Tom Dreyer² and Rob Gawthorpe¹
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Recent research in the subsurface of the Norwegian sector of the North Sea has revealed that relay zones and related hangingwall deformation in the form of fault propagation folds have had a major impact on the distribution of synrift sandbodies. These results complement over ten years of fieldwork by the University of Manchester in Sinai.

In both areas, the growth and linkage of extensional faults bounding tilted fault blocks during the evolution of the rift basin has resulted in a focussed sand supply to the hangingwall depocentres. The main sediment supply route has been via relay zones. Lateral and vertical growth of faults has also resulted in the development of fault propagation folds and emergent fault block crests. Sands are considered unlikely to be laterally extensive in such a complex setting and the outcrop examples indicate rapid lateral thickness variations in relation to the hangingwall folds. These conclusions are supported by 3D seismic data on the west flank of the Oseberg field in the Norwegian North Sea where Upper Jurassic syn-rift sand bodies occur in canyons eroded through relay zones. Extensive use of 3D visualisation techniques (formation sculpting, voxel rendering, virtual reality) coupled with seismic modelling has been used to map the geometry and distribution of the syn-rift sandbodies.

The combination of these technologies coupled with the integration of structural and stratigraphic examples from outcrop has led to an increased understanding of the interaction between fault growth and linkage with the eventual aim of delineating subtle syn-rift plays.

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Pattern Recognition Methodology and Application in E&P Interpretation Flow

A pattern recognition methodology has been developed to optimise the interpretation of complex multi-reflection seismic objects in a 3D domain.

This paper describes the methodology and the applications of implemented semi-automatic techniques that can support the following interpretation activities in the E&P flow:

1) seismic volume pre-screening

the computation of a set of pattern and statistical analysis attributes provide new non conventional parameters that highlight the different seismic texture in the seismic data

2) preliminary pattern description

the description of seismic pattern is performed by the interpretation of a set of cross-plots of couples of attributes; the methodology allows the generation of seismic facies volumes through the definition of "polygons" on those cross-plots which are more suitable for identifying interesting 3D seismic pattern.

3) target oriented pattern classification

more detailed interpretation work is required for characterising the pattern associated with a specific seismic object. This refining work provides a classification of seismic pattern in order to identify in 3D domain the target seismic object.

4) geobody detection

the connectivity algorithm applied to the result of target oriented pattern classification allows the identification of one or more geobodies characterised by "multi-reflection" seismic facies.

5) detailed characterisation of seismic feature in 2D domain

the methodology supports also a data flow focused on 2D domain for a detailed description of the internal pattern of geobodies.

The application of the presented semi-automatic methodology can improve the result of 3D seismic interpretation, offering an approach oriented to the detection of relevant stratigraphic features.

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Characterization of Shear Zones in Porous Sandstone of Sergipe-Alagoas Basin, Brazil

The Sergipe-Alagoas Basin, located in northeastern Brazil, hosts on the border excellent outcrops with very good exposition of deformed rocks, representative of fault zones. The studied outcrop comprises pre-rift fluvial sandstones of Serraria Formation (Neo Jurassic). The absence of detailed information about fault in subsurface made necessary to study outcrop rock analogous with similar conditions of petroleum reservoir, characterizing in greater detail the geometry structure, as well as its petrographic and petrophysical properties, aiming to improve the structural models of fault compartmented fields. Geometrically, the deformation bands present eye-like geometry and high density of deformation bands above of slip plane. Rock deformation occurs through grain comminution without clay, and with low cementation. Band thicknesses vary from millimetric to three-meter thick and may reach up to 3 m in more advanced stages of deformations. Petrophysical experiments show large heterogeneity in permeability values, varying from 3 to 4 orders of magnitude, between deformed and non-deformed rock. Porosity range reaches one order of magnitude. Microscopic analyses in thin section allowed the identification of several deformation bands characteristics, such as fractures and grain orientation, as well as evidence of the generation processes seal structures. Some experiments of capillary pressure set for the sealing capability of deformation bands are as high as 241m of oil column, which make them efficient traps. Initially, the confining pressure causes increase of porosity due to dilation with grain rotation. The deformation increases when the confining pressure reaches fracture level of grains, causing porous collapse, decreasing the petrophysical properties.

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Play Risk and Uncertainty – Probabilistic Modelling of Plays in the Western Desert and the Kom Ombo Areas of Egypt

The hydrocarbon potential of the Western Desert has been exploited for the last three decades and a substantial base of knowledge has been gathered to constrain models. Even so, geologic uncertainties exist that have a dramatic effect on the modeled timing of hydrocarbon generation and expulsion. Deterministic basin models of wells suggest a 53 mW/m² heat flow in the area. The resulting calculated maturity is in good agreement with measured Ro. Yet subtle changes in other parameters using stochastic techniques can vary expulsion timing by up to 80 million years. Clearly, analysis of the whole petroleum system (trap formation, etc.) is necessary to constrain the solutions.

Alternatively, in the sparsely drilled Kom Ombo area of Upper Egypt, the heat flow history is much more uncertain. Furthermore, other uncertainties abound, from facies distributions to source rock properties. In this data poor areas, stochastic modeling is much more efficacious. Here, the full range of geologic uncertainties must be addressed in a petroleum system analysis.

Traditionally modelers have dealt with geologic uncertainties by performing sensitivity analyses, creating multiple scenarios and noting the effects on charge timing; a slow and, oftentimes, limited technique. A stochastic approach to volumetric basin modeling provides an alternative that tests thousands of constrained assumptions creating a probabilistic response. The results that best calibrate with measured data may be extracted yielding the best results from all possible scenarios. The range of calculated hydrocarbon resources resulting from this risk analysis for the Kom Ombo area will be presented.

Mark Cowgill¹ (1) Robertson Research International, North Wales, United Kingdom

The Petroleum Geology and Exploration Potential of the Western Desert Basin, Egypt

The Western Desert Basin of Egypt covers an area of over 1,000,000 km², and can be conveniently separated into two regions: north of 29° the basin is relatively well-explored and comprises a major Jurassic and Cretaceous depocentre; the south of the basin is relatively underexplored and comprises a series of isolated rifts within a relatively stable craton.

In the north of the basin, proven reservoirs comprise Jurassic sandstones and Upper Cretaceous sandstones and carbonates. Traps are developed in east-west oriented fault blocks and horst blocks. The main source rocks are Upper Cretaceous shales and limestones and Upper Jurassic shales and coals. Source potential is also identified in the pre-rift succession.

Little is known regarding the petroleum geology and potential of southern Egypt. Palaeogeographic reconstructions suggest non-marine sedimentation during the Jurassic may have led to deposition of shales in a number of small, isolated depocentres. A marine transgression during the Cretaceous led to deposition of shallow marine and shelfal sands across the region. These sands are the main potential reservoir interval.

By combining the extensive information available in the public domain with Fugro Group non-exclusive datasets, the petroleum systems of this basin have been documented and stored digitally. Within the Western Desert Basin, 11 proven reservoir-seal couplets (plays) have been identified. Analysis of the exploration history and pool size distribution for each play was combined with up-to-date knowledge regarding the development and physical extent of the play. The prospective resources (yet to be discovered hydrocarbons) in each play have been estimated.

Robin Crawford¹ (1) BP, Sunbury on Thames, United Kingdom

Algerian Saharan Platform Hydrocarbon Systems

The Algerian Saharan Platform extends for approximately 1 million sq. km. and is divided into 30 sedimentary basins. All basins have: at least one and sometimes two oil prone excellent quality source rocks; good to moderate reservoir and seal quality rocks; and variable degrees of fault-associated structural development. Burial histories in all of the basins are sufficient to have generated oil and sometimes gas. All but two or three of the basins have recorded indications (tests or shows) of oil or gas in reservoir rocks. A large long-term upstream growth opportunity is provided by the fact that the industry is focused on only seven basins which cover a land area of 240,000 sq. km. (25% of the entire platform) yet the remaining 75% has active hydrocarbon systems but is under explored.

The industry in Algeria is nearly 50 years old but almost 10% of the captured hydrocarbons, including what is one of the country's top five fields, have been found in a single trend in the last 10 years. Seismic acquisition and processing technology has rejuvenated exploration in Algeria. Technology has overcome the issues of deep plays in dune field exploration. Given that similar areas exist in Algeria where all of the elements of the hydrocarbon system are in place then the potential to discover similar trends in the future must be considered as probable.

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Integration of Multiple Techniques to Define A Complex Salt Body in The Flex Trend of The Gulf of Mexico

A recent discovery well drilled by Anadarko underscored the wisdom of integrating salt body interpretation from multiple data sources. Seismic clearly showed a top of salt reflector for both the main salt stock and a laterally extensive salt canopy on a prospective block in 150m of water in the Central Gulf of Mexico. However, neither post-stack time migrated data nor the initial sediment flood of a PreSDM project in progress showed a convincing salt flank or base of salt.

Concern that strong reflectors under the salt canopy believed to be prospective section might actually be a poorly imaged base of unexpectedly thick salt prompted Anadarko to perform a series of prestack depth migrations on an extracted 2D line using various salt geometries. Thicker salt models resulted in grossly distorted seismic and poor imaging at depth. A thinner salt layer (300m to 500m) such that the top and base of salt reflectors interfered with each other produced more reasonable subsalt images.

To aid in this confirmation, the salt body was analyzed using gravity and magnetic data. To our surprise, this analysis showed two allochthonous salt thicks to the south and west of the prospect, both of which thinned rapidly to zero salt at the proposed well location. The drill bit encountered approximately 10m of salt. A VSP subsequently enabled us to pinpoint the unimaged flank of the salt stock. Ongoing drilling, VSP, and seismic reprocessing have all confirmed that this field is located under a complex and rapidly changing salt canopy.

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Acquisition of Highly Repeatable Seismic Data Using Active Streamer Steering

Time-lapse seismic has emerged as a key technology in reservoir management. The success of time-lapse seismic depends upon the repeatability of data, including precise repetition of acquisition geometry. For surveys acquired using conventional towed marine systems this will rarely be achieved, because variable sea currents affect the dynamic behavior and position of streamers.

Since early 2001, vessels equipped with a system for streamer steering have been in operation. The streamer control system contains three components, a) a full streamer acoustic positioning system, b) streamer steering devices, and c) a spread-control module within the navigation system. These components work in a closed-loop manner. Highly accurate positions computed along the streamers are compared with desired positions by the spread control module. Commands that control the streamer steering are then sent to the steering devices, which are a novel type of "bird" having two independent wings. By introducing a small splay between the wings, the device will roll, and in addition to the vertical force needed for depth keeping, will generate a lateral force which moves the streamer towards the desired position.

Data acquired in the North Sea demonstrate the effectiveness of streamer steering. Two adjacent 6-streamer swaths were re-acquired some days later using consistent steering control. Analysis of the navigation data shows streamer re-positioning was achieved within +/-10m. The seismic data were processed using independent deterministic processes, with no cross-equalization between the baseline and repeat data. Difference displays with an absence of visible signal energy confirm the repeatability of the seismic data.

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Benguela Belize - Lobito Tomboco Development, Block 14: Angola's Next Deepwater Hub

Since the mid-1990s offshore Angola has been a world class exploration province and recent deep water discoveries have been among the world's largest finds.

ChevronTexaco and its Block 14 partners (Sonangol P&P, TotalFinaElf, AGIP and Petrogal) have made seven discoveries in the highly prospective Block 14 including: Kuito (1997), Landana, Benguela and Belize (1998), Tomboco and Lobito (2000) and recently Tombua.

The Benguela Belize - Lobito Tomboco (BB-LT) complex, located in the northern portion of Block 14, is scheduled for first oil in 2005. Seven main oil pools make up the development with oil in place approaching 1.5 billion barrels. The complex consists of multiple pools vertically stacked and grouped geographically around structural traps. These characteristics enable production facilities to tap multiple accumulations adding value to the infrastructure. Reservoir properties are excellent (25 to 32 % porosity, 1 to 4 darcies permeability with 24-38 degree API gravity oil), and channel-axis sands are highly prolific with average individual DST's in excess of 10,000 STBOPD.

The BB-LT project will take place in 1300 feet of water and will involve 2 phases of development. The Phase 1 BB development will involve West Africa's first Compliant Piled Tower and a drilling and production topside facility. The facilities are currently designed to process 140,000 STBOPD, 220 MM SCFD gas compression, 240,000 BWPD processing, and 230,000 BWPD injection. Phase 2 of the project encompasses the tie back of the LT fields to the BB Hub using subsea technologies and installation of a 80,000 STBOPD capacity expansion module.

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The Jurassic Depositional System of Morocco; Geology and Exploration Play Concepts

The Jurassic depositional system of Morocco occurred in two distinct geographic domains: (1) Along a complex zone located at the westernmost portion of the Tethys seaway and (2) at the eastern margin of the central Atlantic margin.

Sedimentary deposits resulted, essentially, from the relative sea level changes during the complex successive tectonic phases of continental collision and plate divergence inducing the deposition of various facies ranging from continental and lagoonal carbonate and clastic to open marine deposits. Carbonate, often reefal dominated, were deposited within platforms and along existent shelf edges.

From tectonic point of view, normal faults initiated during the rifting period were reactivated into high to medium angle reverse faults, during Late Cretaceous to Early Tertiary time, inducing the formation of various imbricates and structures within the Mesozoic series.

Recent integrated studies based on seismic interpretation, well data and outcrops, have permitted to assess the hydrocarbon potential of the Jurassic depositional system of Morocco.

Geochemical analyses carried out on samples from drilled wells and outcrops show that rich and mature source rocks are developed within Palaeozoic, Jurassic and Cretaceous series.

Combination of structural assessment with geochemical results and seismic interpretation has permitted to map various kitchens and to define new play concepts within viable petroleum systems. The developed concepts such as sub-thrust have never been tested yet.

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TBA

No Abstract Requested

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3D Reservoir Geometry, Environments and Sequences - A Model for Jurassic Rift Systems - Gebel Maghara, North Sinai, Egypt

Gebel Maghara, a NNE-oriented doubly plunging anticline, in Northern Sinai, has the thickest and complete Jurassic outcrop (~ 2200m) of alternative clastic and carbonate sequences. Three-dimensional outcrops offer typical models of detailed field observations and measurements of the fluvial to shallow marine sands being developed during the successive rifting stages. In the Early stage of Jurassic rifting, fluvial to fluvio-lacustrine sequences were accumulated that were flooded by the organic-rich shallow marine carbonates.

Syn-depositional tectonics continued during the Middle Jurassic and resulted in block faulting, tilting and rotation that controlled the deposition of deltaic and shallow marine sand bodies. The tectono-stratigraphic events lead to the lateral shift of the depocenters, sand-bodies progradation and partial stacking.

Sequence stratigraphic and Cyclostratigraphic concepts were applied where systems tracts and flooding surfaces could be defined and correlation marker events were elucidated. The events are not only relevant to the understanding of the petroleum geological aspects of the eastern Mediterranean area of north Western Desert and North Sinai ; but also for other Jurassic rift basins as the case of the North Sea. Relationship to Jurassic sedimentary section of the Arabian Gulf will be discussed.

Quintin Davies¹, Deborah Bliefnick¹, William Sercombe², Thomas Radford² (1) Badley Ashton and Associates, Lincolnshire LN9 6PB, England (2) BP/Gupco (currently BP Kuwait), Kuwait City, Kuwait

Sedimentology and Depositional Setting of the Lower Miocene Asl/Hawara Member, October Field, Egypt

A sedimentological and petrological evaluation of the Middle Miocene Asl/Hawara Member in October Field, Egypt was provided through a core-based study of several wells. The distribution of reservoir quality was assessed through the determination of depositional facies variation, the influence of tectonics and the nature of the diagenetic overprint with the aim of constructing a reservoir quality framework that would allow prediction of reservoir potential in future wells.

Deposition of the Asl/Hawara Member reflects syn-rift tectonics that dominated the Red Sea region during the Middle Miocene. Uplifted and rotated fault blocks provided sediment sources and established sediment bypass zones along cross faults and relay-ramps. Carbonates formed and accumulated on uplifted fault blocks while siliciclastic material was derived from exposed older source areas and erosion along transform faults. Two principal lithofacies were observed: carbonate-rich packstones/grainstones and quartz-rich sandstones. These lithofacies occur repeatedly as coarse-grained and fine-grained elements that reflect the evolution of a turbidity current/fan system. Both siliciclastic and carbonate lithologies were reworked and ultimately transported to topographic lows surrounding fault blocks.

Reservoir quality is controlled by a combination of primary depositional fabric and subsequent diagenetic modification. Thick, porous sandstones tend to retain their primary interparticle porosity whereas thinner interbedded sandstone and carbonate lithologies are typically extensively cemented and contain relatively isolated macropores.

Paleotopographic highs will, therefore, provide poor reservoir targets due to the lack of siliciclastic material and abundance of carbonate material. Paleotopographic lows, however, will provide the best reservoir targets due to the presence of thicker, relatively uncemented sandstone units.

Giambattista De Ghetto¹ (1) ENI Agip Division, N/A, Italy

Reservoir Management – Present and Future Role of Technology in ENI-Agip

The speech will firstly review the new technologies, relevant the reservoir management, developed and/or applied in Eni-Agip, focusing on field applications: results and lessons learned.

Secondly the on going strong activity to accelerate the application of new technologies will be presented along with a novel approach to estimate their return. Thirdly, the Eni-Agip vision about technologies of the future and their role in the oil business will be discussed.

Sylvie Odile Delisle¹, Vivien de Feraudy¹ (1) TotalFinaElf, Pau, France

Uncertainty Approach for OIIP Estimate of a Fractured Basement Reservoir of Middle East

Basement fractured reservoirs are probably the most uncertain type of reservoir to be characterise and model: difficulties in structural definition, in prediction of facies evolution, in evaluation of a poly-tectonised material.

Our approach enables to define a ranking of the different fracture types (from the micro-fracture to the fault) then to model each of them with proper characteristics through a geostatistical approach with JACTA(TM) software. Stochastic generation of as many parameters as wished using geostatistical methods gives multiple equiprobable images of the field to evaluate.

The building of the 3D model from seismic interpretation is a key point to elaborate a consistent structural pattern of main faults. This is our first scale of fracturing which will be modelled.

Well data (imagery and core) give us crucial information on the two other fracture scales: small scale fracturing and sub-seismic objects.

Small scale fracturing may be sometime considered as a second order player (mineralisation or poor connectivity) whereas sub-seismic objects can play a major role in OOIP amount as well as in productivity. They can be stochastically simulated from parameters calibrated on geological data. Typical parameters simulated are: frequency, strike, dip, length, width, and petrophysical properties.

Influence on OOIP of the uncertainty in each parameter can be evaluated separately giving a good idea of the relative impact of each of them then a ranking of parameters to be refined.

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Geomechanical Fracture Modelling Helps Renew Development of the Coevorden Zechstein Tight-Gas Reservoir

The Coevorden Zechstein gas field consists of a large number of poorly connected, tilted fault blocks and the reservoir is interpreted to have been deposited in carbonate slope/deep water environment. Production from the Coevorden Zechstein wells has been highly variable and where good productivity occurs, it is attributed to the presence of fracture networks.

To predict the distribution of fracture networks, Poly3D, a deterministic geomechanical fracture modelling tool using boundary-element techniques, was chosen. This model computes the stress field related to slip on seismically visible faults based on estimates of the regional stress tensor. The main assumptions of the model - fracturing is related to strike-slip or normal faulting and the rock is isotropic, homogenous and linear elastic - seem reasonable for our setting in that no correlation has been found between folding (curvature) and fracturing, nor has a relationship between dolomitisation and fracturing been found. Additionally, lithological variation across the field seems small given its depositional setting, and no strong diagenetic heterogeneity has been observed.

Using the stress tensor distribution, calculated using Poly3D, brittle failure analysis was carried out to produce failure maps indicating possible areas of connected fracture systems. These failure maps in turn were used to fill the dual-permeability grid of Shell's dynamic reservoir simulator.

History matching revealed that 70% of the wells can be matched using a specific set of brittle fracture parameters and fracture and matrix permeability. An attempt to history match the production behaviour using a random distribution of dual permeability or a much simpler model of fracturing failed. Similarly, no previous subsurface model has been able to withstand testing against dynamic data. Based upon this, the Poly3D methodology is facilitating further development of the Zechstein gas fields.

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Tertiary Petroleum Systems around the World: Sediment Controls from Regional GIS Studies

This story began in the South Atlantic and progressed around SE Asia. A small global new ventures team began combining potential field and other data using GIS (Geographic Information Systems) software. The approach provides such utility that it deserves a new name, here dubbed EGIS (Exploration Geology Information System). We show examples in Tertiary sequences in five basins (Congo Fan, Angola; Baram Delta, NW Borneo; Campos Basin, Brazil; Pearl River Mouth Basin, China; Niger Delta, Nigeria) where striking correlations were observed between geologic features that control sedimentation and signatures of potential field attributes.

The EGIS environment enabled faster, more precise interpretations and digital presentation of results. Long-recognized features not previously imaged in their entirety were reinterpreted, realigned and extrapolated, due to improved data coverages. The data signatures in map view drew unexpected geologic inferences using simple tools and basic concepts.

We first reinterpreted extents of continental, oceanic and proto-oceanic crust with implications for hydrocarbon maturation. Investigations of crustal type and limits revealed surprising correlations between gravity imagery and reservoir and source distribution. This paper illustrates:

- inter-raft sediment pathways, post-salt depocentres and unconfined basin floor fans, Congo Fan
- basement control on Oligocene fans, bypass zones and source pod locations, Campos Basin
- correlations between discovery trends, toe thrust belts and basement structure, Niger Delta
- projections of base of slope/basin floor fans offshore NW Borneo & Pearl River Mouth Basin

The story continues as more detailed data advance our understanding and the simple tools empower improvement in both techniques and interpretations.

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Messinian Incised-Valley Systems in the Mediterranean along the Egyptian Coastline: Paleogeography and Internal Fill: Evidence from Cores and Seismic

The Mediterranean's Messinian salinity crisis triggered development of 5 major paleo-drainage systems along the northern Egyptian coastline. These systems extend up to 100 km basin-ward beyond earlier formed Tortonian deltas. The morphology and reservoir fill of each system is controlled by 1) the underlying structural fabric 2) sub-crop lithology and 3) local provenance.

The Abu Madi system consists of Grand Canyon scale valley networks up to 500 meters deep and 100 Km wide. Multiple episodes of erosion occurred and internal fill consists dominantly of stacked successions of fluvial, tidally influenced fluvial, bayhead delta and central basin mudstone facies. There appear to be no estuary mouth sandstone facies, suggesting an absence of longshore sand transport. Dipmeters and cores indicate valley wall collapse was frequent. The Rosetta system consists of braided and coarse-grained meander belt sandstones that inter-finger north-northwestward with coastal sabkhas.

To the west, the Moghra escarpment drainages overlie a Precambrian age transform fault. Here, at least 10 canyons terminate abruptly northward into alluvial fans and a salt basin. Along the eastern edge of the Nile Delta, a trellis shaped shale-filled valley network (Seti East drainage) lies southwest of the Tamsah structural belt. Lastly, 200+ meter deep canyon incisions north of the Sinai massif terminate in submarine fan systems along the coastline of Israel.

Hydrocarbon exploitation for additional smaller reserves within these trends remains excellent and some large opportunities exist within the undrilled deep-water province.

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Pre-Pliocene Potential in the Nile Delta/Mediterranean, Offshore Egypt: An Emerging Giant Gas and Condensate Play?

In the last five years, deep-water exploration in the Nile Delta has resulted in the discovery of over 14 TCF of gas. The active play has been the amplitude driven Pliocene submarine channel fairway. Gas is both thermogenic and biogenic in origin.

Over fifty untested deep closures have been identified in pre-Pliocene strata. In established trends, a strong relationship exists between the location of Pliocene thermogenic gas and the presence of deeper structural closures. An example is the giant Tamsah anticlinorium, with 3.5 TCF of gas in the Serravalian and an additional 3-4 TCF above in the Pliocene growth fault province. These and other data suggest that charge and migration is largely vertical. Pliocene fields may actually be "seeps" overlying deeper and more liquid-rich accumulations.

Input points to reservoir fairways have remained locked in place since the Oligocene, with a mid-Miocene shift from a dominantly western input point (Rosetta branch of the Nile) to the current location in the central Nile Delta. Oligo-Miocene forced regressions caused a major basinward translation of reservoir that culminated in the Messinian desiccation event. Subsequent erosion beheaded many of the older deltas, providing a pressure release mechanism for many deeper reservoir fairways. In this paper, we look at an integration of pressure, geochemical and stratigraphic data that suggests 60-90 TCF of gas remains yet-to-find, much of which is in pre-Pliocene strata.

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Basement Structural Controls on Sedimentation and Hydrocarbon Charge, Nile Delta, Egypt

Miocene and Pliocene sedimentation patterns in the Nile Delta are highly asymmetric, characterized by a gentle western and steep eastern flank. The cause of this geometry is a deep Jurassic age rift system extending northeastward from the Western Desert and offshore as far as Cyprus. The position of the Nile Delta itself is controlled by the intersection of this fabric with 1) a NW-SE oriented Precambrian age transform (Moghra high) underlying the western coastline of the Mediterranean 2) the Cretaceous hinge line 3) Syrian Arc structural elements.

The Rosetta fault system is the most prominent of the NE-SW oriented features. The large paleo-high footwall of the Rosetta fault limits accommodation space along the western edge of the Nile Delta, creating a gentle slope facies. The eastward tilt creates the over-steepened eastern side.

A continental to oceanic crust transition west of the Rosetta fault forms a series of "down to the basin" fault blocks. A major relay ramp occurs at the intersection of the Rosetta system with the Moghra High, forming the input point for the Rosetta branch of the Nile. Eastern delta sedimentation patterns are controlled by Syrian Arc structural lows.

The structural and sedimentary fabrics of the Nile Delta owe their geometry to the interplay of these underlying features. Intersections of these older trends with younger lineaments or continued reactivation create favorable focal points for vertical migration of hydrocarbons and coincide with the location of a number of giant fields.

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Middle and Lower Miocene Petroleum Systems in the Lower Congo Basin, Block 14, Angola

The Benguela Belize - Lobito Tomboco (BB-LT) complex is located in the northern portion of Block 14, offshore Angola. The field consists of seven Middle to Lower Miocene oil pools with oil quality ranging from intermediate to light (~24-37 API). Depths of the pools range from 5,700' to 10,036'. The subsurface data set consists of a high quality/resolution 3D seismic survey, 14 wellbore penetrations, 9 DST's, 7 cored sections and full suites of logs.

The reservoirs are composed of high quality turbidite sands deposited in a middle bathyal slope valley/incised canyon environment. Reservoir quality sands are found as vertically stacked and nested channel complexes that both erode and aggrade preexisting sediments. The turbidite complexes are typically 500-2000m wide, 10-60m thick, and composed of intercutting sand rich turbidite channels, shale-rich mudflows, debris flows and slumps. Seismically, they display characteristics of laterally stacked sand-prone channels; meanders, differential compaction, and exhibit AVO signatures.

Traps consist of channels draped over broad four-way structural highs or in normal fault trap geometry and are likely controlled by Aptian salt movement and subsequent late stage extensional faulting. Regionally, the channel systems lie beneath highstand shales, providing a high quality seals both laterally and vertically.

The main source rocks are a combination of labe and Lower Malembo with the onset of peak oil generation at 13 Ma and 5 Ma. Deep penetration normal faults may provide migration pathways into the Miocene channels. All Miocene sands in trap position have encountered hydrocarbons of various quality and quantity.

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Sequence Stratigraphy and Facies Development of the Miocene Syn-Rift Succession in Darag-Lagia Basins, Gulf of Suez, Egypt

The sequence stratigraphic concepts and the relationship between depositional sequence and the global cyclic changes in sea level has been applied to establish a regional time stratigraphic units for the Miocene syn-rift succession in the northern Gulf of Suez, Egypt. The major tectonic elements along with the basin subsidence have been played a major role on the facies distribution of the Miocene syn-rift sediments in the Gulf of Suez.

The lower Miocene, Nukhul sequence was deposited during the TB 1.4 & 1.5 3rd order cycles (25.5-21 Ma.). The basal Rudeis sequence (lower Mheiherratt Member) was deposited during the TB 2.1 3rd order cycle (21-17.5 Ma.). The lower Rudeis sequence (upper Mheiherratt & Hawara members) was deposited during the TB 2.2 3rd order cycle (17.5-16.5 Ma.). The upper Rudeis sequence (Asl & Mreir members) was deposited during the TB 2.3 3rd order cycle (16.5-15.5 Ma.). The boundary between the upper and lower Rudeis is placed near the base of Asl Member. This major sequence boundary is thought to have occurred as a result of a regional tectonic event, commonly referred to as the Mid-Rudeis event. Kareem sequence was deposited during the TB 2.4 3rd order cycle (15.5-13.8 Ma.). The top boundary is often defined by the presence of the Markha anhydrite that is closely associated in time with the Gulf wide hiatus at the beginning of the Kareem deposition. Belayim sequence was deposited during the TB 2.5 & 2.6 3rd order cycles (13.8-10.5 Ma.). South Gharib and Zeit sequences were deposited during the TB 3.1 & 3.2 3rd order cycles (10.5 - 6.3 Ma.), which is consequently matched with the significant fall in the eustatic sea level during the earliest Tortonian to Messanian stages.

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Basin Analysis and Hydrocarbon Potentialities of the Darag-Lagia Basins, Gulf of Suez, Egypt

Basin analysis evaluation of the Gulf of Suez rift basin and its reservoir quality, source rock distribution, geothermal gradient, maturation history and hydrocarbon potential are attempted. The investigation was attempted in order to show the reservoir lithology, distribution, quality and porosity; source rock distribution, organic richness, type and maturity; geothermal gradient maps, burial/maturation history models; sealing rock; timing of hydrocarbon generation, migration pathways and entrapment style. The present hydrocarbon occurrences in the northern part of the Gulf of Suez was reviewed with an assessment of the potential reserves and the hydrocarbon potentialities of the study area as well as the areas for future exploration activities.

The area subdivided according to the proposed hydrocarbon migration trends into two major clusters. The northern cluster includes, Darag and Nebwi basins generally dip southwesterly and the southern cluster includes, Lagia basin generally dips northeasterly. The proven recoverable reserves in; Sudr, Matarma, Asl and North Darag fields cumulatively are 0.119 BOEB, while the ultimate recoverable reserves in Darag and Nebwi basins are 1.204 BOEB, which is ten times the proven reserves. The ultimate recoverable reserves in Lagia basin are 1.479 BOEB. Structural or stratigraphic traps, which exists along the migration path should be expected full to the spill point and might be considered for future exploration. Five prospective areas have been identified over the northern Gulf of Suez area, which are: Area I - North Darag, Area II - South Darag, Area III - Nebwi, Area IV - Ras Lagia and Zaafarana and Area V - West Lagia.

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The Paleozoic Petroleum System of the Berkine and Illizi Basins in Southeast Algeria

The Paleozoic petroleum systems of North Africa contain seven giant fields with greater than 1 billion barrels of oil equivalent. Five are located in the Berkine and Illizi basins. This article describes the productivity and maturity of the petroleum systems and addresses their source rock quality and the oil to source correlation based on the fluid chemistry. Lateral and vertical migration is assessed in the Berkine basin through basin modeling and according to the fluid type. The fluids in the system are well preserved in a mature phase of evolution because of a regional evaporite seal and minimal late tectonic disturbance. The regionally extensive Silurian "Hot Shale", believed responsible for more than 80% of Paleozoic-sourced hydrocarbons, has been shown geochemically to contribute less than 20 % of oil produced in Berkine basin. The Devonian hot shale (Frasnian) and the "Serie Argileuse " of the Upper Devonian exhibit the strongest oil generative potential. The Illizi Basin to the south of the Berkine Basin produces oil from Silurian source rocks that were not buried deeply. The Illizi Basin has been described by many workers as a platform. The present day maturation level of the Silurian illustrates that long geologic time combined with low reaction rates can mature the source rock.

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A Review of Pre-Stack Depth Migration (PreSDM) Process Flow Development in the Gulf of Mexico

The past decade has been a period during which rapid advances have taken place in the application of imaging technology and in particular in Pre-Stack Depth Migration (PreSDM). Improvements in the application of PreSDM have been brought about by the need in the industry to resolve increasingly more difficult imaging problems, to understand the fundamentals of complex regional geology, to provide a cost effective PreSDM solution and ultimately to continually strive for the most accurate geological model.

PreSDM can be considered the ultimate link between Geophysics and Geology. In order to obtain the most accurate depth image the pre-stack seismic data must be imaged with a velocity model that is based on the geology and derived through the seismic data. Generating the full velocity model is an iterative process requiring close interaction between seismic processing geophysicists, interpretive geophysicists and regional or structural geologists. PreSDM the ultimate link, is also a catalyst to improved communication between geoscientists in the exploration and development teams.

In the past two years new approaches to PreSDM, other than Kirchhoff, have been implemented. These include for example full wavefield acoustic based shot domain wave equation migration (WEM), plane wave imaging solutions, and grid based tomographic solutions to velocity model building. As well as the inherent advantages of WEM new challenges are also introduced for the processing/interpretation teams. Through massive clusters, recent NEC Earth Simulator has 35,600 GigaFlop capability, PreSDM products include WEM image results both in stack and gather mode, velocity and geological models, and illumination models.

In future Geoscientists will use all of these products and more in a fully integrated environment to enhance their understanding of the geology and to reduce cycle time. Other challenges, including for example anisotropic model building and WEM elastic solutions, in PreSDM remain to be solved in a regular commercial basis.

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Multiple Suppression on Marine Data Recorded in The Middle East

Multiple removal from marine seismic data recorded in very shallow water areas is known to be problematical. In areas where the sea-bottom is very shallow and when the acoustic impedance response is high, the data is generally contaminated with a lot of reverberations between the sea-surface and the sea-bottom.

For optimal interpretation of geological structures, the data needs to be pre-processed to suppress these "reverberations". As generally known, with a shallow sea-bottom, industry standard methodologies for multiple removal are challenging. In this paper the well-known method of predictive deconvolution has been applied and illustrated to marine data recorded in the Middle East.

This dataset appeared to be a good example to validate the suppression of the reverberations and obtaining data quality improvement. The successful removal of strong aliased linear noise and surface-related multiples has resulted in a dataset, which is more suitable for further processing with primaries that are more readily identifiable.

The strong aliased linear noise has been suppressed by determining slope filters that have been applied in the F-K domain. For the prediction of the surface-related multiples, autocorrelations were calculated on shot gathers to validate identification of the reverberation periods. Based on the identified periods, the original data was bulk shifted by the reverberation lag time. The bulk shifted shot gathers have been subtracted from the original data (in the shot domain) using an optimized adaptive least-squares algorithm which uses diverse 1-D temporal filters for diverse order of multiples recorded in the data.

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Geohazard Detection in Deepwater Clastics Basin: A Seismic Technique with Application to Deepwater Mediterranean

Detection of hazardous zones, associated with high-pressured fluids in unconsolidated sands and shales, prior to drilling, is essential for environmental as well as health and safety. Drilling for deepwater targets is associated with high cost and risk, while margins of commercial operations are small. Therefore, it is imperative to control cost through accurate well planning and reliable anticipation of geohazards.

This paper deals with a novel seismic approach that uses the full bandwidth and the entire offset range of the conventional 3D seismic data to detect the presence of hazardous zones. Both in shallow and deeper zones, P- and S-velocities were determined using seismic full waveform prestack inversion. Shallow waterflow (SWF) layers in the deepwater, Mediterranean were identified through the associated high ratios of P- to S-velocities. A new, rock model-based approach especially suited for deepwater pore pressure imaging was applied to predict the presence of both shallow and deeper over-pressured zones.

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The Re-emergence of the Central Abidjan Basin, Offshore Cote D'Ivoire as an Exploration Hotspot - New Insights from 3d Structural Modelling

The Côte d'Ivoire represents an unfinished story of hydrocarbon exploration and academic research following renewed industry interest in this emerging hotspot. Numerous papers have been made on both the North and South Atlantic tectonics, where as the Central Atlantic has had little work to date. The present study has utilised three 3-D seismic data sets in the Central Abidjan Basin that cover the Espoir Field re-development (93 mmbo and 200 bcf of gas remaining recoverable reserves) and the Baobab-1X oil discovery (in excess of 150mmbo recoverable) and other exploration targets.

A 3-D structural model has been built that allows interrogation of the geometrical and kinematical coherence of a WNW - ESE trending fault system that resulted in the generation of a tilted fault block framework during the Apto-Albian. 3-D fault displacement analysis coupled with 3-D structural restorations suggest that the genesis and evolution of the fault array through time may have exerted a fundamental control on the distribution and dispersal of reservoir quality Upper Albian marine sands. The development and subsequent breaching of soft-linked relay ramps lead to the generation and removal of clastic sediment entry points into the basin through time.

It is therefore important that we understand both the regional tectonic regime and the detailed breaching of relay ramps for continued exploration success in the Côte d'Ivoire.

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A Feasibility Study to Determine if the Surface Seismic Method Can Detect Thin Channels in the Presence of Statics and Noise

Exploratory wells found oil-bearing sand channels in a field in Oman. Despite the fact that these reservoirs were less than 5 meters thick, they were still considered to be economic. Conventional 2D and 3D surface seismic programs were conducted, but they were unsuccessful in detecting the locations of the reservoirs. Consequently interest waned in further seismic attempts until the development of high channel count systems was announced.

The mission of this study was to predict if such high channel count systems could detect the sands. The chief tool used was modeling. In addition to handling signal, all major noise components were comprehended. These included multiples, scattered ground roll, air waves and ambient noise. The effects of inelastic attenuation and intra-array statics were also considered.

Although results showed that high channel count systems could indeed provide significantly better signal-to-noise ratios than conventional systems, the bandwidth inherent in vibrator surveys was found to be too restrictive for direct detection of the reservoir sands in conventional wiggle trace sections.

However, prestack inversion was also executed using the modeled records and those results were found to be quite promising.

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Risk Assessment to Allocate Commingled Production in Multi-Highly Heterogeneous Reservoirs

The present article introduces the recent work done in Shoab Ali field governed by Gupco in GOS to study the impact of the production reallocation from different seven reservoirs. It was recognized that some reallocation of production should be required to match the reinterpretation of individual reservoir tops, analysis of the total 44 PLT and TDT logs available in the field. In addition, production reallocation took place in the light of production performance, pressure history, available PVT and core reports. Shoab Ali field production reallocation was a cornerstone for overall production allocation with offset fields; so metering and piping system, connecting it with other fields was also monitored.

Shoab Ali field has experienced significantly more faulting than most fields in the Gulf, resulting in a unique structural style. In addition, many stratigraphic units thin to the south, giving rise to uncertainty in stratigraphic correlation. Due to faulting and local uplift associated with initial rifting during early Miocene times, there is significant variation in the distribution and thickness of pre- and earliest Miocene units. This is a function of cross-cutting unconformities and fault-controlled deposition. All of these factors combine to provide a challenging problem for the interpretation.

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Effect of Mesozoic and Tertiary Deformations on Hydrocarbon Exploration in Northern Western Desert, Egypt

A detailed structural study of a segment of the northern Western Desert (Khalda concession areas) reveals the effect of Mesozoic and Tertiary deformations on hydrocarbon exploration there. An early rifting phase in the Jurassic and Early Cretaceous formed several half graben-like basins with intervening platforms having basin and range geometry. Thick wedges of Jurassic and Lower Cretaceous sections were deposited in these basins and include potential source rocks. Rift-bounding faults are oriented E-W, ENE-WSW, and WNW-ESE. NNE-SSW oriented faults locally bounded some basins as well.

Late Cretaceous (Maastrichtian) dextral wrenching on the E-W to ENE-WSW oriented faults deformed the syn-rift and post-rift sediments. This led to the development of NE-SW oriented folds, NW-SE oriented normal faults, WNW-ESE oriented dextral-slip faults, and a few NE-SW oriented reverse faults. Wrenching also led to positive inversion of old NNE-SSW oriented normal faults bounding some early rift basins.

A late phase of post-Cretaceous extension mildly affected this area and rejuvenated a few of the old faults by normal slip. Structural traps in the northern Western Desert include NE-SW and NNE-SSW oriented folds formed by Late Cretaceous wrenching and inversion as well as tilted fault blocks formed by Jurassic and Early Cretaceous rifting. Drilling has not tested the latter. Fault related stratigraphic traps also exist. These traps have never been explored either. En echelon faulting formed by Late Cretaceous wrenching most likely increases the sealing capacity of faults bounding hydrocarbon fields.

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Nile Delta – Where is the Oil?

With many companies now concentrating their exploration and production efforts on the Nile Delta, new insights into the origin of charge are urgently required. The geological controls on oil versus gas distribution in the Nile delta are also still debated.

Regional geochemistry data together with seepage data (via piston coring and fluid inclusion results) have been used to improve the understanding of the Nile Delta hydrocarbon system - specifically addressing charge, potential source rocks and hydrocarbon typing issues.

The identification of additional prolific source rocks with multiple oil-prone sources in several stratigraphic intervals provides additional working hydrocarbon systems which should provide new exploration opportunities.

The most likely source for gas appears to be a kerogeneous source rock of different maturities. Dry gas found in shallower reservoirs with reservoir temperature less than 70 degrees C and depth less than 2000m, may have undergone a degree of bacterial alteration.

On the other hand, oils are inferred to originate from Tertiary & Mesozoic source rocks, deposited under marine - paralic conditions. The postulated involvement of Cretaceous - Jurassic source rocks in the origin of crude oil is attractive because of the lack of potential source rock and thermal immaturity of Tertiary rocks in some areas.

The overall distribution of oil and gas / condensate is depth-dependent, controlled probably by type of source rock, maturity levels and reservoir conditions.

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Essential Link between Ancient Exploration Tools and the Latest 3D Reprocessing Techniques: A Rule for the Recent Geological Modeling in Very Complex Area (Ashrafi Field – Gulf of Suez, Egypt)

The sub-salt image in Ashrafi Field, southern Gulf of Suez, Egypt was re-mapped by using seismic reprocessed data applying the 3D Pre-Stack Depth Migration and a new methodology recently implemented by ENI_Agip Div.: the Phase Shift Plus Interpolation (PSPI) migration.

In the past poor seismic image related to seismic energy attenuation within the thick salt section, complex sub-salt structural pattern, steep dip in the pre-Miocene, high Basement relief, fast and drastic changes in the water depth hindered previous imaging and mapping projects in the area.

Analog surface models from the nearby Gebel El Zeit outcrops (Western Gulf of Suez Rift shoulder) indicated highly tilted pre-rift normal fault blocks (55 degrees dip) overlapped by different syn-rift facies with numerous unconformities.

Structural modeling of the recent improved seismic image in the Ashrafi field area supported by subsurface facies maps, formation tops and dipmeter data analysis from the drilled wells accompanied by a diligent study of the nearby outcrops models led to re-shaping the pre-Miocene block geometry and to identify new areas with remaining hydrocarbon potential.

The study reveals also the locations of the major accumulation of the Miocene syn-rift clastics reservoir by predicting their paleo-drainage and sediments entry points. As Ashrafi area remained significantly high during early and mid rifting time, erosion at the crests of the pre-Miocene blocks and deposition at their flanks controlled the syn-rift clastics rich areas.

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Contribution of Geophysics and Geology to Physical Planning Map of Egypt 2017

The Physical Planning Organization in Egypt conducted a regional geotechnical study to develop Egypt within the period 1992- 2017. This multidisciplinary scientific approach included geophysical and geological land use maps on scale 1: 2, 000, and 000 as a base. This geotechnical study covers natural hazards, mineral resources, petroleum production and potentialities. Topographical and engineering geological impact on land use maps. Groundwater and geothermal energy resources and potentialities are discussed. Geological tourism is suggested. Natural hazards include historical and instrumental seismicity, forthcoming climatic changes and expected changes in sea level etc. GIS was used to add these layers in addition to the multidisciplinary scientific layers as infrastructures, social and population studies, economics etc. to achieve land use and physical planning maps for Egypt 2017.

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The Eocene Ramp Complex of Al Jabal al Akhdar, Cyrenaica, NE Libya: A Surface Analogue for Nummulite Reservoirs

The well-exposed and continuous outcrops of Al Jabal al Akhdar, Cyrenaica, are appropriate to study the nummulite body's geometry, which form major hydrocarbon reservoirs in the offshore of Libya and Tunisia. The Eocene succession forms a shoaling up megasequence up to 600 m thick. It consists of interbedded mudstone and porous chalk-dominated, Apollonia Formation, which grades upward and laterally up the regional structural axis into porous nummulite-rich facies of Dernah Formation. These represent outer, and middle-inner ramp facies belts respectively.

Sedimentation of the ramp complex was controlled by the pre-depositional inversion configuration of Al Jabal al Akhdar anticlinorium. It influenced the regional facies belts width, their thickness, and the change of the mid-ramp facies from nummulite dominance west of the area to coralgall-reefal dominance to the east. Syndepositional reactivation of the structures also, triggered mass transport of the nummulite deposits into deeper waters, and controlled the accumulation, geometry and internal heterogeneities of the nummulite bodies.

Since the nummulite bodies were accumulated in an essentially mud-rich, low-energy environment, reworking by waves and currents led to improvement of the grain-mud ratio in upward shallowing sequences. Meanwhile, the outer-ramp transport of lime-mud, enhanced by mass-movement of mid-ramp deposits produced seaward prograding clinoforms on which the nummulite facies and associated inner-ramp shoals advanced. Below sequence boundaries, eustatic and tectonic controls were not only necessary in improvement of the grain-mud ratio of the nummulite bodies, but also led to enhancement of the rock pore network by subaerial meteoric water diagenesis over structural highs. Deepening events led to transgression of operculina-rich mudstone facies up to the nummulite platform.

Four depositional ramp models are characteristic of the Cyrenaican inversion setting. These depend on facies-type dominance, ramp slope angle and depositional energy distribution in relation to structural orientation.

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Seismic Stratigraphy and Facies Architecture of Northern Part of Nile Delta

The extensive deltaic, coastal progradation and paleo-channel courses of Pliocene Nile as well as the base of slope failure deposits of Cretaceous and Oligocene produced by syndepositional structural development have been recognized in the study area. The seismic characters of a grid of seismic data (i.e. configuration, continuity, amplitude and frequency, interval velocity and external form and association of seismic facies) tied to several well log data) were applied to define the sequence stratigraphy, seismic facies architecture and depositional environment of Nile Delta Area. The identification of seismic sequences requires that their boundaries would be defined and correlated on seismic data, these boundaries can be accomplished by locating reflection termination on seismic data.

High frequency sequences are identified within the deltaic complex on seismic data, these sequences, were probably in response to the high frequency cycles of relative changes in sea level that were produced by variable rates of subsidence and uplift. These sequences are precisely mapped with great lateral continuity, and within these sequences it can be possible recognized all system tracts which were hypothesized by sequence stratigraphy models. Also, the paleo-channel courses of Pliocene Nile, Protonile were also mapped.

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Application of Palynology to Exploration in the Lower Cenomanian Sequence, Bahariya Formation, Kenz Field in Khalda Concession, Western Desert, Egypt

Five palynozones were identified into the Bahariya section and were helpful in better understanding the reservoir geometry of the main productive zone into Palynozone Two.

The integration of palynological, sedimentological, seismic and E-Log data provided valuable paleoenvironment information. It indicated that the Bahariya sedimentary section was deposited in relatively deepening upward environment where it ranges from more terrestrial in the lower part of Lower Bahariya, to fluvial dominated deltas which has been largely controlled by tidal current, and to prograded shallow marine to shallow marine for the Upper Bahariya.

Sequence and parasequence boundaries are determined with the help of palynology, and this was found to be supported on the inverted seismic section, while it was not clear on conventional seismic data.

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Fault Definition Improvements in the West Abu El Gharadig Concession Using Prestack Depth Migration

The West Abu El Gharadig concession is located in the Qattara depression in the North of the Western Egyptian Desert. The surface geology is complex, Sabkha deposits cover about 50% of the area of the study. Dynamite was used to collect the data in this areas. The rest of the area is flat rocky desert, where vibroseis was used. We selected four lines, one of which was a strike line, for prestack depth migration. The area presents a geologic structure affected by an intense extensional faulting that deforms the sedimentary sequences. Faulting induces strong lateral velocity variations, creating false pull-up and sags in the seismic data which distort the true geologic structure. An exploratory well was drilled from an interpretation of time-migrated data, but the well could not confirm the interpreted fault locations. To reduce the risk of drilling, a velocity model was built guided by the well information and the seismic data. A 3-D velocity model was built to unify seismic and well information, and to tie the velocity model for the four lines. This velocity was used to run prestack Kirchhoff depth migration on the four selected lines. A second well was drilled from a re_interpretation of the fault location using the depth images. The second well confirmed the location of a major fault plane in the area. At the target depth of about 4000 ft, there is a 2000 ft displacement across the fault. Depths from the seismic data had a satisfactory tie with the well.

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Hydrocarbon Generation, Expulsion and Migration in Geisum and Tawila Oil Fields-Southern Gulf of Suez

Geisum and Tawila fields are located in the southern province of the Gulf of Suez and produce oil from the pre-rift Eocene, the lower Senonian sandstones, fractured Precambrian basement, and the post-rift Miocene Kareem and Belayim sandstones.

The study aims at determining the main source rock units and oil characterization for better understanding the time of generation, expulsion, and migration pathways of hydrocarbons.

Three main source rock units are investigated. The first source type is found in the Upper Senonian carbonate-rich sediments, the Brown Limestone.

The second source includes clastic - rich sediments, the Miocene Rudeis Formation.

The third type is the clastic - rich lower Senonian Matulla / Wata Formations.

The bulk composition for the crude oils shows two separate oil groups. The first group is the Geisum oils which are charged from the Brown Limestone, a marine carbonate-rich source.

The second group is the Tawila oils which appear to be charged from Miocene and the Lower Senonian, clastic - rich sources.

The hydrocarbon migration routes show that the main reservoirs in the Geisum field are charged from the Brown Limestone in the flank of the basin located south - west of Geisum.

The Tawila oils seem to be charged from the Rudeis and Matulla/Wata rocks in the basin located south of the field.

In addition, the hydrocarbon migration pathway may charge undiscovered prospects within the Geisum and Tawila concessions.

The correlation between the calculated expelled and trapped hydrocarbons and the proven reserves in Geisum and Tawila indicate that nearly half of the estimated reserves are not discovered yet.

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Facies Analysis and Sedimentary Environments of The Jurassic - Cenomanian Rocks in Ras Budran Oil Field and Surroundings, Gulf of Suez, Egypt

Gulf of Suez basin is the most prolific oil province in Egypt, although its complex nature, it contains the largest part of production and reserves. Production is derived from clastic and carbonate sediments that range in age from Paleozoic to Miocene. Most of the oil occurs in sands of the carboniferous, Cretaceous and Miocene ages. In Ras Budran oil fields, the Jurassic-Lower Cretaceous sands are the main hydrocarbon reservoir, while the Cenomanian forms a reservoir rock of some adjacent oil fields. The intent of the present research is to determine the sedimentological characteristics and palaeoenvironments of the Jurassic-Cenomanian siliciclastic/carbonate sediments in Ras Budran oil field and surrounding areas. This sedimentological study deals with the description and interpretation of the various sediment types and their microfacies associations, depositional cycles and palaeoecologic conditions that were prevailing during the sediment accumulation. Determination of lateral facies variations, geometry and orientation of sand bodies, sedimentation breaks and main tectonic events that affected the area will be involved. The study helps to formulate ideal sedimentation models for the studied successions. Moreover, time correlative sediments widely prevalent in the adjacent localities will be reviewed to enable a more visual view for the facies development in the area.

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An Early Depositional History and Stratigraphic Architecture from the Eastern Margin of the Suez Rift, Egypt

The present work is a follow-up of an earlier research phase during 1997-98 in Nukhul- Markha area: a tilted, fault-bounded block with a hanging-wall syncline on the eastern margin of the Suez Rift. The early syn-rift Oligo-Miocene sequences are exceptionally exposed in three-dimensional outcrops portraying facies architecture of a NW-trending, depocentre on a gradually rotated hanging-wall. Transverse to the depocentre axis, southwestwards stratal convergence and onlapping record the degree of rotation. The pre-rift Middle Eocene limestone is truncated by the initial rift unconformity and overlain by the earliest syn-rift alluvial and fluvio-lacustrine sediments with volcanoclastics and frequent stacked palaeosols and interfluvies. These predominantly red beds, known as Tayiba Formation, belong to the Late Oligocene and show angular unconformable relation to the overlying Aquitanian Nukhul Formation. The latter had been deposited in a variety of restricted marginal marine environments with strong tidal influence being maximized in narrow tectonic corridors and embayments. The study area offers an excellent surface analogue for modeling the reservoir sand distribution and geometry within a similar tectonic framework in the subsurface.

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Sequence Stratigraphy and Sedimentary History of the Neogene Nile Delta

The Neogene System is increasingly considered as the primary target for hydrocarbon exploration in the Nile Delta. The present work aims at constructing a regional stratigraphic framework to help understand the reservoir distribution. Proximal-to-distal variation of depositional sequences are inferred from regional, geoseismic transects calibrated by well data. Thirteen third order sequence boundaries and 6 maximum flooding surfaces were identified.

The development of the Nile Delta/River system was controlled by both the East Mediterranean basin evolution and the African Hinterland. The Nile system started during the Late Miocene with deep canyon incision into pre-existing Cenozoic/Mesozoic sequences leading to transportation of huge amounts of sediments to the Mediterranean. At least three incisions are seismically recognized with type-I sequence boundaries: the oldest is Tortonian and the youngest is Messinian. The proximal in-fill of these canyons is thick, coarse alluvium getting sandier with more marine influence northwards. The far reaches of these canyon systems bear a great potential of excellent low-stand reservoir.

More than 2km thick salt is seismically defined in the far-offshore and assigned to the Late Messinian salinity crisis. In the near-offshore only few tens to hundreds of meters of evaporites exist, while almost absent from the onshore area.

Excellent Plio-Pleistocene reservoir is mainly linked to the lowstands, where sands were conveyed to the outer belts through incised canyons in the upper slopes tracking to submarine fans farther northwards. Mega-slumps were particularly active during Late Pliocene to Recent. They form significant stratigraphic packages in the lower-slopes and basin plain areas.

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Rift Basin Development Across Inherited Deficit Zones of Wrenching and Impact on Hydrocarbon System, Great Bitter Lake, Egypt

Numerous published works on the Gulf of Suez basin insinuate rifting cessation at the northern Gulf tip. Present work proves the continuation of rifting further NW by integrating outcrops, seismic data and well penetrations.

The study area acquires SW-dip polarity of fault blocks as prevailing in the northern dip-province of the Gulf. The fault blocks extend in the NW-Clysmic direction with SW-trending divergent sedimentary wedging of Miocene syn-rift sediments. The western segments of the master coastal fault system show 5 km offset across an ENE-trending transfer zone. The latter is represented by mixed-dip regime and shallow basinal subsidence. The deposition of Miocene sediments above the tilted footwall of the coastal fault indicates a leaky rift shoulder at this part.

Further NW, the extensional Clysmic faults cessate across an inherited wrench belt of 11-15 km in width. This structural belt is represented by ENE-trending transpressive flower culminations that were developed during Upper Cretaceous tectonics forming ridges in the later Upper Senonian-Eocene basins. This orthogonal belt represents a rift deficit zone. Northwest of this zone, the rift dilutes and shows offset for mild faults. Further NW, the rift is additionally diluted by crossing another inherited wrench deficit zone. This progressive attenuation of rifting through interference with deficit zones marks the abortion of Gulf of Suez rifting.

The exposure of deficit zones before rifting resulted in restricted deposition of Upper Senonian-Eocene source rocks, and the diluted rift segments show shallow subsidence and thin syn-rift sequences.

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Eonile Canyon, Ancestor of the Nile River, Geology and Structural Implications

The Eonile Canyon represents the Upper Miocene Nile River ancestor through which clastics were transported to Mediterranean where several gas fields are discovered. This work provides a detailed mapping of the upstream onshore river system utilizing subsurface data which shows structural control of canyon entrenchment during Tortonian low-stand.

South of Cairo, cliffs of 200-500 m high of Eocene carbonate plateaus face narrow Eonile-path which runs along-strike of a major flexure-zone that shows 1600-1900 m drop for Eocene sequences. This flexure represents a Post-Eocene drape over a blind-inherited fault-zone of basement-suture.

North of Cairo, this suture and the Eonile pathfinder cross ENE-trending belts of Upper Cretaceous wrench-faults and culminations with entrenchment into the Cretaceous to Jurassic sediments. Further north, several NW-trending gorges of tributaries flux into the main Canyon with slope-gradient of 1:30 where large volume of Middle-Miocene to Eocene rocks excavated and transported to the main Eonile-Canyon.

The calculated depth of entrenchment reaches 1400 m south of Cairo and sunk to 2400 m in the north with 1:185 slope-gradient. This reflects steep gradient relative to 1: 4000 gradient of the Nile River, indicating powerful hydraulic system that was able to cascade the Mid-Delta hinge and transport huge amounts of coarse-reservoir clastics to Mediterranean in Upper Miocene. In Early-Pliocene high-stand, the Mediterranean transgressed the Eonile Canyon depositing thick prism of source rock shale. Upward in the sequence, ripple marked and burrowed shallow-marine carbonates exist and partially scoured and capped by channel deposits of Late Pliocene to Holocene.

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Evaluation of Different Interbed Multiple Attenuation Techniques, a Case Study from Kuwait

Seismic data from the State of Kuwait is typically contaminated with multiple energy, particularly interbed, that is resistant to conventional data processing attenuation techniques. Multiples impact the accuracy of structural and stratigraphic mapping and the reliability of seismic attribute measurements. The Geophysics Team of Kuwait Oil Company (KSC), Exploration Group, has implemented a program to test and evaluate seismic data processing multiple attenuation techniques during its major re-processing projects targeted at both exploration and field development objectives.

Surface and interbed multiples frequently do not exhibit significant velocity discrimination and are too complex in nature for statistical methods such as deconvolution to be effective, especially if true amplitudes are to be preserved. Conventional techniques based on both velocity discrimination and deconvolution have been ineffective in attenuating multiples in the deep Jurassic to Permian formations from onshore 3D seismic data from Kuwait.

This case study will present the different techniques applied and focus on the latest results achieved using an advanced wave equation consistent modeling and adaptive subtraction approach that has been successfully applied for the first time to onshore 3D data. The presentation will review the extensive test work that has been performed to identify the key multiple generating horizons through integrating the skills of the interpretation and processing geophysicists with available VSP and synthetic data.

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Integrating 3-D Seismic Attributes and Well Logs for Mapping Bypassed Reservoir and Meandering Fluvial Architecture, Stratton and Agua Dulce Fields, Texas Gulf Coast, USA

A study of the basal section of the Oligocene middle Frio Formation in Stratton and Agua Dulce fields tests the effect of synthetic and antithetic growth faults on the fluvial architecture. Gross- and net-sand thickness maps, log facies maps, and well-log cross-sections define channel belts. Correlation analysis confirms that seismic amplitude delineates the lateral extent of channel-fill deposits. RMS amplitude anomaly maps of the F11 interval show that meandering features relate to net pay and hydrocarbon pore volume thickness.

Bypassed reservoir is indicated from the 3D seismic mapping. This reservoir is a potential candidate for infield reserve growth in the northern Stratton area.

This area is dominated by the major Vicksburg and Agua Dulce growth faults, along with several synthetic and antithetic faults. Seismic and well log analysis show that subsidiary faults displace the stratigraphic units into several discrete compartments and result in different stacking patterns of the fluvial channel-fill deposits. The F11 reservoir unit is made up of several meandering channel belts. A broad northwest-southeast valley-fill, up to 4300 ft width, in the footwall block is controlled by the Agua Dulce fault at its southern boundary. In the hanging wall block, a wide avulsion complex is made up of east-west trending narrow meander channel-belts that are up to 1980 ft wide. In the southern part of the field, broad northwest-southeast meander channel belts are present in the hanging wall block. Post-depositional faulting along crestal-collapse antithetic faults offset these channel belts.

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Enhanced Productivity of Carbonate Reservoir by Cross-Dipole Shear-wave Logging in the Bakr/Amer Field, Gulf of Suez, Egypt

Earth stress patterns give a general indication of the most likely fracture orientation or maximum stress trend. Nonetheless, local variations and the effects of localized structures, such as large faults, can modify the stress pattern, counteracting or adding to the regional stress.

Thus, such a local stress and fracture profile information can be very meaningful to many petroleum exploration and development related aspects, such as, selecting perforation intervals and strategy, planning hydraulic fracturing operations, optimum well placement, wellbore stability, sand production, and hydrocarbon migration.

In this study, cross-dipole shear-wave anisotropy logs, acquired in several wells of the Bakr/Amer field (Gulf of Suez), were used to enhance the productivity of the Nullipore carbonate reservoir by determining the orientation and magnitude of the principal horizontal stresses and detecting major fractured intervals. Currently, the Bakr/Amer field accounts for 55% of the General Petroleum Company's (GPC) daily oil production. Approximately, 40% of this amount is solely produced from the uppermost reservoir known as the "Nullipore". The cross-dipole shear sonic data was processed to obtain oriented fast and slow shear waves. This information was then used to determine the direction and magnitude of the in-situ earth stresses, and the orientation of fractures. Zones showing significant shear-wave anisotropy were detected as open fracture systems, using the shear-wave anisotropy data in conjunction with the Stoneley-wave chevron patterns and other available logs. These intervals were subsequently perforated and produced significant amounts of hydrocarbons.

Further application of this technique in several wells of the Bakr/Amer field proved that the Nullipore reservoir productivity is primarily controlled by the flow contribution from natural fractures. New highly deviated wells were completed over the Nullipore on the basis of the newly acquired information and excellent results were obtained. Moreover, older wells were restudied and recompleted on the same basis and a large increase of production was attained.

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Petrography and Petrophysical Characterization of the Precambrian Hydrocarbon-Bearing Reservoirs, Gulf of Suez, Egypt

The present work deals with the geology and petrophysical characteristics of the Precambrian basement rocks and their hydrocarbon potentialities in the southern subprovince, Gulf of Suez. The available data are wireline logs, ditch cuttings and selected core samples of 13 wells; ten of which represent two oil fields: Ashrafi and Zeit Bay.

The petrography revealed coarse to medium crystalline granites with some exceptions in Abu Nigar-C-1 well where granodiorites are recorded. In Umm Agawish-1 well some diabase occurs across the granitic suits. Microfractures are found in two types: oriented sets along crystal contacts and cleavage planes and random sets crossing the crystals and framework. Secondary minerals filling these fractures are: carbonates, sulphides, iron oxides and sulphates. Some of these rock suites were differentially affected by alteration being manifested along cleavage planes and/or fractures. Three alteration stages could be deduced: the first during the Precambrian uplift and erosion phase; the second during the pre-Carboniferous uplift and erosion phase and the third was Pre-Miocene.

The integration between petrophysical and petrographical interpretation revealed the following main results: 1. The leaching of the alteration products of the feldspars in the granitic rocks led to the decrease of Gamma Ray and an increase of effective porosity. These also enhanced the calculated rock permeability. 2. Alteration along crystal margins is more effective for the reservoir performance. 3. The granitic suites being subjected to partial alteration under the effect of acidic water have a lower reservoir quality than those being affected by alkaline water.

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Petroleum Systems Offshore North Africa — Satellite Remote Sensing Applications Highlight New Potential

From the prolific onshore petroleum systems of Libya, Tunisia and Algeria to the remote, under explored deepwater basins of north and northwest Africa, integrated remote sensing solutions are revealing the structure, geology and hydrocarbon habitat as well as direct hydrocarbon evidence in northern Africa. Modern, high resolution optical, radar and hyper spectral satellite imagery, integrated with various geological, geochemical and geophysical data, can be mapped and interpreted at regional and prospect scale to reveal new prospectivity. Offshore, the direct evidence of seeping hydrocarbons in the Mediterranean and offshore NW Africa, again combined with various potential field and geophysical data, provide valuable insights into the extent and activity of active hydrocarbon systems.

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Geochemical Correlation of Crude Oils in the Northwestern Niger Delta, Nigeria

Sixty-six oils from eleven offshore and onshore fields in the northwestern Niger Delta, Nigeria were analyzed for their biomarker and isotopic composition. Biomarker and isotopic source parameter distributions grouped the oils into three oil families. Family A oils, located in the onshore swamp to the transitional area received charges from predominantly Upper Cretaceous or younger age marine source rocks deposited in a sub-oxic to oxic depositional environment. Family B oils occur in the near offshore area and are derived from Tertiary age source facies that received mixed terrigenous and marine organic matter. Family C oils, which dominate the offshore area, were derived from Tertiary age source rocks typical of deposition in oxic near shore or deltaic settings receiving significant terrestrial organic matter. Biomarker maturity parameters reveal the onshore (swamp) oils were generated at the peak of the oil generating window, while the transitional to offshore oils were expelled at the early stage of oil generation.

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Lowstand Systems Tract Identification and Prospectivity in Southern Red Sea

Seismic characters of Maqna2 Formation show lowstand systems tract geometries in southern Red Sea. Several seismic criteria such as geometries, patterns, and attributes have been observed within Maqna2 seismic facies. The slope fan seismic facies is a text-book example in this area, deep marine fan and low standwedge were interpreted relative to it. This seismic facies characterized in strike direction by mounded shape, convex upward reflection pattern with bi-directional downlap, common occurrence of high amplitude reflection on the upper surfaces due to the velocity contrast between the basinal shale-prone sediments and the underlying middle and/or lower fan sand-prone sediments, three dimensional fan shape, velocity pull-up for the underlying sediments due to the difference in velocity between the slope fan sands and in between shale-prone lowstand wedge, and finally the differential compaction between the sand-prone mounds and the adjacent the shale-prone sediments which cause drape of the overlying sediments across the fan edges. The low stand wedge shows onlap relation on the older slope fan filling the area's between the fans. On dip direction these lowstand sub marine fans demonstrate shingled progradational clinoform pattern, which indicate a shallow water prograding system, deep marine fan shows low relief bi-directional mound basin word from the slope fan which downlap onto it, and lowstand wedge onlaps onto the slope fan with retro-gradational pattern. The slope marine fans characterized by thin turbidite sands, with poor reservoir properties. These lowstand systems tract have significant structural and stratigraphic exploration potential.

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Arabian Platform Tectonic Events and Their Exploration Applications

The long offset 2D seismic data (7,200 m) along with the Deep Gas wells were a great help to understand the giant oil and gas fields growth history in the Arabian Platform. The Arabian Platform underwent six major tectonic events; each one has had a significant impact on oil and gas Field development throughout geologic history. These tectonic events were the principle contributors to trap geometry, timing and reservoir development of the giant structures.

These tectonic events are: 1) The Pre-Cambrian extension event, which has been documented seismically by the Infra-Cambrian Basins all over the Arabian Platform. These basins have a proven petroleum system in Oman., 2) The Hercynian Tectonics, represented by E and SE regional tilt in addition to NE-SW compressional forces, which resulted in NW-SE Haradh-Jawb trending growth structure. Stratigraphic and fault bounded traps could be controlled by this event., 3) The Permo-Traissic growth, which was the initiator of the Arabian Platform giant structural traps and contributed significantly to the development of the reservoir facies over these giant structures., 4) The Late Triassic NNW tilt, which developed a major basin in the Dibdibah Trough. This frontier basin has a great exploration gas potential especially with the relative deep targets (13,000 to 16,000 feet), and 5 and 6) The Upper Cretaceous and Neogene's NNE tilt, which formed the final hydrocarbon traps for Arabian Platform structures.

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Mediterranean Deep-water Tertiary Play Across a Typical Western Desert Domain (Offshore Matruh, Egypt)

A deep-water (1-3 km) play across the southern Mediterranean shelf north of Matruh City exists in a NNE oriented U-shaped trough. Gravity and magnetic data suggest that this trough extends along the axis of the onshore Matruh inverted basin. This 35-45 km wide trough has steep eastern and western slopes and a northward dipping basal detachment. A 3-km thick sedimentary section of Oligo-Miocene age filled the trough and was later affected by northward gravitational gliding over a thick base Cretaceous shale section (>1400 m thick). Gravitational gliding of the basin fill formed several northward dipping listric normal faults soling down on the basal detachment and associated with rollover anticlines. The top part of these folded rocks was truncated during the Messinian crisis of the Mediterranean and covered later by a thin veneer of post-Miocene sediments.

Structural traps (anticlines and tilted fault blocks) and stratigraphic traps (lenticular bodies on the backside of folds and fault blocks) represent the main plays in the area. Jurassic and Lower Cretaceous shales underlying the trough are good source rocks. NNE oriented faults dissecting these source rocks form hydrocarbon migration conduits into the overlying Tertiary reservoirs. Oligo-Miocene sediments derived from the Western Desert are the main clastic reservoirs and shale sections within the trough are the main sealing rocks.

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Deepwater Sequence Stratigraphy and Reservoir Prediction

The early Karoo basin of southwestern South Africa was segmented into the Tanqua and Laingsburg sub-basins through the growth of antiform/synform pairs oblique to the dominant shortening direction in the bounding Cape Fold Belt. These structures grew episodically during deposition in the Laingsburg area but did not affect the Tanqua sub-basin. Detailed sedimentological analysis and regional 3-D mapping of basin floor and slope turbidite complexes from both sub-basins has allowed development of a high resolution sequence stratigraphic model with modifications to account for the influence of episodically growing basin floor topography in the Laingsburg sub-basin. Individual basin floor fans (50 - 300 m thick) can be divided into high frequency sequences that include sandy growth phases (lowstand systems tracts) separated by fan-wide zones of reduced sand deposition (transgressive and highstand systems tracts). In both sub-basins, these high frequency sequences form zones for reservoir modelling and stack in progradational, aggradational and retrogradational styles, which controls vertical and horizontal effective permeability. The main effect of punctuated growth folding on the Laingsburg basin floor fans was to elongate fan geometries parallel to the fold axes and to concentrate sand-rich flow fractions in syntectonic lows, resulting in starvation on and beyond highs. Saddles in the antiforms allowed cross-structure sand transport. The main effect of growth folding on slope systems is episodic cycling (in space and time) between ponded accommodation and bypass, resulting in complex facies patterns, net:gross trends and connectivity.

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Stratigraphic Prediction in Tectonically Active Basins

Sequence stratigraphy can be applied successfully to tectonically active basins in terms of the 4-D evolution of accommodation and sediment supply. In extensional basins and growth-faulted margins, fault linkage and growth history are critical parameters in understanding spatial accommodation distribution and, when convolved with transfer zone/relay sediment entry points allow prediction of facies. In foreland basins, the interaction of basement discontinuities with the flexural load result in differential accommodation generation, which affects shoreline orientations and character of lowstand deposits. In both extensional and foreland basins, salt withdrawal results in aggradational stacking patterns and suppressed sequence boundaries. Structural topography may amplify tidal conditions at multiple regional sea level positions, without the presence of incised valleys. In complex strike-slip settings local areas can evolve from excess accommodation, through filled accommodation to negative accommodation as blocks subside, rotate, lock and invert.

Although stratal geometries vary in tectonically active basins, the fundamental cornerstones of accommodation and sediment supply remain the key parameters in understanding and predicting facies and therefore reservoir/seal distribution. Examples will be used from the North Sea, the U.S. Western Interior Basin and the Russian Far East.

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Recognition and Prediction of Permeability in a Carbonate Ramp Environment, Abu Dhabi

This paper illustrates how field-wide permeability baffles may be predicted by combining hi-resolution FMI image analysis with cyclostratigraphy.

Image attributes of core-calibrated FMI logs have been used to identify carbonate facies in a Lower Cretaceous carbonate ramp of Abu Dhabi. Recognized facies in FMI logs include rudist, grainstone, Orbitolina, Bacinella and bioturbated wackestones. The occurrence of facies is linked to third-order eustatic variations in which low sea-level was associated with the development of high permeable coarse-grained facies, and major flooding events with the development of fine-grained low permeability facies. The gentle slope of this carbonate ramp allowed the almost synchronous occurrence of major exposure and flooding events fieldwide. In addition to the low order eustatic variations, high frequency fluctuations in sea-level were responsible for the cyclic occurrence of diagenetically-enhanced <1ft thick dense resistive streaks. These streaks are believed to constitute vertical flow barriers within the reservoirs with some of them extending across several wells, and often undetected by non-microresistivity logs.

The high and low permeability layers can be confidently detected at high vertical resolution through image attributes of FMI logs. Spectral analysis of the FMI attributes indicates that Milankovitch-band climate-forcing controlled the occurrence of these thin resistive streaks, and therefore can be used to predict their occurrence where FMI logs are not available.

This study has shown that the combination of image log attributes with gamma-ray, neutron and resistivity logs allows a reasonable prediction of permeability for the different facies in carbonate-ramps.

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Principal Component Analysis of Seismic Data and Reservoir Sequence Stratigraphy: Powerful Allies in Reservoir Modelling and Waterflood Management, Gbokoda Field, Nigeria

Principal component analysis (PCA) of seismic data, combined with reservoir sequence stratigraphy, creates a powerful method for mapping and modelling pressure compartmentalization. Understanding compartmentalization during waterflooding is key to locating water injectors and producers to maximize sweep efficiency.

Gbokoda Field is located onshore Niger Delta and contains over 850 mmb oil-in-place. The main A-05 reservoir is a shoreface sandstone and was placed on peripheral waterflood during primary development due to anticipated weak aquifer support.

After 3 years of waterflooding, our pressure surveillance program indicated pressure compartmentalization with ~350 psi of differential depletion across the field. Several western wells ceased production due to low tubing pressure, despite good injection from a horizontal injector downdip. In contrast, the eastern portion of the field showed minimal depletion. Analysis of the log and seismic data within the western area showed a poorly expressed incised channel.

Starting with Gbokoda 3D seismic data, we used PCA to perform seismic curve shape comparison to group the different curve shapes into mappable clusters. Amplitude and phase form the largest contribution to the variance of the clusters. Clusters represent different rocktypes, facies, and fluids creating high-resolution mappable units.

By combining the PCA-based mapping with log and core-based sequence stratigraphy, we determined the producers were located within the shoreface sequence, whereas the injection well was located within a disconnected incised valley fill sequence.

After updating our simulation model, we restored production and reversed the pressure depletion by reactivating the producers and completing a new horizontal injector within the shoreface sequence.

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The Hydrocarbon System of Blocks II and III in the Eastern Black Sea Offshore the Republic of Georgia

Anadarko Georgia Company and the Georgian National Oil Co have completed seismic, gravity, and aeromagnetic surveys in two blocks offshore Georgia in the Black Sea.

The geological history of the area is complex because of the repeated opening and closing of various portions of the Tethyan seaway since the Early Triassic. The onshore geology is dominated by two fold and thrust belts, the Greater Caucasus to the north and the Achara-Trialet to the south. The thrust fronts are separated by a series of Neogene foreland basins, the Kura, the Kartli and the Rioni in the west.

The interpretations show that the Achara-Trialet complex terminates very abruptly close to the coastline. Offshore, the long axis of some of the Neogene to recent folds are over 50 kilometers long and change trend from east-west in the northern and eastern portion of the study area to southwest-northeast in the southern and western portion of the blocks. The structural deformation decreases basinward.

The sedimentary package contains strata that are younger and thicker than those onshore and some have seismic characteristics that are attributable to reservoir facies, especially in the Miocene and Plio-pleistocene sections. The Maykop Formation (Oligocene-Miocene) is recognized regionally as a very productive, oil prone source rock that is identified in the offshore by its distinctive seismic character where it is up to 5000 meters thick. Basin models indicate that at present the Maykop Formation is in the oil window throughout most of the two blocks. Vertical migration is expected via faults. Oil seeps were identified on repeated satellite images over the crests of two of the anticlines.

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Understanding of the Reservoir Behavior Based on the Reservoir Pressure and Fault Block Communications of the Nubia Sandstone, October Field, Gulf of Suez

The Nubia sandstone reservoir in October oil field is one of the most prolific reservoirs in Egypt. It is represented by a massive sandstone body separated by shale beds. The most effective of these shale beds is the M II shale, which extends throughout the field and appears to form a vertical barrier to the flow of fluids and pressure equalization and production in the field.

Pressure analysis of the Nubia sandstone reservoir helped to understand the degree of communication between the units, above and below the M II shale. The analysis of the RFT, TDT, PLT, core data, and production data are used to explain reservoir heterogeneity.

Construction of water movement cross sections is a good tool to understand the progressive of water front advancement through time, which in turn will help to quantify areas of bypassed oil and consequently recommend further infill-drilling locations.

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Integration of Core, Log, and Petrographic Data For Petrophysical Analysis of The Nubia Sandstone Reservoir, October Field, Gulf Of Suez

A detailed geological and petrophysical study of the Nubia sandstone reservoir in October Oil Field has been made to interpret the reservoir heterogeneity and factors affecting reservoir damage. Using a computer processed log analysis program, the reservoir has been subdivided into six zones based on the shale content, porosity, and permeability variations. A continuous shale beds have been identified throughout the drilled section, which probably act as a barrier to the vertical flow of the fluids through the reservoir.

The constructed reservoir geology model shows that the water encroachment can be explained as edge water drive, and is controlled by the continuous shale beds, which prevent the vertical fluid flow.

The factors affecting reservoir damage and variation in the petrophysical characteristics of the reservoir should determine programs for efficient water flooding which may increase the maximum oil recovery.

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Amal Field Case History: An Approach to New Plays, Prospects and Development of Old Producing Fields

Amal field is located in the southern province of the Gulf of Suez; the first oil discovery was in 1968, the first production was in 1989, the field passed through different exploration & development phases, each phase reflects specific objectives.

Strategic goals and objectives usually amended by time even for the same firm, especially in oil business, thirty years ago investments usually were directed to oil exploration & production nowadays global demands of energy sources are directed to gases, but oil is still on the top rank.

Evolution of Amal field is an example for this subject through subsequent operators, where the first exploration phase targeting deep oil reservoirs, huge oil reserves and paying no attention to gas discovery & production as gases was not considered one of the main exploration objectives in addition to, the agreement regulations at that time. The first exploration phase does not fulfill the main objectives even with oil and gas discovery in shallow reservoirs.

The Second phase reflects a new strategy to explore and produce limited reserves. The lifetime commercial production for the estimated reserve was about seven years.

The third and current phase, efforts to extend lifetime for the field were successful. Also, making use of new technology to revive the Amal field potentialities, delineate new plays, prospects, and overall field development.

In brief, the aim of this study is to explore and produce any commercial hydrocarbon reserves in one of the old fields "Amal field".

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PS-Wave Birefringence Analysis at the Emilio Field for Fracture Characterization

3-D converted P to S-waves (PS-waves) provide an excellent opportunity to exploit up-going shear-wave (S-wave) birefringence for delineating reservoir fractures. In azimuthally anisotropic media, fracture intensities and orientations are directly related to travel-time differences between fast and slow S-wave, and the polarization direction of the fast S-wave, respectively. The Emilio 3-D survey, acquired over a fractured carbonate reservoir in the Adriatic Sea, demonstrates that these S-wave velocity properties can be determined from azimuth-supergather analyses, average velocity ratios between the fast (PS1) and slow (PS2) converted waves, and 2Cx2C Alford rotation and layer stripping. Exploiting the high uniform fold of coverage at all offset and azimuth ranges, separate volumes for the different wavefield propagation directions were produced (eight PS-wave restricted azimuth datasets). The PS-wave azimuth volumes were combined through Alford rotation for the final fracture analysis. Birefringent velocity properties of the overburden must be determined and removed prior to estimating fracture properties at target horizon. Upon removing the splitting effects below the sea-bottom (almost isotropic), further Alford rotation and layer-stripping analyses allow for the determination of birefringent properties at intermediate levels and the target level in the carbonate Scaglia formation. The results from this analysis at target level near the well locations were in good agreement with the borehole information.

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Early Paleozoic Depositional Cycles of Eastern Algeria; Sequence Stratigraphy and Paleogeography, and Insights into their Regional Correlation in Northern Gondwana

Cambrian-Silurian siliciclastic rocks are an important objective of petroleum exploration in eastern Algeria. They contain a major early Silurian source rock, and include sandstone reservoirs that hold over 20 BBOE. The Lower Paleozoic of SE Algeria is a 450 to 2000 m thick sand-prone depositional unit that fills the Berkine, and Illizi intracratonic depressions.

The Cambro-Ordovician interval consists of thick and laterally-extensive fluvial and shallow marine sandstone intervals separated by conspicuous offshore shale tongues, and major unconformities. The uppermost Ordovician are tillites, glaciogenic sandstones, and glaciomarine shales deposited during the short-lived Ashgill glaciation. The succession is followed by marine shales of early Silurian age deposited during the post-glacial transgression, covered by a mid-late Silurian fluvio-deltaic progradational sequence-set..

The series shows an overall parallel stratal-stacking pattern in its lower Cambro-Ordovician portion that changes to a low angle sigmoidal progradational architecture within the Silurian tracts. It lies over the late Proterozoic Pan-African igneous-metamorphic basement and its top is marked by the tectonically enhanced "Caledonian" Unconformity of terminal Silurian age. Low subsidence rates and a long-term early Paleozoic eustatic high created limited but widespread accommodation throughout the paleo-Tethys Gondwana margin. This, combined with a high sediment supply from the Pan African orogenic relief to yield widespread largely tabular sand-rich depositional packages. Major regional unconformities separate the series into five megasequences: Cam 1 (Early Cambrian), Cam 2 (Mid-Late Cambrian), Ord 1 (Late Cambrian- base Arenigian; peak transgression mid-Tremadocian), Ord 2 (Early Arenigian-Ashgillian, peak transgression Llanvirnian), and Sil 1 (Ashgill-Pridolian, peak transgression Llandoveryan).

We have observed similar depositional cycles in Morocco and the Middle East and we postulate that they are Gondwana-wide cycles linked to eustasy and major tectonic events.

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Normal Fault Population Evolution and Stratigraphic Response: An Example from the Hammam Faraun Fault Block, Suez Rift, Egypt

The evolution and linkage of fault segments to form continuous, basin-bounding normal fault zones is recognised as a first-order control on the size, shape and stratigraphy of sedimentary basins within areas of continental extension. We present results of an integrated structural and sedimentological study of the late Oligocene-Recent evolution of the Hammam Faraun fault block, Suez rift that allows the temporal evolution of fault populations to be investigated. Initial fault activity was distributed across the fault block on short (1-4 km long), low displacement (<1 km) segments, with most faults attaining their maximum length soon after the onset of rifting. Over the first 6-8 Myr of rifting, these initial segments either linked to form longer, segmented fault zones, or became inactive and died. Following this rift initiation phase, displacement became progressively localised onto >25 km long border fault zones bounding the fault block and many of the early intra-block fault zones became inactive. The locus of fault activity continued to migrate following linkage, with post Middle Miocene displacement focused on the western margin of the fault block. The dynamics of fault population evolution illustrated here are comparable to those suggested by analogue and numerical modelling studies and have important implications for the tectono-stratigraphic evolution of rifts and for understanding complex and often subtle syn-rift plays and structural compartmentalization of major fault blocks.

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Sequence Stratigraphic Evolution Rift Tectonics: Examples from the Sinai Margin of the Suez Rift, Egypt

The evolution and linkage of fault segments to form continuous, basin-bounding normal fault zones is a first-order control on the size and shape of sedimentary basins in extensional settings and their stratigraphic evolution. We document the tectono-sedimentary evolution of the Hammam Faraun fault block, located on the Sinai margin of the Miocene Suez Rift, Egypt to illustrate: i) the evolution of a fault population from rift initiation to the development of a major crustal-scale tilted fault block, and ii) the temporal and spatial development of syn-rift sequences in response to this structural evolution, and the influence of other controls on stratigraphy.

The initial syn-rift succession of the Hammam Faraun fault block comprises the fluvio-lacustrine Abu Zenima Formation and the tidal Nukhul Formation. These are locally developed in growth synclines and half graben adjacent to short (1-4 km long), low displacement (<1 km) segments distributed across the fault block. Onlap and facies relationships record growth folding and fault linkage during Abu Zenima and Nukhul times.

The overlying Rudeis Formation, however, is characterised by basinal, mudstone-dominated depositional environments, with local coarse-grained deltaic and turbiditic units in the immediate hanging wall of the major border faults to the Hammam Faraun fault block. The thickest development of the Rudeis Formation, and the restriction of footwall-derived coarse-grained clastics to the immediate hanging wall of the border faults, suggest that activity on many of the intra-block fault zones ceased due to the localisation of slip onto the major border faults bounding the Hammam Faraun fault block.

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Offshore Potential of the Shallow-Water Portion of Apache's West Mediterranean Concession

The offshore portion of the West Mediterranean concession is located west of Alexandria in water depths less than 100 m. A 760 Km² 3D seismic survey was acquired January 2000 over a shallow-water portion of the concession. Pre-Stack Depth Migration was applied employing global tomography to construct the velocity model.

The main play is an extension of the onshore Western Desert Cretaceous play. Primary objectives include Bahariya/Kharita clastics, fractured Alamein dolomite and Alam el Bueb sandstones. Jurassic source rocks are thought to be present and mature for oil in the basin to the north and west.

Two wells have been drilled in the shallow-water portion of the concession. The Shaqiq-1X stopped at the base of the Tertiary section and is a dry hole. The Marakia-1X penetrated much of the Cretaceous section and recovered oil from the Alam el Bueb formation. The Marakia-1X oil is typed to Jurassic oils from the adjacent onshore oil fields.

The main structures are northwest trending Late Cretaceous to Early Tertiary normal faults. An older east-west structural grain is also evident. The east-west grain is parallel to Lower Cretaceous and Jurassic-aged structures onshore, and is considered to be Early Cretaceous or Jurassic in the offshore as well. The interaction of the two structural trends defines several fault-dependent, 3-way dipping prospects.

The potential for a "buried hill" play exists in the shallow marine portion of the concession. In the northern part of the shallow marine area Messinian and older unconformities cut deeply into the Cretaceous section. The erosional surfaces define north-south trending canyons and intervening ridges which are projected north beyond the limits of the shallow-marine 3D coverage.

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Large Volume Reconnaissance AVO and Anisotropy Prediction: OPL 256 Nigeria

In 2000 a reconnaissance 1850sq km 3D survey was acquired in OPL 256/7 offshore Nigeria. The purpose of this 3D seismic survey was to image and accurately map tectonic features of the area. In addition to identifying hydrocarbon accumulations, the aim was to obtain high-resolution data for the mapping of the fault systems and deltaic packages. Since multiples pose a significant problem in this area, one of the main challenges was to effectively attenuate the multiples present in the data.

The OPL 256/7 area, offshore Nigeria, is characterised by a thick Neogene section deposited in a deepwater setting in the outer compressional zone of the Niger Delta. Target structures within the sand/shale Agbada Formation consist primarily of a series of shoreward-dipping toe-thrusts that sole out in the over-pressured shale of the Akata formation, together with large turtle-back anticlines. Proven reservoir facies within the Agbada Formation were deposited in channel and turbidite lobe environments.

In this paper we outline the acquisition parameters and discuss in detail the pre-stack imaging sequence, paying particular attention to the subjects of AVO analysis, as well as lithology prediction from transverse anisotropy measurements.

We present a selection of AVO attributes which include the fluid factor, and show how, using a 3D visualization system, our ability to interpret these volumes is enhanced. We describe also our methods of predicting bulk anisotropy parameters from pre-stack analysis, and show how these can be used to describe large scale shale distributions.

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The Rio Muni Basin: An Emerging Deepwater Hydrocarbon Province

The Rio Muni basin underlies the continental shelf of the West African republic of Equatorial Guinea, located between Gabon and Cameroon. The basin is situated above a section dominated by a northeast-southwest trending oceanic fracture zone and its continental extension. This fracture zone constitutes the boundary between the Equatorial Atlantic margin and the West African salt basin.

Despite its location between the prolific hydrocarbon provinces of the Niger delta to the north and the Gabon coastal basin to the south, the Rio Muni basin has been overlooked by the industry for much of the last decade. Previous wells have proved a viable source rock, but no accumulations. Triton Energy licensed Block F & G in 1997 and drilled the Ceiba 1 discovery well in 1999, proving a new hydrocarbon system in the deep water, Late Cretaceous post rift sequence. Deformation by Santonian-Coniacian transpression caused uplift of the shelfal area and deposition of a thick. Slope fan sequence. Contemporaneous salt deformation of rafted deposits and the development of a base of slope compressional belt area also evident. The resultant turbidite sequences form the reservoirs in the Ceiba field. First oil from the Ceiba field was achieved in record time of 14 months. The field has been on production for over a year now and over 20 MMBO have been produced to date. Subsequent exploration drilling focussed by AVO studies has led to the discovery of five new fields in the current play fairway. Future exploration will continue to evaluate the large untested areas of the block.

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The Permo/Triassic of Iran, Mainland and Offshore

An update is available on the surface and subsurface of the Permo/ Triassic of Southwest Iran, in particular highlighting its stratigraphy, sedimentology, and paleontology.

To gain a more in-depth understanding of the great profusion of the natural gas, some 30% of the total gas reserves of the world, details on a) the surface (high mountains of the Zagros region) and b) subsurface (Southwest Iran to the mainland and offshore area of the Persian Gulf), will be presented.

Sedimentologically, seven regressive sedimentary cycles are distinguished in the Permo/Triassic sequence. Reservoirs are restricted to the grain supported textures with some local variations, which may have caused by anhydritization, dolomitization and varying intensity of anhydrite leaching. Fissures and fractures also play in later upgrading of the reservoir potential. Diagenesis and reservoir distribution seem to be restricted to the Dalan and Kangan Formations, which may contain the main gas reservoirs.

Palentologically, thin section study of the Permo/Triassic sediments in the surface and subsurface provided some sixty different foraminiferal and algal forms to be used for local and regional correlation and supporting evidence for the Permian/Triassic boundary. The Permian section penetrated in the waters of the Persian Gulf area is also discussed.

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Samail Ophiolite Obduction and New Structural Constraints from Saih Hatat and Hawasina Windows

The popular view of Samail Ophiolite emplacement involves Late Cretaceous closure of the former Tethys Ocean by "piggy-back" thrusting with northeast to southwest emplacement of successively lower "thrust slices" from an external oceanic domain over and towards a "passive" Arabian continental margin. The recognition of major NE-facing isoclinal fold closures in carbonates of both the Saih Hatat and Hawasina windows however, provides a major contradiction for the Oman Mountains. Isoclinal folds that verge away from the Arabian craton have been previously recognised, but have been simply related to back-thrusting. These folds are extensively developed however, have regional scale and extent, and are the major structures of the Saih Hatat dome. Their presence 1) indicates that for at least part of the history the platform to slope carbonates sequences were "thrust" to the northeast, and 2) requires non-passive margin behaviour for part of the ophiolite obduction.

Ar-Ar geochronology from the Saih Hatat window requires Late Cretaceous (~76 to 70Ma) movement of the para-autochthonous Arabian margin rocks to the NE due to underthrusting of the margin. This is an important part of the tectonic evolution (and ophiolite obduction) that has not been previously recognised.

Therefore, models involving craton-directed thrusting with domal culminations related to deep-seated, footwall and lateral ramps are too simplistic for the overall tectonic evolution of this part of the Arabian Peninsular. Such models may however, be more applicable to the Tertiary structure and Tertiary evolution of the Mountains.

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Using Seismic Information to Predict Pressure Variations and Fluid Migration Pathways to Optimize Reservoir Development Plans

Reservoir Geophysics focuses on imaging geometry, inferring lithologic properties of the subsurface, and on the direct identification of hydrocarbons under certain conditions. Other important reservoir parameters in reservoir dynamics are stresses and the resulting pressure fields within the reservoir. These stresses affect the fluid migration pathways, optimized location of hydrocarbons and recovery schemes throughout the life of the reservoir. We present a technique where seismic information is used to estimate the changes in stresses and reservoir pressures within a reservoir and infer fluid movement and hydrocarbon accumulations zones within the reservoir.

The Dynamic Fluid Method, or DFM, couples basin stress evolution models, which correspond to subsurface fluid movements, with predictions of seismic response and specialized processing to emphasize that response. This technique has applicability optimize field development plans, identify redistribution of pressure within the reservoir due to production, identify missed pay and zones most conducive to recharging.

Our technique allows estimation of pressure variations within a defined reservoir zone. We can define zones or compartments of abnormal pressures, or areas that are most likely areas of fluid accumulation based on the derived parameters of fluid flow. In essence, the total pressure and it's variation in the geological time scale determine the fluid dynamics and make the fluid migrate from the regions of compression into the regions of low pressures (the areas of decompression).

Besides discussion of the methodology of this technique, several case histories of this technique are provided, in both clastic and carbonate reservoirs.

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Competing in the World Energy Market: The Key Factors for Investing in Oil and Gas Ventures

Over the next decade, the worldwide energy industry estimates it will invest more than tens of billions of dollars in the development of global oil and gas resources. Determining where to spend these dollars is a complex process, and Ocean Energy has developed a unique portfolio modeling method that combines a number of factors from a geo-science, engineering, commercial and political perspective to guide its international investment strategy. In this presentation, James T. Hackett, chairman, chief executive officer and president of Ocean Energy, Inc., one the largest independent oil and gas companies in the United States that is active in eight countries, will discuss the sophisticated approach his company utilizes and the type of partnership arrangements it seeks from host governments to encourage new and continued investment.

Maher Haddad¹, Ahmed H. Ahmed¹, Fielding Turlington¹, Paul Henning¹, Ron Krenek¹, Bruce May¹, Gary Mercado¹, John Petler¹ (1) GUPCO, Cairo, Egypt

Development Of The West Ramadan Field, Blocks GS30² and SB²93, Gulf Of Suez, Egypt

The development of the West Ramadan Field since it's discovery in June 2000 has presented challenges and risks that are best addressed with a multi-disciplinary approach. The field produces from the Miocene Hawara Sandstone in a down thrown block west of the prolific Ramadan Field. The key challenges to developing the Hawara Sandstone include; sandstone and reservoir distribution, reservoir continuity, drive mechanism, performance and trap definition. Economic risks and benefits are being addressed by the development of parts of the West Ramadan Field from the existing infrastructure. An active program of data collection; reservoir pressures, well performance and core address some of the reservoir challenges. Material balance work provides feedback to reservoir distribution and trap geometries defined by seismic and geological data. This multi-disciplinary approach leads to the identification of additional opportunities, better risk management and an understanding of reservoir performance.

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The Over/Under Acquisition Test - Taking the Seismic to the Technical Limits

Most of the 3D seismic surveys in the Nile Delta were acquired to address dual exploration targets: Pliocene and Pre-Messinian. Shallow Pliocene objectives require a high resolution image that is optimally achieved through shallow gun/streamer depths. In contrast, deep Pre-Messinian objective requires good penetration and signal/noise ratio that can be best obtained through deep gun/streamer depths. Therefore, conventional surveys with towing depths of 6-7m were conducted as a compromise between both objectives.

The Over/Under acquisition technique combines the data acquired using different cable depths and blends both high and low frequencies in a single image that could satisfy the requirements of both exploration objectives. Inspired by the results of the WesternGeco experiment in the Mediterranean, BP Egypt conducted an Over/Under acquisition test in the Nile Delta.

The vessel "Geco Diamond" recorded several vessel passes over an existing conventional 3D in the Western Nile Delta. The vessel was simultaneously towing four streamers of 8000m length at alternating depths of 7m and 11m at 50m separation. One data set of 4m streamer depth was generated from the combination of the Over/Under 7m & 11m data. Another set was generated from the combination of the new 11m and the old 7m data. Both sets were compared to the conventional data to assess the gain achieved at both high and low ends of the spectrum.

Comparisons and contrasts of the results of these tests could open new opportunities for acquiring superior shallow and deep data quality to reduce exploration risk in Nile Delta.

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Recent Advances in Coring and Core Analysis for Reservoir Description

The main goal of core analysis is to reduce uncertainty in reservoir evaluation by providing data representative of the reservoir at in situ conditions. Core analysis has to be integrated with field and production data to minimize reservoir uncertainties that cannot be addressed with other data sources such as well logging, well testing or seismic. These requirements define the coring objectives, core handling and core analysis schedule. These objectives cannot be achieved by coring a single well. Coring program is thus an integral part of the reservoir history cycle.

The post- eighties economics of the petroleum industry, expressed as a need for ever more cost effective technology, combined with the need to evaluate thin bed and non conventional reservoir by means of vertical and horizontal wells, serve as both the controlling factor and driving force, respectively, behind the development of new techniques of coring and core analysis. Techniques are constantly being improved or new ones are introduced. In proper core analysis the concept of automatic geological core description is growing with the use of the mini-permeameter and the proliferation of sophisticated analysis methods such as SEM / EDX, X-ray CT, NMR and PIA. These Hi-Tech methods provide a wealth of micro structural and microscopic information previously undreamed of.

This paper presents the recent and emerging developments and trends in coring technology and core analysis. This is to enhance the reservoir description and evaluation processes. Eventually the main challenges in core analysis and recent trends affecting future tool developments will be provided.

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Multilayer Map Based Hydrocarbon Modelling, a Sensitivity Study from a Frontier Area, Norwegian Continental Shelf

A multilayer migration technique is used to model hydrocarbon systems where the oil and gas migration occurs vertically upwards within mudrock sequences and faults. Lateral hydrocarbon migration occurs within well-defined carriers.

This presentation aims to highlight hydrocarbon charge risks based on a complex geological model in a frontier area. The geological model consists of 16 interpreted horizons and 5 constructed surfaces. Four source rocks and six carriers are also incorporated in the map based computer model. Maturation and expulsion modelling are performed on the four source rocks. The temperature model used for maturation and expulsion is calibrated with temperature data, and modelled maturity against measured vitrinite reflectance. The source rocks are assumed to charge directly three of six carrier beds, all in different stratigraphic positions. Hydraulic leakage and capillary leakage from hydrocarbon traps are presumed to be a vertical sourcing mechanism to above lying carriers.

The prospectivity is assessed based on maximum, minimum and most likely cases for each of the source rocks' richness and extent. The same classification is used on the lateral extent of the carriers. Sensitivity to vertical trap-leakage rates is assessed both for hydraulic and capillary leakage. The effects of detailed reconstruction of palaeo-water depth on trap configurations are explored for six timesteps within the last 2.7 million years. The trapped hydrocarbons are calibrated against known fields and a match with hydrocarbon phases in the traps is obtained.

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Phanerozoic Regional Cycle Chart of Sea Level Changes for the Arabian Platform

The global eustatic Cycle Chart continues to be an important first-order tool in exploration geology. In addition to being a chronostratigraphic correlation tool, the relative magnitude and frequency of sea-level rises and falls and the duration of subaerial exposure are valuable exploration criteria. The Arabian Plate has had a complex tectonic history, in addition to being influenced by broad eustatic changes. Tectonic events led to changes in the direction, rate, and/or locus of subsidence that created major accommodation for sediment deposition, while causing erosion-al hiatuses elsewhere. Consequently, both eustasy and tectonics play important roles in the development of sedimentary sequences and in determining the characteristics of the reservoir, source and seal facies on the Platform. A regional cycle chart of relative sea-level changes based on the Arabian Platform that is compared to the eustatic Cycle Chart could enhance the usefulness of this exploration tool for this region. A new Regional Cycle Chart for the Phanerozoic of the Arabian Platform is presented that ties the regional events on the Platform with global cyclicity. Hence, comparisons for any given interval can reveal when tectonic influences were predominant, or conversely, when eustasy was prevalent. The comparison of the two curves will also yield better chronostratigraphic estimates and assure improved global correlations. The Regional Cycle Chart will also be an ideal accompaniment for sequence-stratigraphic studies on the Platform.

Stephen Hart¹, Marc Gerrits¹, Hans Meyer¹, Renaat Demyttenaere¹, Eleanor Rowley¹, Magda Nour El-Din¹, Hala Zaki¹, Aly Nassar¹, John Stainforth², Ahmed Abdel-Aal² (1) Shell Egypt N.V, Cairo, Egypt (2) Shell Deepwater Services, Houston,

Finding the Sweet Spots in a Large Under-Explored Block – Refocusing Exploration in the Northeast Mediterranean Deep Water Area

Shell Egypt operates the deep water Northeast Mediterranean concession (Nemed), with partners ExxonMobil (25%) and Petronas (12%). The concession extends over approximately 41,500 km² of the offshore Nile Delta in water depths ranging from 800-3,000 metres, covering a variety of Plio-Pleistocene and older plays.

The Shorouk-1 and Leil-1 wells were drilled in Nemed in late 2000-early 2001, targeting Pliocene turbidite reservoirs. The well results were encouraging, and to further optimise Shell Egypt's exploration strategy in Nemed, a regional framework study was undertaken, involving calibration with the whole offshore Nile Delta. The current hydrocarbon discoveries in the area (c. 36 Tcf of gas) fall into a number of discrete trends. The aim of the study was to use a full hydrocarbon system analysis to understand the controls on these trends. The remaining exploration 'sweet spots' across the area have been predicted, where the chances of optimal charge, migration, reservoir, trap and retention coincide. This integrated approach has helped to re-focus the exploration activity in Nemed, so as to maximise the chance of future success.

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Composition, Structure, Evolution and Formation of Hydrocarbons in the Earth Crust of Lesser Caucasus

Based on laboratory and numerous geological and geophysical data, we suggest petrophysical section and the model of evolution of Earth crust and formation of fluids and hydrocarbon components.

By us at formation of structures and different processes definite part play serpentized layer. This layer was "dis-tricted" partially, intruded on deep faults, suffered dehydration, partially preserved in the form of lens- shaped structures on the foot of the Earth Crust.

As a result of dehydration of the mentioned rocks are secreted fluids and gases, containing hydrocarbon components, which migrate to higher horizons of the Earth Crust and are accumulated in the rocks possessing collector properties.

Other source of fluids and gases are considered metamorphized layer, which is represented by limestone's, marbles, graphitized schists etc, from which take place squeezing out of organic substances.

We suppose that the territory of Lesser Caucasus the part of marginal sea of Tethys ocean.

According to our notions low velocity layers on the depth of 5-13km, are formatted as a result of accumulated fluids, gases and hydrocarbons, most perspective oil-gas -bearing structures at the territory of Armenia.

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Determination Of Water Injection Efficiency In The Multi-Layered Garra Field Using The Formation Tester Tools

The Kareem formation in Garra field is under water flooding using 40 Kppm salinity water which is different than the formation connate water salinity (330 Kppm). Currently, the Kareem formation is producing oil with 80% watercut with a mixed produced water salinity (80 Kppm).

The Reservoir Description Tool, RDT, was run. Twenty-nine pressure points, many with in-situ compressibility and bubble point measurements were taken, and seven PVT quality fluid samples retrieved to:

- 1) Obtain pressure data for each layer,
- 2) Identify fluid contents
- 3) Obtain water samples for water injection monitoring
- 4) Examine the existence of gas zones
- 5) Determine reservoir permeability
- 6) Obtain PVT samples.

The RDT results show that the upper part of Kareem formation is a high permeability layer with low formation pressure. The water sample from this layer has the same salinity as the injected water, indicating that this layer is completely swept, and that most of the water produced is probably coming from this layer. The lower part of Kareem formation showed higher pressure and lower permeability with sample salinity corresponding to a mix between injected water and formation water.

In the Rudeis formation, the RDT showed the existence of a gas cap with low formation pressure, followed by an oil zone with much higher pressure, and ending with a water zone containing water similar to original formation water.

With the above information, new completion techniques are planned for the Garra field to improve the water injection and reduce water cut.

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Development of Secondary Porosity in Jurassic Deep Reservoir in Western Desert

For long

Jurassic reservoir in the Western Desert of Egypt represents a challenge for explorationists as it usually occurred deeply buried, hence

many think that the primary porosity of this reservoir will be damaged due to subjection to enormous overburden pressure.

Detailed petrographic examination of rock samples shows that the dissolution, corrosion and leaching of some rock samples play great role in developing secondary porosity in clastic Jurassic reservoir.

The average recorded porosity obtained from the study was ranging from 8 to 14% at depth 14000 ft.

All porosity data were plotted using Nagtegall's curve and extrapolated the porosity values to different depths.

The result of this study encourages exploring the Jurassic reservoirs in the deep horizons of the Western Desert and opens new era of extensive exploration.

Gulf of suez
petroleum company . P.O.Box.2400*
Speaker**

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Density Effects on Seismic Reflectivity of Upper Eocene-Upper Jurassic Rocks in the Northern Western Desert, Egypt

The present study is concerned to set some relationships between seismic reflectivity and the physical properties (porosity and density) and the lithologic composition of the Upper Eocene-Oligocene (Dabaa Formation) to the Upper Jurassic (Massajid Formation) in the area located to the east of Khalda oil field. The available well logging data are used to determine the lithologic components, porosity and density of the studied rocks in four wells (Sultan-1, Ashour-1, IG-24-2 and IF-24-1). The velocity and density data are interpreted in order to define the seismic reflectivity at the interface of the rock units. The results proved that the reflection coefficient estimated from velocity and density is maximum at the boundaries between clastic and non-clastic rocks

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Sequence Cyclostratigraphy, and Sedimentary Facies Modelling of the Cretaceous Sandstone Reservoirs in Geisum Oil Field-Southern Gulf of Suez

Geisum oilfield lies in the southern province of the Gulf of Suez. The Precambrian Cretaceous sandstones are the main oil-bearing reservoirs in the southern part of the field. This work highlights the stratigraphy and the depositional systems of this succession aiming better understanding of the reservoir geometry and its distribution.

The study results show that eleven sedimentary litho-facies units could be distinguished, included in seven 3rd order cycles of Precambrian age. The lowermost sedimentary sequence is of Barremian(?) age represented by fluvio-lacustrine facies overlying the Precambrian basement complex. It is followed upwards by a poorly fossiliferous shallow marine Turonian sandstone/shale sequence of tide-dominated setting channels, bars and prograding sand waves. The overlying sequence of Coniacian-Santonian age is built-up of sandstone/shale with carbonates of tidally influenced setting of wide spectrum mixed sand/mud flat to retrograding tidal bars. The succession is flooded at top by an open-marine sequence of shoreface and foreshore domains, being dominated by carbonates with subordinate shale and thin sandstone of Campanian age.

The correlation of the 3rd order cycles and facies belts show the direct impact of the fluctuating global sea-level and syn-depositional tectonics on the distribution of the reservoir units. The inter- and intra-cycle breaks are the critical elements that influence the subsequent depositional and diagenetic patterns, which control porosity development.

The distribution of the interpreted rock facies will lead to more reliable reservoir modelling and hence more chances for finding new potential hydrocarbon-bearing reservoirs.

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The Influence of Incipient Rift Geometries on Early Syn-Rift Deposition in the Suez Rift, Egypt

Syn-rift deposits are primary exploration targets in the Suez Rift, Egypt. In the southern Suez Rift, the Nukhul Formation records early syn-rift deposition and is an important exploration target and major producing zone. Production from the Nukhul Formation in the Hilal, East Zeit, and Shoab Ali fields averages 4 million barrels of oil per well. However, Nukhul sand thickness is highly variable and predicting the distribution of Nukhul sands within individual fields much less between fields is difficult. Defining the depositional setting for these sands is critical to opening this play for future exploration.

Deposition of the Nukhul Formation appears to be controlled by pre-rift structural fabrics. High-resolution magnetic data calibrated by subsurface well data and 3D seismic provides a tool to identify and model the initial rift geometry. The data indicate that early faults defined a system of NE-SW striking horsts and grabens, possibly related to earlier Syrian Arc or Precambrian basement features. As rifting progressed, exploitation of the older trends was abandoned in favor of dip slip movement related to the principle extension direction. Large scale rift-parallel oriented (NW-SE striking) normal faulting that dominates the Suez Rift basin has subsequently overwhelmed and masked the incipient, Nukhul-age, rift geometries.

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Applications of Landsat-5 Satellite Imagery to Exploration and Production

ABSTRACT

Applications of Landsat-5 Satellite Imagery to Exploration and Production

Many common problems faced in exploration and production can be solved in part with the assistance of satellite imagery. Examples, using Landsat-5 data, are shown which illustrate the use of imagery in statics, seismic line/well location, regional mapping and correlating surface conditions with seismic data quality and reservoir characterization. Where there is 3D coverage, digital terrain models are used to enhance the Landsat data. Examples are shown to illustrate the utility of satellite imagery and digital terrain models in correlating poor seismic data zones with surface conditions. In a production application, an example is given which shows the application of satellite imagery to reservoir characterization.

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Using Shear and Vp/Vs to Predict Overpressure in Petroleum Basins

Most pressure predictions in overpressured basins are aided by deriving interval velocity from surface seismic and using several approaches to convert velocity to formation pressure. These techniques are valuable and are being continuously improved. More recently techniques have been developed to evaluate overpressure from shear velocity and the vertical to shear velocity ratio, Vp/Vs. Shear velocity and Vp/Vs measured by dipole sonic logs, four component surveys, and wellbore seismic provide additional measurements to augment interpretations based on compressional velocity. Shear velocities and Vp/Vs in some cases may be the only reliable data when compressional velocities are difficult to obtain in gas prone sequences. Also shear velocities are more sensitive to changes in compaction state, rock type, and overpressure. Of immediate application only Vp/Vs can be reasonably determined from vertical seismic profiles (VSP) without an expensive walk away acquisition as a look ahead tool for pressure prediction while drilling. VSP techniques have long held out the promise of ahead-of-the-bit pressure predictions, but a variety of data acquisition and interpretation issues have limited this potentially important application. In particular, compressional wave (P-wave) velocities ahead of the bit can not be determined directly. However, a simple interpretation technique requiring only the picking and registration of upward traveling, that is P-waves, and mode-converted shear waves allows straightforward determination of Vp/Vs ratios ahead of the bit using only zero-offset VSP data. The Vp/Vs ratios are derived without explicit knowledge of either the interval P-wave velocities or the interval S-wave velocities.

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A Comparison of Deepwater Petroleum Systems: Southern and Central Morocco and the Northeastern United States and Nova Scotia

Exploration and research studies have been undertaken for 40 years on the deepwater margins around the world. A number of industry and research seismic lines are available for the Northeastern United States, Nova Scotia and Central and Southern Morocco. Stratigraphic control is provided from the DSDP/ODP and oil industry well reports. A paleogeographic reconstruction of the North Atlantic prior to the opening of the Atlantic juxtaposes Nova Scotia to Central Morocco and the Northeast Seaboard of the United States to the Southern Territories of Morocco. Kerr-McGee is currently evaluating 3.3 million acres in deepwater Nova Scotian waters and has recently signed a large reconnaissance permit covering approximately 27 million acres along the shelf and deepwater of the Southern Territories of Morocco.

In progress evaluations of both areas have identified numerous similarities and differences in the structural history, depositional processes and play developments of each area. The presentation will cover these ongoing evaluations and compare and contrast the variability in play type and development resulting from these differences.

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Using Reservoir Saturation Monitoring and Production Logging to Improve Waterflood Sweep Efficiency in the Badri/Morgan Complex

Badri and El Morgan are a side-by-side pair of giant reservoirs located offshore in the Gulf of Suez in Egypt. Production began in 1967 with startup of El Morgan and together the reservoirs have produced 1.53 billion barrels. The complex still accounts for 26% of the total daily production of the operator, Gupco.

Recovery factor varies significantly within the complex. The thick, well connected, well waterflooded sand layers in El Morgan appear to have reached as high as 70% recovery, exceeding the predicted 'ultimate' field recovery of 55 percent. However, the thinner, more faulted, less efficiently waterflooded areas have only reached an average of 35% recovery. As the average watercut is now 89 percent, cost of water handling is becoming a determining factor in the economic viability of the 200 plus wells in the complex.

The exploitation team continually monitors and optimizes the waterflood, redirecting injected water through the thinner, more faulted, less efficient areas. Making the task more difficult, the complex is broken up aerially into dozens of fault blocks, separated by isolating or semi-isolated (leaky) faults, and vertically into the Belayim series with its four layers (Z1 thru Z4) and the Kareem with its eight layers (K1 thru K8). Each layer within each fault block must be individually considered as a waterflood unit.

The Reservoir Saturation (RST) tool has proved beneficial to these efforts, helping identify which sand layers in a given area are not swept by the low salinity injection water. This leads the team to better waterflood management decisions.

This paper will present the findings of this work in several fault blocks, show results of the successful sweep efficiency improvement work, and how the results were achieved.

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Using Magnetic Resonance Logging to Evaluate Thin-bedded Oil Bearing Formations in the Gulf of Suez: A Case Study

In the highly saline Hammam Faraum sands of the Belayim formation, zones with greater than 2 ohms are regarded as potentially oil productive, yet many of these do not produce at all. Traditional sonic and nuclear porosity measurements do not clearly identify the productive intervals. In an effort to better differentiate productive versus non-productive zones and thus design more cost-effective completions, nuclear magnetic resonance (NMR) technology was introduced.

The formation was deposited as inter-bedded mudstones and arkosic sands in a fan delta complex. Above and below the Hammam Faraum are thick evaporite beds. A typical well has a dozen or more sand bodies, each of which may contain oil, mobile water or no mobile fluids at all. The salt saturated water and the numerous thin clays cause resistivity log baseline of less than an ohm.

During the reservoir description phase, NMR contributes to improved estimates of effective porosity, free fluid volume and qualitative permeability. With several dozen wells drilled to deeper targets in the field, cores and logs had been taken and analyzed to establish interpretation parameters.

In adding the new measurement, a third fluid is defined; irreducible water. This is equal to porosity minus NMR Free Fluid Index and is used to define the 'ineffective' pore space. In the two larger sand bodies, known to produce clean oil, the irreducible water from NMR logs is very low and the new measurement makes only a slight difference. In the thinner, less well defined sands, the new measurement correctly identifies which have high irreducible water. Adding irreducible water in the formation evaluation procedure improves the recognition of pay zones which otherwise would not be perforated.

Other log data has proven inconclusive in the thinner, more marginal intervals. NMR free fluid index helps to decide whether to perforate a sand. This method saves testing and perforating costs without reducing production.

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When Carbonate Platforms Emerge: Complicating Reservoir Heterogeneity in Natih Fm, Cretaceous, Oman

The Natih formation comprises three major transgressive-regressive sequences (I-III). Higher frequency cycles, which may be correlated regionally over several hundreds of kilometers, are shown to provide best fits between stratigraphic subdivisions and reservoir flow units.

The Natih platform system emerged at the turnaround from sequence I to II, and at the top of the Natih. Complex heterogeneity developed from incisions within the upper 20 metres of the Natih E. Incision fills are made up of several genetic units, with a variety of dolomitised and carbonate facies composing smaller scale channel forms and infills or wider reaching marl-limestone cycles.

3D seismic from North Oman shows complex channeling of the surface of the Natih. Several hundred metres wide channels, fairly straight to slightly sinuous in pattern but with significant depths, contrast with narrow, highly sinuous channels showing meander loops and cutoffs. Natih E features, commonly ascribed to pull-down artifacts from Natih A channels, have been assessed by seismic forward modeling.

The data from field exposures alone are not sufficient to allow interpretation of channel patterns. However, the seismic is not sufficiently detailed to show the nature of the channel fills. The combination of seismic images with outcrop data, at the scale of facies and genetic units, allows reconstruction of the heterogeneity that affects the upper 20m of the Natih E. Understanding and predicting this heterogeneity will be crucial for the choice of drive mechanisms (water flood or GOGD) in future EOR field development planning.

Jean-Marc Hosanski¹ (1) TotalFinaElf, Paris La Defense Cedex, France

The LNG Trade New Territories: Opportunities and Challenges

No Abstract Requested

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Exploration and Development Challenges in the Triassic of North Africa

The Trias Argileux Greseux Inferieur (TAGI) of Algeria & Tunisia has proven to be a highly successful hydrocarbon play in North Africa in the last couple of decades of the 20th Century. The reservoirs are clastic and predominantly continental in origin. However, the geographical extent of the reservoir system is truly continental in terms of scale and variations are observed.

The TAGI was deposited in a low aggradation setting, resulting in extensive sheet-like packages of reservoir. Extensive reworking of sediment from a limited sediment provenance is observed, together with substantial early post-deposition modification of initial sediment characteristics. These have resulted in an extensive overlap of sedimentary and petrophysical/reservoir engineering properties.

This presentation aims to demonstrate the applicability of various methods of assessing and predicting sedimentological, petrophysical and reservoir engineering properties, at both exploration- and development-scale to an important North African reservoir.

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Sequence Stratigraphy Applied to a Continental Clastic Reservoir in a Low Aggradation Setting: The TAGI of Algeria & Tunisia

The Trias Argileux Greseux Inferieur (TAGI) of Algeria & Tunisia has proven to be a highly successful hydrocarbon play in North Africa in the last couple of decades of the 20th Century. The reservoirs are clastic and predominantly continental in origin. However, the geographical extent of the reservoir system is truly continental in terms of scale and variations are observed.

Several workers have applied sequence stratigraphic principles to the Triassic interval of Algeria & Tunisia. Much of this work has been based on a sparse regional dataset and at various scales, varying temporally from the Triassic as a whole to just the reservoir interval, and varying spatially from the sub-regional exploration-scale to field development-scale.

Anadarko, in association with Sonatrach and various foreign partners in the region, has acquired a significant basin-scale database. The database includes over 8 km of core (mostly continuous over the reservoir interval), more than 80 wells with image logs, access to more than 200 wireline datasets in the region and production history/test data of several sizeable fields.

This presentation aims to demonstrate the applicability of sequence stratigraphic principles (the relative roles of eustacy, climate and tectonics) at various scales (temporal and spatial) to key business issues (exploration and development) in this important North African reservoir system.

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Analysis of the Wavefields Around the Borehole During Acoustoelectric Logging

This study is aimed at understanding the wave propagation mechanism of the acoustic and electromagnetic fields during acoustoelectric well logging. The coupled acoustic and electromagnetic fields excited by a point pressure source in a fluid-filled borehole are formulated by introducing potential functions in cylindrical coordinate system, and by applying Pride's governing equations and the boundary conditions at the borehole wall. Transient full waveforms of acoustic pressure and electric fields in a borehole are numerically simulated. The components of the displacement vector and components of the electric and magnetic fields in the porous formation outside the borehole are also calculated. It is shown that both the acoustic and the electromagnetic waves propagate along the borehole in a way different from plane waves in an unbounded uniform medium. The critically refracted shear (S-) wave causes radial and axial displacements. So does the critically refracted compressional (P-) wave. Both of them cause accompanying electric and magnetic fields. The radiating electromagnetic (EM) wave is stronger in the center of the borehole than on the formation wall. This EM wave is comparatively large and can be the dominant component wave in the full waveform when the frequency is high and the receiving position is near to the acoustic transmitter. As a check of our simulation process, we calculated the acoustic field separately using Biot's theory, and simulated the converted electric field using simplified coupling equations and by assuming the electric field to be quasi-static. Numerical examples show that the calculated waveforms of the electric field by the approximate method are in complete agreement with waveforms using the full coupling theory.

Tianyue Hu¹, Fei Hong¹, Runqiu Wang², Guofa Li³ (1) Peking University, Beijing, China (2) University of Petroleum, Beijing, China (3) Dagang Oil Field, Tianjin, China

3D Multiple Attenuation for a Deep Reservoir Case Study

Among the deep part of seismic data from a 3D survey at Qianmiqiao area in Dagang Oil Field, some remarkable internal and full-path multiples are generated by various sets of over-burden sediments such as the groups called Minhuazeng, Guantao, and Dongying. These multiples interfere with the primaries over 3500 meters significantly and become a big threaten for enhancing signal to noise ratio for the deep weak signals. Also, these multiples affect velocity analysis, DMO stack and migration. As a model based multiple attenuation method, Beamforming is developed to estimate and attenuate multiples efficiently from the recorded seismic data. The principle of beamforming is to extract seismic signals without distortion, whilst minimizing residual power. The key point of beamforming multiple attenuation method is to separate primaries and multiples in terms of the difference of their moveout. The results of applying beamforming technique show that after removing multiples, some misleading in seismic interpretation can be avoided and the structure shape and state of the internal reflection inside dive can be clearly shown out.

Geraint W. Hughes¹, Robert S. Johnson², Rami A. Kamal¹ (1) Saudi Arabian Oil Company, Dhahran, Saudi Arabia (2) Saudi Arabian Oil Company

Midyan; Window into Saudi Arabia's Red Sea Geology

Within the Midyan area of northwest Saudi Arabia is exposed the most comprehensive succession of lithostratigraphic units deposited in the present Red Sea region during the Late Cretaceous to Pleistocene. The varied lithologies include siliciclastics, carbonates and evaporites, each of which relates to a different depositional episode in the region's geological history that resulted from anti-clockwise rotation of the Arabian Plate away from Africa. The region experienced additional deformation related to the transition from an Oligo-Miocene Red Sea extensional regime into the Aqaba Fault Zone left-lateral transtensional regime during the latest Miocene.

Upper Cretaceous shales of the Adaffa Formation unconformably overlie basement, and are unconformably overlain by the Neogene succession that displays significant lithological similarities to that described from the Gulf of Suez hydrocarbon province - the lithostratigraphic equivalents are given in parentheses. The Tayran Group (Nukhul Formation) includes marginal marine siliciclastics of the Al Wajh Formation (Shoab Ali Member) and represents the earliest rift-associated sediments deposited during the earliest Miocene. Lower Miocene shallow marine carbonates of the Musayr Formation (Gharamul member) unconformably overlie the Al Wajh, and are locally developed. Lower Miocene submarine evaporites of the Yanbu Formation (Ghara Member) were regionally deposited under locally restricted conditions but are not exposed in the Midyan region. Rapid Early Miocene subsidence enabled a thick succession of deep marine, planktonic-foraminiferal mudstones and thick submarine fan sandstones of the Burqan Formation (Rudeis Formation). Carbonates, marine mudstones and submarine evaporites of the Maqna Group (Kareem and Belayim Formations) unconformably overlie the Burqan Formation, and were deposited during latest Early Miocene to earliest Middle Miocene. Within the region, thick anhydrites of the Mansiyah Formation (South Gharib Formation) were deposited extensively during the Middle Miocene, and are overlain by poorly exposed sands, shales and thin anhydrite beds of the Ghawwas Formation (Zeit Formation), deposited during the Middle to Late Miocene.

Michael L. Hulver¹, Riyadh A. Rahmani¹, Patrick M. Rutt², Ronald J. Steel³, Robert S. Johnson², Randall G. Demaree²
(1) Saudi Aramco, Dhahran, Saudi Arabia (2) Saudi Aramco, (3) University of Wyoming, Laramie, WY

Saudi Arabian Silurian and Devonian Sequence Stratigraphy, Paleogeography and Play Concepts

A third-order sequence stratigraphic model of the Silurian and Devonian systems in Saudi Arabia has been constructed, using detailed sedimentologic, lithostratigraphic and biostratigraphic data from 50 wells and approximately 10000 feet of core from the Kingdom's Paleozoic basins. Eight third-order sequences were identified and correlated from the base of the Silurian Qusaiba Member to the Devonian Jubah Formation. Six depositional systems tracts were recognized in the section: offshore marine highstand, offshore marine lowstand, offshore marine transgressive, tide-dominated transgressive, fluvial-deltaic forced regressive, and wave-dominated forced regressive.

Mapping of the systems tracts highlighted several key features: 1) the ongoing influence of Infra-Cambrian basins on Silurian and Devonian paleogeography; 2) a clear second-order basinward progradation of the shoreline during the Devonian; 3) a persistent clastic depocenter on the eastern side of Ghawar; 4) development in the northwest of a broad shelf with local carbonate sedimentation; and 5) periodic Devonian exposure of the Qatar arch, which - along with the stable east edge of Ghawar and the Niban arch to the south - formed a recurrent embayment in which were deposited restricted marine facies, including the reservoir units of the Jauf Formation.

In light of this new sequence stratigraphic interpretation, analysis of trap elements has enabled better risk assessment of various existing play types, and has helped identify new play concepts.

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Integrated Seismic and Well Characterization of a Wara Formation Channel Complex, Greater Burgan Field, Kuwait

A detailed reservoir model of a Wara Formation channelized depositional system has been successfully constructed using seismic inversion, seismic attributes, principal component analysis and geostatistical modeling.

The Upper Cretaceous Wara Formation is a significant oil resource in the Burgan Field of Kuwait. Even after a long production history (since the '50s), the Wara Formation has large opportunities both for primary and enhanced recovery. The Wara Formation is a complex fluviodeltaic system in which the sand is organized into both stacked and isolated channels. The key to optimal development of the Wara is to understand the lateral extent and interconnectivity of these sand sequences. Unfortunately, previous attempts to characterize these sands used only well data and found the task quite difficult.

We have successfully characterized a large channel system in the southwest part of the Burgan field through an integration of well and seismic data. A variety of seismic tools including attributes, inversion, classification and principal component analysis were integrated with well-based data in the characterization. A further refinement of the characterization was done by constructing a new reservoir model using the 3-D post-stack seismic inversion to guide a stochastic well-based interpolation.

A validation of the channel characterization and reservoir model can be observed through a comparison to Wara production. Wells within the channel system exhibit significantly higher fluid production rates. Through the more detailed understanding of Wara reservoir extent and producibility, KOC has been able to provide for better reservoir simulations and better plan infill wells and future development.

Mahbub Hussain¹, Mustafa Hariri¹, John Warren² (1) King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia (2) University Brunei Darussalam, Bander Seri Begawan, Brunei

A Quaternary Eolianite Sequence in the Arabian Gulf Coastal Region, Northeastern Saudi Arabia: A Modern Analogue for Oomoldic Porosity Development in an Arid Setting

Close to the City of Dammam, the Gulf Coastal Province of the Eastern Saudi Arabia are several isolated outcrops of linear ridges that have been previously identified as the part of the Eocene-age Dammam Formation. The ridges are interpreted as Quaternary coastal eolianites that define one or more former sealevel highstands; their origin is similar to documented eolianite ridges in the Bahamas and southern Australia. The noticeable difference is the widespread preservation of leached vadose textures, still in the original depositional framework. This probably reflects their arid hydrogeochemical genesis compared to the humid to semiarid coastal setting in the Bahamas and the semiarid setting in southern and western Australia.

The ridge sands are made predominantly of well-sorted, poorly cemented ooid or skeletal grains. Some of the former ooids are characterized by the presence of over-sized quartz nuclei. Dissolution and breakage, however, damage the great majority of the grains. Many grains now lack a nucleus, probably reflecting the leaching of the aragonitic precursor (oomoldic and skelmoldic porosity). The relatively low levels of intergranular cement, coupled with a high degree of sorting, broken cortices and leached nuclei results in very high effective porosity in the ridges (up to 60%). The bulk and trace element chemistry, especially the distribution of Sr⁺⁺ (up to 5445 ppm), in the sands indicates that the diagenetic waters were derived by the meteoric leaching of the former aragonite nuclei in this arid vadose setting. The high aridity of the setting means the same aragonite probably also acted as the local source for the calcite cement rinds. This is reflected in the very high Sr⁺⁺ content in the current ridge sands; unlike their more humid counterparts, the Sr⁺⁺ is simply not leached from this arid-zone coastal eolianite system.

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TBA

No Abstract

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Assessment and Remediation of Petroleum Contaminated Sites

Many petroleum industry sites have been contaminated from previous activities or become contaminated through accidental releases of hydrocarbons. These sites include old pits, onshore release sites of hydrocarbons, and places where oil slicks from offshore releases are blown onshore. In many cases, remediation will be required to restore the impacted area.

Unfortunately, the complex pore structure and fluid transport pathways of soil can make remediation difficult. However, hydrocarbons can be found in various places. Most are trapped by capillary pressure as a discrete liquid phase within the soil's pores. If a sufficient volume of hydrocarbons has been released, it can exist in separate, mobile phase that floats on the groundwater. Hydrocarbons can also be found as a vapor in air-saturated pores. Due to the complex contaminant's distribution in soil, a comprehensive site assessment should be carried out, to assess the potential impact to the human health and the environment before the optimum remediation process can be selected and properly implemented. Some of remediation processes are suitable for cleaning up contaminated soil or subsurface groundwater, while others are suitable for cleaning up contaminated shorelines. These processes vary significantly in how completely they remove the contaminants, in the time they require, and in their associated costs. Since the most of the remediation processes entail their own environmental hazards.

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Middle Triassic to Upper Jurassic Palynofacies, Paleoenvironment, Source Rock Potential and Organic Thermal Maturity of Radiometric-dated Sequence, Qatar - Arabian Gulf

Strontium isotope analysis ($^{87}\text{Sr}/^{86}\text{Sr}$ ratio) have been conducted on core samples representing, from top to base, the Hanifa, Araej, Izhara, Hamlah and Gulailah formations, onshore Qatar. They gave an overall age range from 157.80Ma to 233.30Ma, Oxfordian to Ladinian.

Deposition of the Gulailah and lower Hamlah formations (Ladinian-Norian) were took place in a lacustrine environment. The middle Hamlah Formation may have been deposited in shallow, normal marine environment, whilst the upper part was deposited in a hypersaline environment. A mixture of kerogen type II-III, oil and gas-prone is inferred for the Gulailah-basal Hamlah formations (TOC higher than 0.3%). Kerogen type IV, inert material is suggested for the upper Hamlah Formation. Thermal alteration index (TAI) is ranged from 3- to 3+, interpreted as peak oil to onset gas generation.

The Izhara, Araej and Hanifa formations are dominated with marine microplankton, dated early Hettangian to Oxfordian. They were deposited under shallow marine environment grading from oxic, dysoxic to anoxic shelf respectively. The organic matter is almost exclusively of marine algal origin. Izhara Formation is mature to over mature of kerogen type III-IV, gas-prone to inert material. Mature kerogen type II-III (oil and gas-prone material) is deduced for the Lower and Upper Araej, while the stylolitic limestone of the Uwainat Member has weak source. Mature kerogen type I-II, highly oil-prone, is possible for the black limestone Hanifa Formation. It is considered as the prolific petroleum source rock for the underlying and overlying reservoirs of the Uwainat (Bathonian) and the Arab "D" (Kimmeridgian) respectively.

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Small Fields Evaluation - New Concept, Gulf of Suez, Egypt

The EEMM field is located on the southwest side of the Gulf of Suez. Magawish was formed after the announcement of commercial production in 1995 from well EEMM-2 with average rate of 180 B/D.

The first well drilled in the Magawish concession FE 87-9 in 1988, tested 400 B/D from fractured Basement and was then abandoned.

Later Total decided to relinquish the concession being non-economic to exploit. Several other exploration companies acquired the concession and they all reached the same conclusion as Total.

In 1997, Magawish decided to exploit the proven potential of well FE 87-9. A twin well EEMM-1A was drilled from the existing well course by sidetracking. This well produced 2500 B/D.

In 1998, a strategic development plan was designed to deal with the difficult conditions of developing such reservoir with old seismic data in hand.

The main objective of this plan was to determine the future size of the company. The concept used in this phase was drilling a few exploratory wells to delineate the possible potential areas, while in the next phase the concept was to drill more wells using the step- by- step approach.

In the first phase, two exploratory and one development wells were drilled leading to two discoveries. The production of the company increased more than 100 % and the reserves were increased drastically .

This phase was decisive in determining the size of the company and its production facilities.

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New E&P Onshore and Offshore Blocks of Libya: Ranks, Potential, Undeveloped Fields and Discoveries

A detailed review of the current 139 offshore and onshore new E&P blocks of Libya has been performed by utilising published well records, well logs, stratigraphic sections, structural sections, and stratigraphic, geochemical, tectonic and structural maps of Cyrenaica, Ghadames, Murzuq, Sirt, Tripolitania, and offshore Basins of Libya.

Due to the large number of parameters, and to impartially assess, compare, and rank the E&P potentials of the blocks, one map and, a set EXCEL, | databases were compiled to summarise well data, exploration records, and geological, geochemical, and tectonic parameters of the new blocks.

The first set of E&P databases summarises the drilling, engineering and geological data per block (31*139 data entries). An exploration risk equation was modified to rank the relative E&P potential of the individual blocks, via comparing the source, reservoirs, cap rocks, tectonics, remaining undrilled anomalies, and exploration results of each block. Three sort variations of the first database were generated in order to rank every one new block.

The second set of E&P databases lists drilling, engineering and geological data, status and results of about 666 wells in all blocks (28*666 data entries). One sort variation of the second database was generated to alphabetically list well data per each block.

Results indicate that database analysis can produce an impartial ranking of the relative E&P potentialities of a large number of blocks, in several basins with different stratigraphic, thermal and tectonic histories, and tabulates and graphically illustrates the reasons for ranking the blocks, per basin, and per several basins.

Ibrahim Ahmed Ibrahim¹ (1) Egyptian Natural Gas Holding Company, Cairo, Egypt

Egypt LNG: An Evolving Industry

The paper will present the gas potential in Egypt and discuss the key drivers which contributing in boosting the LNG industry in Egypt.

This includes gas reserves compared to other LNG producers , review of the growing gas market in the Mediterranean region and Europe in the next decade , distance advantage of LNG from Egypt to the potential gas markets, and low shipping cost along with availability of several existing and planned re gasification terminals in the Mediterranean . In addition to recent development in the LNG plant size & technology which reflects favourably in the unit liquation cost and competitiveness of LNG price against pipe gas and finally availability of well experienced gas industry in Egypt

The paper will also provide update of the current LNG projects in Egypt. These include Union Fenosa LNG project and Idku LNG project. It will also highlight the benefit of these projects for the region and strategic importance to the Egyptian economy.

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Condensate/Gas Ratio Variability and Prediction in the Obaiyed Field, Western Desert, Egypt: Integrated Technology for Effective Near-field Exploration

The development and application of reliable methods for predicting condensate-to-gas ratio (CGR) in the area of Obaiyed field in the western desert of Egypt, is a critical issue for both near-field exploration activities and ongoing redevelopment efforts within the field. As is commonly the case for gas/condensate assets, liquid production in Obaiyed has a significant impact on overall financial performance. CGR prediction is best approached from an integrated perspective that combines aspects of reservoir engineering, geochemistry, and petroleum systems analysis. The current study comprised the following elements: (a) a comprehensive evaluation of CGR variability based on PVT analyses and production test results (b) detailed investigation of condensate and gas geochemistry data aimed at establishing the underlying controls of CGR variability and (c) a 3-D basin modeling study to provide a regional understanding of source and migration factors impacting CGR. The results of the study showed:

- Gases and oil/condensates in the Obaiyed field and satellites are all from a common Khataba source, but multiple kitchen areas have contributed to the accumulations.
- The bulk of the 'condensates' are oils dissolved in the gases. Gases, in particular, show a large variation in maturity and vary systematically across the field. CGR values show a strong correlation with the gas maturities.
- Lateral and column height variations in all geochemical parameters dominate over stratigraphic variability at any one location.
- The CGR variability in Obaiyed is caused by incomplete mixing of several phases of charge that have entered the trap over time (i.e., oil, wet gas and dry gas). The gradients in fluid properties are likely due to (1) insufficient time for homogenization and/or (2) the presence of barriers/baffles in the Lower Safa Fm.

The key control on CGR in Obaiyed and surrounding prospects is whether there is charge access to highly mature dry gas coming out of the Matruh trough.

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Depositional Environment and Reservoir Heterogeneity of Bentiu Formation (Albian-Cenomanian), Muglad Rift Basin

Bentiu Formation is a major oil sandstone reservoir in the Muglad rift basin of interior Sudan. Subsurface lithofacies analysis allows the subdivision of Bentiu Formation in lower, middle and upper parts and each part is characterized by distinct facies assemblage and different depositional pattern. The lower part indicates deposition in moderately deep mixed-load high sinuosity stream showing transition to lacustrine delta. The middle part suggests deposition in low sinuosity braided sand-bed dominated stream. The upper part which is dominated by gravelly sandstone and sandstone facies indicates deposition in outwash plain of low sinuosity braided shallow channels.

The sandstone facies range from trough and planar cross-bedded to massive and horizontally bedded sandstone. Fine grained facies include rippled fine grained sandstone and laminated to massive siltstone/mudstone facies. The facies assemblages suggest deposition within channels, bars, overbank and floodplain environments.

Large scale heterogeneity and dimensions of Bentiu sandstone bodies and the siltstone/mudstone barrier/baffle units vary within the lower, middle and upper parts of the formation. Small scale reservoir heterogeneity includes sandstone composition, grain size change and diagenesis such as quartz overgrowth, clay infiltration and authigenesis, feldspar alteration and carbonate cementation and dissolution. The latter appear to have influence on secondary porosity production and enhancement.

The reservoir heterogeneity of Bentiu Formation reflects the intra-basinal and extra-basinal control on the lacustrine/fluvial system through space and time. Understanding of these controls within a depositional model framework is essential for the prediction and assessment of reservoir quality of Bentiu Formation.

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A Team Approach to Processing Quality Control is Successful in Optimizing the Processing Flow for a Challenging 3D Seismic Data Area

A successful study was performed to optimise the seismic processing work flow and parameter selection of a newly acquired 3D seismic volume to achieve a high-resolution seismic image with optimum amplitude preservation and wavelet stability. Acoustic impedance inversion was found to be an essential step to highlight details that were important to achieve the survey objectives.

A 3D seismic survey was recently acquired over a major field in Abu Dhabi, to better map the reservoir units and quantify reservoir properties. The processing of the new seismic data would need to produce a high-resolution volume that would permit detailed structural mapping and additional geophysical analysis to derive quantitative attributes for improved reservoir characterisation. This study was performed using a team approach on a 40 km² test cube extracted from the new seismic data.

Interpretations made on key reflectors with different processing flows showed that the final seismic images were very sensitive to velocity picking, multiples and coherent noise in the data. Top reservoir structure was sensitive to the static solution method and parameters. Well synthetic ties to the seismic helped differentiate real seismic events from multiples and highlight where the seismic images was good and poor. Acoustic impedance inversion was used to evaluate thin bed resolution and relative amplitude preservation. The resulting acoustic impedance volumes were compared quantitatively to acoustic impedance profiles from the wells to determine which processing flow produced the best match to the known answer at the well.

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The Seismic Method 10 Years Ahead

It is not difficult to extrapolate current trends and R&D programs into the future. The main areas of development will be:

- Speed of manipulation and analysis
- HSE awareness
- Visualisation, & interpretation methodology
- Data management (Storage, Transmission, Retrieval, Mining)
- Land seismic catches up with marine
- Step function improvement in seismic resolution
- Visibility on pressure and fluid changes in the reservoir
- An integrated, automated environment - the "e-Field"

The paper will cover all of these and will concentrate on the last three items.

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Rift, Compartmentalisation and Evolution of Tilted Fault Blocks as Expressed by the Lower Miocene Abu Zenima and Nukhul Formations Suez Egypt

Although tilted fault blocks are common traps within rift basins more subtle and complex structural and stratigraphic traps can be developed during fault zone evolution by the growth, interaction and linkage of fault segments. The early syn-rift Abu Zenima and Nukhul Formations (Lower Miocene) of the Suez Rift can be used to determine the early rift structure. Outcrop studies in the Hammam Faraun fault block indicate that initial fault activity was distributed across the fault block on short (1-4 km long), low displacement (<1 km) segments. These initial segments either linked to form longer fault zones, or became inactive during the first 6-8 Myr of rifting. Displacement progressively localised onto >25 km long border fault zones that bound the present-day major tilted fault block, and many of the early intra-block fault zones became inactive. In the N. October and East Tanka areas in the central Gulf of Suez, the Abu Zenima and Nukhul Formations form hydrocarbon accumulations that are compartmentalized, commonly lack hydrodynamic continuity, and which have different oil/water contacts and hydrocarbon types. Reservoir distribution and compartmentalization is interpreted to reflect deposition in early fault-controlled depocentres that formed prior to the development of the main faults controlling the October and East Tanka fields. Thus understanding the growth, linkage and death of fault segments and reconstruction of the early rift structure has important implications for subtle trap and reservoir distribution in rift basins.

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Characterisation of a Tight Gas Reservoir using Seismic Attributes, Ohanet Field, Algeria

The Ohanet Field is situated in the Illizi Basin 400 km. southwest of Hassi Messaoud, Algeria. The field is a NW - SE trending, fault-bounded anticline 35 km. long by 5 km. wide, and has 2 productive horizons: Silurian fluvio-deltaic sands and Ordovician glacio-marine sands. In July 2000 a Risk Service Contract was executed between SONATRACH and a joint venture led by BHP Billiton Petroleum with Japan Ohanet Operating Company, Petrofac Ohanet, and Woodside as partners to commercialize the gas reserves in the 2 reservoir intervals, together with reserves in 2 other reservoirs. Included in the work commitment was the recording of ~1000 sq. km. of 3D seismic.

The primary Ordovician reservoir consists of tight (0.5 - 40 md. permeability) turbiditic sands consisting largely of 2 facies: stacked channels, and thick lobes displaying mega-ripple marks. The sand is 30 - 50 m. thick, which is just above seismic tuning thickness, and is acoustically hard compared to the encasing shales. Petrophysical modeling predicts that the presence of porosity reduces the positive impedance contrast between the overlying shale and reservoir sand, such that the reflection strength weakens. A crossplot of well average porosity vs amplitude provides confidence that seismic attributes can predict areas of better quality reservoir.

Seismic attributes were extracted from the 3D seismic data, and were used to statistically guide population of reservoir properties in a geocellular model. The attribute work revealed geological features that tied with facies determined from core in old wells, and that were substantiated in newly drilled wells. The resulting model is being used to guide the continuing development of the reservoir, and to predict ultimate recovery.

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The “Hercynian” Disturbance in Arabia and North Africa

Analysis of gravity and magnetic data and over 1600 wells from Arabia and North Africa suggest that the “Hercynian” collision of the Mauritanids was simultaneously associated with a massive mantle plume that affected most parts of Africa and Arabia during the Permocarboniferous. The plume(s) resulted in a series of N-S arches during the Early Carboniferous. Some of these arches were associated with extensions in the Early Permian. Volcanicity is known only from the Karoo system of S and E Africa and from the margins of Arabia. At the Indian Ocean-Arabian Sea-Zagros triple junction, SE of Oman, Alpine-type Gondwanan glaciation affected southern Arabia. The “Hercynian” N-S arching resulted in the removal of a large thickness of Lower Paleozoic sequence, during both the Early Carboniferous, and Early Permian where extension did not follow arching, (for example in Jordan and the Tibesti region of Libya). On the other hand where extension did occur, during the Early Permian, fluvio-lacustrine clastics were laid down in narrow basins over L Paleozoic rocks, (in Central Arabia and E Algeria). The hydrocarbon systems related to the “Hercynian” disturbance are outlined.

The highly disturbed Mauritanids tectonic block seems to be in sharp contact with a virtually undisturbed tectonic block to its east, and it is thought that a dextral strike slip fault might be the culprit.

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Events Surrounding the Rutba Uplift in Western Iraq

The Rutba Uplift refers to a broad region covering W Iraq, NE Jordan and NE Syria and represents an Early Triassic inversion of a very pronounced Paleozoic basin in which the full Paleozoic sequence might be present. The shape of the uplift fluctuated between elongated N-S and NE-SW high throughout the Triassic and Jurassic and ENE-WSW oriented high throughout the Cretaceous. Against the popular belief, the Rutba uplift is neither related to Mardin nor to Hail uplifts in Turkey and Saudi Arabia respectively.

A combination of repeated tectonic uplift and eustatic changes in sea level characterized the uplift from Late Triassic to Cenomanian. Twelve transgressive-regressive cycles within the above time frame can be distinguished and correlated with basinwise sedimentary cycles. During Campanian-Maastrichtian to M Eocene, the uplift was influenced by N-S and E-W tectonism which was associated with upwelling and phosphorite deposition due to disturbance in the basin resulting from Late Cretaceous obduction along the Zagros suture. The uplift was finally abandoned by the sea from the Late Eocene and remained tilted towards the NE till the present.

Due to low Mesozoic and Tertiary sedimentary cover, only Paleozoic petroleum systems can be expected as proven by drilling in W Iraq, SE Syria and NE Jordan.

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The Role and Value of Biosteering in Hydrocarbon Reservoir Exploitation

Of all the recent developments in the role of production biostratigraphy, none has had a more immediate and perceptible impact than biosteering. Driven by the need for reservoir-scale stratigraphic control during the drilling of high angle and horizontal wells, biosteering has rapidly become a fundamental and cost-effective part of the geosteering tool-kit. The resultant aid to the optimisation of well-path has provided substantial savings in drilling costs, boosted reserves and well productivity.

Production biostratigraphy entails high resolution reservoir subdivision into discrete, correlatable time-slices, using field-specific microfossil bioevents. This frequently provides greater precision than seismic and greater discrimination than wireline logs. Biosteering enables this subdivision to be defined whilst drilling, providing a real-time monitoring of well-path relative to reservoir. This allows reservoir penetration to be maximised by discriminating between non-pay above, below and within the reservoir, and defining unpredicted exits due to sub-seismic faults. Through the use of biosteering well trajectory can be redirected back into reservoir. Furthermore, in the supra-reservoir interval, well angle-build can be calibrated to optimise reservoir entry, using ongoing comparison with offset data to predict proximity to top reservoir, and TD can be called with the assurance that all pay intervals have been penetrated. Of substantial benefit to high resolution biostratigraphy in high angle wells is the oblique cutting of stratigraphy, giving a greater long-hole penetration of individual time slices, allowing an enhanced resolution relative to vertical offsets.

Case histories using different microfossil groups are described from a range of clastic and carbonate facies from the North Sea, Colombia and Sharjah.

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Superior Seismic Imaging in the Gulf of Suez - Aspects of VSP Design, Acquisition and Processing

Seismic imaging in the Gulf of Suez is well known to suffer from multiple-generating shale and anhydrite sequences and also complex salt geometries which can severely contaminate the seismic reflection signal. Recent experience from East Zeit well A-21 in the southern Gulf of Suez suggests that careful VSP modelling, acquisition with new multi-receiver arrays and subsequent processing with an emphasis on noise rejection is capable, in some cases, of delivering higher quality seismic images than previously observed, not only in VSP's but also compared to surface seismic.

Modelling was performed to establish viable illumination geometries for zero-offset and multi-level walkaway VSPs acquired over this highly deviated well. The profiles were designed to image dipping reservoir units of Cretaceous age, important bounding faults and to improve confidence in ties to the existing depth-migrated 3D surface seismic. A twenty-four level 3-component geophone array was deployed with a standard airgun source.

While results from the zero-offset survey quickly produced a high quality image, the walkaway data presented significant noise challenges. Dip-based noise rejection was ultimately successful in enhancing the signal to noise ratio such that the reservoir and a critical bounding fault could be confidently identified and tied. These results demonstrate that primary seismic reflection energy may be effectively recovered from the target section in this area, despite significant noise, through careful planning, acquisition and processing.

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The Artistic Science of Reservoir Quality Prediction of the Khuff Formation Gas Reservoirs in the Subsurface of Eastern Saudi Arabia

Within the confines of eastern Saudi Arabia, Late Permian Khuff sediment was cyclically, and overall aggradationally, deposited on the very broad, shallow marine, low gradient, Arabian Shelf. It will be sedimentologically demonstrated that today's structural highs correspond closely to Late Permian topographic highs. Optimal reservoir development was contingent on the palaeotopographic highs that enabled early porosity-enhancing diagenetic mechanisms to kick in. Different types of reservoir development occurred on and around these topographic highs. Strings of diversely-shaped topographic highs are irregularly strewn, archipelago-style, along today's Ghawar substructures. Regional and even subregional reservoir predictability is contingent on finding the original topographic highs (including partially subaerial "islands").

Throughout the history of Khuff deposition, water depth has also continued to change. The nature of the sedimentary depositional components throughout the history of Khuff deposition was a function of relative sea depth. The consequence of this additional dimension meant that the products of diagenesis, i.e. the reservoir facies, vary in the vertically-stacked Khuff A, B and C reservoirs.

Traditional sequence stratigraphic methodology will not have much bearing on the quest to predict reservoir quality development in any of the three Khuff reservoirs. This is chiefly due to the fact that the reservoirs are shelf, not shelf-edge, deposits, and seismically-identifiable clinoforms are indiscernible. The trick is to map the ancient topographic highs that are today relief features on irregular structures. The surviving ancient topographic highs are identifiable through depositional sedimentology and the reservoir facies that they carry. These topographic highs and their surrounding topographic lows can be initially mapped through well control. Acoustic impedance maps are the best hope for defining the interwell extensions of previously identified reservoir facies. Improved seismic imaging and improved seismic resolution will have a direct impact on improving the ability to more precisely predictively map our reservoir facies in the Khuff Formation.

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Lessons Learned >From Applying Environmental policy to Cross Country Pipeline

Some useful lessons, related environmental aspects, have been learned from design, construction and operation of 36" Intersinai Gas Pipeline crossing Suez Canal to El-Arish (200 Km Length) .

The major environmental categories considered are:-

- Physical environmental aspects
- Socio-Economic aspects.
- Culture aspects
- Autonomous development aspects
- Alternative of no project.

The challenges of executing this project included crossing arid land water flooded swamp areas and the suez canal tunnel crossing .

with particular consideration to its strategically situation importance.

we have followed a proper environmental practice during all construction work activities to avoid damage in environment . this has been covered by:-

- Mitigation measure embedded in engineering design considered the best route of the pipeline to minimize the risk of accidents and environmental impacts that could rise from the project activities.
- The pipeline basic route and its alternative were evaluated and selected after various consultations with all the concerned authorities.

This detailed process of consulting the relevant authorities enabled the early Consideration of many environmental issues including:-

- Attention to national security issues.
- Interference with utilities and roads.
- Minimum crossings of Railway ,agriculture lands and drainage Canals .
- Adequate buffer zone for protection of adjacent properties along the route.
- Blockage of wildlife passage ways.
- Attention of precious ecology.
- Protection of historical heritage.
- Avoidance of tourist locations.
- Avoidance natural protectorate.
- Slow down or a ceased work in birds' migration seasons.

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Using 3D Seismic Technique in Predicting Bahariya Reservoir Facies of the Kenz Field in Khalda Concession, Western Desert, Egypt

The discovery of the Kenz field is considered a paradigm (milestone) shift in Khalda's exploration policy, which led to an outstandingly successful oil and gas development phase. The kenz discovery proved the existence of multi oil and gas reservoirs within the Bahariya and Alam El Bueib formations of the Lower Cretaceous.

The Bahariya formation is the main oil reservoir in the Kenz field as well as in nearby fields. The main productive zones in the Bahariya are the Upper and some of the subzones in the Lower Bahariya formation. The cumulative oil production from the Bahariya reached nearly over 5 MMSTBO, which represents more than 90% of the total oil production of the Kenz field.

The Bahariya formation is geographically well distributed in the Kenz field as well as the Khalda-West concession, without remarkable thickness variation. However, severe facies variations were observed from well to well. The Bahariya deposits are typical of muddy inner shelf and tidal flat environments, with sequences of small channels and bars. Thus, their quality and orientation represents the main risk factor to be taken into account for assessing the reservoir uncertainty.

This paper is a trial to employ amplitude information from 3D seismic data, integrated with geological and petrophysical data to predict and model the facies distribution of the Bahariya reservoirs. Acoustic impedance inversion data has been used to derive amplitude maps for each reservoir subzone in order to construct facies maps that were calibrated with standard lithological data from wells. Amplitude maps for each reservoir subzone were derived from acoustic impedance inversion data in order to construct facies maps and calibrate them to standard lithological data from wells.

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A Simple Seismic Forward-Modelling and Processing Study of the Effects of Multiples on Interpretation-Gulf of Suez, Egypt

Multiple contamination has long been recognized as a major obstacle to correct seismic interpretation in the Gulf of Suez (Egypt). By using simple modeling and processing techniques and integration of seismic and well information, we are able to determine some of the challenges facing seismic interpreters. For example, we created a simple model of horizontal multiple generators overlying a deeper faulted structure. By comparison of modeled and actual data before and after processing, we can see many examples of the potential pitfalls to interpretation, such as: false seismic stratigraphic indicators, false structural lineaments and obscured hanging wall and footwall correlations. We also demonstrate the power of integration of geological information (dipmeter, model parameterization and depositional inferences) and processing techniques (SRME, dip-filtering, auto-correlation analysis and iterated decon) to separate reality from artifacts.

A simple dip discrimination map shows a small percentage of the multiples in the Gulf of Suez are amenable to dip filtering techniques, because in many areas the main multiples are potentially parallel to the primaries and the deep data is concentrated in a low frequency band. This observation indicates that much of the present exploration opportunities are still obscured by hard to remove multiple energy; therefore, understanding of the artifacts through modelling work and direct observation of the data can provide a list of pitfalls and guidelines (as discussed) to help reduce seismic interpretation risk as well as help guide interpretational processing. This also points to the future hope for unveiling untapped resources beneath the blanket of multiples.

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Rupturing Continental Lithosphere: Initiatives of the U.S. Margins Program and Collaborative Research Goals in the Gulf of Suez, Northern Red Sea and Gulf of Aqaba

The northern Red Sea/Gulf of Suez system was selected by the US scientific community as one of two crucial regions worldwide for coordinated research under the National Science Foundation MARGINS Program on rupturing cratonic continental lithosphere and the formation of new oceanic lithosphere. The reason is clear - the northern Red Sea is in the latest stages of continental rifting and starting its transition to seafloor spreading whereas active extension characterizes the Gulfs of Suez and Aqaba. This region provides excellent exposure of faults and syn-rift sediments that record the earliest phases of extension and subsequent structural reorganization as breakup is approached.

We are planning a coordinated research program in collaboration with Egyptian and Saudi colleagues. If successful, work will proceed by characterizing geophysically and geologically the entire rift system at a scale and resolution necessary to generate a framework for future geological, geodetic and geochemical studies. Our projects will consist of large-scale active and passive seismic experiments, marine multichannel seismic and geophysical surveying, integration of existing industry stratigraphic and structural data, focused outcrop studies of fault development and interactions, and numerical modeling. The proposed research hopes to build upon an already funded passive seismic experiment across the Gulf of Suez rift. The proposal objectives are to: 1) determine the strain partitioning across the Gulf of Suez and Red Sea extensional systems as functions of space and time within the upper and lower crust, and 2) map the degree, distribution and patterns of lower crustal and lithosphere mantle flow.

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Influence of Depositional Fabric, Diagenesis and Structural Controls on Arab D Oil Production, Ghawar Field, Saudi Arabia

Ghawar Arab-D production behavior is the result of a complex interaction of geological processes. Depositional, diagenetic, and structural events occurring through geologic time have produced a pattern of porosity and permeability which is sometimes dominated by one factor but, more often is the result of the interaction of all three elements. It is the lack of recognition of the interaction of primary depositional fabrics, different dolomite textures, and fractures on a wide variety of scales and characteristics which has made many production phenomena difficult to explain in the past.

New technologies employed at Saudi Aramco as well as new, integrated work flows which have emerged within the past 10 years have contributed to a quantum leap in our understanding of this behavior and our ability to predict reservoir architecture and its resulting flow patterns. Sequence stratigraphic analysis of depositional processes has significantly improved our ability to predict original rock textures and their permeability between wells. Recent isotope studies have suggested a complex history of diagenesis resulting in predictable reservoir parameters and distributions for different types of dolomite. 3D seismic surveys, image logging and geomechanical studies have given us a detailed picture of fractures ranging from the micro to the macro scale.

Examples of production dominated by each of these processes are shown along with their characteristics. Key studies devoted to sequence stratigraphy, diagenesis, and fracture distribution are summarized and examples of their impact on production patterns are illustrated. Also shown are areas in which all three fundamental aspects of reservoir architecture must be invoked in order to understand and predict reservoir performance.

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Fractured Carbonates as a Significant Secondary Reservoir in Qarun Field, Western Desert, Egypt

Qarun Oil Field lies on the Southeast flank to the Kattaniya uplift and the Northwest Flank of the Gindi basin. Oil is produced from NE plunged anticlines of Cretaceous age (L. Bahariya & Kharita sandstone), bounded by reverse faults on their North Western sides and dissected by NW-SE normal faults.

Significant high gas and oil shows were observed while drilling of Apollonia carbonates and Abu Roash C and D carbonates in some wells. Accordingly two wells were drilled specially to evaluate these secondary objectives. Oriented cores, FMS, and Petrophysical analysis showed that fracture porosity accounted for the pore space. Oil has been tested and produced from the two wells.

Oil migrated updip towards the structures of Qarun field along the leaking segments of the NW - SE faults. These faults act as conduits for oil that reached the fractured Apollonia carbonates on the up thrown side of the faults and Abu Roash C & D carbonates in the silver blocks

This paper highlights the importance of the fractured carbonates as a secondary objective in Qarun area

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Rift Architecture and Growth Sedimentation across a Main Accommodation Zone, Northern Gulf of Suez-Egypt

The Gulf of Suez rift shows asymmetry and reversal dip-polarity between central and northern segments. Onshore physiographic asymmetry and reversal locations of rift troughs are reflected by rift development across inherited deficit zones of wrenching-ridges that acted as rift-accommodation zones. The interference areas of rifting and deficit zones show narrow Early Miocene rift that gradually overcomes the effect of deficits and being wider by additional over-stepping fault-propagations in the older rift-shoulder.

The rift volcanics are geographically controlled by these deficit zones. The early syn-rift sediments show development of the rift-shoulder faults and deposition over flexure zones. Carbonates predominate in blocks close to the rift-shoulder faults, while reservoir clastics were charged from wadies on other side of the rift. Late Aquitanian-Burdigalian progressive rifting and accelerated fault subsidence were associated with divergent sedimentary-wedging of open marine source rocks and surface wadies continued charging reservoir clastics. Rift shoulder uplifting and shallowing of earlier troughs took-place in Langhian with manifestation of NE-trending fault segments.

The northern Gulf experienced exposure in Upper Miocene where deposition of evaporites diverges south-ward. Blocks south of deficit zones received continuous subsidence and deposition of thick salts. Renewed activities on the northern rift faults accommodated space for deposition of up to 7000 feet thick clastics of Pliocene-Holocene. This younger activity formulated petroleum traps where discoveries are located.

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Pre-Neogene Tectonics and Basin Inversion, Northern Gulf of Suez - Egypt

The northern structural province of the Gulf of Suez acquires its own Neogene rift architecture and sedimentation as impacted by rift superposition on inherited ENE-cross structural belts. The excellent outcrops on both sides of the Gulf and extensive database of seismic and wells gave good opportunity in studying this part of rift.

The inherited belts represent Early Mesozoic rift segments with bounding ENE- trending extensional faults. Bimodal volcanics predominate in the southern rift blocks while sedimentation of Triassic-Jurassic rocks prevails north-ward with accelerated tectonic subsidence of the rift blocks. The fault-bounding basinal segments were tectonically inverted in Late Cretaceous, forming four transpressive belts of faults and culminations. The inversion promoted extensive uplifting of the area occupied by the younger Gulf of Suez rift, while the rift shoulders of the latter host mild culminations. This was associated with sub-aerial erosion of the structural niches and restricted deposition of the Upper Senonian and Eocene rocks. The areas of down plunge direction of the wrench-related anticlines and termination of the wrench-belts coincide with thick sedimentation of stacked Senonian - Eocene carbonates source and reservoirs. Oil discoveries in the Pre-Neogene sediments are restricted to these areas.

The inherited structural belts played as deficit zones during the development of the orthogonal Neogene rift and resulted in rift segmentation and diversity in thickness and facies of the syn-rifting sediments.

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Applied Analog Structural Models in Hydrocarbon Exploration in the Offshore Mediterranean, Egypt

The entire Nile Delta region can be separated into three structural sub-provinces; the Delta Back in the south (onshore), the frontal Sub-province in the north (Facing Cyprus) and the middle in the near offshore. The southern domain of the active Delta subsidence has migrated from the near Cairo Latitude during Oligocene-Early Miocene to about 60km distance from the present day Mediterranean shoreline in the present (Bardawil sub-marine escarpment). Seismic interpretations indicated that these three structural sub-provinces includes four tectono-stratigraphic sequences; 1) Deep inverted Pre-Late Cretaceous, 2) Early Tertiary filling section, 3) Oligocene to Middle Miocene with combined Suez type of rift structures and Delta sedimentation and 4) Late Miocene to Recent prograding Delta complex.

Structural investigations in the offshore Mediterranean, Egypt indicated three major sources of deformation applied over pre-existing fabric since Late Cretaceous to the Present. These sources are; 1) superimposed tectonics related to the anti-clockwise rotation of the Southeastern Mediterranean since Late Cretaceous to the Present, 2) predominate shale composition of the Oligocene-Present succession causing diapirism 3) differential compatibility of the Nile Delta section causing detachments at listric faults while block motion and subsidence. Contemporaneous differential subsidence rates with the reactivation of the pre-existing fabric distinguished the sub-provinces and controlled the role of each source of deformation.

Trapping mechanisms in the area are related to the deep inverted Cretaceous structures, tilted normal fault blocks (Suez type of rift structures), rollover folding related to listric faulting and diapirism, gentle and strong folding, thrusting during Miocene-present.

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The Effect of Improved Palaeobathymetry Estimation in Hydrocarbon Migration Modelling

Palaeobathymetry is a crucial input in the modelling of hydrocarbon migration through geological time, as even small changes in the basin morphology may affect the amount of trapped hydrocarbons. Commonly, palaeo-water depth in basin models is either ignored or treated as a flat surface with fixed water depth. Considerations of 2D or 3D bathymetry through geological time are rare. Palaeobathymetry is in the present work estimated in 3D by combining relevant information from depositional geometries, sedimentological indicators of shallow or zero water depth and micropalaeontological interpretation from cores and cuttings. In addition, decompaction and flexural isostasy are accounted for. Several tests on data from the Norwegian continental shelf have been carried out in order to quantify the significance of palaeobathymetry in modelling. In each test a separate scenario was carried out, whereby palaeobathymetry was ignored. It has been shown that constrained palaeobathymetry may change the hydrocarbon migration direction through geological time, indicating that both the hydrocarbon fill history and phase trapping history will be different. There are no easy way of determining which hydrocarbon traps in a basin that are sensitive to palaeobathymetric input and which are not, except for modelling the whole system.

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Shear-wave Anisotropy in Very Porous Oil-bearing Sands: Applications in Perforation Strategy and Production Optimization

In this case-study, shear-wave anisotropy data was acquired by dipole shear sonic logging over several porous sandstone formations, intersected while drilling a well in the Gulf of Suez. The cross-dipole shear-wave data from the dipole shear sonic imager tool was processed to obtain oriented fast and slow shear waves. Anisotropy was then used to determine the orientation and magnitude of the principal horizontal stresses. Several highly porous sandstone zones exhibited significant shear-wave anisotropy. This observation indicates that the shear-wave anisotropy, which occurs in sands of about 30% porosity is more likely attributed to a significant stress imbalance. So far, the general perception has been that shear-wave anisotropy occurs more often in tighter rocks, e.g., carbonates or low porosity sands.

The observed shear-wave anisotropy azimuth has a NW-SE orientation, which is consistent with the known tectonic regime of the Gulf of Suez stress trend, i.e., the Clysmic-fault trend. Due to anisotropy, there is a significant difference between the magnitudes of the minimum and maximum horizontal stress. The anisotropy information proved to be very valuable in optimizing the perforation and production strategy due to the fact that sanding was suspected to occur. Sanding analysis was thus performed prior to the test and maximum critical drawdowns were calculated taking into consideration the shear-wave anisotropy.

The main technology value obtained from this study is that it clearly demonstrates the presence of significant shear-wave anisotropy in shallow deposited, oil-bearing and highly porous sands, which to the authors' knowledge has very seldom been reported in the literature, if ever. Therefore, this observation may assist in promoting and enhancing the usage and benefits of the shear-wave anisotropy technology in highly porous-sands.

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Using Cross-Dipole Sonic Logs and Rock-Physics Principles for Enhanced Detection of Commercial Gas Sands from Seismic Data in the Offshore Mediterranean, Egypt

Recent exploration in the offshore Mediterranean, Egypt, has resulted in many gas discoveries, at various depths reaching down to 4.5 Km, approximately. One of the main challenges in this environment is the ability to accurately detect commercial hydrocarbon plays from seismic information. Variations in density and velocity result in impedance changes which, under favorable conditions, can be detected from seismic amplitudes. However, the probability of success of this technique heavily depends on several reservoir parameters, i.e., depth, lithology, rock and fluid properties, pore pressure, etc.

This paper is a case-study of using cross-dipole sonic logs and Rock-Physics principles for a better understanding of the gas-effect on the elastic-wave propagation in porous sands, and thus enhancing the probability of commercial gas detection from seismic data.

In a recent exploration activity, offshore Mediterranean Egypt, a well was drilled aiming to encounter light hydrocarbons at a depth of approximately 2000 m. The strong seismic amplitude response observed at this depth indicated the presence of a gas bearing sand. However, later on, all acquired log and test data indicated that the sand is effectively water-bearing with probably only small amounts of residual gas being present. To improve the knowledge of the reservoir quality, several high-tech logging tools were acquired, including NMR, Cross-Dipole shear-sonic, high resolution induction and laterallog resistivity logs, in conjunction with formation pressure and mobility measurements. Following the log data acquisition, a detailed evaluation of petrophysical and geophysical properties, was carried out. This integrated evaluation proved the following: presence of minor amounts of residual gas and no evidence of shear-wave anisotropy over the sand. Moreover, the rock-physics evaluation indicated that the Kuster-Toksoz elastic-wave propagation model matched the measured P- and S-wave velocities and thus may explain the strong seismic amplitude anomaly observed.

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Graphic Correlation Analysis of Upper Tertiary Rocks in the Gulf of Suez and Nile Delta, Egypt, and the Adana Basin, Southern Turkey: Advantages and Improvements in Stratigraphic Resolution for Exploration and Production

Graphic correlation illustrates the relationship of rock sections to geologic time. A line of correlation (LOC) drawn through paleontological datums that have been calibrated to geologic time depicts this relationship. The LOC consists of oblique line segments separated by horizontal lines or "terraces." If not fault related, these terraces represent hiatuses produced by erosion (unconformities) or transgression (condensed intervals). The oblique segments are rock sections with continuous deposition, or "chronostratigraphic sequences." Sedimentation rates and missing geologic time are estimated from the LOC's, and their integration with seismic and geologic data on the workstation enhances stratigraphic interpretations in exploration and production.

Graphic correlation of Upper Tertiary rocks in two tectonic and one deltaic basin in the eastern Mediterranean region indicates that they consist of several chronostratigraphic sequences. The Upper Tertiary section of the Gulf of Suez is divided into nine widespread sequences that reflect basin evolution through rift initiation, climax, and post-rift phases. Play types are related to rift phase: half-graben fills during rift initiation, turbidites and fans at climax, and deltas and evaporites in the post-rift phase. Hiatal events within the syn-rift section reflect major tectonic events. Correlative rocks in the Adana Basin of southern Turkey consist of four chronostratigraphic sequences whose hiatal boundaries are also related to tectonism. The Messinian-Quaternary section of the Nile Delta, however, contains six widespread hiatuses produced by eustatic fluctuations. Those formed by regional flooding are effective gas seals in the Nile Delta.

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Reservoir Characterization through Seismic Visualization and Sequence Stratigraphy - An Approach to Reveal Reservoir Properties and Well Planning Strategies in Novogodneye Field - Russia

Reservoir Characterization through seismic visualization and Sequence stratigraphy - An approach to reveal reservoir properties and well planning strategies in Novogodneye Field - Russia

Delinationand exploration wells have been drilled on the Novogodney Field so far. These wells did not explore the field into details. Well spacing in the Novogodneye field allowed for certain uncertainties in reservoir characterization, hence difficulties in characterizing the reservoir heterogeneity with well data and 2D seismic alone.

A 3D survey was performed in 2001. This 3D seismic enables interwell heterogeneity description, and reduce the risk in locating development wells in the future.

Integration of 3-D seismic data with petrophysical information about the reservoir and reservoir simulation history match results has improved our understanding of the reservoir complexity and improved the mapping of porosity distribution of the Jurassic reservoir intervals in Novogodneye field.

The field is confined to the Vyngapyakutinsky local rise, located in the central part of Vyngapurovsky megadome, complex Yamalo-Purovsky avlacogene of the Tomsk-Yamal tectonic belt. This region is characterized by large tectonism in Neogen- Quaternary times, which manifests itself in a large amplitude and length of linear submeridionally stretched megadomes, with deer faults of disjunctive enhanced thermal field abnormalities. Vyngapiakutinsky uplift is the most elevated one, compared to the adjacent Vyngayakhinsky and Vyngapurovsky uplifts.

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Petroleum System and Exploration Potential of the West Alboran Basin

The offshore West Alboran Basin, which covers ca. 3000 sq. km., lies between the Moroccan and Spanish continental shelf, in the hinterland of the Rif-Betic fold-thrust belt. Conoco recently acquired 3200 km of 2D seismic, gravity, and magnetic data, as well as swath bathymetry and seabed piston cores, in order to evaluate the tectonic evolution and hydrocarbon potential of this little-explored basin.

The new seismic data reveal a coherent sedimentary column up to ca. 12 km in the basin, which is much greater than that estimated in previous studies. Mud volcanoes and mud diapirs, which originate near the base of the section, occur throughout the basin center. The roots of some of these are clearly associated with early rifting, which possibly started during Early Miocene. Several large, E-W-trending half grabens developed at this time are the most likely locations for source rock deposition. Deposition of the likely reservoir sand facies occurred mainly during Middle Miocene.

The presence of thermogenic gas and oil seeps in several seabed cores provides strong evidence for the presence of a functioning petroleum system in this basin. Oil and gas expulsion started in Late Miocene, which coincides with the initial phases of structural deformation within the basin. The Messinian shales as well as interbedded Middle Miocene shales provide seals for hydrocarbon accumulation.

Evaluation of the key exploration risks of this petroleum system continues with the results defining our future course of action.

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Evolution of the Levant Platform - Cretaceous-Paleogene Surfaces and Sequences of the Golan, West Jordan, Sinai and the Galalas

The Levant Platform (LP) extended from Syria in the northeast to Egypt in the southwest and was subdivided into four platform-units PU1 to PU4, each separated by key surfaces. Stratigraphic and sedimentologic analyses allow to interpret facies variation, depositional geometry, and architecture within the depositional sequences and to describe platform progradation and retrogradation. The studied surface sections represent different stratigraphic intervals of the LP and are from northeast to southwest:

- the Golan record - Berriasian to Albian (PU1-PU2),
- central west Jordan record - uppermost Albian to Turonian (upper PU2-PU3),
- the Sinai record - Aptian to Coniacian (PU1 -PU3)
- the Galala Heights / Eastern Desert record - Campanian to Paleogene (PU4).

Outcrop methodology and detailed lithologic, sedimentologic, paleontologic, and paleogeographic data allow to identify and to organize the genetic depositional elements within the LP hierarchically. We define six sequence sets (SST1 to 6), each composed of up to twelve depositional sequences. The SSTs are portrayed by prominent changes of tectonic episodes (uplift and subsidence) or changes in the paleoceanographic regime, both inducing major changes of the platform environments. Depositional processes within the Late Aptian - Paleogene sequence sets reflect 38 relative sea-level oscillations marked by third-order SBs; additionally two second-order SBs are indicated within the Late Barremian - Early Aptian interval. Comparisons with neighbouring platforms and charts indicate several mismatches of the LP- sequences that may be due to local uplift, clastic input or subsidence variations.

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Managing Information in the World of the Virtual Oil Company

Technological change has been one of the key drivers of business evolution over time. The current business climate is again being profoundly influenced by a technology, especially the Internet. This changes the value structure in many industries. The oil and gas industry is no exception.

The spirit of competition between oil companies, suppliers and the regulatory authorities is becoming one of shared risk taking, collaboration and co-operation.

There is a global consolidation in the supply of E&P information, with purchase and delivery of information updates via the web now common place. The information vendors will supply their products in 'analysis-ready' components that 'plug & play' with each other and common software packages. Increasingly, the 'bits & bytes' management of base data is something more efficiently done by service providers than in-house.

'Heavyweight' Information Management no longer provides competitive advantage. What does provide advantage is the ability to rapidly create a decision-making environment where the E&P professional is provided with just the right information and analysis tools.

With application and data delivery over the net, the commercial models will also change. Fixed licences will have to be replaced by "pay as you go" and data may not just be bought once at a high price, but instead be paid for when actually used. This in turn will significantly increase the flexibility of the oil companies and allow them to focus on efficient evaluation of the best opportunities.

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Waveform Gather Inversion and Attribute-Guided Interpolation: A Two-Step Approach to Log Prediction

We present a two-step approach to predict log information. In the first step nonlinear waveform gather inversion is used to estimate VP, VS, and density from the full seismic gathers. This estimation is useful in areas with little or no well control, as well as in mature basins where log information might be available but might not be complete. Waveform gather inversion is computationally intensive, and therefore, difficult to apply to every gather in a seismic volume. In the second step, seismic attributes are used to guide the interpolation of the predicted logs for the entire seismic volume. Interpolation of log properties can be done in several ways. A traditional way is to use hybrid inversion, elastic impedance inversion, or poststack amplitude inversion. These methodologies depend exclusively on amplitude information and use no other attributes. This traditional inversion is also strongly dependent on the interpretation of horizons. The interpretation in certain areas could be challenging, as in the following types of geologic settings: carbonate buildup, channel complex, crossing fault, angular unconformity, or turbidite. Furthermore, certain poststack inversions might be too sensitive to the interpretation, which is not always desirable. Neural network interpolation does not require horizon interpretation. Our two-step approach overcomes the high cost of waveform gather inversion, and results in a parallelized workflow where the inversion and neural network interpolation are done independently of the structural interpretation of the seismic data. This overcomes the bottleneck of a linear workflow of processing, interpretation, and inversion.

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Fracture Characterization Methods for Tight Gas Sandstones

Ongoing research is aimed at enhancing exploration and production for fractured reservoirs by development and integration of emerging and existing technologies for the observation, prediction, and fluid-flow modeling of natural fractures. Macroscopic fractures produce the largest impact on fluid flow through fractured rock, however they are orders of magnitude less abundant than microscopic fractures. Macro-fractures in subsurface reservoirs typically are poorly represented by data acquired with conventional techniques. Due to the abundance of microfractures, they can be well studied even in small samples from the subsurface. We are exploring the hypotheses that micro- and macro-fractures are different size fractions of the same fracture sets, and that microfractures can be used to predict the critical characteristics (in terms of fluid flow) of associated macro-fractures.

Previously invisible microfractures are readily observed and characterized when their cathodoluminescence is imaged using scanning electron microscopy. This facilitates determination of the orientations, timing (relative to diagenetic events), and sizes of the numerous microfractures typically present in prospective fractured reservoirs. These observations may be made systematically on a bed-by-bed basis. Orientations and timing of microfractures commonly compare favorably with those of associated conductive macro-fractures.

Microfractures are sufficiently abundant in the numerous fractured units we have studied that the size distributions can be readily quantified. Under special circumstances, the sizes (i.e., mechanical apertures and/or lengths) of both micro- and macro-fractures can be reliably measured in the same fractured rock volume. The spatial frequency of fractures, as a function of fracture size, follows power-law distributions over at least 4 to 5 orders of magnitude in these cases. This confirms that microfracture sizes can be used to quantitatively predict spatial frequencies of associated macro-fractures.

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Cement Patterns Control Fracture Porosity Preservation in Tight Gas Sandstones

Comparisons of measured stress directions and orientations of open, flow-controlling fractures show that open fractures in the subsurface are not necessarily parallel to maximum compressive stress (SH_{max}) and that fractures perpendicular to this direction may be open. Examples from the upper Gulf Coast basin, the interior compressional stress province, and western U.S. extensional stress province have stress, fracture, and production data from depths of 2400m to 6400m.

The divergence between open fractures demonstrably contributing to fluid flow and SH_{max} ranges from a few degrees to 90 degrees. Moreover, sealed fractures parallel to SH_{max} are numerous. Parallelism of modern-day principal stresses and open fractures is not good evidence, by itself, that modern day stress controls the orientation of open fractures. A determining factor for fluid flow is the degree of mineral cement deposited within fractures. This is a function of fracture size and the rock's diagenetic history. In most subsurface opening-mode fracture systems, fractures are partially filled with a synkinematic cement deposited at the time of fracturing. This cement tends to form strong mineral bridges that prop the fracture open. The remaining part of the fracture is open or may be filled with postkinematic cements precipitated after fractures ceased opening.

For the many reservoirs where opening mode fractures are the key flow pathways, cement patterns rather than stress data may provide the insight needed to determine which fractures are open to fluid flow.

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The Role of LWD-MWD and Real Time Data Transmission in Reducing the Drilling Cost in Deep Water Operations

The costly Drilling and Formation Evaluation in deep water represent a challenge to the oil industry. This challenge requires collaborative efforts to combine the available technology and obtain the optimum rock and geo-science information. The new Logging While Drilling LWD technology fulfill some of the requirements to relax these challenges.

Regarding Drilling, The Pressure While Drilling tool solved the problems of Monitoring the hole cleaning, increased the effectiveness of the carrying capacities of the drilling fluid in the open hole as well as in the riser section and provided means of detecting of the shallow hazards (gases or water flow). The borehole stability, failure analysis, seismic-tie-in and pore pressure can also be obtained using the acoustic LWD, the density LWD and the Pressure while drilling.

Regarding Formation Evaluation, The combined Tripple combo LWD, NMR-LWD and The BAT (Bi-Modal Acoustic Tool) provides the means to obtain the porosity, water mobility, fluid types and fracture identification.

The ability to provide all the above using Real Time Operation, RTO, represents a vital technology to speed up the decision making and reduce the rig time to wait on changes.

In this paper, Examples from the Mediterranean Sea Deep Water operations are discussed and the future role of the LWD and Wireline formation evaluation with real time operation is explained.

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**Numerical Simulation Modeling of Hydrocarbon Migration into and Through Sand Reservoirs in the Pabst Field
(Main Pass Block ²59), Northern Gulf of Mexico**

Numerical simulation modeling of hydrocarbons charging reservoir sands provides a better understanding of the distribution of hydrocarbons in reservoir compartments and assists in the development of numerical simulation models used during the development and production. Herein, we report results of numerical simulation modeling of migration of hydrocarbon liquids into the 10,300-ft sand of the Pabst field in the northern Gulf of Mexico. The model is based on and constrained by geochemical, seismic and well-log data. Seismic amplitudes serve as proxies for gas-condensate distribution.

Sands in the Pabst field appear to have been deposited as delta-toe or turbidites on an upper paleoslope. The field is complexly faulted. Three main NW-SE trending growth faults and numerous low-throw NE-SW trending faults divide the field into numerous compartments. The numerical simulation models indicate that the three major growth faults mainly seal. Some communication between two of the growth faults may have occurred across a local high-standing block. The NE-SW trending low-throw faults mainly form barriers. The main migration pathways appear to be the two structurally lower growth faults. Geochemical data shows that present condensate is highly mature and that it arrived late in the field, flushing the earlier, heavier liquids as it migrated. The 10,300-sand contains mainly condensates but other sands contain remnants of the earlier, heavier hydrocarbons.

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An Integrated Approach to Reservoir Characterization of the Upper Jurassic Arab Formation, Onshore Abu Dhabi, UAE

Detailed sedimentological description and interpretation of recently acquired data from four cored wells was integrated to produce a new sequence stratigraphic, sedimentological and diagenetic model for the Manifa, Hith, Arab-ABC, Arab-D and Upper Diyab Formations. Six distinct palaeoenvironments were identified during the study; a supratidal sabkha setting with localised salinas, an intertidal environment, a low-energy sub-tidal setting, a high-energy inner ramp environment, a moderate-energy mid-ramp setting, and a low-energy outer ramp setting.

Correlation within a sequence stratigraphic framework has constrained the distribution of these palaeoenvironments across the field and has established that this is a complex reservoir controlled by fourth order aggradational and progradational cycles composed of fifth order shallowing-upward cycles. Appraisal drilling results have confirmed that well productivity in the Arab ABC is predominantly controlled by the development of thin permeable dolomite streaks associated with these fifth-order shallowing-upward cycles. An overall progradational geometry towards the east-northeast has been established.

Diagenetic modification of the sediments, by processes such as syndepositional dolomitization, displacive anhydrite formation, non-ferroan calcite burial cementation, and leaching, prohibited the establishment of a direct relationship between primary depositional facies and rock properties, therefore a rock-type scheme was established to encompass all lithostratigraphic units. Standard core-analysis data acquisition and attribution of saturation functions to the static and dynamic model were performed on a cell-by-cell basis using these established rock types. Upscaling was performed with an emphasis on preserving the cyclicity and thin increased-permeability streaks in the dynamic model. The series of extracted dynamic simulation models allowed definition of the development requirements of the reservoir.

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Mechanisms of Sedimentary Dispersal on the Nile Deep Sea Fan

Depending on the areas, dominant sedimentary dispersal mechanisms can be observed on the Nile deep-sea fan:

- In a western province, a single feeder canyon, and related ramified channel-levee system ending by large sandy lobes (well identified on backscatter data and sampled by coring) guide turbiditic flows directly into the abyssal plain. Avulsions are frequent; and huge slope destabilizations have led to westward migration of successive main active channels.

- In a central province, mass wasting processes seem to prevail, at least in recent times: Eastwards, active salt tectonics interrupt channels, and prevent from any steady channel-levee development. Westwards, sediment waves are observed over large surfaces. The presence, within this field, of a few channels, as well as of minor chaotic block rotations and discontinuities, suggest interactions between turbidity currents and creeping processes to form sediment waves.

- In an eastern province cross-cut by a wide NW-SE tectonic corridor, disrupted channels are frequently observed, and echo-character analysis evidences the importance of mass wasting deposits nearby the main tectonic features. Successive channel activities and disruptions, as well as the presence of sandy ponded basins, suggest significant trapping of turbiditic deposits within the tectonized belt.

- In a levantine area, a single sinuous channel, likely originating from the Sinai Peninsula, is observed on nearly 200 km. To the north, it merges with levantine channels. This composite system constitutes a path allowing turbiditic deposition south of Cyprus.

- Finally, upslope the eastern provinces, sedimentary dunes, probably generated by easterly longshore currents, have been identified.

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Shallow Structure of the Nile Deep-sea Fan : Implications on Sedimentary Dispersal and Fluid Ascents

In many areas of the Mediterranean sea, deformations result from interplays between thick-skinned, crustal tectonics and thin-skinned, gravity-driven deformation of Messinian evaporites and overlying sediments. The Nile deep-sea fan (NDSF), recently surveyed by swath bathymetry, backscatter images and seismic data, is a good example of downslope progression along salt-bearing passive margins: There gravity spreading of the salt-sediment package induces proximal thin-skinned extension and distal contraction. The NDSF however displays a strong lateral dissymetry. Its Western and Central provinces are poorly deformed, while its Eastern domain displays a more than 200 km long, NW-SE oriented tectonic corridor, bounded to the NE by a 400 meters high salt-bearing scarp, facing the Eratosthenes seamount (ESM). The origin of this corridor being controversial (deep-seated or salt-related?), structural analysis and physical experiments were carried out. They emphasize the importance of Messinian paleo-topographies on gravity spreading. Messinian paleo-reliefs, such as ESM, constitute passive buttresses whereas depressions, infilled by thick piles of evaporites, form preferential channels for further gravity spreading. Features, such as paleo-messinian shelf-breaks, localize linear fault zones within the plio-pleistocene sedimentary cover. These reliefs, possibly generated by previous crustal tectonics, and re-shaped by erosional processes, seem to have induced most of the structural features observed in surface.

The Messinian heritage has thus strong implications on the location of deep-sea channels, that appear restricted into the tectonized Eastern province, and highly ramified elsewhere. Fluid ascents and releases seem also to be influenced by salt distribution, itself depending on interplays between gravity spreading and Messinian paleo-reliefs.

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Hercynian Deformation and the Creation of Fractured Reservoirs along Wrench Faults of the Central Sahara

Several continental-scale, north-south trending faults extend northward from the Hoggar massif into the central Saharan platform. These faults originally formed during late Precambrian time but were re-activated in late Paleozoic time to create reservoirs in the overlying, early Paleozoic sandstones. Surface expressions of the faults consist of broad anticlines, abrupt folds, vertical offsets with abrupt changes in the sense of motion along strike, and east-west directed thrusts. These characteristics are suggestive of east-west compression but are also compatible with transpression along the faults, a more regionally plausible interpretation. Right-lateral, kilometer-scale, wrench offsets accommodated northward and northeastward translation of the Mauritanian craton during the Hercynian orogeny, ultimately related to collision between Africa and the Americas and recorded by thrusting in the Mauritanides chain along the west coast of northwest Africa. Simultaneous northeast-southwest shortening across the Ougarta arch, where northeastward motion of the craton was directly accommodated by folding and thrusting, supports this model. Strata overlying the sinuous and multi-stranded faults were folded and faulted at fault bends, offsets, and asperities during wrench faulting. These structures formed as a result of local strain partitioning in the shallow strata, and are a common feature of other continental-scale transpressive fault zones as well as of published sand-box models. Deformation and folding of the strata along faults created traps for hydrocarbons and fracture-related permeability within the local well-cemented Paleozoic sandstones. More systematic, regional fractures are present throughout the minimally deformed strata found between faults.

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Mesozoic Carbonate Facies and Reservoirs in Central Palmyrides, Syria

In central Palmyrides on the onset of the Permian rifting and opening of Neo-Tethys, post rift Triassic Formations; Amanus Shale, Kurrachine Dolomite, K. Anhydrite, Butmah, Adayah, Muss, Allan and Sergelu consists of carbonates and evaporites of various thickness deposited mainly on the stable, sometimes very shallow carbonate shelf. Locally in the Uppermost Triassic sedimentary hiatus is present before the deposition of the Sergelu Fm. The transgression that had begun in the Upper Triassic continued in the Lower Jurassic as well. Jurassic Formation-Hara Moun is composed of carbonate rocks. Dominant are biomicritic and micritic limestones and dolomites. The Jurassic surface is heavily eroded and karstified. The Late Jurassic hiatus and erosion continued also in the Cretaceous. In Early Cretaceous in addition to extensive unconformity, volcanism is widespread. In regional sense, E. Cretaceous transgression covered the most of the area with continental and shallow marine clastics of Rutbah Fm. Slow subsidence continued in Albian-Turonian and thick portion of shallow platform carbonate deposits are present in the entire area (Hayan and Judea Fm.). At the end of Cretaceous in Senonian, sedimentary facies indicate increasing in water depth. Deposits of the Soukhne Group (Coniacian-Campanian), Rmah Chert and Arak Marl Fm., exhibits an increased marl content. The Maastrichtian, Shiranish Formation consist of pelagic marly limestones and marls indicating great water depth. The main HC reservoirs in the region K. Dolomite, Butmah, Hayane and Judea are studied in more details using outcrops and wells data.

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Seismic Classification – A Case Study in the Niger Delta

The effective utilization of available data to reduce risk, improve cycle time, and increase reserves is a major challenge in today's E&P industry. The extraction and exploitation of seismic attribute information provides an innovative means of creating supplementary data sets that can be accessed and interpreted. Seismic classification using neural networks to segregate facies and identify potential hydrocarbon bearing zones based upon the analysis of extracted attributes is a modern approach to interpretation and data utilization. Seismic classifications can be unsupervised - made using extracted attributes only - or they can be supervised - using existing well information to train the neural network as part of the classification scheme. Using information from seismic attribute extractions in combination with 'ground truth' information from the drill bit, these new classification algorithms provide a unique opportunity for the interpreter to enhance their understanding of the subsurface and to reduce the risk associated with oil exploitation. In this study, information from ten wells was combined with 3D seismic interpretation data (extracted seismic attributes) over a shelf/slope environment to investigate and understand the uncertainty associated with amplitude anomalies in the prospect area. The resultant facies classification yielded valuable information, which was used to guide the placement of a future well. Although the location has not yet been tested, the approach affords us a unique opportunity to utilize available information in a new way to achieve a better understanding of potential reservoir targets

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Geochemical Exploration in The Offshore Nile Delta

The major objective of Geochemistry in Exploration phase is to reduce the risk of drilling dry wells by applying geochemical concepts. This paper covers the eastern and central sub-basins in the offshore Nile Delta.

Risk reduction involves selective mapping of quantity, quality and maturity of petroleum source rocks, identification of the possible migration pathways from the mature sources to the prospective traps, effectiveness of regional or local seals and geologic processes, which are controlling all these factors.

Integration of geological studies and geochemical measurements & correlations help in identifying the charged closures, which exist in the hydrocarbon migration pathways in the study area.

The Oligocene sequence can be pointed out as the source rock for the most of the hydrocarbons found in the Nile Delta area. The early Miocene (Qantara Formation) can be considered as a secondary source rocks. Some Mesozoic intervals could represent effective sources and co-sources for the hydrocarbons found towards the north Sinai domain. The migration mainly occurred from the deepest part of the basin located in the North to North West area towards South to SouthEast. Secondary migration along lateral paths may be quite effective, as proven along the Abu Madi paleo-valley.

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A Feasibility Study for a 3-D, 4-C Seabed Seismic Survey in the Arabian Gulf

We present a feasibility study, designed to investigate whether 3-D seabed, multi-component (4-C) seismic recording over the Zuluf field would lead to an improved structural and stratigraphic interpretation. A primary objective of the study was to determine which of the potential benefits of 4-C recording could materialize into tangible benefits for the case of the Zuluf field.

Surface seismic datasets consisting of towed streamer and OBC (2-C) data from a neighboring field were analyzed and compared. Multi-component VSP data was also used both to evaluate the amount of shear wave energy generated by mode conversion and to predict the achievable bandwidth and vertical resolution. Earth models built from the P and S logs were used to model P and S offset reflectivity and create realistic elastic synthetics.

We have been able to predict those aspects of the proposed 4-C survey that would provide additional new insight and those aspects that are less likely to succeed. For instance, whereas the use of S-waves for imaging low P-impedance contrasts does not seem promising for the main producer to date, the Khafji Main sand, converted S-waves are expected to bring improved imaging for the overlying Khafji and Safaniya stringer sands where most of the remaining reserves are located. There is also scope for S-wave data to provide additional constraints on the interpretation through the use of Vp/Vs analysis. Combined interpretation of the two data volumes (PP and PS) could provide both a reservoir quality indicator and a means for lithology and fluid discrimination

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The Application of Shallow Structural Mapping to Understand the Deep Structure in the October Field Area, Northern Suez Rift, Egypt

Many Gulf of Suez oil fields produce from pre-rift, Paleozoic through Cretaceous aged reservoirs located in the foot-walls of tilted fault blocks bounded by NNW-SSE striking (rift-parallel) normal faults. However, in some cases, faults oriented in directions oblique to the axis of the rift serve as bounding faults for oil accumulations. Correct understanding of these structural elements is key to success in finding new fields. However, seismic imaging across much of the Gulf of Suez is difficult because of mid Miocene, syn-rift evaporate-rich intervals, which generate multiples that mask the primary energy.

Many methods have been developed to enhance seismic data quality, and to improve the confidence of using seismic data for structural interpretation. We demonstrate the use of some simple mapping techniques in the shallow syn-rift section, above the effects of multiples where the seismic images is more reliable, to better understand structure at deeper pre-rift reservoir levels. The techniques used include the generation of late syn-rift structure and isopach maps, 3D displays, and integration with onshore geology and edge detection maps.

The application of these techniques allows us to identify linkages between late rift and early rift structures and how these linkages vary with respect to salt thickness. It allows us to identify subtle structures, and can be used as a tool for quick regional interpretation and to constrain the structural geometry of oil fields.

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Obaiyed Field: A Major Challenge for Hydrocarbon Exploration in the Western Desert of Egypt

Obaiyed is the largest Jurassic gas/condensate field in the northern Western Desert of Egypt. It represents a combination trap on the western flank of the Matruh basin; a NNE trending Jurassic-Early Cretaceous rift that was inverted in the Late Cretaceous - Early Tertiary. The field lies within the up-dip side of a large easterly-tilted half graben. It produces from Bathonian sandstone unconformably overlying pre-rift Paleozoic sequences. Integrated analysis of borehole and seismic data helped outline the 3D geometry of the field and define the seismic signature of the Paleozoic - Mesozoic unconformity.

Predicting the reservoir distribution above this unconformity is a challenge for exploration and development of the field. Understanding the paleogeography and tectonostratigraphy of the area as part of the Matruh Basin is inevitable for constructing a predictive depositional model of this reservoir. This task is further challenged by the inversion overprinting the original paleo-relief.

Three main tectonic trends controlled the deposition of the early rift clastics. These are rift-parallel NNE faults forming depositional compartments, a few ENE faults, and WNW pre-rift shear zones. The fault-bounded corridors acted as estuarine embayments with amplified tidal energy. Coarse Pebbly sandstone was deposited proximal to paleo-highs and on the hanging walls of main active faults. Muddy sediments dominated the central and outer reaches of these embayments and fluvial influx supplied sands to them.

Does Obaiyed represent a unique play in the northern Western Desert? Alternatively, it might provide a hydrocarbon exploration analogue for other similar settings.

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The Future of 4D in the Nile Delta

4D or time-lapse seismic is now an accepted technology for reservoir management. There are numerous documented successes in oil reservoirs from the North Sea, Gulf of Mexico and elsewhere. The science behind the 4D technology is beautifully simple: as oil or gas is produced from the reservoir, the reservoir experiences pressure and saturation changes. Provided the magnitude of these changes is large enough, repeat seismic surveys over the field may be able to track flood fronts or recognize flow barriers, identifying bypassed pay and extending the life of the field.

While numerous 4D success stories can be credited to oil reservoirs, little work has been done on applying the technology to gas reservoirs. Although time-lapse effects are expected to be generally smaller in gas reservoirs, recent modeling studies show the effects should still be visible. Strongest effects are expected to be seen in shallow gas reservoirs with good quality 3D seismic datasets. This includes most of the Pliocene in the Nile Delta, where 14 Tcf of gas have been discovered, with current production from numerous fields. If 4D technology could be applied here, it could provide a great cost benefit by enabling the cost-effective management of gas reservoirs through field life.

This paper presents recent rock property work on BP Egypt's Ha'py field, which suggests that time-lapse seismic may have been an appropriate technology for reservoir management. The commercial benefits are explored and some predictions made about the level of repeat seismic activity that may be justified in future years.

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Seismic Challenges of Developing the Pre-Messinian - Akhen Field Offshore Nile Delta

BP's recent drilling results in the Akhen field, offshore Nile Delta, provide an excellent case study into the seismic challenges of drilling and developing the Pre-Pliocene in the Nile Delta. The challenges are significant: Pliocene overpressure cells, variable thickness and rugosity of Messinian anhydrite, deep and complex structural elements and seismic quality challenges.

Recent work suggests that the Serravallian aged reservoir sands present in the Tamsah-Akhen area are likely turbidite channel complexes that were deposited over the structure as it started to form. Both seismic scale and sub-seismic scale channels are evident in the 18 wells drilled to date across the structure. Rock properties studies of the Serravallian aged sediments suggest that the sands are acoustically hard, with little acoustic difference seen between brine charged and gas charged sands. The sands are primarily Class 1, suggesting the sands remain hard at far offsets, regardless of pore fluid.

In 2001, BP drilled the first development well for the Akhen Field, West Akhen-2, which targeted three stacked channel sands. The well results suggest a higher degree of complexity and faulting than previously interpreted. Results of the re-processing, including the use of tomographically derived velocities, clearly show the structure at the West Akhen-2 well location has become much tighter, indicating event movement of 100-120 meters up-dip. In addition, the increased resolution from the near stack dataset revealed the presence of slump faulting, which had removed part of the primary objective section.

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Evidences of Fluid Escape Structures and Mud Volcanoes on the Nile Deep Sea Fan

At continental margins, fluids are emitted into the ocean via the sea floor. The forms of emissions vary from diffusive fluid flow to focused flow through seeps and vents, often associated with over-pressured mud constructions.

Marine geophysical data show that these features are variably expressed on the sea floor, as pock-marks, mud volcanoes and/or sub-circular, flat, mud «cakes».

Extensive swath mapping (bathymetry and backscatter images) and seismic profiling (including a few 3D seismic data) from deep-water Egypt, have revealed the presence on the sea floor of many features interpreted to be evidences of fluid releases and associated mud flows. A field, characterized by many small mud cones (few hundred meters in diameter), lies on the lower slope in the north-west of the Nile deep sea fan, by water depth around 3000 m. In the same area, caldera-like, subdued depressions (up to 8 km in diameter) are detected on the sea floor. These features are associated with numerous growth faults that cut across this area of the continental slope. Isolated, sub-circular, gas chimneys (characterized by transparent or chaotic seismic signature), or clusters of important mud volcanoes, are seen in several regions of the upper slope, around 800-1000 m of water depth. These structures are either associated to recent sedimentary destabilizations, to growth faults, or to sets of cross-cutting active faults. Finally, many pock-marks, well revealed by backscatter signatures, are identified in several domains of the deep sea fan, particularly within its central province, where exist evidences of important slumps and debris flows.

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Structural Model Assessment in Deep-Water Compressional Settings: Exploration Impact in the Gulf of Mexico and Amazon Slope Basins

BP's active exploration of several deep-water slope basins presents recurring exploration risks which are being addressed partly through integrated structural-geological interpretation and modelling.

The large prospective structures which are frequently developed in the 'down-dip' compressional-toe regions of the Gulf of Mexico and Amazon deep-water environments have been generated by gravitational movement of the entire slope basin, which in the Gulf of Mexico has involved substantial synchronous salt flow.

This presentation is focussed on key elements of the structural workflow, integration between structural interpretation and basin modelling, and the resultant contribution to risk reduction which has been applied recently during exploration of these basins.

Key exploration-scale issues include crustal structure, heat flow, source presence, trap geometry and complexity prediction in sub-salt settings, and palaeo-structural impact on charge history and depositional system evolution. A selection of examples will be presented which illustrate application of exploration-scale structural workflow prior to recent field discovery and during ongoing appraisal within the Gulf of Mexico, and during early exploration in the Amazon slope basin.

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Turbidite Slope Channels - Patterns of Reservoir Distribution and Heterogeneity

Turbidite slope channels contain potentially complex reservoirs that offer a number of challenges to reservoir development. Although there is a degree of uniqueness to each channel, recognising recurring aspects of channel development, provides a process for systematically evaluating the problems that may need to be resolved during field appraisal and production.

The distribution of the reservoir and the heterogeneity patterns is inevitably a function of three aspects; the facies, multi-phase fill and stacking patterns.

The facies is dominated by four components -

A basal lag which overlies the erosional surface. In most cases this comprises coarse sand and granules but may also be composed of mud-clast conglomerates or 'by-pass' shale drapes.

Slumps and debris flows derived from the walls of the channel or from longer distance transport.

Stacked high N:G channels dominantly composed of massive sands but also with more interbedded marginal facies.

Sinuuous low N:G channel levees often form the last phase of the channel fill.

This simple pattern is made more complex as the large erosional conduit is re-occupied during several episodes of cutting and filling. This process has at least two important impacts on reservoir volumes and the development of the heterogeneity patterns -

- Erosion by a later channel may leave the channel axis of previous channels preserved only as erosional remnants
- One or more of the phases of channel fill may be dominated by muds or debris flows.

Numerous styles of stacking patterns in the large channels can be present and stacking patterns may vary radically over short distances within a field.

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Paleohydraulic Analysis of the Lower Part of Hasawnah Formation, Libya

Palaeohydraulic analysis has proved useful in reconstructing a variety of flow parameters in meandering and braided river systems, mainly with a view to comparing the flow variables with modern rivers of broadly similar scale. However, these flow parameters have been estimated for individual bars or a relatively small number of representative bars for a specific reach of the river system, and no attempt has been made to continuously monitor flow variables through time in a thick, cyclically deposited braided river system. These variables not only provide clues to how flow variables changed through time but also whether they show any pattern or cyclically which may be related to allocyclic or authocyclic factors affecting deposition and flow conditions in that particular part of the river system.

Palaeo flow parameters of ancient river systems have been estimated using three main approaches: (1) these based on the dimensions of sedimentary structures, most notably cross - bed generated by the river system and how these related to the water depths and flow velocities; (2) those based on textural analysis of cross beds and their relationship to flow velocities; (3) those based on cross bedding measurements and the sinuosity of the channel.

In this study we have used palaeohydraulic analysis based on the mean thickness of cross bedded units with in individual, vertically - stacked fining up ward cycles with in th lower part of the Cambrian Hasawnah Formation in the Ghadames Basin of western Libya, in order to estimate flow depth and flow velocity, both with in individual cycles and through out the suction, which was deposited by a sandy braided stream.

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The Structural Evolution of the Berkine Basin, Algeria

Anadarko has been successfully exploring the Berkine Basin of Algeria for more than a decade and has access to an extensive seismic and well database. Interpretation of these data suggests the Phanerozoic rocks record a polyphase tectonic evolution.

The Late Palaeozoic to Recent evolution of the Berkine Basin is closely related to kinematic plate movements along the margins of the African Craton. The first effects of the collision of Laurasia with Africa occurred during the Late Devonian and result in major changes to the sediment provenance areas in the Berkine Basin. Within the Berkine Basin the effects of the Hercynian Orogeny resulted in uplift and tilting of the Palaeozoic intervals followed by erosion.

Major extensional rifting occurred in Late Triassic/Liassic times related to break-up of Pangea and the opening of the Central Atlantic. During the drift phase, in Middle Jurassic - Early Cretaceous, Africa moved eastwards relative to the Iberian plate, resulting in sinistral movement along the Newfoundland-Gibraltar Fracture Zone (NGFZ). The stresses resulted in transpressional folds with NW-SE trending axes (Austrian Event). Opening of the North Atlantic, during Late Cretaceous-Oligocene, changed the relative movement of Iberia and Africa along the NGFZ resulting in dextral wrench tectonics with a NW-SE compressional component (Pyrenean Event). The Berkine Basin was uplifted, Palaeogene sediments were eroded and some pre-existing NE-SW oriented fault zones were structurally inverted. Finally, the effects of Late Tertiary (11 - 5 ma) Alpine collision of Africa into Europe were felt in the Berkine Basin and resulted in mild regional tilting and gentle inversion.

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Application of Hyperspectral Technology for Offshore Oil Slick Mapping - A World First for BHPBilliton

BHP Billiton and Joint Venture Partners, ChevronTexaco and Kerr McGee, have recently conducted an extensive air-borne hyperspectral survey for mapping surface oil slicks in their deep water acreage, offshore NW Australia. The survey follows an intensive phase of research and development, including Calibration Trials over the past year and is believed to be a global first for the industry.

BallAIMS, an Australian Company which is part of the major, USA based, Ball (aeronautical/space) Corporation own, operate and develop, a number of high technology systems. In 2000 BallAIMS teamed up with Resource Management (Australia), a Perth based business specializing in Remote Sensing Methods, and undertook research and calibration Trials using the BallAIMS CASI Hyperspectral sensor. The success of these trials led to an approach to BHPB in 2001.

The CASI hyperspectral sensor provides a very high, resolution slick mapping capability over basin scale areas at resolutions of less than 1m. The sensor is uniquely programmable and can deliver up to 288 separate channels of data. The detailed spectral content of the data results in improved oil slick detection and few 'false positives' compared to conventional techniques.

Results from the oil calibration Trials conducted in 2000 and 2001 are presented which demonstrate the application of hyperspectral data in mapping a full range of different oil types from heavy oil to 55 API condensate in varying sea state conditions.

An example of multiple oil slicks mapped during the recent BHPB survey in some 1500m water depths is provided and the application of this technology to other areas is discussed.

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Geostatistical Modeling of the Third Upper and Third Lower Sands of the Burgan Formation, Greater Burgan Field, Kuwait

A geostatistical modeling study of the Burgan Third Upper (3U) and Third Lower (3L) sands was used to examine reservoir geology uncertainty issues prior to a finite difference flow simulation study. Separate models for the 3U and 3L units were generated for two representative portions of the Greater Burgan field. A variety of approaches including Gaussian Sequential Simulation (GSS), Sequential Indicator Simulation (SIS), Collocated Cokriging with GSS, and Boolean Modeling were evaluated. The following final workflow was used to model the 3U and 3L units: (1) Multi-binary SIS to distribute two facies ("sand" and "shale"); (2) GSS to distribute effective porosity within each facies using appropriate facies and geological interval-specific data; and, (3) facies-dependent transform to add permeability to the reservoir models. The "sand" facies represents higher quality reservoir rock (shale volume less than 40%, effective porosity greater than 10% and permeability greater than 100 md). Sand volume ranges from zero at the top of the 3U and 3L to over 50% at the bottom of the units.

Multiple realizations of the data-driven models and a set of models for which the semivariogram parameters were altered to generate models with varying connectivity were evaluated using a 3D streamline-based flow simulator to establish the appropriate cases for finite-difference fluid-flow simulation. Water breakthrough times were 1300 +/- 130 days for the data-driven base case, 1100 +/- 37 days for the enhanced connectivity case, and 1450 +/- 80 days for the lower connectivity case.

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The Siluro-Devonian of Illizi Basin (Algeria): An Example of Cratonic Clastic Sedimentation Systems

The Illizi basin (Algeria) is one of the most prolific basin in North Africa which was a part of the Gondwana super continent during the Paleozoic times.

The sedimentary architecture of the siluro-devonian series reservoir correspond to cratonic sedimentation and constitute two long term cycles.

The first one correspond to a long term progradation from the Llandoveryan to Pridoli. This cycle is subdivided to six third order sequences (S1 to S6). The second cycle corresponds to transgression from the Lochkovian to Emsian and is made by two third order sequences (D1, D2). The limit between the two cycles corresponds to Caledonian unconformity.

Sedimentary facies are various: the marine facies correspond to wave and tide progradational ramps deposited in an continental sea and tide dominated estuaries. The fluvial facies include proximal braided systems passing to meandering and straight systems to North of the basin.

The sedimentation of this cratonic area is principally carracterised by:

- A very low subsidence rate during Silurian and Devonian which is specific to cratonic basin during the Paleozoic.
- A high sediment supply rate with thick fluvial units of regional extension and systematic North-West direction of paleocourants.
- Evidence of tectonic activity during Siluro-Devonian sedimentation with the differenciation of sub-basin.

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Biostratigraphy, Facies Models and Reservoir Architecture of Tin-Fouye Field (Illizi Basin, Algeria)

The "F6" reservoir dated Upper Silurian-Lower Devonian is a major reservoir unit in the Tin-fouye field. A new sedimentological and biostratigraphical study based on core and outcrops description will be presented here: This biostratigraphical study prove: 1- the existence of Pridoli (Upper Silurian) in the Tin-Fouye area which is the equivalent of the "Talus à Tigilittes" formation in the Tassilis outcrops. 2- the occurrence of a major unconformity on top of reservoir eroding the Emsian shale. The Givetian shales overlay directly Lower Devonian units.

The sedimentary facies models of the Silurian sequences correspond to: of shore shales, progradational wave and tide dominated ramps, braided, straight and meandering fluvial systems and tidal complexes. The Devonian sequences are principally related to straight and meandering fluvial systems evolving upward to coastal plain complexes ("C2" unit equivalent to "Trottoir" formation). The coastal plain consist of floodplain shales with isolated ribbon channels. Roots are frequent and are related to earliest development of vegetation.

The Lower Devonian fluvial reservoir ("C1" unit, equivalent to "Barre moyenne" formation in the Tassili outcrops) makes a continuous but heterogeneous fluvial sand sheets with an irregular basal erosional surface. Thickness variation suggest the occurrence of a main SE/NW channel axis.

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IBAMA Environmental Control in Brazil: Criteira and Tools

Since 1997/98, with the new scenery in the oil/gas exploration in Brazil, IBAMA, (Brazilian Institute for Environment and Renewable Resources), is facing a quite different situation from the one it usually used to dealt with. From 1953, and up to 1997, Petrobrás had the privilege and opportunity to develop the oil industry in Brazil, thanks to the oil monopoly. However, before 1953, very few IOCs (International Oil Companies) risked in oil exploration in Brazil. Mostly, IOCs invested in gas stations. Since 1998, IBAMA has received a torrent of requests of environmental studies related to the concession area in offshore blocks offered and authorized by ANP (National Agency of Petroleum).

Consequently IBAMA had to make considerable efforts to organize an environmental branch office, the ELPN (Escritório de Licenciamento de Petróleo e Nuclear), to deal with such big demand of processes on environment. IBAMA contracted specialized professionals to perform environmental analytical studies of the potential impacts related to the seismic surveys, drillings and production offshore. In addition, some of bad quality environmental studies have been presented by the seismic operators, besides the numerous oil spills and cable losses events that happened in the last three years. Delay in the licencing procedures was the reason given by some seismic operators to perform irregular, not licensed and not authorized seismic surveys. Nevertheless, IBAMA has grated issued LO (Operation Licenses) for those who had good quality environmental plans, prepared by particular seismic and oil operators.

Presently, IBAMA is able to make the environmental analyses, in adequate time period, related to the oil activities offshore, and to prepare a regulatory norm that will control the environmental impacts.

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Effects of Faults and Fracture Corridors on Gas Productivity

Gas production from tight (3% porosity) carbonate reservoirs is possible only with the presence of a pervasive fracture network. Production simulation requires a modeling in which the fracture network is implicitly integrated. Mass transfer and depletion can be modeled, using lateral transmissivity variations where necessary. Barriers with decreased permeability would thus be zones of ineffective fracturing.

Even in case of weak aquifer activity, well production may rapidly be altered by water breakthrough. The case study shows erratic water production at depths that defy the gravity law of GWC uprise, and at pressures and times which lead to the certainty that vast reserves will remain inaccessible from the water-invaded wells.

In order to recover the gas, the challenge consists in localizing the faults and fracture corridors which are responsible for the water drainage into the wells, and to avoid triggering them (with side-tracks...). Results show that these water-prone corridors occur at various scales from a fault with evident throw to a localized fracture corridor made of closely spaced open joints. The physical connections to the aquifer must thus be evaluated, as wells located away may be protected.

Field examples of comparable tectonic history provide guidelines for the representation of the various scales of the fracture network, as well as rheologic laws (i.e. the relationship between the density of the brittle fabrics, the competency and the thickness of the reservoir).

Ahead of simulation the recognition of fabrics that may be responsible for water breakthrough is thus encouraged in a pluridisciplinary approach in order to optimize development operations.

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Flow Unit Characterization in Pliocene Reservoirs: Derived from Core Analysis, Capillary Pressure and Wire Line Logs, Offshore Nile Delta, Egypt

Abstract

Recent deep-water Pliocene discoveries in the Offshore Nile Delta established the Pliocene sequence as a primary hydrocarbon potential target. Core analysis and wire line data from recent slope channel discoveries in the North Alexandria Concession provide a typical example of reservoir facies and saturations within these trends.

Three major flow units are present 1) channelized high quality reservoirs 2) low permeability debris flows 3) thinly laminated turbidities. MDT pressure and samples in addition to well test data show that the thinly laminated facies contains significant gas pay. Conventional wire line logs consistently underestimate gas volumes or miss the pay zones entirely, resulting in a classic "low resistivity" pay identification problem. In addition, seismic imaging of these laminar zones is difficult.

Detailed core analysis in conjunction with Dipmeter Image Analysis and NMR Data show that thinly laminated reservoirs exhibit a wide variance of gas saturations from high quality multi Darcy reservoirs to seals. The formation pressure data to date, suggests that laminar seals are laterally ineffective, with all zones communicating vertically. Thin sections and x-ray diffraction data show thin and high quality reservoir laminations even in micro scale, with a strong preferential horizontal permeability and less vertical permeability.

The wide variance in rock type makes accurate quantification of Sw difficult in the low resistivity horizons, but the overall volume of potential pay is both recognizable on FMI and CMR logs, and can be quantified, giving substantial potential upside in each new slope turbidities discovery made.

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Facies and Reservoir Quality of Zarqa Formation (Turonian-Late Senonian), in Heglig and Unity Fields, Muglad Rift Basin , Sudan

The sedimentology and reservoir characteristics of Zarqa Formation in the Muglad rift basin were investigated using cores, wire line logs as well as petrographic analyses. The subsurface lithofacies analysis reveals that Zarqa formation comprises three major units, fluvial- dominated, fluvial-lacustrine and lacustrine-dominated facies units. The fluvial unit is composed of stacked fining upward facies sequences of fine to medium grained channel sandstone and overbank/floodplain siltstone and claystone facies. The fluvial/lacustrine unit consists of mixed interbedded fine to medium sandstone and claystone facies. The lacustrine-dominated unit consists mainly of claystone and siltstone facies interbedded with high sinuosity meandering stream facies. The three units of Zarqa Formation reflect the fluvial and lacustrine system response to base level change change as controlled mainly by tectonism and climate. In part, autocyclic controls such as channel processes , discharge rates and sediment load also played a role in that respect.

Zarqa Formation sandstone are mostly arkosic arenite, mainly fine to medium grained, poorly to moderately sorted, subangular to angular and cemented by calcite and argillaceous cement. Secondary porosity is introduced as a result of partial or complete dissolution of carbonate, feldspar and clay cements. Heavy and clay minerals composition indicates the control of climate , tectonism, source rocks, environments and diagenesis. Reservoir quality of Zarqa Formation is controlled by the macro scale facies architecture, geometry and dimensions of sandstone bodies and claystone/siltstone barrier and baffle units. Sediments detrital sources, compaction diagenetic alteration and dissolution are influential on micro scale.

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Integrated Reservoir Management Succeeded to Revert Production Decline in Belayim Land Mature Oil Field

Belayim land field was discovered on the eastern coast of Gulf of Suez in 1954 and was put on production one year later. The field reached its maximum daily oil production of 62,000 BOPD in 1963 then declined to reach its minimum rate of 28,000 BOPD in 1983. Since that time, continuous reservoir management efforts succeeded in reverting the field decline and it began to rise again to reach 61,000 BOPD which is a step in the way to reach 65,000 BOPD. The objective of this paper is to present Petrobel successful experience in handling mature fields with proper reservoir management.

The field rejuvenation started with the integrated reservoir and seismic studies that yielded the long-term reservoir management strategies. These studies covered all production horizons regardless of reserves. Exploration activities ran parallel to development works where 2D and 3D seismic surveys were carried out, particularly on the southern and western parts of the field.

The development program covered water injection and monitoring, artificial lift optimization, horizontal wells drilling and stimulation by hydraulic fracture. Since the first remarkable successful of horizontal drilling application on well 112-71 which started production at a rate of 2,500 BOPD, a total of 14 horizontal wells were drilled adding a total of 14,000 BOPD.

These actions revealed the fact that with proper field management the reserves can be doubled from 360 MMSTB in 1963 to 830 MMSTB in the beginning of year 2002.

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Implementing Technology with Efficiency: A Case History of 3D Seismic in Egypt

In 2000, Apache became involved in what subsequently became one of the largest 3D land surveys ever to have been shot in Egypt (close to 5000 sq.km of data will be finally processed). By performing an evaluation of the traditional methods of seismic acquisition which had been implemented at the beginning of the survey, and making fundamental design changes, it proved possible to improve the seismic data, and acquisition in all ways: Data Quality through higher fold and better noise attenuation; Longer offsets; Broader Azimuth distribution and of equal importance, better efficiency of acquisition. For such a large survey, small improvements in efficiency can have a large impact on the total cost of the survey.

In this paper we will review the changes that were made from the traditional approach that was initially implemented, and show examples of the improvements. By reviewing the ideas that were implemented to change the fundamental philosophy for shooting data, we will show how balancing the various aspects of work on a seismic crew can lead to better overall efficiency, in this case increasing the average acquisition area per day by 40%. Additionally, an examination of the azimuth distribution in the data shows why better azimuth distribution can (and did) lead to more noise attenuation.

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Effective Use of Seismic and Well Velocities to Build a Regional Velocity Field for Depth Conversion, Geological Integration and Pressure Prediction

A regional velocity field calibrated to well data for the entire Nile Delta has resulted in a comprehensive velocity field and "living" database that is maintained and updated constantly with new wells and seismic data. It can be used for simple, accurate and reversible time to depth conversions, geological integration and pressure prediction.

The Nile Delta encompasses almost 250,000 square kilometers. More than 15,000 square kilometers of 3-D seismic velocities, 20,000 line kilometers of 2-D seismic velocities and 50 wells have been used. Intensive quality control for each velocity function reduced errors, allowing high quality interpretations.

Calibration of seismic velocities with wells established a correction curve at each well location. Corrections were then applied to the seismic velocities. Horizon based gridding techniques using twelve regional horizons further increased precision and defined regional trends. This gridding method accurately accounted for rapid changes of water depth or for the presence of any local fast layers.

The velocity maps and "deviation from compaction curve maps" (relative measures of shale pressure) show a strong correlation with depositional fairways. These maps appear predictive up to 4000+ meters below mud line. Finally, interval velocity data, when coupled with quantification of pore pressure from wells and test data, has been converted to pore pressure, defining favorable drilling fairways and potential drilling hazards.

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Maturation Assessment of Oils and Condensates from Abu El Gharadig Basin, Western Desert, Egypt

Analyses of seven oils and condensates from three fields in Abu Ghradig basin in the Western Desert of Egypt indicated that fluid phase and hydrocarbon compositional variations in Upper and Lower Cretaceous reservoirs were related to maturity levels of source rocks. Maturity parameters such as 4-MDBT/1-MDBT, dimethyl dibenzothiophenes (DMDBT), MPI3 and DNR ratios of aromatics correlate well with maturity indicators based on saturate fractions of petroleum. Molecular parameters of aromatic sulfur compounds work well over a wide range of catagenesis, showing no reversal at the advanced levels of thermal evolution and can efficiently discriminate very mature petroleum. The abundance of dibenzothiophenes of the oils is comparable to fluorenes and phenanthrenes. This distribution of PAH is typically characteristic for siliciclastic. The ratio of DBT/P, calculated as the ratio of the sum of all dibenzothiophenes and all phenanthrenes, ranges between 0.39 and 0.73 (average 0.5), which is also distinctive for siliciclastic sediment sourced oils. The comparable PAH distributions in all oils and condensates presumably reflect that they have been generated from a similar source rock under consistent depositional conditions.

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Composition, Distribution and Sources of Polycyclic Aromatic Hydrocarbons (PAHs) in Sediments of the Western Harbour of Alexandria, Egypt

The composition, distribution and the source of polycyclic aromatic hydrocarbons (PAHs) in surficial sediments of the Western Harbour of Alexandria were investigated. To document the spatial PAH input, surficial sediment samples from 23 locations throughout the harbour were analysed. The total PAH load determined in the surficial sediment samples ranged from 7.9 to 131149 ng g⁻¹ dry wt. Generally, most of the samples having total concentrations of PAHs greater than 5000 ng g⁻¹ dry weight. The highest concentration of total PAHs was recorded in sediments of the inner harbour. Ratio values of specific compounds such as phenanthrene to anthracene, fluoranthene to pyrene, methyl-phenanthrene to phenanthrene, methyl-dibenzothiophenes to dibenzothiophenes, alkylated to non-alkylated and high molecular weight to low molecular weight PAH, were calculated to evaluate the possible source of PAH contamination in the harbour sediments. However, chrysene and perylene were used as indicator of terrigenous input. Two main sources of PAH in the study area have been found: pyrolytic and petrogenic. Interferences of rather petrogenic and pyrolytic PAH contaminations were noticed for most samples. The dominant sources of PAH appear to be the combustion processes through run-off, industrial and sewage discharges, and atmospheric input. The concentrations of PAHs were generally above levels expected to cause adverse biological effects.

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Mapping the Fractured Zones Affecting Qanawat Dam Area, Syria: A Geoelectric Application

Qanawat Dam was built on basaltic bedrock, and is designed to collect and store about 3,000,000 m³ / year of run off water received from Qanawat basin, which covers an area of about 350 km², and is located to the south west of Syria. A considerable amount of water loss is recorded due to seepage and percolation through fractured basalt. Mapping of these fractured basaltic zones based on geoelectric resistivity assessment of these zones, is the main target of this work.

Geoelectrical resistivity survey have been carried out in two phases, conducting Schlumberger 4-electrode array with maximum current electrode spacing of 1000m. The first phase have been achieved by carrying out 12 Vertical Electrical Sounding stations (VESes), distributed along Qanawat basin to delineate the main geoelectric characteristics. The second phase is conducted by 64 VESes distributed in 8 profiles and concentrated in an area of 4 km², surrounding the Dam. The depth and thickness of massive basalt, the bedrock of the Dam, is determined.

Geoelectric profiles and panel diagram, have been constructed to follow up the massive and disconnected fractured basaltic zones. The depth to this zone is varying from 3.8m to 25.6m. It exhibits a thickness ranging from 3.5m to 33.3m. Fracture distribution map was constructed. The location of seepage water areas from the lake and the body of the Dam was delineated.

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Effect of Basin Geometry on Locating Promising Hydrocarbon Traps: Tiba Natrun - Kattaniya Inverted Basin, Northern Western Desert (Egypt)

The Tiba Natrun - Kattaniya basin is a Jurassic-Early Cretaceous rift basin bounded on the north by ENE-oriented faults linked by NE- and WNW-oriented transfer faults. Late Cretaceous-Early Tertiary inversion of the basin due to WNW-ESE shortening involved a component of right-lateral slip on the ENE-oriented faults. The ENE- and NE-oriented faults at the rift boundary were predominantly reactivated by reverse slip leading to enormous uplift of the hydrocarbon source rocks from the depocenter of the basin. In contrast, continuous subsidence of the WNW-oriented rift segments (e.g. at Tiba Natrun sub-basin) allowed hydrocarbon maturation and expulsion from potential source rocks.

Intra-basin structures formed by inversion include NE-oriented folds and reverse faults forming excellent hydrocarbon traps (e.g. El-Ahram, Qarun, N. Qarun, SW Qarun, and N. Harun oil fields). Thick, syn-inversion Eocene rocks were deposited in a foredeep basin lying south of the highly inverted area allowing maturation of Cretaceous source rocks. Extensive exploration in the area indicates that hydrocarbon traps in the highly inverted part of the basin are not suitable sites for hydrocarbon accumulation due to halting hydrocarbon maturation (as a result of inversion) and lack of trap integrity (breaching by erosion, absence of top seal, high fracturing, etc.). Intra-basin hydrocarbon traps are the best prospects within the inverted basin. Continuously subsiding parts of the basin at the WNW-oriented rift segments are also promising areas for hydrocarbon maturation and expulsion into updip structural traps.

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Structural Style and Timing of Syrian Arc Deformation in Northern Egypt

Syrian arc structures form a NE-SW oriented belt of compressional features affecting the Mesozoic rocks in northern Egypt. They extend from N. Sinai to the NE part of the Western Desert in excellent exposures but gradually get buried westward where they are recognized in the subsurface. Integrated surface (field mapping) and subsurface (seismic and borehole) studies indicate the tectonic evolution of these structures and its effect on the hydrocarbon systems in northern Egypt. These compressional structures were formed by positive structural inversion of old extensional basins formed during the Jurassic and Early Cretaceous opening of the Neotethys. Although the early normal faults have a predominant ENE orientation, other trends are also common, e.g. NNE and WNW. The magnitude of inversion increases northeastward where total inversion is clear in northern Sinai. Inversion took place in several phases. It started mildly in the Turonian but was severe during the Campanian-Maastrichtian and late Middle Eocene phases. Many of the Syrian arc folds formed islands in the Eocene seas while the intervening (synclinal) areas witnessed continuous sedimentation. Positive structural inversion in response to WNW-ESE shortening due to the convergence between the Afro-Arabian and Eurasian plates reactivated the Early Mesozoic normal faults differently based on their orientation. Pure reverse slip reactivated the NNE-oriented faults whereas oblique-slip with dextral component reactivated the ENE-oriented faults. Late Cretaceous-Early Tertiary Syrian-arc shortening ended in the Oligo-Miocene time in northern Egypt by opening of the Gulf of Suez-Red Sea rift orthogonal to the Syrian arc compressional structures.

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Matruh Basin: Hydrocarbon Plays in an Inverted Jurassic-Cretaceous Rift Basin in the Northern Western Desert of Egypt

Matruh basin is a large Jurassic-Early Cretaceous passive rift in the northern Western Desert with a unique NNE-SSW orientation inherited from reactivated Paleozoic fabric. Eastwards dipping and thickening Jurassic/Lower Cretaceous syn-rift sediments contain excellent reservoir/source rock combination. TOC values are up to 10% in the Jurassic, 5% in the Lower Cretaceous, and 75% in some coal seams. Two main rifting phases are recognized in the Jurassic and Early Cretaceous. In the early stage of Jurassic rifting, fluvio-lacustrine conditions with frequent subaerial exposure deposited red beds associated with minor volcanicity. Block faulting and tilting controlled the distribution of fluvial deposits. Basinal conditions prevailed in the Middle-Late Jurassic. Resumed rifting in the Early Cretaceous deposited thick mature sands with excellent reservoir quality.

Late Cretaceous-Early Tertiary positive tectonic inversion of the basin formed NNE-oriented fault-propagation folds dissected by NW-oriented normal faults. The latter dissect the Upper Cretaceous post-rift rocks and die out in Albian clastics whereas the rift-parallel NNE faults dissect the underlying syn-rift rocks. The NNE-oriented folds form excellent structural traps in four fields in the basin producing mainly gases with some oil and condensates. Combination traps at the western flank of the basin include syn-rift sands derived from nearby Paleozoic highs and deposited at the Paleozoic-Mesozoic unconformity within gently dipping, down-faulted areas. Total discovered gas reserves in the basin are about 3 tcf. However, several structural traps have yet to be tested and other reservoir units represent the future for hydrocarbon plays in the basin.

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PreSDM and PoSDM Imaging of Sub-Salt Structures in Southern Gulf of Suez, Egypt

Subsalt seismic imaging in the southern Gulf of Suez, Egypt, is hampered by destructive multiples and high frequency attenuation in the Miocene supra-salt Zeit Formation and by large lateral velocity contrasts associated with salt swells and diapirs. Pre-stack depth migration has been applied to alleviate the smearing of seismic energy in conventional stacks due to distortion of ray paths across the salt flanks. However, uncertainty in the exact location of these boundaries limits the ability of pre-stack depth migration to accurately position the low signal-to-noise seismic energy.

A regional 3D survey covering 570 square kilometers in the southern Gulf of Suez was recently acquired. The objective was to image the prolific B-Trend, a structural trend with several moderate sized mature oil-fields and significant additional potential. The survey was acquired in the strike direction with respect to the salt swells and main structural trend. A post-stack depth migrated volume was generated for initial interpretation, and a pre-stack depth migrated volume was generated for comparison and evaluation.

There are significant differences in the seismic image in the pre-stack versus the post-stack depth migrated volumes. The pre-stack migration is the preferred dataset. However, well-control suggests the post-stack volume is able to image structure where the pre-stack image is overwhelmed by multiples. This is primarily attributed to the enhanced signal-to-noise of the post-stack volume in poorly illuminated areas, and suggests that, until a better solution for the multiple contamination problem is found, both datasets need to be integrated in the final interpretation.

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Low Resistivity Pay in Offshore Nile Delta: Quantification using Multicomponent Induction Logging

Abstract

Accurate quantification of low resistivity pay is a challenge within the gas reservoirs discovered in the WDDM Concession. Until recently NMR and image logs have served as the primary logs to evaluate the laminated sections. NMR logs can improve the estimate of hydrocarbon storage capacity and image data can improve the quantification of net sand, saturations in the sand laminae are difficult to quantify. In wells drilled near perpendicular to bedding conventional resistivity instruments measure the resistivity along bedding, the horizontal resistivity, this measurement is dominated by shale conductivity, which makes it difficult to quantify saturations of the sand laminae in low resistivity pay sections. A measurement of the resistivity perpendicular to bedding, vertical resistivity, is more sensitive to resistive, hydrocarbon bearing sand laminae. This type of measurement was previously unavailable. Horizontal and vertical resistivities have been obtained with the 3D ExplorerSM Multicomponent Induction Logging Instrument (3DEXSM) in a well on a WDDM discovery. These data, in combination with standard open hole log data, are used in a robust petrophysical model utilizing macroscopic electrical anisotropy to determine both laminar shale volume and laminar sand resistivity. When integrated with the conventional Thomas-Stieber porosity model a significant improvement in hydrocarbon saturation is obtained. The tensor resistivity petrophysical results are confirmed against pay observations from core and image data. Bulk volume hydrocarbon meters computed from 3DEX data show an increase from 27% up to 179% over several intervals of this well.

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New Play Concepts in Carbonate Exploration, Gulf Of Suez, Egypt

The classic sandstone reservoirs in the Gulf of Suez are exploratory mature, So. Explorationist should pay attention for the developed pre-Miocene carbonate sections of Eocene , U.Senonian and Turonian . This is due to the ambiguity of hydrocarbon habitat, source rocks, migration, seals and traps, which raise the exploration and development risks in the study area.

In the light of encouraging carbonate production of wells ARS-6 & WFA-1 (Eocene). 113-71, BM-61 (U.Senonian) and Sidri-8 (Turonian), the main objective of this paper is to construct a meaningful model for the scattered producing carbonate wells in the central province oil fields. Based on the implementation of all geological, petrophysical and engineering concepts.

To achieve this objective a detailed E-log correlation for many wells, core analysis, petrography , petrophysics and reservoir data are extensively studied.

The GR/Sonic. Caliper logs are highly helpful tools to trace the fractured carbonate intervals. Also the carbonate production of these scattered wells comes from a fractured reservoirs of faulted block model specially in the areas of intersection between clismic faults and other fault trends.

The study supports drilling horizontal wells underbalance in this fractured carbonate rocks. The downthrown blocks are optimistic carbonate targets.

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El Nezzazat, Feiran and Abu Durba Heavy Oil Reservoirs, a Clue for Heavy Oil Reservoirs Potential at The Edges of The Gulf of Suez, Egypt

Unconventional crude oil production will expand as the production of conventional oil declines after the year 2020. Production from the richest portions of the largest unconventional oil resources are forecasted to increase as escalating oil prices permit profitable operations. This paper stresses the need to understand and re-evaluate the heavy oil reservoirs in El Nezzazat, Feiran and Abu Durba blocks as a clue for ascertaining the potentialities of heavy oil reserves at the edges of the present Gulf of Suez, Egypt.

The encouraging oil potentiality (proven oil of API gravity ranging from 11.4° to 19° in Miocene and pre-Miocene sandstone) of El Nezzazat, Feiran and Abu Durba blocks will add more oil reserves for the future shallow structure exploration phase. Heavy oil occurs in geologic settings, which are unconventional by accepted standards, yet they are economically interesting prospects in the light of modern methods of production. It is worth mentioning that the two main crude oils in the Abu Durba Recent sediments and the Kareem Formation sandstone, of well GS 277-1 have different nickel/vanadium ratio, indicating derivation from two different possible sources.

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Evolution of DHI Techniques in Offshore Nile Delta

The first wells in the offshore Nile Delta, positioned solely on structural seismic interpretation, were drilled based on oil agreements resulting in the abandonment of early gas discoveries. The advent of the Gas Clause Article in the mid 80's, where EGPC improved gas terms making it more lucrative to explore for gas, resulted in more than 25 gas discoveries throughout the offshore Nile Delta.

More than 100,000 kms of 2D and 30,000 km² of 3D seismic data has been acquired in the Nile Delta. Advances in seismic acquisition and processing techniques during this period have resulted in improved data quality with successful application of DHI techniques. These included early "bright spot" and "flat spot" observations, AVO analysis and the use of seismic polarity to pinpoint gas filled zones. These were all influential in the drilling of discoveries such as Denis, Seth, Hap'y and Baltim.

Seismic inversion and flat spot enhancement techniques have proven useful in evaluating the more complex submarine canyon and channel/levee facies that the latest phase of Pliocene drilling has encountered in Fayoum, Libra, Aztec, Ruby and Abu Sir. Seismic inversion has been used to estimate net pay thickness and to generate hydrocarbon pore volume maps.

Current challenges for DHI techniques center around more accurate prediction and calibration of how thin "single cycle" gas charged sheet sands might be, distinguishing between residual and producible gas, and understanding differences between conventional gas pay in clean sands and "unconventional" silty, thin bed or low resistivity pay.

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Integration of Sequence Stratigraphy, 3D Seismic Data Visualisation and Quantitative Risk Assessment - Towards a Stratigraphic Trap Exploration Portfolio in Cooper-Eromanga Basin, South Australia

The future for petroleum exploration in the predominantly non-marine Cooper-Eromanga Basin of onshore Australia, lies in the identification and appropriate risk assessment of stratigraphic traps. Using an integrated approach of sequence stratigraphy and 3D seismic data visualisation, a variety of stratigraphic trap prospects were identified in the Permian and the basal Jurassic successions.

The geologic chance factors for an effective stratigraphic trap include reservoir, top seal, lateral seal, bottom seal within each depositional systems tract, the seal effectiveness of the adjacent depositional systems tracts and the appropriate spatial arrangement of these factors. To assess the chance of geologic success, the confidence values for the existence of geologic chance factors were estimated according to the genetic-stratigraphic interval (e.g. lowstand, transgressive, highstand systems tracts). For probabilistic reserves estimation, geologically reasonable ranges were estimated for each parameter employing Monte Carlo simulation to calculate the reserves distribution.

When a series of possible exploration portfolios, including single or multiple prospects from a prospect inventory are plotted regarding the chance of geologic success vs. the mean value of the reserves estimate, an efficient exploration frontier emerges. The portfolio candidates on the efficient exploration frontier were assessed with regard to the expected net present value (ENPV) using a simple cash flow model. The results indicate that appropriate portfolios include multiple prospect exploration especially with lowstand systems tract plays using multiple exploration wells. The portfolio construction approach for stratigraphic trap exploration should be made consistent with conventional play types, to enable an assessment of all exploration opportunities.

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Guneshli Field. Productive Reservoirs Description

Main hydrocarbon reservoirs of the Guneshli field are terrigenous depositions of the Middle Pliocene productive formation.

Predominant source in formation of sand depositions of the Absheron threshold was north and northwest paleoflow sediments from the Paleo-Volga.

Main sand reservoirs of the Guneshli field within productive formation were deposited in fluviodeltaic and shallow marine environments.

Depending upon the depositional setting main hydrocarbon saturated sand formations differ in reservoir properties as well as in continuity over the field area.

Sand depositions of Pereriva Suite and Balakhany VIII have the best reservoir properties that were deposited in delta setting. Sand bodies of Balakhany X, IX, VII, VI, V, IV are characterised by relatively worse reservoir properties what is in the first place connected with the sedimentation environment of shallow water.

There is a total tendency of reservoir properties deterioration up the section what is closely connected with the entire deepening of the basin and with the processes related to this.

Cyclo-stratigraphic analysis of the log data and detailed correlation of sand horizons allowed identifying the vertical and lateral distribution of sand formations and their reservoir properties over the Guneshli field.

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Stratigraphy, Sedimentology, Geochemistry and Diagenesis of the Aptian-Albian Lacustrine Systems of the Araripe Basin, NE Brazil

This work is the synthesis of the modelization of the Aptian-Albian lacustrine deposits of the Araripe basin, NE Brazil, their control factors and influence. The sedimentary post rift fill of the Araripe basin is represented by the Santana Group, that include the Rio da Batateira, Crato, Ipubi, Romualdo and Arajara Formations. The Aptian-Albian terrigenous and carbonate sedimentary record initiated with a transgressive pulse over the fluvial units of the Rio da Batateira Formation and closed with the development of discontinuity surface, upon which were deposited the evaporites of the Ipubi Formation. The lacustrine successions are grouped as transgressive-regressive sequences of different hierarchy orders which have had a marked expansive tendency. The Crato Formation is the focus of this work and is defined as a group of interfingering terrigenous and carbonate bodies, being the carbonate bodies that was detailed in this work. Six mainly lacustrine carbonate episodes of sedimentation were recognized and their geometry are related to the detritic facies of deltaic-fluvial system. The six carbonate units are composed by two lithofacies: clay-carbonate rhythmites and laminated limestone, both characterized by syndepositional deformations (loop bedding and microslumps). The paleobiological record of the laminated limestone includes well preserved fish, insect and plant fossils. Trace and rare earth elements analyses indicate that the source area do not vary substantially and the d13C and d18O covariance points to a hydrologically closed system. The origin of the organic matter is mainly terrestrial, but there are some contributions of planktonic elements.

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Depositional Framework and Reservoir Potential of the Silurian Qusaiba Member, Eastern and Central Saudi Arabia

Although well known for its organic rich "hot shales", the Qusaiba Member also contains sand-prone intervals with exploration potential. In this multi-disciplinary study, new biostratigraphical, sedimentological, petrophysical and seismic analyses have been integrated to develop a framework for the age distribution, depositional setting and reservoir properties of this member in eastern and central Saudi Arabia.

The Qusaiba Member comprises four, third-order depositional sequences of Llandoveryian age in the study area. Sedimentation occurred on a marine shelf that progressively shallowed-upwards and became more storm-influenced based on faunal, palynological and lithofacies analyses. Wireline log correlations of these age-constrained sequences, combined with regional seismic profiles, indicate that deposition in the Rhuddanian was significantly condensed over major intra-basinal (basement-cored) highs, whereas large sediment thicknesses accumulated in rapidly subsiding basin lows (typically underlain by Neoproterozoic grabens). Syn-depositional tectonism appears to have been minimal. In the Aeronian, the "Mid Qusaiba Sandstone" was subsequently deposited as a widespread low-stand unit across the entire basin, followed by further regressive (silt and sand-prone) sedimentation through the Telychian. The relatively layer-cake system tract correlations suggest a ramp geometry for this shelf, and that any shelf-slope break (if present) was located far to the northeast in Paleo-Tethys.

The "Mid-Qusaiba Sandstone" has been penetrated in approximately 25 wells in the Ghawar and western Rub' Al Khali areas. These sands typically contain significant gas shows and have flowed up to 3.3 MMscf/d. Although reservoir quality is typically moderate to poor (5-15% porosity and <5 mD permeability), natural fractures are thought to significantly enhance deliverability in wells located near major faults. Hence there is both exploration and fracture stimulation potential for this reservoir.

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Interpolating Wavelet Multiscale Inversion for Seismic Waveform

A method of interpolating wavelet multirescale inversion (IWMI) based on interpolating wavelet transform (IWT) is first proposed to inverse seismic waveform. The problem is solved in multiresolution interpolating space rather than traditional physical space. The stability of modeling, local minima, computational burden and perturbation of optimization parameters can be improved effectively due to the properties of the interpolating wavelet. It is a promising method because of its low dependence on the initial model, convergence efficiency and robustness. Numerical results show the effectiveness and potential of the method.

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Reservoir Characterization of the Benguela Belize Field, Offshore Angola, using Principle Component Analysis

The Benguela Belize field is one of a series of sand filled turbidite channel reservoirs that have been discovered in the deep waters of Block 14, off the coast of Angola. With sparse well control and good 3D seismic, characterization of the reservoir for detailed reservoir simulation has focused on the use of seismic attribute processing to help define channel geometries and make rock property predictions.

This poster describes how Principle Component Analysis (PCA), a long established statistical technique used to transform and analyze multivariate data sets, is being used in a new, innovative way to make better predictions of rock properties, and help refine the definition of reservoir geometry and quality. The process also addresses reservoir management issues such as, water-flood sweep efficiency, well positioning, producing guidelines, and completion tactics.

Predictions of Vshale using PCA were made using ChevronTexaco's PCA proximity transform algorithm. Which in basic terms takes seismic attribute data such as far-offset amplitude, and rearranges it into multi-dimensional principle component space. The method presented combines well data with principle components and uses an inverse distance interpolation to predict rock properties at log resolution scale. In addition, clustering of data within PCA space identifies geobodies which help to improve the imaging of the reservoir's complex amalgamated channel geometries. By integrating the cluster analysis and proximity transform results into our reservoir model we were able to improve definition of reservoir geometries and provide a good prediction of Vshale from which porosity and permeability properties were populated using cloud transforms.

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Basin Architecture and Evolution of the Gulf of Aqaba

The Gulf of Aqaba represents arm of the Red Sea, separating between Saudi Arabia and the Sinai Peninsula. It varies in width from 19 to 27 km and is 160 km long. The gulf lies in a pronounced cleft between hills rising abruptly to about 600 m. The Aqaba strike-slip fault system, perhaps the world's finest natural laboratory for investigating the different stages of development of strike-slip basins, the least understood of all basin types. This study will integrate structural mapping, paleostress analysis, and structural techniques to examine the diverse origins of strike-slip related basins in the Gulf of Aqaba.

The Aqaba fault system is characterized by Late Cenozoic Arabian-Nubian shield transtensional reactivation of Palaeozoic basement terranes in an intercontinental, intraplate region. Seismically active strike-slip and oblique-slip faults cut the region and bound uplifted blocks that are the sediment source areas for adjacent alluvial basins. Internally drained basins exist in various stages of development from juvenile to mature in association with the regional fault network.

This work will be a multi-disciplined investigation of the complex spatial and temporal relationships between facies distribution and faulting, which exist during basin evolution in a tectonically active intracontinental setting. This paper was supported standard paleostress techniques, including structural methods, detailed mapping of deformed clastic sedimentary successions and brittle fault analysis. The aim of the fieldwork was to gain a three-dimensional picture for the tectonic system that have operated in the Aqaba basins through time, and to understand the interplay between faulting, basin margin deformation, facies distribution and architecture, and adjacent mountain building.

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Tomographic Velocity Images by Artificial Neural Networks

In order to obtain velocity image from a borehole to borehole seismic tomographic experiment, the artificial neurone networks of Elmen type, were trained to reconstruct the velocity from the travelttime. This type of network offers an advantage of training simplicity by the Back-propagation conjugate gradient algorithm. The behavior observed of networks on training data is very similar to the one observed on test data. The efficiency of these networks is tested with the complex geologic model, and the results were very encouraging. A comparison with algorithms ART and SIRT was made, and the superiority of networks of neurons was noted.

Keywords : neurones networks; training; Elmen; Back-propagation; velocity; tomography; ART; SIRT

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Multilateral Technology and its Possible Applications in Egypt

Multilateral technology was developed to reduce overall field development costs by using complex drainage architecture to increase the amount of reservoir exposure. The use of multilateral technology can be instrumental in maximizing economic value.

Multilateral systems enable multiple reservoirs to be produced simultaneously. The technology connects a lateral, or a multitude of lateral wellbores, to the main borehole at the multilateral junction. The junction can be designed in a new well application or created in an existing wellbore for a re-entry application. From the lateral bore, additional laterals, branches, or splays can be added to access additional reservoir targets. The main and lateral bore designs can be vertical, directional, or horizontal with multilateral system selection based on the individual requirements of the reservoir.

Multilateral systems offer the opportunity for reduced drilling and completion costs, increased production, and more efficient reservoir drainage. When properly applied and executed, multilateral technology can deliver enhanced reservoir management capabilities and help increase recoverable reserves with significant reductions in overall development expense.

In Egypt, multilateral systems could bring a great value in re-entry wells both in the Sinai fields and the Gulf of Suez. New wells off shore the GOS are another strong candidates for the substantial savings in the lifting \$cost/bbl associated with the implementation of such technology.

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Integrated Carbonate Reservoirs Studies - Linking Static and Dynamic Models to Expand Evaluation Validity in Space and Time

The permeability distribution of most carbonate reservoirs is extremely heterogeneous and profoundly affects the reservoir behaviour when subjected to rapid fluid withdrawal. Variations in rock texture, diagenetically altered layers, secondary porosity, solution channels, faults or fractures, all contribute to the complexity of the fluids flow and the reservoir pressures distribution.

In carbonates, conventional open-hole petrophysical logs do not provide enough permeability information to allow the building of a realistic reservoir model. Recent developments in the fields of electrical conductivity and NMR images evaluation are now providing a much clearer picture of the permeability distribution. Other recent developments in the interpretation of cased-hole pulsed neutron spectroscopy data in carbonate reservoirs allow the accurate evaluation of depletion profiles in cased hole.

The knowledge of the permeability profile acquired in newly drilled in-fill key-wells can be extended through the evaluation of depletion profiles in selected cased hole wells and this can be further extended to field-wide permeability mapping through fast, efficient, geo-statistical techniques integrating 3-D surface seismic if available, open-hole, cased-hole and production log data with historical well performance data.

Geo-statistical tools were used to match observed water breakthrough and to predict future water breakthrough. They are based on proportion curve analysis and on a network approach which is guided by some simple physical rules. It allows to detect or exclude specific high permeability paths, such as faults interpreted from seismic or diagenetically altered layers detected from open hole or production data.

An application of this integration is presented in a typical carbonate reservoir.

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Evaluation of Laminated Gas Reservoirs Integrating Resistivity Anisotropy Measurements, Magnetic Resonance and Formation Micro-Conductivity Images

Many deltaic reservoirs feature thinly bedded laminated sections that contain significant hydrocarbon pay and make-up a non-negligible amount of total reserves. Using conventional resistivity data, quantification of the hydrocarbon saturation of those sections is difficult, since the data is dominated by the conductivity of the laminae of shale. This situation is even further exacerbated when the hydrocarbon is gas; due to its high mobility, it is capable, over geological times, to displace capillary bound water in silts and to be produced from such poor quality reservoirs.

New developments have been made in the derivation of resistivity data in a plane parallel to the tool axis, which have facilitated the evaluation of such reservoirs by removing the domination of the shale laminae. This work is focussed on the development of a resistivity anisotropy-based saturation evaluation method that integrates information derived from consonant well-logs (i.e. with comparable vertical resolution) with NMR and micro-conductivity images. The resistivity anisotropy model includes shale micro-anisotropy, a prevalent condition in the Nile Delta, where this technique was validated.

The relationship linking resistivity anisotropy to a reservoir model including shale, silt and sand is explicitly developed and the sensitivity of the vertical resistivity derivation to input parameters is studied. The petrophysical evaluation results from the model are confirmed against a variety of independent data, including surface seismic interpretation, reservoir pressure profile and well test. The bulk volume of gas derived from this technique is compared to results from conventional evaluation and to hydrocarbon storage capacity estimated from NMR data.

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Structurally Controlled Syn-Rift Deposition in the Northern Suez Rift, Egypt: the Asl and Hawara Formations (Sequence 30) in the October Field Area

ABSTRACT

The Miocene syn-rift Asl and Hawara formations, defined biostratigraphically as Sequence 30, are a mixed clastic-carbonate, syn-rift turbidite deposit. Exploration and development drilling in the northern Gulf of Suez, Egypt, has shown reservoir quality to be highly variable. Understanding this variability is critical to continued success in the Sequence 30 play.

The integration of gross isochores, net sandstone maps, log, core and outcrop information has led to a complex depositional model for Sequence 30 in the northern Gulf of Suez. Wadi Araba, a Late Cretaceous aged Syrian Arc compressional feature on the northwestern rift margin, served as the major source for quartz-rich, axially transported turbidites. Tilted fault blocks, both along the coast (Gebel Nezzazat) and within the basin (October fault block) may have provided local sources for carbonate debris and turbidites, which became interbedded with the axially transported quartz-rich turbidite systems. Other sources for more quartz-rich turbidites may have been focused in the transfer zones of major normal faults.

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Structural Control on Syn-Rift Oil Accumulations in the Northern Suez Rift, Egypt

ABSTRACT

Since its serendipitous discovery in 1989, the play involving the Asl and Hawara formations (biostratigraphically defined Sequence 30) in the northern Gulf of Suez, Egypt has yielded more than 75 million barrels of oil. The structural geometry of the play has controlled the distribution of reservoir facies and of oil accumulations. Structurally, all the Sequence 30 discoveries are downthrown fault blocks fault-juxtaposed against oil accumulations in pre-rift reservoirs in the footwalls of large normal-fault blocks. Geochemical analysis indicates that the oils of Sequence 30 and pre-rift formations are compositionally similar. Fault plane maps demonstrate juxtaposition of Sequence 30 against the oil-bearing pre-rift formations. Comparison of oil water contacts (OWC) and lowest known oils of the pre-rift and the Sequence 30 reservoir suggests a possible common OWC for the accumulations. Sequence 30 may have been charged by a secondary migration of oil originally trapped in the pre-rift footwall reservoirs. In contrast, no hydrocarbons have been found in Sequence 30 rocks on the footwalls of major structural blocks.

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Petroleum Systems through the Value Chain from Exploration to Refinery

Petroleum Systems, from BP's perspective, is an integration technology that brings together geology, geochemistry and basin modeling to formulate a holistic model of the basin's petroleum fluid system.

Classically, application of petroleum systems has impacted mainly the exploration business, in the areas of source rock, access to charge, product type, etc. However, understanding seal capacity constraints expands the impact into the area of prospect volumetrics; an understanding of detailed product composition (both gas and stock-tank liquids) further impacts prospect value. Well cost is further impacted through well design constraints imposed by the results of pressure prediction.

Moving into reservoir exploitation (appraisal / development / production), the role is much larger than providing a reservoir fingerprinting study: integration of oil and gas chemistry with pressure data, the filling history from the basin model and the structural and stratigraphic architecture of the reservoir container all need to be considered. The reservoir itself is a petroleum system!

Downstream, forward predictions of assay parameters such as sulfur, nitrogen, metals content and acid number in stock-tank liquid streams and ethane in gas streams are of great use to forward planning in marketing and refining.

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Time to Move to Anelliptic Time Processing

Standard time processing attempts to focus seismic data step by step, from pre-stack to zero-offset, the goal being to preserve the major part of the recorded reflectivity. Because the sole purpose is to focus the pre-stack energy at the correct location, the only input needed is the well-known VRMS velocity field. However assumptions of small incidence angles and isotropic media are now stretched to the limit. Long streamers and an anisotropic earth means that focusing the far offset data, especially dipping events, through an anisotropic subsurface cannot be achieved using only the VRMS field.

Moving from standard time processing means opening the focusing process to the anellipticity of the effective media. We demonstrate here a Dix-type effective medium, where two velocities could describe the full time processing. The ratio of these two velocities points out the anellipticity strength, which is represented by the well-known $f\theta$ parameter. Effective $f\theta$ encompasses two travel path effects: vertical inhomogeneity and transverse isotropy. In the case of anelliptic media the velocity picks, sparse or dense, are extended on two parameters. Interpolated and filtered parameter fields can be estimated thanks to Dix properties of stacking and anelliptic velocities. Normal and Dip Move Out as well as Pre-Stack Time Migration operators are made using an anelliptic shifted hyperbola approach. We will demonstrate the application of this A+ anelliptic time processing approach through a series of examples illustrating the key steps. This homogeneous description of the focusing process now allows for time processing to take into account the anellipticity of the media.

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Jurassic and Cretaceous Tectonics of the Egyptian Western Desert

Over the past 5 years Apache Egypt has acquired nearly 7000 km² of high quality 3D seismic datasets in the Western Desert of Egypt. Interpretation of these datasets and integration with well data has resulted in a detailed understanding of the Jurassic and Cretaceous tectonic evolution of the Western Desert Basins.

In general, the Jurassic is characterized by normal faults that formed in conjunction with the opening of the Neo-Tethys to the north. Jurassic grabens and half grabens control the deposition of Jurassic source and reservoir rocks. Rifting and normal faulting continued into the Early Cretaceous as indicated by growth across normal faults in the Alam El Bueh Formation. By Albian-Aptian time rifting and associated extension ceased in the Western Desert.

The Late Cretaceous and Early Tertiary is a period of renewed tectonic activity in the Western Desert. A period of widespread extension resulting in pervasive, but typically small throw, normal faults initiated in the Santonian-Campanian. This is followed almost immediately by a period of compressive tectonism (Syrian Arc deformation) in which many of the Jurassic and Cretaceous normal faults are reactivated as reverse faults. Detailed isopach maps of the Cretaceous demonstrate that the Syrian Arc period of compressive tectonism in the Western Desert is not associated with widespread strike-slip deformation. Compression continues and reaches a peak in the Paleocene to Early Eocene. The Late Tertiary tectonism which is key to the Gulf of Suez and Nile Delta plays had an insignificant effect on the Western Desert structural geometry.

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Exploration Portrayal of the Geometry of Major Unconformities of the Arabian Plate

This paper stems from construction of a plate-wide tops and age database of greater than 46,000 records for the Arabian Plate. The premise of the paper is that a regional understanding of the geometry of unconformities can facilitate exploration. A "database query to GIS mapping process" is developed to enable recognition and characterization of the major unconformities of the Arabian Plate. Plate-wide plots of ages versus age-count enable age stratigraphy of the major unconformities. Maximum and minimum age queries at unconformity surfaces allow structural mapping of unconformities. The process facilitates mapping of the time value of individual unconformity lacunae and the geographic position of amalgamation with underlying and overlying unconformities. Individual queries for time missing above and below the unconformity surfaces, mapped in combination, portrays transitions from truncation-domination to onlap-domination along unconformity surfaces. Queries tying age to stratigraphy enable worm's eye and subcrop map construction. Mapping recognizes three situations of unconformity impact on Arabian Plate hydrocarbon distribution: a) "juxtaposition", b) "edge", and c) "basal sandstone". "Juxtaposition occurs if an unconformity results in a reservoir and source connecting at the unconformity. The "edge" situation occurs if truncation or onlap makes an edge-termination of a seal. Hydrocarbon leakage focuses at the "edge". The "basal sandstone" situation occurs at the base of a sequence overlying an unconformity. The sandstone caps the unconformity surface and taps carrier systems (stratigraphic or structural) that are truncated by the unconformity. The mapping goal is to make visible geometries that portray these situations.

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Paleo-Stress Analysis and Fault Mechanical Stratigraphy of the Gulf of Suez Margin from Signal Processing of Fracture Data

Paleostress determinations gathered from eleven field observations of fractures along the Gulf of Suez margin, Republic of Egypt, were analyzed by a novel signal processing adaptation of the "Angelier" method. When applied to noisy fracture populations, one may effectively discriminate out clear signals, i.e. delineate spatially and temporally discrete fracture populations. These data were filtered, separated into populations by cluster analysis, transferred into the frequency domain, deconvolved, and analyzed statistically both within and between stations. At least three among many other principal direction populations of para-coulombic fracturing are readily apparent. The paleostresses inferred for these three principal fracture population trends (to the northeast to west-northwest, to the north-northeast, and to the northwest) can be related to specific tectonic events predating, coeval with, and post-dating the crustal extension of the Gulf of Suez, with some fracture populations indicating responses to multiple tectonic events. In general, the inferred paleostress directions support existing models of Mesozoic and Cenozoic tectonics in the region. An understanding of the regional and local mechanical stratigraphy of the fracture architecture of Gulf of Suez reservoirs derived from the signal processing method may assist in their optimized exploration and exploitation.

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Syn-Rift Deposition and Structural History of the B Trend, Southern Suez Rift, Egypt

The B trend is a complexly faulted NW-SE striking (rift-parallel) structural high in the southern Gulf of Suez, Egypt. It exhibits a complex structural and syn-rift depositional history. Miocene syn-rift rocks host 42% of the 398 million barrels of oil produced to date, necessitating an understanding of these reservoirs. Net sandstone and interval isopachs were generated for five syn-rift horizons, using over 200 wells, 65% with biostratigraphic control, allowing us to determine the structural evolution of the B Trend.

The Early Miocene (pre-Aquitania) erosion pattern reflects a mix of Late Cretaceous Syrian Arc (compressional) and Oligo-Miocene rift-parallel structural trends. Locally, the pre-rift section is deeply eroded, and several bald highs developed. The earliest syn-rift rocks of the Nukhul Formation were deposited in basins which were generally oblique to the rift-parallel trend. Nukhul isopach patterns suggest that the B Trend was not yet developed. Interval isopachs of the Burdigalian and Langhian Rudeis Formation reflect the emergence of the B Trend as a prominent high block. The isopach and subcrop patterns of the overlying Ayun Musa Formation illustrate significant thinning over the crest of most of the B Trend (with local exceptions). Locally, high blocks were extensively eroded after deposition of the Ayun Musa Formation, forming unconformities and supplying sediment to downthrown structural blocks. Sandstone thickness increases dramatically on these blocks, forming the basis of an untested play. Supercrop maps on the post-Ayun Musa unconformity and the isopachs of overlying units identify local persistent positive features.

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Tectonic Control of the Campos-Santos Basins, Offshore Brazil – A Discussion

Several tectonic events were responsible for generations of the oil fields in the Campos-Santos Basins, offshore Brazil. Distensive processes probably started as early as the end of Paleozoic, beginning of Triassic. However, tectonic activity was recorded approximately 130Ma and developed up to nowadays. The brittle regime which prevailed during those events produced ENE-WSW prominent fracture system, which aligned the coastal flat-lying gneisses at Rio de Janeiro. Diabase and phonolite dikes and plugs were emplaced along some of the fractures. Sills occur in the proximities of the joints. Thermal output generated by the magmatic activity was favorable for hydrocarbon formation and/or migration. These system imparted characteristic magnetic anomalies detected by the aeromagnetometric surveys. Almost orthogonally disposed to the fracture system there is another set of fractures, which produced a basculated type of structure, by a rotation along one of the fault lines. This structure has been designaled as resequent tilt-blocks. From onshore, there are sets of splays diverging from the Paraíba do Sul Megashear Zone and related structures. Reactivation of the splays contributed significantly to the opening of the basins and sub-basins during the Cretaceous. A graben-horst system was developed, and several troughs filled by the high sedimentation rates dominated by turbidites. Salt diapirism, probably triggered by tectono-magmatic activities and/or gravitational differences, initially developed in depocenters, have facilitated the formation of the oil traps.

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Migration and Accumulation of Hydrocarbons in Cretaceous and Tertiary Reservoirs of Iraq: Implications of a 2D/3D Basin Modeling Study

Multilayer, 2D/3D petroleum system modeling was undertaken to evaluate the origin and extent of hydrocarbon (HC) generation, expulsion, and secondary migration in the Upper Jurassic Sargelu/Naokelekan source rock system of Iraq. Structural restorations of source rock surfaces, regional isopach and facies maps, and thermal maturity data were used as input to the model. Petroleum generation and potential migration pathways on the top of a (Lower Cretaceous) composite reservoir unit immediately overlying the principle source rock unit were modeled for three geologic time periods: 25, 8, and 0 Mybp. Petroleum accumulations predicted by the model were compared with the location of known fields that produce from the Cretaceous reservoir interval. Modeling results show that in the early Miocene, at about 25 Mybp, the first major stage of HC generation and expulsion was initiated in two depocenters. The petroleum that migrated laterally from these areas began to fill most fields in northern Iraq and the largest fields in southern Iraq. By 8 Mybp, in the late Miocene, the area of main stage HC generation extended along the Zagros Mountain Front due to extensive foreland basin deposition associated with the Zagros Orogeny, and folding and faulting caused larger petroleum drainage basins to be segmented into smaller subbasins. Related southwest tilting set up a northeast-southwest HC flow pattern across the region. Modelling results demonstrate that Cretaceous reservoired oil in northern Iraq remigrated vertically along faults and fractures ultimately charging younger Tertiary reservoirs. At present day, most subbasins containing hydrocarbon accumulations are underlain by active source rock, and most fields lie on or close to migration pathways and have been subject to filling and spilling. It follows that prospects closest to modeled pathways are highly likely to be charged and thus have low exploration risk.

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Syn-Rift Lowstand Wedges: An Emerging Stratigraphic Play in the Suez Rift, Egypt

The dominant play type in the Suez Rift, Egypt, is the upthrown, 3-way closure on footwalls of major normal-fault bounded structural blocks, with reservoirs in pre- and syn-rift rocks. To date, more than 90% of the ~9 billion barrels of oil that have been discovered in the basin have come from these types of traps. The remaining reserves are from a few downthrown syn-rift reservoirs located in the immediate hanging walls of major structural blocks, and even fewer traps with stratigraphic components.

What has remained unexplored is the potential for large, syn-rift depositional features preserved in the centers of grabens between major blocks. We show examples of syn-rift, lowstand, basin-floor fan deposits from the Gulf of Suez portion of the rift. These deposits are not controlled by well penetrations, but are predicted using the syn-rift stratigraphy in wells on surrounding horsts. We use biostratigraphically controlled syn-rift sequences and their bounding unconformities to predict the location, both temporally and spatially, of these basin-center deposits. We also use seismic-derived isopachs and seismic-stratigraphic interpretations to locate and map these features. However, due to the poor quality of seismic data caused by multiples generated from overlying middle Miocene evaporitic rocks, these depositional features are difficult to image and accurately map. Thus the lowstand wedge remains a high risk play type.

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Syn-Rift Stratigraphy and its Record of Structural Evolution in the Central Suez Rift, Egypt

We used syn-rift stratigraphy to determine the evolution of major normal-fault bounded structural blocks in the central Suez Rift, Egypt. For each block, we used the difference between hanging wall and footwall gross-interval thickness for each biostratigraphically defined syn-rift sequence as a proxy for fault displacement during deposition of that sequence.

Sequence-20 (Mheiherrat Fm.), generally recognized as the "rift-climax" stage, saw maximum sediment thickness, sandstone thickness, sedimentation rate, fault-displacement and fault-displacement rate. These parameters generally decrease in the overlying syn-rift sequences, and in the underlying Sequence-10 (Nukhul Fm., early rifting).

Point sources for coarse-clastic material were located at both ends of the Morgan transfer zone, which separates the region into 2 dip provinces (SW dipping faults north of the transfer zone, NE dipping faults to the south). The two point sources were established and also peaked during Sequence-20 deposition, but their contribution of coarse sediment to the basin was episodic.

Bald high blocks, which were raised above sea-level during or soon after deposition, occur near the rift margins, but also in the basin center during early (Sequence-10) and late (Sequence-55, Belayim Fm.) rifting. High displacement-rate faults generally occurred near the basin margins, except for during Sequence-10 deposition, when they were distributed throughout the basin, and during Sequence-55 deposition, when the highest displacement rate fault was in the basin center.

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Geology and Hydrocarbon Potential of the Makran Thrust Belt, Southwestern Pakistan

New 3D seismic data, geological mapping, shallow coring, and quantitative structural reconstructions allow improved understanding of the Makran hydrocarbon system. Thick turbidite sands, clearly-defined structural traps, and evidence of an active hydrocarbon system encourage further exploration.

The 500-meter thick sands of the Miocene Panjgur Formation were deposited on oceanic crust as part of the proto-Indus Fan, and later buried by prograding slope mudstones of the Parkini Formation. These sediments were scraped off the Indian Plate to form the present Makran thrust belt. Syntectonic sedimentation of the Parkini is indicated by angular unconformities visible in outcrop, and downlap sequences apparent from seismic data. Prograding Pliocene through Holocene slope to paralic sediments buried the thrust ridges and provide a vertical hydrocarbon seal. Balanced reconstructions suggest approximately 40-50 percent structural shortening.

Much of the offshore Makran thrust belt is covered by recent 2-D seismic, and a new 2100 square km 3D survey. 3D imaging to seven seconds permits interpretation of thrust fault planes to the decollement surface. The 3D has delineated thirteen structures along a series of imbricate thrusts. The average areal extent of the closures is 3100 acres.

Due to structural complexity, four wells drilled in the last fifty years failed to test Panjgur sands observed in outcrop. Gas seeps, gas plumes observed in the 3D data, and hydrocarbon observations in wells indicate an active hydrocarbon charge. Gas is economically attractive here because of the proximity to major South Asian markets with a constantly increasing appetite for clean gas fuel

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First Experience of Use of Detailed Geological-Commercial Model of the Orenburg Oilfield for the Planning of Development of Hard Recoverable Stocks of Gas

First experience of use of detailed geological-commercial model of the Orenburg oilfield for the planning of development of hard recoverable stocks of gas

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The Orenburg oil field and gas is dated to carbonated adjournment of the Carboniferous-Low-Permian age; in a powerful productive section (the thickness reaches up to 500 <) it is allocated three operational objects divided by packs of dense practically impenetrable carbonates. Hardly recoverable stocks of gas are concentrated in the first operational object, which permeability of collectors on the average 1-2E10-15 m2. For 20 years of development from it there was recovered less than 30% of initial stocks while from the lower objects it was recovered 66%.

The main reason of the weak entrainity of the stocks of the first object in development is neglecting at planning development of its specific geologo-commercial features. Main from them - thin porous structure of collectors, low matrix permeability, high gypsuminity and bituminity, presence of faults and stitolites.

One of directions of increase entrainity of stocks of the first object in development is the kickoff of horizontal trunks from low production vertical chinks. Prime for kickoff chinks, directions and structures of horizontal trunks are chosen on the basis of digital geologo-commercial model of a deposit. The model is created in the program "Reservoir Modeling" done by firm "GeoQuest Schlumberger" and contains the parameters necessary for definition of characteristics of a section, an estimation of stocks of gas and predicted efficiency of horizontal trunks.

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Seismic Geomorphology and Seismic Stratigraphy of Deep-Water Depositional Elements

Analyses of 3-D seismic data can yield significant insights with regard to spatial and temporal relationships of near-seafloor depositional elements in deep-water settings. These analyses can be based on a broad range of horizon attributes, such as amplitude, time/depth structure, dip azimuth, dip magnitude, curvature, and roughness, as well as interval attributes such as frequency and amplitude distribution, and seismic facies based on waveform. The great complexity of deep-water depositional environments can be simplified by grouping depositional elements into five major categories: 1) turbidity-flow leveed channels, 2) channel-overbank sediment waves and levees, 3) frontal splays/distributary channel complexes, 4) crevasse splay complexes, and 5) debris-flow channels, lobes and sheets. Each depositional element type displays a unique morphology and seismic-stratigraphic expression. Their reservoir architecture is a function of the interaction between sedimentary process, sea-floor morphology, and sediment grain size distribution.

Turbidity-flow leveed channels can range from nearly straight to highly sinuous; channel meanders in most instances migrate down-system. In some instances, high-sinuosity channels are associated with channel-overbank sediment wave development, especially in association with outer channel bends. Where levees can no longer be resolved seismically, high-sinuosity channels feed frontal splays/low-sinuosity distributary channel complexes. Low-sinuosity distributary channel complexes commonly are expressed as lobate sheets. A variation on frontal splays are crevasse splay deposits, which comprise smaller lobeforms associated with levee crevasses commonly located at channel bends. Debris-flow deposits can form low-sinuosity channel fills, elongate lobes, and sheets and are characterized seismically by contorted, chaotic, low-amplitude reflection patterns that commonly overlie striated/grooved pavements.

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Analysis of the Slip Sweep Technique

In order to prepare a 2D slip-sweep simulation experiment, a preliminary analysis was conducted using synthetic data. Various types of noise were isolated and the corresponding data contamination analysed. Signal-to-noise ratio maps were generated for various slip-sweep configurations. The same analyses were conducted on the actual data after slip sweep simulation, correlation and standard processing.

This study has allowed us to classify various type of noise and to describe the effects. Despite inherent limitations, namely, inexact analysis of ambient and uncorrelated noise, this simulation presents the unique advantage of providing a reliable signal-to-noise ratio estimate. Since data contamination by both ambient and uncorrelated noise would be smaller in an actual 3D slip-sweep recording, these ratios are a low estimate of the actual case. In this example, we found a ratio larger than 20 dB for a slip time of 10 s everywhere signal can be recognized in the data. A slip time of 5 s removes less than 5 dB from this ratio. This analysis can help define accurate slip-sweep parameters, which optimise productivity versus S/N ratio on stacked data.

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Late Carboniferous and Permian (Unayzah/Gharif) Paleogeography of Saudi Arabia and the southern Arabian Plate: Implications for Reservoir Trends

A series of 12 paleogeographic maps depict the changing paleogeography throughout Saudi Arabia, Oman and the United Arab Emirates from latest Carboniferous to latest Permian time (approx. 305-245 MYBP). The maps illustrate an overall climatic amelioration from alternating glacial/interglacial periods to arid-tropical and their resultant reservoir facies. A representative well is used from the Haradh/S. Ghawar field (Hrdh 601) to illustrate the stratigraphic positions of the reservoir sands and their nomenclature. The suggested sequence stratigraphy of this Permo-Carboniferous interval is reviewed so as to explain the maps/reservoir trends plus their positions on a local relative coastal onlap curve.

The often contemporaneous Unayzah C/Haradh and Unayzah B/Jawb (Juwayl) are predominantly braided and meandering facies respectively. Desiccation followed, overlain by the marine transgression of the "Haushi Lmst"/Lower Gharif/Saiwan/Unayzah. This represents an initial rift/failed breakup unconformity and connection to paleo-tethys. Contemporaneous and younger aeolian dune deposits are suggested to the west (A2 Unayzah reservoir). Subaerial exposure of the Lower Gharif/Unayzah is overlain by beach/shoreline, then fluvial meandering facies of the Middle Unayzah/Gharif. This in turn is unconformably succeeded by incised valley fill of the Upper Unayzah/Gharif of Murghabian age.

This period is followed by transgression of the lower Basal Khuff Clastics succeeded by sea level drop and incised valley fill of the upper Basal Khuff sands (A1 reservoir), with potential downdip forced regressive shorelines deposited intra-ramp in paleotopographic lows.

Ultimate breakup/drift resulted in transgression of the basal Khuff carbonates westwards, which completely flooded the low relief ramp, effectively shutting off clastic sedimentation.

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High Resolution Sequence Stratigraphy of the Devonian Jauf Formation Gas Reservoir. Ghawar Supergiant Field, Saudi Arabia

The Devonian (Pragian to Frasnian) Jauf Formation in Ghawar Supergiant Field thickens from 650 feet in the west to 1100 ft thick in the east, and comprises a marginal to shallow marine siliciclastic succession. It consists of a lower 3rd order sequence (S55), the Lower Jauf, which is dominated by a sand-prone progradational falling stage systems tract (FSST) and totally lacking an overlying coastal plain facies. Whereas the upper 3rd order sequence (S60), the Upper Jauf, is comprised of a mud-prone, estuarine transgressive systems tract (TST), forming the Jauf Embayment and an overlying highstand systems tract (HST) composed of progradational shoreface and overlying coastal plain deposits. A key aspect of the succession, and a critical point in making a predictive model for a wider area, is that the Jauf 3rd-order sequences can be subdivided into higher frequency 4th order depositional sequences of transgressive-to-regressive character. Sequence S55 consists of 16 fourth order sequences, while sequence S60 consists of 15 fourth order sequences. The D3B biozone, an extensive stratigraphic marker consisting mainly of dark colored shale, occurs at the top of the TST of sequence S60 and marks its maximum flooding surface (MFS).

A notable feature of 4th order sequences is that the transgressive tract tends to thicken significantly landwards whereas the highstand tract thickens in the opposite direction. This trend becomes an important tool in prediction into unknown areas.

Third order sequences are mappable on the regional scale, and are very useful exploration mapping tool. Fourth order sequences are of more local extent, and are extremely useful stratigraphic tool for reservoir characterization purposes on field scale as they furnish a high resolution "window" on depositional environments. Long distance shoreface progradation was accomplished mainly during falling stage of sea level.

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Silurian Slope Turbidites: A Predictive Sequence Stratigraphic Model for the Exploration for New Accumulations of Mid-Qusaiba Sand Reservoir, Saudi Arabia

In central and eastern Saudi Arabia evidence suggests that deposition of Silurian Qusaiba Member was dominated by slope mudstones and episodes characterized by introduction of slope and basin floor fan sandy turbidites (Mid-Qusaiba Sand) during and following periods of sea level lowstands. These slope clinoforms prograded by downlapping on the underlying Qusaiba "Hot Shale", a rich hydrocarbon source rock. It is believed that at periods of lowstands, the Qusaiba deltas, to the west, must have reached the shelf margin to form shelf-margin deltas. Sediments from these deltas spilled past the shelf break to the slope, in the form of gravity flows, to deposit the Mid-Qusaiba Sand (MQS) amongst Qusaiba mudstones. In northern and northwestern Saudi Arabia MQS turbidites have not been reported, therefore suggesting the absence of a shelf-slope break in these areas. The Qusaiba-Sharawra unconformity, or any of the disconformities reported within the Qusaiba Member, is here interpreted to have been caused by the same relative sea-level drop that resulted in the progradation of Qusaiba deltas to shelf margin and lead to the delivery to the slope of MQS turbidites. Thus it is believed that basins with shelf-slope breaks formed locally in areas that experienced faster subsidence, perhaps through reactivation of older basement faults.

This shelf to basin slope relationship becomes an important tool in prediction of new MQS accumulations into unknown areas. It implies that locations of Qusaiba thick deltaic lobes in periods of sea level lowstand should lead in the deeper offshore to discovery of MQS turbidite accumulations.

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Hydrodynamic Model for Biogenic Gas Trapped in Low Permeability Sands - Western Plains of North America

Gas trapped in tight reservoirs in the Western Plains and Rocky Mountain Basins of North America forms a substantial unconventional gas resource. Three play types with distinct hydrodynamic signatures are recognized:

1. Shallow biogenic gas
2. Deep Basin gas
3. Basin-Centred gas

All are hosted in Cretaceous-Tertiary clastic reservoirs. Deep Basin and Basin-Centred gas have been discussed in the literature in recent years. This paper focuses on current developments in understanding of the shallow biogenic gas (SBG) play. SBG generally occurring at depths of less than 1,000 m (3,300 ft) represents a poorly understood by-passed resource. A potential for greater than 70 TCF of gas-in-place has been determined in the Western Plains region extending from central Alberta in Canada into the U.S. mid-west. The play potentially continues south to the Gulf Coast.

A broad areal extent, subnormal formation pressures ranging from 20 to 70% of hydrostatic and occurrence in low permeability sand-shale sequences characterizes the resource. Subnormally pressured gas-charged sands often show a transition updip to normally pressured water-wet sands. Downdip flow, which is usually observed in the water-wet section, may enhance the trap in some cases. SBG is often by-passed due to deep invasion, relatively high water saturation (45-75%) and fresh formation water (<10,000 ppm), which together invalidate conventional petrophysical analysis and testing techniques.

Recognition of the unique hydrodynamic signature and an understanding of the basin evolution required for its occurrence are key to identifying and exploiting the shallow gas resource and extending the play into other basins.

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Electro-kinetic Effect Modelling

In this paper we will present our last results in modeling and measuring the electro-kinetic effect. We will show a classical WRW model applied to this effect in which the sources and receivers, both electro-magnetic and seismic, are taken into account. Finally we show some fieldwork results comparable with our model.

The electro-kinetic effect represents a class of processes in which there is a conversion from electromagnetic to kinetic energy and vice versa. The interaction between seismic and electromagnetic waves is due to the relative motion of the electrically charged ions in the pore fluid when a seismic or an electromagnetic wave is passing by. The waves then generated, both seismic and electromagnetic, can be measured and provide us with information about the medium properties.

Based on a WRW approach, in which propagation, reflection and transmission of waves are represented by operators, we have developed a very general model applicable for any source-receiver geometry in a multilayered medium. Resulting from the model we see that this effect is very sensitive to the changes in the pore fluid chemistry and in the porosity between two mediums.

The applications of this model and the electro-kinetic method can go from the shallow subsurface monitoring like groundwater detection and of pollutant migration to wellbore tool and crosshole measurements. Since it is so sensitive to changes in the chemistry of the pore fluid it can be useful to determine permeable formations or monitoring multiphase flow through porous areas

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Exploration of Raghavapuram Petroleum System (.) : An Enigma or a Point to Cogitate ?

Krishna- Godavari basin is conspicuous and decipherable by a bite on North-East aligned passive continental margin of Indian peninsula. The structural grain is aligned parallel to this trend and owes its origin to rift-drift phenomenon of Indian plate from Gondwanaland and the arcuate shape fits well and explicitly explained by Smith & Hallam fit (1970).

Seven Petroleum systems ranging from Triassic to Mio-Pliocene are being probed & are under exploitation in this basin. Out of these, the Raghavapuram Petroleum system (.) of Early Cretaceous age is the most enigmatic and by an estimate around 17 MMt (O+OEG) in place hydrocarbon still remains untapped in this play alone.

Till date a total Of 23 well's have been explicitly targeted for exploring this play out of which 5 met with success in form of gaseous and liquid hydrocarbon strikes, the number does not include serendipity. Subsequent delineation of specific prospect has not yielded positive results, as the reservoir facies encountered in a well could not be traced in next well. This adds to the enigma of hydrocarbon hunt in Raghavapuram petroleum system (.).

A sequence stratigraphic approach to the problem was adopted, aimed at establishing a spatial process response model based on well data, electrologs, seismic investigations (2350 LKm) and Stratotype studies. This has clarified the relationship of stratal stacking patterns and facies to their controlling variables, accommodation space and sediment supply.

By the comprehensive Sequence stratigraphic studies authors have conceived a model to mitigate the exploration and delineation problems for Raghavapuram Petroleum system and identified possible locales for better reservoir development which will lead to comprehensive understanding for exploration and exploitation of this hitherto enigmatic play of Krishna-Godavari basin.

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The Effect of Transfer Faults in Shaping a Major Hydrocarbon Trap - October Field, Suez Rift, Egypt

October field, in the Gulf of Suez, Egypt, is one of the largest oil fields in the basin, with nearly 1 billion barrels of oil reserves. The field is controlled by north-northwest striking, rift-parallel faults as well as northeast and north-west striking transfer faults. It consists of a number of linked, northeast dipping fault blocks and is bounded by a major rift-parallel normal fault which dips to the southwest. The northern end of the field is bounded by a north-west dipping transfer fault. The southern side of the field is bounded by a southwest dipping transfer fault.

The northern and southern transfer faults define the structural geometry of October Field. The major pre-rift reservoirs are brought below the oil water contact on the downthrown sides of these faults. In addition, the growth and timing of fault linkage has strongly controlled syn-rift sedimentation on the flanks and within the field. Syn-rift rocks are thicker and more sandstone-rich on the downthrown sides of some transfer faults, where they are also locally fault-juxtaposed against oil accumulations in pre-rift reservoirs, creating additional oil accumulations. Structural and syn-rift stratigraphic relationships around October field provide excellent analogues to other traps in the Gulf of Suez basin and rift basins worldwide.

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Fault-Propagation Folding in the October Field, Northern Gulf of Suez, Egypt

A detailed study of seismic and well data of the giant October Field in the northern Gulf of Suez, Egypt shows a steeply dipping monoclinal western flank dissected by normal and reverse faults. A major southwest dipping rift parallel normal fault, formed during early rifting, dissects pre-Miocene (pre-rift) rocks, forming the western (up dip) boundary of the field. Upward propagation of this fault through the overlying, predominantly ductile Miocene syn-rift rocks at later stages of rifting is accommodated by a fault-propagation fold.

Although the monoclinal flank of this fold is dissected by steeply dipping normal faults and a few reverse faults, the predominantly shale-rich syn-rift section acts as a good lateral seal for pre-Miocene reservoirs of the field. Fault-propagation folds are a common structure bounding the updip side of several tilted fault blocks in the rift on the surface and in the subsurface. Similar folds have previously been mapped on the Sinai Peninsula, the eastern exposed margin of the Suez rift. We compare and contrast these outcrop features with those of the subsurface at October Field.

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Fracture Analysis at St. Paul Monastery, Egypt: Insight into the Tectonic History of the Gulf of Suez

In an attempt to interpret the paleo-stress history of the western Gulf of Suez, detailed fracture analysis were conducted at three measurement stations on the St. Paul Monastery grounds west of the main Red Sea highway. The study was conducted in the Albian Malha Formation sandstone, the Cenomanian Galala Formation limestone, and the Santonian Matulla Formation chalk. The fracture orientation data reveal multiple yet indistinct populations when viewed as conventional stereoplots and rose plots. However, a signal analysis approach is revealing when: (1) populations are separated using cluster analysis which reveal the level of similarity between populations at each measurement station; (2) fast Fourier and inverse fast Fourier transforms are performed on the data for frequency and pulse-width analyses; (3) cross-correlations between the stations are conducted in order to determine differences in population phase; (4) the data between stations are deconvolved in order to show what data are unique to each; (5) population breadth is determined through the calculation of spherical variance; and (6) construction of paleostress tectonic history using earthquake pseudo-focal mechanisms constructed from the fracture data. The analysis reveals at least three distinct local tectonic events to have affected the rocks at the St. Paul Monastery, with probable fracture reactivation during successive events. The three main fracture populations present are: (1) a Cretaceous NE to WNW trend (2) a mainly Eocene trend to the NNE, and (3) Eocene and younger NW trends.

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The Northern Egyptian Red Sea - A New Deepwater Frontier- Part I

A multidisciplinary evaluation provides a more promising assessment of hydrocarbon potential in the pre-Miocene section of the northern Egyptian Red Sea. Existing well and seismic data from the 1970s and 1980s were reprocessed and reinterpreted. Reprocessing of the seismic data using pre-stack depth migration and SRME resulted in substantially improved imaging. Gravity and magnetic data were integrated with seismic and surface data to estimate depth-to-basement and highlight structural trends.

The reconstructed tectonic history of the northern Red Sea is congruent with that of the Gulf of Suez up to the initiation of Aqaba transform motion in the Miocene. Opening of the Gulf of Suez and northern Red Sea was initiated in the pre-Miocene as a series of dextral pull-apart basins that became integrated in the Miocene. Previously unidentified pre-Miocene basins are inferred to exist in the northern Egyptian Red Sea; outcrop data from the adjacent onshore indicate that Cretaceous clastics (Nubia) should be preserved in regionally down-thrown structural areas. These basins are similar in style and scale to the prolific pre-Miocene systems in the Gulf of Suez. Prospect risk for the pre-Miocene play is thereby substantially reduced. Mapped structures in the tendered blocks are estimated to contain significant resources: economics and an access assurance project determined that top-quartile deepwater opportunities could exist in this new frontier. Reprocessing of existing 3D data over the blocks and acquisition of new 3D could substantially reduce prospect risk.

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Seismic Stratigraphy And Facies Architecture of The Late Messinian Abu Madi Fm. in Baltim Area, N. Nile Delta, Egypt

Baltim area is located in the northernmost part of Abu Madi Paleovalley where recent and extensive exploration and development drilling took place. Abu Madi reservoir sandstone is interpreted as a fluvial dominated incised valley fill deposited mainly during rising stages of relative sea level changes.

The integration of 3 D seismic, cores and wireline logs helped us to frame Abu Madi Paleovalley, reconstruct the depositional history and predict the sand distribution within the valley in Baltim area.

The first target was reached by building a regional geoseismic cross section running from El Qara field to Baltim field through Nidoco field. Such seismic/sedimentological integrated approach made possible to determine the stratigraphic continuity of all reservoir levels, their facies variations in down current direction and the definition of a homogeneous reservoir nomenclature for all the fields.

At Baltim Leases scale, three gas bearing reservoirs were recognized and named, from bottom: 3 Lower, 3 Lower Uppermost, 3 Main. All reservoir levels are arranged in a transgressive vertical stacking pattern with a landward backstepping of the fluvial-coastal depositional systems and an overall shaling out to the north.

Eventually, 3 D block diagram sand distribution maps were produced in order to explain the reservoir depositional model and to provide a predictive tool for future exploration and field development.

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An Integrated Approach to Geophysics and Near Surface Geology in Southern Tunisia Using GIS Techniques

Geographic Information System (GIS) technologies provide exploration teams with excellent tools with which to combine many disparate types of data into an integrated subsurface interpretation.

We demonstrate how Anadarko has used GIS to merge the diversity of exploration data collected over the last thirty years in southern Tunisia.

In creating a large, evolving database of remote sensing, geophysical, geological, geochemical and engineering data, the database itself became the primary data management and archival tool.

GIS works as a data manipulator and spatial analysis tool, by which geographic patterns and relationships between features can be quickly ascertained from very large data sets in a wide variety of formats.

Roads, pipelines, well pads and old seismic lines identified on satellite imagery were resurveyed. Digital elevation models were used to check elevations against old survey data. Combined spatial analysis of refraction statics attributes and high-resolution aeromagnetism was used to optimally position new seismic lines. Seismic recording and positioning attributes, correlated against terrain and outcrop geology, were used to select survey parameters.

Stratigraphy and surface structure were mapped from outcrop with the assistance of geological interpretation of satellite imagery. Geologists updated their interpretation directly into the database on computers in the field.

The interactivity of GIS, the volume of data available and the spatial analysis tools facilitated far better integration of geophysics and near surface geology than was practical in the past. Such integration was paramount in the interpretation of the subtle geological structures and defining the optimal drilling locations.

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The Jurassic Megasequence in Egypt

Deposition of the Jurassic Megasequence commenced during rifting in the Early Jurassic and terminated in latest Jurassic with uplift, block rotation and erosion.

Relative movement between the European and African plates produced a NW-directed extensional stress regime in northeastern Africa, resulting in NE-trending normal faults and basins in Egypt. In the Western Desert, most of the producing fields lie along these northeasterly Jurassic structural trends.

Basement structure and composition fundamentally controlled the development and compartmentalization of Jurassic sub-basin depocentres. Jurassic extensional subsidence was confined to the north and east of a NW-trending PreCambrian basement shear zone that extends from northeastern Libya to southeastern Egypt, including the Nile Valley region. Jurassic basin development was further compartmentalized by a NNW-trending accommodation zone which coincides with the upper Nile Valley. NE-trending Jurassic half-graben depocentres (and the Jurassic shoreline) stepped far to the NW across this zone, resulting in rapid and dramatic changes in facies from marine carbonates in the east to non-marine clastics in the west.

Lateral variation in facies in the Western Desert indicates a broad ramp-like shelf that dipped to the NE. Minor base level changes produced large lateral shifts in facies and environments, and resulted in the vertical juxtaposition of marine carbonates and coals. Marine deposition reached its greatest landward extent during the Late Jurassic maximum transgression (Masajid Formation), and has been interpreted as far south as the Komombo-1 well. Although the stratigraphic evidence was largely removed during uplift and erosion at the end of the Jurassic, much of the Nile Valley Region and Eastern Desert could have experienced this marine flooding event.

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An Alternative Model for the Plio-Pleistocene Channelised Sandstone Bodies Within the Framework of the Sedimentary and Tectonic Evolution of the Nile Delta Area (WDDM Concession, Nile Delta Offshore, Egypt)

Channelised sand belts encased by dominantly mudstone deposits, represent the main exploration target in the Plio-Pleistocene succession of the WDDM concession. Their origin, time and space distribution and facies characteristics largely depend on a close interaction between the tectonic and climatic evolution of the Nile Delta area. These deposits, characterized in amplitude maps by moderately to highly sinuous shapes like many modern deep-water examples developed along passive continental margins, were genetically linked to the paleo-Nile fluvio-deltaic system.

Reconstruction of a regional geologic-stratigraphic framework shows that sedimentation was essentially controlled by deltaic processes linking marginal wedges to low-gradient shelfal and slope regions lying at moderate water depths during the Pliocene, and gradually increasing due to the flexural subsidence affecting the area through time. Channelised sandstone belts only occur north of the Rosetta Fault and originated from (1) sediment failures along the seaward edge of prograding delta lobes and (2) hyperpycnal flows exiting river mouths during periods of severe flooding. Sediment failures were triggered by the complex interaction of the tectonic instability of the Rosetta fault zone, severe floods, and probable sealevel lowstand conditions. These failures generated flows which were accelerated on tectonically-steepened clinoform slopes and moved seaward as inertia-driven dense flows forming extensively channelized sand belts. Individual sandstone bodies show very complex facies associations and stacking patterns that can be described by an evolutionary model implying three stages of growth reflecting the continuous interplay between changes in flow volumes through time and an evolving sea-floor topography.

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A Regional Evaluation of the Pliocene Nile Delta Pore Pressure Regime

The rapid accumulation of clastic sediments resulting from the progradation of the Nile Delta during Plio-Pleistocene times has resulted in the development of an overpressured province in the offshore Nile Delta. The primary overpressure mechanism in the Pliocene is undercompaction, since up to 5 km of sediment have been deposited in less than 5 Ma in the basin's depocentres. Thick shale packages of the Kafr El Sheikh Formation trap overpressures as little as 500 m below the seabed.

A Joint Operator Study was initiated to enhance understanding of the regional Nile Delta pore pressure regime. The aims of the study included investigating the existence of overpressure mechanisms other than undercompaction, such as inflationary and hydrocarbon generation mechanisms; finding methods to more accurately identify overpressured sequences; and developing effective well plan strategies. Particular emphasis was also given to assessing whether the pressure signature was extractable from seismic interval velocities and developing best practices for picking velocities for pore pressure prediction work.

All 3 operators are embarking on deepwater exploration programs where the problems of encountering overpressures are enhanced by the often narrow envelope between mud and fracture gradients in the shallow unconsolidated sections of the well.

A byproduct of the Joint Operator Study was a multi-well and seismic trade between the 3 participating companies - Shell Egypt, BP Egypt and IEOC, helping to enhance our overall understanding of the geology of the Nile Delta.

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Improving Borehole Quality With New Suite of Drilling Tools has Significant Effect on Drilling Efficiencies

This paper presents a suite of drilling tools that have been designed to eliminate bit side-forces, even while drilling directional wells. The mechanisms that cause unwanted bit side-forces are outlined and the techniques and principles used to eliminate them are described. Examples of the improved borehole quality that results from their elimination and the overall improvement in drilling efficiencies will be cited both from international and Middle-East operations.

In an ideal world a borehole would be a perfect cylinder with a smooth, frictionless interior and retain the original diameter of the drill bit. However, in the real world this can never be achieved. A number of factors contribute towards this less-than-perfect borehole, such as formation instability, and interactions between the drilling and formation fluids. Another major contributor is the actual mechanics of the drilling process itself and the resulting effect this has on the borehole geometry.

The phenomena of borehole spiraling is being increasingly recognized to be a result of the inefficiencies of conventional drilling assemblies. This short-pitch micro-tortuosity and the mechanisms that cause it are responsible for many of the problems described above. It has been found that borehole spiraling can largely be eliminated by adopting a 'point-the-bit' design rather than utilizing bit side forces.

The application of this range of tools can have a significant effect on drilling operations, especially in the field of horizontal and extended-reach drilling, where the improvement in hole quality can impact well design and economics.

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Generation and Migration of Hydrocarbons from Pre-Tertiary Source Rocks of the Kamundan Area, West Papua, Eastern Indonesia

The Kamundan area, West Papua, Eastern Indonesia is located to the north of the giant gas field, the Wiriagar Deep, discovered by Arco Indonesia in 1992 within the Jurassic sandstones. This discovery is important for the Kamundan area since showing of how the possible pre-Jurassic source rocks generated and migrated hydrocarbons to the Wiriagar and the Kamundan areas.

To understand generation and migration of hydrocarbons for the Kamundan area, the expected source formation and the Jurassic reservoirs were mapped. The source and gas samples from available wells were geochemically analyzed. Heatflow history reflecting tectonic and source maturation history was generated using BasinMod - 1D and -2D softwares. The migration routes of the generated hydrocarbons then were modeled.

Thermal modeling carried out for Ayot-2, Tarof-2, and Wiriagar-1 wells show that the sources have been mature since 240-260 Ma (Permo-Triassic). The maturation of the source is considered to relate with rifting subsidence during the Triassic. In 210 Ma (Late Triassic), the hydrocarbons have migrated and charged the whole intervals of the Jurassic reservoirs. Migration kept taking place and charged the Cretaceous reservoir until tectonic activity of the mid-Cretaceous uplifted the area and changed the migration routes. Afterwards, the hydrocarbons re-migrated along the porous beds at the Cretaceous unconformity and charged the Late Cretaceous and the Paleocene reservoirs. This is considered to have caused the significant hydrocarbon accumulation in the Paleocene reservoirs.

The study concluded that the petroleum system of the Kamundan area is Permo-Triassic : Jurassic and Paleocene.

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Present and Potential Oil Systems in the Mesozoic Strata of the Mesopotamian Basin, Southern Iraq

Mesozoic strata of the Mesopotamian Basin host more than 90% of Iraq's recoverable oil reserve. There are six present oil systems; all of them are within the Cretaceous rocks, with several other potential systems mainly in the Cretaceous and Jurassic strata. The present petroleum systems are found within the Sula'iy and Yamama formations of the lower Berriasian-Valanginian cycle; the Ratawi and Zubair formations of the Valanginian-Barremian cycle, the Nahr Umr and Ma'udud formations of the middle Aptian-Albian cycle, the Mishrif Formation of the Cenomanian-lower Turonian cycle, the Khasib and Tanuma formations of the Turonian-lower Campanian cycle and the Hartha Formation of the Campanian-Maastrichtian cycle.

These stacked reservoirs are bounded by local and regional seals and charged mainly by Lower Cretaceous and Upper Jurassic source rocks.

Potential oil systems include the Upper Jurassic sediments of the Najmah Formation, the extension of the Ratawi, Yamama and Mishrif reservoirs outside the present areas, the presence of oil in formations that are not considered as reservoirs yet such as the Tanuma and Sa'di and the limestone member of the Ahmadi Formation, the stratigraphic traps resulted from the basin-margin rudist buildups within the Shu'aiba and Mishrif formations, or the clastics of Zubair and Nahr Umr formations, and those requiring the use of modern technology such as the delineation of any possible dolomite reservoirs within the evaporites of the Gotnia formation.

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Oil Seeps in Central-Northern Tunisia as Indicators of Actual Active Petroleum Systems

The occurrence of hydrocarbon seepages in Central-Northern Tunisia has been recognised since the start of the Century and, together with the presence of surface anticline features, provided a stimulus for early exploration in that area. Several wells drilled close to the surface oil seeps on the basis of only surface geologic survey, were encountered encouraging oil and condensate shows. Some of them were abandoned before reaching the objectives. Almost all the seeps are encountered in the Nappe zone and in the Triassic salt domes zone within Triassic to Miocene levels. They could be subdivided into 5 main categories based on their nature and origin: source rock or false seeps, updip seeps, seeps along fractures and oil along unconformities or cap-rock.

Potential source rocks identified in that zone belongs to the Albian (L. Fahdene Fm), Late Cenomanian-Early Turonian (Bahloul Fm), Ypresian (Bou Dabbous Fm) and Oligocene-Miocene (Numidian shales).

The origin of the oil seeps has been comprehensively investigated using different geochemical techniques. Oil/source rock correlation based on biomarker distribution and carbon isotope composition allowed to group these oil seeps into 4 main families related to the source rocks mentioned above.

The Aptian and Numidian sandstones as well as carbonate units of Aptian, Albian, Cenomanian, Turonian, Campanian-Maastrichtian and Ypresian are the most probable reservoirs that have hosted oil accumulations.

Structural studies based on outcrops and confirmed by more available seismic data indicate a variety of small and large potential traps both in the allochthonous and in the autochthonous which could be charged from mature source rocks.

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Superimposed Mesozoic Deformations and Hydrocarbon Play Concept in the Northern Western Desert, Egypt – Example from Umbarka Area

A detailed study of 2D and 3D seismic and borehole data of the Umbarka area illustrates the effect of two superimposed Mesozoic deformations on hydrocarbon potential and entrapment in the Umbarka field. An early phase of Jurassic and Early Cretaceous rifting led to the deposition of thick source rocks in a northward tilted half graben (South Umbarka basin). Late Cretaceous right-lateral strike-slip movement on the basin bounding fault (Umbarka fault) formed second order wrench structures (folds and faults) above the depocenter of the early rift basin. A combination of hydrocarbon migration from mature source rocks in the South Umbarka basin and the presence of good reservoir rocks in these wrench folds, that provided optimum trapping conditions, established the Umbarka field. Similar conditions apply to other fields in the northern Western Desert.

The Umbarka fault is oriented E-W to ENE-WSW and separates the northward tilted South Umbarka basin from the Umbarka platform. The latter had gentle northward tilt where its updip (southern) part was above the Jurassic sea level leading to erosion of its Paleozoic cover. Tectonic subsidence of the South Umbarka basin probably continued at a slow rate during the Cenomanian affecting the net sand distribution in the Bahariya formation. Second order wrench structures formed by Late Cretaceous dextral movements along the Umbarka fault formed WNW-ESE oriented right-lateral strike-slip faults (Riedel / field shears). Dextral slip on these faults led to the development of NE-SW oriented folds in the syn-rift and post-rift sequences, which include the main reservoir rocks of the Umbarka field. The en echelon WNW-ESE oriented faults join at depth with the Umbarka fault and probably formed a migration pathway of hydrocarbons from the deep source rocks in the South Umbarka basin into the fold traps in the overlying reservoir rocks.

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Reactivation and Fault Activity Mapping of the Late Cretaceous Sequence in Abu Roash Area, North Western Desert, Egypt

The detailed structural analyses of fault zone characteristics and other reactivation criteria in the Late Cretaceous sequence of Abu Roash area unraveled the reactivation history of this geologically important sector.

The NE-SW trending major faults acted as a southern marginal fault zone to the Natrun Basin in the north during Late Cretaceous sedimentation. Changes in distribution and nature of deformation products within the zones of these

faults suggest syn-sedimentary Late Cretaceous movement was dip slip and normal. A later most probably Santonian phase of dextral transpression is also indicated. Syn-sedimentary fault deformation of the hangingwall sediments increases towards the major NE-SW trending faults. The fault zone characteristics of these minor faults revealed both distributed and localized shearing. Thrust movement overprinted the older hangingwall minor synthetic extensional faults. The common NW-SE, N-S, and ENE-WSW faults have no evidence of syn-sedimentary pre- Santonian movement and are interpreted as the echo of Late Santonian dextral transpression and the associated basin inversion.

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3D Reservoir Characterization and Reservoir Management Study — October J Nubia Field, Gulf of Suez, Egypt

An extensive, multi-discipline field study was completed in 1999 on the October J Nubia reservoir, located in the Gulf of Suez, Egypt. Although this field is relatively small (7 active wells, 132 MMBO OOIP) as compared to other Gupco's fields, the study proved worthwhile, generating three development prospects. All of them have been drilled and resulted in a rate increase of 6000 BOPD at a reserve gross of 6.6 MMBO.

The study team built a comprehensive, 3-dimensional Earthvision reservoir property model which was an excellent building block for understanding reservoir volumes and performance. The property model provided the tools necessary to understand fluid migration across faults in a 3-dimensional setting. The structural analysis began with the re-interpretation of a full-field, 3-dimensional seismic data set. The structural model was then populated with petrophysical parameters to produce the property model.

Extensive reservoir performance mapping also helped our understanding of fluid movement within the reservoir and helped identify areas of bypassed pay. As an example, watercut maps constructed for each of the fourteen reservoir subzones helped determine primary pathways of water encroachment.

The reservoir is a tilted fault block encompassing 750 acres. The producing formation is the highly prolific carboniferous Nubia sandstone with an average gross pay thickness of 600 feet, net pay thickness of 375 feet, porosity of 23 percent, and permeability in the darcy range. The reservoir has a fairly strong natural waterdrive, helping maintain reservoir pressure above the bubble point.

Even though the reservoir was forecasted to recover 48% of the original oil-in-place, the study located three areas of poor sweep. The three authorized drilling prospects are estimated to recover an additional, risk-weighted reserves of 9 MMBO. In addition, a detailed zonal performance analysis helped identify perforation and conformance work in existing wells, which should recover an additional 3 MMBO.

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Basin Hydrodynamic Considerations in Planning and Drilling Exploration Wells in the Deepwater

Planning and construction of deepwater wells require accurate pre-drill geopressure prediction as well as real-time monitoring. One of the most critical elements of the pre-drill geopressure estimation is the recognition of hydrodynamic effects in fluid-filled sand bodies that will be penetrated by the planned well. Depending on the structural position of the well penetration into sand structures, the pressure in the sand can be significantly higher or lower than the bounding shale. Failure to account for and anticipate such hydrodynamic effects (typically called the Centroid effect in recent literature) may lead to an incorrect well plan, and ultimately, to significant drilling problems, which may force premature well abandonment (not reaching target).

Conventional geopressure estimation methods are based on estimating pore pressure from compaction-dependent geophysical properties. Compaction is lithology-dependent and is greatest in shales. The assumption of pressure equilibrium between sand and shale is not reliable in many cases. Pore pressure anomalies between sand and shale should be investigated. One of the causes of pressure differences is the updip pressure transfer (Centroid effect). We present a methodology for recognizing the Centroid effect from offset well data. In addition, we discuss the effect of well position and other factors that affect the estimated pore pressure profile in shale and sand bodies. The intricate complexity of the physical and chemical systems involved in the evolution of the Centroid effect is demonstrated in several real world examples.

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Geopressure Prediction Uncertainties in Deepwater -Part 1: Pre-Drill Estimation

Risk is an important element of pore pressure prediction in deepwater. In deep water, the margin between the pore pressure and fracture gradient can be very narrow, requiring several casing points in the shallow portion of the wellbore to stay within gradient limits.

Pore pressure derived from known seismic velocity may only represent the dominant lithology and does not reflect changes in pore pressure in sand bodies and may not be sensitive to geologic conditions such as uplifting, erosion, diagenesis, etc. The basin modeling approach is perhaps best suited for accounting of some of the major geologic and structural effects. Often, in an exploration environment, the lack of sufficient offset well data to build a basin model limit its application.

We will address the effect of seismic data quality on the predicted pore pressure in the absence of offset wells. A Monte Carlo simulation model has been developed to generate seismic-based maximum and minimum pore pressures bounds along with the "mean" pore pressure value at any given depth. Armed with this data, the drilling engineer can consider the uncertainty in pore pressure prediction and its implication on well planning. In addition, the results can be used to justify the additional costs that are required to obtain more certain prediction results. For example, the cost of reprocessing seismic data, or obtaining a high resolution seismic hazard survey might be justified if a more certain pressure prediction make it possible to eliminate a casing string.

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Seismic, Centroids and Sealing Capacity

Amplitude and AVO anomalies are commonly identified as drilling targets. Sometimes when these prospects are penetrated, they are found to be wet. The hydrodynamic concept known as the Centroid effect may account for some of these exploration failures.

This lithology-dependent difference in pressure gradients has significant consequences. Wells drilled high on a structure may encounter overpressures far in excess of that in the surrounding shales, even in completely water-wet sections. The overpressures at the crest may approach the fracture gradient of the topseal. Formation water flows up-structure from the deep, overpressured, downdip part of the sand and escapes at the weakest point of the topseal. As the water moves from high temperatures and pressures to lower ones, any gas contained within it may exolve. This gas, at low concentrations (5% or less), may be responsible for some of the amplitude anomalies that have been drilled. Use of the Centroid concept may help in the evaluation of topseal and hydrocarbon risk for undrilled prospects. .

Amplitude and AVO analysis can sometimes indicate the presence of gas in a potential reservoir interval, but has difficulty in distinguishing between low (noncommercial) and high gas saturations. A method is shown to determine whether an amplitude anomaly of a given measured vertical height is capable of being a hydrocarbon column or whether it is more probable that it is wet.

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Estimation of Radioactive Heat Production from Airborne Spectral Gamma-Ray Data of Gebel Duwi Area, Egypt

Radioactive heat production is governed by the amount of potassium, uranium, and thorium in rocks. Airborne radio-metric surveys provide a fast estimate of the surface concentrations of potassium, uranium and thorium. However, utilization of airborne gamma- ray surveys in estimating radioactive heat production has not been presented. In this paper, we attempt to estimate the radioactive heat production from airborne spectral gamma-ray data of Gebel Duwi area, Egypt. A map of radioactive heat production was constructed from airborne gamma-ray data. The validity of estimating heat production from airborne data was confirmed using ground measurements. The area possesses a range of radioactive heat production varying from 0.21 mWm⁻³ to 3.09 mWm⁻³. The sedimentary rocks of the study area show values (0.25 mWm⁻³ to 3.09 mWm⁻³) higher than those given for the crustal sedimentary rocks. Meanwhile, the igneous rocks show average value (1.48 mWm⁻³) below the average for the crustal granites. The high values of heat production in the sedimentary rocks are mainly related to the relative increase of uranium content in Duwi phosphate formation. The reduced heat production of igneous rocks indicates that additional components combine with the radioactive heat production to the heat sources in the Gebel Duwi area. Generally, the results indicate that the use of airborne gamma-ray data to produce heat production map is a promising technique.

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Evaluation of the P.I. in Non Flowing Wells -Case History

One of the most important problems facing reservoir management and additional development in depleted fields multi layered reservoirs is the definition of the Productivity Index for non flowing wells.

Permeability data, from core analysis and initial tests correlated with petrophysical characteristics of the rock from open hole logs are widely used in numerical simulation models of the reservoir dynamics. This approach, basically followed to evaluate well productivity, doesn't take into account the mechanical damage of the formation through the different phases of drilling, completion and workover.

In this paper the results of different methods (open hole logs, production test, PLT using Y-tool, back calculations of the ESP pumps, fill up tests...) are summarised and compared to evaluate the actual PI of all the wells producing from the reservoir of Kareem Rudeis in Belayim Marine field (70 wells with a daily rate of 85000 bopd).

Wells were categorised based on their completion factors (P.I. actual over P.I. by correlation) and work-over activities schedule has been planned in order to optimise the production and injection rates (accurate pump design, reperforations, vacuum, back surging...).

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Morphology of the Nile Deep-sea Fan from Combined Swath Bathymetry and 3D Seismic Data First Arrivals

A bathymetric synthesis of the Nile marine fan, from the shelf to the northern bordering abyssal plain, has been compiled using different data sets: swath bathymetry from scientific surveys using respectively Simrad EM12 and EM300 dual systems, and first arrivals from 3D surveys made available by BP-Amoco Egypt along the shelf and upper slope. Locally, in deeper areas, this detailed map has been completed using regional ICBM data.

This compilation allows to define and illustrate different morphological provinces, and particularly to stress the drastic contrast between an Eastern province whose morphology is clearly controlled by active tectonics, and a Western domain, chiefly characterized by important channel-levee systems in prolongation with the onshore-offshore Rosetta feeding system.

Four 3D views of selected areas allow to better visualize key-processes of the deep-sea fan:

(1) A first one shows the detailed morphology of the Rosetta canyon, that cuts the continental shelf from a depth of 60 meters up to the upper slope, and constitutes the main active turbiditic path for the deep-sea fan.

(2) A second 3D block shows, in the same province, the contrasted morphology induced by combined growth faults and “mud-volcanoes” features, probably releasing huge quantities of fluids.

(3) Eastwards, the Eratosthenes seamount appears cut by normal and strike-slip active faults that are triggering well-imaged sedimentary destabilizations.

(4) Offshore of the Nile Damietta branch, the morphology of the Eastern province is strongly controlled by a complex interplay between salt-related polygonal slope basins, sub-linear tectonic faults, and large, almost circular, mud structures.

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E&P Data Management Procedures and Techniques - GUPCO Model

Data management is key to a successful exploration and production business. A clear vision is critical when dealing with huge data as in oil business.

Investment decisions, drilling exploratory or development wells, production, reservoir management and processing are all areas where E&P Data Management plays a critical role.

In 34 years GUPCO, as a leading company in oil business in Egypt, has gathered enormous volumes of traditional E&P data types and media. In the era of information technology this needs to be stored and accessed digitally.

GUPCO has adopted this idea, defining procedures and techniques throughout the process. In doing so GUPCO has become a pioneer in applying such concepts in Egypt.

This has involved site assessment studies, planning, implementation, control & development.

Techniques include standardization, data source definition, quality control, interfacing with other databases and transparency. This has been underpinned by training both for Data Management team members and data users.

The study illustrates GUPCO's work in Data Management. It also shows how customer feedback is a major business drive and a success indicator. Customers include shareholders, management and E&P asset teams.

Many of these lessons learned throughout the whole process are discussed. Recommendations for better E&P Data Management in Egypt are stated.

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About the Geological Structure of the Caspian Sea

In recent years a large volume of geophysical studies and drilling operations have been conducted in the Caspian Sea (especially, the North Caspian) which resulted in discovering large fields in Kazakhstan and Russia. The Caspian Sea has been studied with regional seismic survey works (1970 -1990s up to 2001). However, on the whole an overage density of seismic operations is not high.

Considerations of the previous studies on the whole allow drawing the following conclusions.

The major part of the promising North Caspian is not studied or has been very poorly studied with few seismic profiles due to extreme shallow water zones (1-2 m). Vast transition zones and zones of reclaim of the North and Middle Caspian, the delta of the Volga and the sea cost of the Kalmic Republic, between two rivers - Terek and Sulak, Terek and Kuma have not been studied. There is no new data on structure of abyssal zones of the sedimentary cover, intermediate complex and basement within the North and Middle Caspian. Nature of joining of the East-European Pre-Cambrian platform with the Scythian-Turan epi-Paleozoic platform as well as natural of the latter with displacements of the Alpine folded belt has not been studied. The nature of joining the Turan and Scythian plates as well as their interrelations have not been defined. It is not clear whether it is a single platform or two independent geostructures.

On the whole there are no valuable geologic-geophysical materials for detailed evaluation of geological structure in Caspian regions.

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The Relation between Old Wadis and Miocene Clastics in the Gulf of Suez

The Relationship between Old Wadis and Miocene clastics in the Gulf of Suez Rift

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Abstract

The Miocene clastic sediments in the Gulf of Suez rift lie between the pre-Miocene rocks and the Miocene evaporites. These clastic sediments are found in three main longitudinal basins in the Suez rift (the African, central, and Sinai basins). The Nubia Sandstone and basement rocks on both sides of the Gulf of Suez were the source of the Miocene sands deposited in the central and southern parts of the gulf. Rifting occurred at the end of Eocene - Early Oligocene when block faulting formed horsts and grabens. These horsts and grabens influenced the depositional character of the Miocene clastics. The Miocene clastic sediments of the northern Gulf are poor in sands compared to the sand-rich areas in the central and southern parts of the Gulf. The Miocene clastic sediments were deposited on the flanks of local pre-Miocene basement highs near the mouths of old wadis. In this study, there will be an explanation for the relationship between these old wadis and the sand deposition in the Gulf of Suez as well as an explanation for the main wadis formed during the Miocene time.

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Geologic Definition and Resource Assessment of Continuous (Unconventional) Gas Accumulations- the U.S. Experience

The U.S. Geological Survey (USGS) is currently assessing continuous gas resources of the U.S. (including basin-centered gas, shale gas, tight reservoir gas, and coal-bed gas) as these resources are becoming increasingly important to the U.S. energy mix. Based on geologic criteria, a continuous gas accumulation (1) is regional in extent, (2) can have diffuse boundaries, (3) has existing "fields" that commonly merge into a regional accumulation, (4) does not have an obvious seal or trap, (5) does not have a well-defined gas-water contact, (6) has hydrocarbons that are not held in place by hydrodynamics, (7) commonly is abnormally pressured, (8) has a large in-place resource number, but a very low recovery factor, (9) has geologic "sweet spots" of production, (10) typically has reservoirs with very low matrix permeabilities, (11) commonly has natural reservoir fracturing, (12) has reservoirs generally in close proximity to source rocks, (13) has little water production (except for coal-bed gas), (14) has water commonly found updip from gas, (15) has few truly dry holes, and (16) has Estimated Ultimate Recovery (EUR) of wells that are generally lower than EUR's from conventional gas accumulations. The USGS has developed a cell-based methodology for assessment of continuous gas accumulations, in which a probability distribution of potential untested geologic cells (a cell is related to the drainage area of a well) is paired to a probability distribution of EUR's of untested cells to arrive at a probability distribution for undiscovered resources in a continuous accumulation.

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Assessment of Undiscovered Oil and Gas of the Lower Silurian Qusaiba-Paleozoic Total Petroleum Systems of the Arabian Peninsula

The Lower Silurian Qusaiba Member of the Qalibah Formation was deposited over the northern and eastern part of the Paleozoic passive margin that now forms the eastern part of the Arabian Peninsula. The Qusaiba Member is a major source rock for hydrocarbons from the Wadi-Surhan Basin in the north to the Rub al Khali Basin in the south. The Qusaiba source rock in these basins is as much as 75 m thick, with TOC values ranging up to 20 weight percent, averaging about 4 weight percent. Qusaiba source rocks are generally mature or overmature for gas in the central parts of the basins, and are mature for oil along the margins of the basins, as demonstrated by the recent light oil fields discovered in central Saudi Arabia. Reservoirs are mainly carbonates of the Permian Khuff Formation and sandstones of Ordovician, Devonian, and Permian age. Six assessment units defined within the Lower Silurian Qusaiba-Paleozoic Total Petroleum Systems in the Arabian Peninsula were assessed for undiscovered petroleum resources, providing total mean estimates of 808 TCFG, 37 BBO, and 51 BBNGL. Most of the hydrocarbons discovered and produced to date from the Lower Silurian Qusaiba-Paleozoic Total Petroleum Systems have been gas in fields from the Qatar Arch and in fields along the extension of the Qatar Arch in Iran. Significant potential may exist in other areas, including the Rub al Khali Basin.

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Seismic Based Fluid and Lithology Discrimination in Turbidite Systems: Case Studies from West Africa, Angola

Discoveries in the deep-water blocks of offshore Angola are dominated by Miocene and Oligocene mid-slope turbidite reservoirs. The seismic data are ideal for identifying AVO anomalies and fluid contacts as the rock and fluid properties combine to produce some of the highest quality seismic data in the world. As the cost of deepwater appraisal wells is huge, there is an increasing dependence on seismic data to predict critical reservoir parameters such as net-to-gross and hydrocarbon presence, often far from well control. In response, BP now routinely generates fluid and lithology specific seismic attribute volumes in Angola in order to capture information historically generated through appraisal well drilling.

Seismic reservoir characterization in deep-water environments has been aided recently by extended elastic impedance theory, which can be used to determine seismic projections that enhance or diminish fluid and lithology responses. Seismic projection angles are determined by analyzing fluid and lithology relationships on seismic or log cross-plots, and those angles are used to generate seismic attribute volumes. In offshore Angola, the resulting lithology and fluid attribute volumes have consistently yielded additional information about the reservoir, often information not readily available from conventional stacks. Deriving the best projection angles is not yet an exact science and angles derived from seismic and logs are not always the same. This paper will present, through a series of case studies, a methodology for deriving projection angles from log and seismic data, and some of the striking seismic image enhancements that can be achieved through utilizing those projections.

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Depth Maps Calibration Using Fluid Contact Evidences: A Case History

Conformity to trap geometry is usually required for validating seismic amplitude anomalies and flat spot reflections as Direct Hydrocarbon Indicators.

This case history refers to an offshore field, where the interpretation of reprocessed seismic, supported by seismic modelling and sedimentology revision, allowed to recognise DHIs with high confidence.

Inconsistencies with structural map have therefore been interpreted as zones of poor map precision, and utilised for depth map calibration, providing a tool for improving geophysical maps precision.

The field is characterised by two culminations separated by a saddle. The reservoir is very uniform in terms of thickness and petrophysical properties, and extends continuously all over the area. The pay area shows clear amplitude anomaly.

Two types of calibration have been implemented:

1. saddle area. We modelled the relation between amplitudes and gross pay, due to interference between top reservoir and OWC reflections. An amplitude-based gross pay map has been produced, that, added to the OWC depth, provides the reservoir top in the OWC area. The maximum correction was -80 ft.
2. flank area. A clear flat-spot is visible, which towards the Northern structure significantly departs from depth contours. The map has been forced to OWC depth along the intersection between reservoir top and flat spot reflections, significantly modifying the mapped dip and azimuth. The maximum correction along the flat-spot is -150 ft.

A well drilled close to the flank hit the top reservoir with only 9 ft error, compared with 35 ft of the map calibrated with wells only.

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Petrography and Diagenesis of the Acacus Formation, Ghadamis Basin, Libya

Evaluation of core samples and composite well logs shows that the Acacus Formation in the Ghadamis Basin can be subdivided into three members. The lower and upper members are sand dominated whereas the middle member is mud dominated. Sand-shale ratios for the lower member show that it becomes more mud-rich from south to north and a similar relationship is apparent for the upper member although here there is some evidence that additional sources from the east and possibly from the west began to play a part in introducing sand to the basin.

The texture and composition of the sands and muds of the Acacus Formation in the Ghadamis Basin show that they are commonly very iron-rich. In general the thicker sandstones, with and without mud clasts tend to be the most iron-rich although they are interbedded with some relatively clean thin beds of quartz sandstones. These may represent high energy winnowed deposits where all mud has been removed.

The framework silicate grains are dominantly quartz varieties, both mono- and polycrystalline. Feldspar is rare and usually partially dissolved - it is, however, dominantly K- feldspar. Muscovite is an important component in some sandstone levels forming thin mica-rich laminae. Glauconite and detrital chamosite occur as replacement of mica and faecal pellets. Chamosite is also present as the cortex of ooids which have been transported into the sands from an adjacent ooid "factory". These have been classed as inherited grains. Detrital siderite is also present. Phosphate fragments of teeth, bone and scale tend to occur at the top of the iron-rich layers although apatite is also present as rare grain coating.

The iron content is comprised largely of pore-lining and pore-filling chamosite and pore filling siderite which comprise the main cements. Iron oxides are very important in the red beds which occur at the top of some of the shoaling-up successions. Quartz overgrowth and rare feldspar overgrowth are also present and quartz overgrowth is particularly important in some of the clean sandstones. Apatite and pyrite are important cement, although it is present in small quantity only.

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Geohistory Analysis, Mapping of Source Beds, Timing of Hydrocarbon Generated, and Undiscovered Reserves in East Abu Gharadig Basin, Western Desert, Egypt

The sedimentary sequence the eastern Abu Gharadig basin, west of Lake Qarun includes several potential source units; Abu Roash "F" Member and intervals within Khoman Formation; Abu Roash "G" Member, Bahariya Formation and the Safa Member of the Jurassic Khatatba Formation. Maturation models of several drilled sections, supported by models of interpolated basinal sections, suggest that migration would have been initiated in the depocenters from potential Jurassic source beds during early Senonian and thus trapped in pre-Laramide structures. As the basin center subsided throughout the latest Cretaceous and Tertiary, potential Jurassic sources passed through the "oil window" and could have expelled oil. The mature area of the Jurassic expanded away from the depocenters, concomitant with the subsidence process. The least preservation risk is considered for hydrocarbons expelled from Jurassic rocks bounding the basin away from the depocenter, as these rocks were late in reaching peak generation, past the Oligo-Miocene. However, preservation of re-migrated hydrocarbons is also valid. For the Cretaceous source beds, timing of the structural growth indicates that Laramide-related potential prospects were existing during the Late Eocene, the time of hydrocarbon migration from the Abu Roash "F" source rocks. Hydrocarbons expelled by Cretaceous source rocks are considered well preserved. Estimated recoverable total reserves in the area are about 670 million oil-equivalent barrels, based on geochemical mass balance.

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Assessment of Hydrocarbons Generated and their Preservation Through Integrated Geological Geochemical Modeling in the Central Gulf of Suez, Egypt

Seven time rock units were identified and characterized in the central Gulf of Suez as sources of hydrocarbons. These are Mheiherratt, Thebes, Esna, Lower Sudr (Brown Limestone), Matulla-Wata, Abu Qada-Raha formations, and Nubia "B" lithostratigraphic unit. The Thebes and Lower Sudr formations are the most prolific effective source rocks for generating oil and minor gas. Three oil generating and expelling troughs are recognized and delineated in the area namely: South Belayim, East Ramadan and East July troughs. The time of hydrocarbon expulsion postdates the main disturbing tectonic events affected the area. Such timing, relative to the timing of the structural events, is excellent for the preservation of hydrocarbons. The prevailing northeast dip regime in the Central Gulf of Suez controls the migration paths of the expelled hydrocarbons towards the southwest. The above mentioned troughs are considered the main feeding source to the producing oil fields in the area. The estimated ultimate recoverable reserves from the generating troughs are 2.7 billion oil equivalent barrels (boeb), while the proven ultimate recoverable reserves from all producing oil fields in the area are only 1.2 boeb. The remaining undiscovered oil (1.5 boeb) is expected to have been accumulated in the northern and northwestern extensions of July Field and near SG300 Field. Recent discoveries in both fields, made by the Gulf of Suez Petroleum Company (Gupco), are online with the conclusions reached in this work. Other prospective areas are recommended for further exploration.

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The Role of Micro-Quartz Cementation in Porosity Preservation in Deep Paleozoic Sandstone Reservoirs, Saudi Arabia

For the first time in Paleozoic samples from Saudi Arabia, grain-coating microcrystalline quartz cement has been observed during petrographic and SEM examination of Pre-Khuff (Permo-Carboniferous) sandstones. The microquartz is found in quartz arenites from the deeply buried (>13000 feet) pre-Khuff section deposited in shallow to marginal marine environment. The micro-quartz crystals are 2-5 micrometers in length and grow in optical continuity with the parent detrital grain. These crystals occur as a dense coating on detrital grain surfaces and are intergrown with short (~ 5 micrometers) illite filaments, which are also attached to the detrital grain. Where there is incomplete coating of microcrystalline quartz, large euhedral macro-quartz crystals grow as optically continuous overgrowths partially occluding the intergranular porosity.

The presence of microcrystalline quartz cement apparently reduces the growth of the normal euhedral macro-quartz cement. In the absence or paucity of authigenic clays (e.g. illite and chlorite) it appears that the microquartz coatings play an important role in the preservation of relatively high (12-15%) porosity in these deeply buried sandstones. The recognition of such preservation due to the presence of these coatings may allow explorationists to successfully predict sands with relatively good reservoir quality in deep Paleozoic structures.

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Sedimentology and Sequence Stratigraphy of the Bangestan Group, Lurestan Province, Zagros Mts, Iran — A Working Model

The Albian-Campanian aged Bangestan Group contains some of the most prolific reservoirs of the Zagros hydrocarbon province of Iran, predominantly within neritic carbonates of the Sarvak Formation. These units form extensive outcrops in the frontal fold belt of the Northern Zagros mountains, thus affording a unique opportunity for pseudo-3D reservoir characterisation as an aid to understanding producing fields in the subsurface.

The Lower Sarvak Formation comprises a thick (500 m +) predominantly aggradational section of ramp interior to ramp margin facies. Reservoir facies are predominantly within “grainy” facies, including rudist shoals, but are also developed within supra to intra-tidal facies. Reservoir heterogeneity is marked, related both to primary facies variations and to late-stage fracture controlled dolomitisation. The top of the Lower Sarvak Formation is marked by a regionally extensive transgression leading to deposition of ammonite-bearing deep ramp/basinal facies.

The Upper Sarvak Formation is up to 270 m thick and can be divided into 2 large-scale strongly progradational ramp sequences separated by a regionally extensive karst surface of Upper Cenomanian-Early Turonian age. Reservoir facies are again predominantly developed within the more “grainy” facies, although locally developed dolomitised mud-mounds on the deep ramp can represent excellent reservoirs. The Top of the Sarvak Formation is represented by a regionally extensive flooding followed by deposition of mudstones of the Surgah Formation. Neritic carbonates of the Ilam Formation abruptly overlie the Surgah Formation and pass retrogradationally into hemipelagic carbonates of the Gurpi Formation related to final drowning of the ramp system in Lurestan.

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Anatomy of a Half Graben: Structural Style and Stratigraphic Fill – A Case Study from the Sinai Margin of the Suez Rift, Egypt

The past decade has seen increasing research on the interaction between fault growth and stratigraphic architecture in extensional basins. In particular, variations in accommodation development associated with the vertical and lateral propagation and linkage of originally isolated normal fault segments have been investigated as a primary control on sediment dispersal and stratigraphic architecture. The aim of this contribution is to document the structural style and stratigraphic fill of a well exposed half graben from the Suez Rift, with emphasis on understanding the dynamic interaction.

The Wadi Nukhul half graben is a well exposed example of a “rift initiation” depocenter. The segmented border fault system to the half graben is exposed over 6 km, and comprises distinct NW-SE and N-S striking elements. Displacement is at a maximum in the south and decreases northwards towards a well defined tip point and fault-tip monoclinial fold. Folds are evident parallel and perpendicular to the border fault. Fault perpendicular folds are associated with distinct fault segments, while folding parallel to the boarder fault is associated with a faulted monocline configuration.

Contemporaneous syn-rift sediments show marked thickness and facies variations about the structural elements. The non-marine Abu Zenima Fm is thickest in hangingwall depocenters adjacent to NW-SE striking segments of the border fault, and is thinnest over transverse anticlines associated with N-S striking segments. In contrast, the estuarinal Nukhul Formation is thickest and more “marine” in nature at the southern tip of the Nukhul Fault, and shows progressive northwards thinning, onlap and overstep parallel to decreasing fault displacement.

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Depositional Setting of the Seafloor and Near-Surface Interval on the Nile Cone, Deepwater Egypt: A View Using 3D Data from the Northeastern Mediterranean (NEMED) Seismic Survey

Investigation of southern Northeastern Mediterranean (NEMED) Deepwater Block offshore of Egypt (on a large 3D seismic survey of ~7000 km²) to assess potential drilling hazards provided an opportunity to conduct a regional study of the seafloor and near-surface stratigraphy (upper 500 ms of seismic data) seaward of the Nile Delta in 900 to 2200 m of water depth. Analysis of the seafloor morphology revealed two distinct styles. The western two-thirds of the survey is characterized by flat first-order topography that is highly crenulated on a second-order scale of 1 to 10 m. Significant structural relief that exceeds 250 m in a well-developed graben system characterizes the eastern third of the survey. The near-subsurface interval reflects equally diverse stratigraphic patterns. Highly channelized packages dominate one stratigraphic near-surface interval of the western survey. Most channels features are single channel-levee systems, but one prominent channel-belt system exists. Ponded-fan sequences dominate the near-surface eastern survey. These fans occupy minibasins that occur throughout the near-surface section. Review of the deeper subsurface section indicates the thickness of Upper Miocene (Messinian) evaporites correlates well with the map and stratigraphic thickness of Quaternary and Upper Pliocene section. The structural control of evaporite thickness seems to be the primary control of seafloor morphology and near-surface stratigraphy. The striking variation of morphology and stratigraphy along strike is an exceptional example of the structural control of sedimentation, rarely observed in continental slope settings.

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Deepwater Field Development, Offshore Angola - Reservoir Management Strategies for a Complex, Turbidite Channel Environment

The Benguela Belize - Lobito Tomboco fields, located offshore Angola in 1300-ft of water, are composed of several, deepwater, turbidite-channel complexes of Miocene age. The pools are combination structural, fault, and stratigraphic traps with cumulative STOOIP approaching 1.5 billion barrels.

High-quality, 3-D seismic allows the construction of high-resolution geologic models for each oil pool. The seismic data provided a sound basis for spatial distribution of reservoir properties high quality mapped based OOIP estimates were made using all available data. Through detailed seismic stratigraphic interpretations and seismic attribute extractions, a map-based probabilistic approach was used to understand the impact of geologic uncertainties on volumetrics. Processes were then followed to define effective porosity, irreducible water saturation, and permeability from the seismic attribute predictions calibrated using cloud transforms. Simulation models were scaled up and created for each field and sector models were developed to further understand the details of displacement and subsurface development options. The results of these simulation models and all the sensitivities run were used to gain a consensus recovery for each channel, fault block and zone within the Block 14 partnership.

This overall approach supports a consensus building methodology with structured products (maps, displacement mechanisms, profile/recovery uncertainties, recovery efficiencies, well placements, well spacing issues, recoveries by reservoir element) at specific points in the modeling process. These work products from 3-D sector and full-field simulation models allow all stakeholders the opportunity to analyze and understand the results and that form a basis for developing forecasts, creating economics and making decisions.

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South Africa: The Unpicked Fruits of the Durban and Zululand Basins

The South African East Coast is characterised by two distinct rift basins that developed during the Late Jurassic-Early Cretaceous break-up of the Gondwana super-continent:

- (1) The Zululand Basin with its onshore extension, forms the southern extent of the Mozambique Basin.
- (2) The Durban Basin structurally more complex offshore, lies to the south of the Zululand Basin.

The mid-Cretaceous geology of the East Coast is dominated by sediment input from the Tugela River. With limited well control and regional seismic data, the stratigraphy has been correlated from the modern shelf into the deep-water areas of the basins. The basin geometry consists of horst and graben systems and a thick post-rift sedimentary section beyond the modern shelf edge. Seismic mapping reveals extensive systems of untested basin floor fan complexes.

The Tugela Submarine fan is extensive and prospectivity associated with the fan remains unexplored. Thermal modelling associated with the fan indicates that potential source rocks in the area have reached levels of maturity, with peak hydrocarbon generation occurring during the late Cretaceous. Background gas associated with two of the four wells drilled offshore, provides empirical evidence for a mature source basin-ward.

Reservoir quality sandstones have been documented regionally in Mozambique, and within wells and outcrops in the Zululand. Sandstone units with porosities up to 23% were penetrated in the onshore Zululand Basin.

This paper demonstrates how the above elements of a petroleum system relate to the various plays identified. Plays, which may reveal some of the juiciest fruits yet to be tasted!

Ravi K Singh¹ (1) Saudi Aramco, Dhahran, Saudi Arabia

An Integrated Approach to Imaging and Interpreting Minor Faults in the Evaluation of Hydrocarbon Migration

Seismic attributes, 3D visualizations and subsurface geological data were used to interpret minor faults and to investigate the stress field orientations in the Rub' al-Khali basin of Saudi Arabia. An area southwest of Gahwar covering the Shama-Murradaf anticline trend was investigated. The work focused on the effectiveness of seismic 3-D volume interpretation, visualization techniques, seismic attributes and use of well data in imaging and mapping faults in the Permian systems.

The interpretation revealed a detailed fault pattern demonstrating complex fault zones consisting of several fault blocks. In addition to predominant N-S oriented faults E-W trend fault systems were identified. These E-W fault systems offset the regional N-S fault systems. The younger faults have small amounts (5-100 feet) of vertical displacements that are difficult to see on the conventional vertical seismic data but were delineated using attributes volumes. The faults appear to be left lateral and show local lateral movements of up to five kilometers on the seismic time slices. Since a horizontal stress direction perpendicular to, or an angle to these lateral faults could enhance the fault seals, the dipmeter and FMI data were investigated to identify the principal stress direction. Additionally, the fault dynamics, particularly cataclasis and cementation processes, were considered in evaluating the fault seals.

The positive results from the study have improved our knowledge of the regional and local stress field orientations. The integrated method provided for the mapping of faults with small displacements, and for the investigation of their sealing properties.

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The Northern Egyptian Red Sea - A New Deepwater Frontier - Part II

Reevaluation of existing outcrop and sample data along with petroleum system modeling provide new insights into the petroleum resource potential of this frontier area. Pre-Miocene sequences may provide high quality reservoir potential. Regional evidence points to extensive Cretaceous clastics (Nubia) that should be preserved in regional down-thrown structural areas. Porosity preservation in quartz-rich sandstones at comparable depths in the Gulf of Suez exceeds minimum reservoir cutoffs. Thermal modeling indicates that high heat flows associated with rifting are not detrimental to reservoir preservation along the flanks of the rift. Miocene shales and marls of the Lower Rudeis provide cross-fault seals. The extent and richness of a pre-Miocene source rock can be demonstrated from outcrop and well data. Geochemical typing of offshore well data shows that the Cretaceous Brown Limestone is in an oil source facies and has generated hydrocarbons. This work demonstrates a working hydrocarbon system with a mature Cretaceous source and the potential for a pre-Miocene reservoir. Mapped structures in the Egypt 2001 tender blocks are estimated to contain significant resources. The key remaining risk is imaging preservation of the Cretaceous reservoir intervals in structural closures. Economics and an access assurance project analyzed drilling cost and potential developments and determined that if enough resources could be found that top-quartile development opportunities could exist in this new frontier.

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Unordinary Interpretation of Paleozoic Rocks Pyrolysis Rock-Eval Data

It is studied the Paleozoic samples area from Predkolymyskaya structure loop at the Northeast of Russia. The Silurian, Devonian carbonate-clay rocks are accumulated in reef and lagoon conditions of carbonate platform. The clear rhythms are stand out in this section, the content of clay increasing to subface of stratum. In the region are spread different petroleum shows - from gases to solid bitumen.

The quantity of organic carbon (TOC) is changing very sharply from 0,1 to 5 %. When the carbonate content is decrease the TOC is increase. It is note the increasing of TOC to subface of stratum.

Based on hydrogen index (HI) vrs oxygen index(OI) part of the samples belong to the zone of II type kerogen, several - to the I type, and part - to the III type (terrestrial OM). But in Lower Paleozoic rock we can't found terrestrial OM - we must search new explanation of the same pyrolysis data. The most of samples are in the zone of dislocated OM, which characterized by the more high S₁ (free hydrocarbons), sufficiently low T_{max} (less than 3800C) and wide range of HI (although the samples are from the sufficiently homogeneous section). It is interesting that this dislocated OM associate with carbonates in general and the OM of argillites is characterized by classical pyrolysis parameters. There is note a several samples with high maturity. It means that they were found at the places of contact with intrusions or thrusts zones. All samples can be classified like from ex-source rocks with exhausted generation potential.

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Geological and Geophysical Study of the Maunie Fault in the Wabash Valley of the Illinois Basin

The Wabash Valley Fault Zone, located in southwestern Indiana and southeastern Illinois, contains more than 26 separate oil fields in Illinois that have produced over 400 million barrels of oil since its discovery in 1938.

Understanding the nature and origin of these faults is important to future exploration and development of the oil and mineral deposits of this area. This structural zone has been proposed to be the result of reactivation of the New Madrid Rift Complex. The Wabash Valley Fault Zone is composed of many faults that run north from the northern bounding fault of the Rough Creek Graben approximately 55 miles to the LaSalle Anticline. The faults are typically high angle, 60° to 90° normal faults which have a tendency to splinter as they approach the surface. The Maunie Fault lies on the eastern side of the Illinois Basin. Deep seismic, shallow seismic, georadar, and electric log data from drill holes, show a graben-like feature northeast of Maunie, IL. From electric log data, displacement along the edge of this feature is approximately 90 feet at the top of the Beech Creek limestone. Shallow seismic and georadar data show that the Maunie Fault was reactivated as recently as the Quaternary and possibly during the Holocene. These data are all generally consistent with the hypothesis that the faults are related to a reactivated rift complex.

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Integrating New SCAL Technology into Reservoir Management Decisions

In the recent years, several new developments have occurred in the area of Special Core Analysis. We will especially discuss some recent developments impacting dynamic reservoir behaviour.

First, laboratory measurement conditions nowadays are much closer to those of the reservoir. Here, a combination of good quality laboratory measurement techniques is often required to overcome the physical limitations of individual SCAL methods. Moreover, history matching of experimental SCAL data with a reservoir simulator generates more confidence in the measured relative permeability measurements and hence the subsequent reservoir simulation and planning.

Next, measurement and interpretation capabilities are continuously upgraded, to meet the challenges of the continuously changing EP world. Recently, a fully automated steady state set-up capable of handling four samples at the same time (called "Skyscraper") has been developed and deployed. It simultaneously measures the oil and water relative permeabilities in addition to the resistivity index enabling measurement of Archie's saturation exponent. The water saturation is continuously monitored by X-ray scanning to check the steady state conditions and enhance the reliability of the technique. A more sophisticated version of the Skyscraper capable of measuring core samples under reservoir conditions (high pressure, high temperature and with crude oil) is being developed.

In the past few years, abovementioned and other new SCAL techniques have been used in the study of complex reservoirs, e.g. gas condensates, oil transition zones and enhanced oil recovery projects. The impact of these studies has been several hundred of millions US\$.

Currently, the relationship is being studied between SCAL properties (like relative permeability and capillary pressure) and other rock parameters, to investigate in how far such properties can be obtained from downhole log measurements.

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On the Deep Origin of the Messinian Salt in the Mediterranean

Revision of the geological data on salt-bearing formations of various basins of the world showed that accumulation of salt occurred synchronously with intense tectonic movements and in the basins of salt accumulation simultaneously with erupting lavas. The presence of effusives in salt indicates that accumulation of salt did not occur in basins semi-isolated from the sea but in tectonically active depressions in which faulting was manifested.

The study of geology of salt-bearing basins of the world testifies the wide distribution of effusives mainly of basic composition among salt rocks of different age. Basalts, diabases, ophiolites, melaphyres and other volcanic rocks occur in salt as bedded and dykes in addition to breccias as component parts of the cap rocks on the salt domes. Volcanogenous rocks are found among halogenic formations so commonly that they, together with anhydrite, gypsum and limestone, may be considered as component part of these formations.

The rate of salt accumulation is very high and is comparable only with the rate of formation of volcanic rocks. Halite was precipitated in the troughs, whereas volcanogenous-sedimentary rocks were accumulated on the uplifts. All available data on the geology of salt-bearing basins allow to ground ideas on the endogenous nature of halogenic formations precipitated from juvenile hot brines which entered the upper zones of the earth's crust along deep faults.

Taking into account the paragenetic relation of salt accumulation and volcanic eruptions I suppose that the geological section of the Messinian salt of the Mediterranean must also contain somewhere volcanogenous rocks.

Peter G. Stuart-Smith¹, Jon Teasdale², Karen Romine², Lynn Pryer², Tom Loutit² (1) SRK Consulting, Deakin West ACT, Australia (2) SRK Consulting,

A New Understanding of Basin Distribution and Architecture in Egypt Revealed by the Application of Non-seismic Exploration Techniques

A new view of the onshore and offshore basins of Egypt has been the result of two recent projects (EARS and MARS)* based on a combination of mineral and petroleum exploration techniques. Understanding basement composition and structure and the tectonic evolution of each basin were the focus of the studies, involving the systematic calibration, integration and interpretation of non-seismic, principally magnetic and gravity data, with seismic datasets. The results demonstrate that potential field data when rigorously integrated with seismic and other datasets are cost-effective and efficient tools in remote areas at both regional and concession scale.

Proterozoic and Pan-African metamorphic and igneous basement terranes and structural elements control the distribution, size and geometry of Paleozoic and Mesozoic basins. Terrane boundaries and major NW-trending Pan-African shear zones provide the principal control on basin distribution and geometry, with basement composition and structural fabric controlling individual basin architecture. Egypt's basins can be grouped according to the "character" of the underlying basement into five groups: Western Desert, Nile River Basins, Gulf of Suez/Red Sea, Sinai and the Eastern Mediterranean. The results of the study provide a consistent base for volumetric assessments and a knowledge platform for designing exploration and acquisition strategies. The studies have also resulted in an improved understanding of the distribution of source-rock, reservoir and basement-involved traps, and can be used to predict first-order fluid flow directions, river drainage and sediment composition across the basins of Egypt.

*EARS - Egypt Area Regional Study (Apache Egypt, BP Egypt, IEOC, Repsol-YPF, Shell Egypt and SRK Consulting)

*MARS - Mediterranean Area Regional Study (BP Egypt, Apache Egypt and SRK Consulting)

Peter Stuart-Smith¹, Karen Romine², Tom Loutit², David Allard³, Jan Schreurs⁴ (1) SRK Consulting, Deakin West ACT, Australia (2) SRK Consulting, (3) Apache Egypt, Houston, TX (4) PDO, Oman

**Integrated Regional Study of the Shoushan-Obaiyed-Matruh Basins Architecture of the Western Desert of Egypt
...OKMR**

The Obaiyed, Khalda and Matruh Regional study (OKMR) was conducted to improve resolution of the current basin architecture and understanding of the basin history of this prolific producing area of the Western Desert of Egypt. The results, including new structural-style observations and interpretations of basement composition and evolution, can be used to mitigate risk in prediction of reservoir distribution and hydrocarbon migration. The technology employed included non-seismic data integrated with well tops and seismic data. The study builds on the recent Egypt Area Regional Study (EARS)*.

Proterozoic metamorphic and igneous rocks form basement with Pan-African and older structural elements, controlling the geometry of Paleozoic and Mesozoic extension. Basement highs such as the Faghur and Kharaman Platforms and the Khalda High comprise relatively rigid basement blocks dominated by granitic rocks.

Basins throughout the region can be differentiated on the basis of their underlying basement structural control with local architecture in onshore basins being controlled by the interplay of three main fault sets: NE-trending Jurassic growth faults (Proterozoic lithological trends); NNE-trending reactivated Proterozoic faults; and E-W Cretaceous growth faults.

Using a new depth to basement model, fluid pathway and focus analysis shows a strong association of basement highs with the majority of oil and gas fields in the Western Desert. New target areas can be readily identified. The new understanding of the basement structure and basin architecture resulting from study forms an excellent framework for detailed sequence and paleogeographic analysis.

*EARS, 2000- Egypt Area Regional Study (Apache Egypt, BP Egypt, IEOC, Repsol-YPF, Shell Egypt and SRK Consulting)

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Exploration of Offshore Togo (Benin Embayment); a New West African Play Type

Togo Hunt Oil Company's contract area offshore Togo covers approximately three thousand two hundred square kilometers (3200 km²), ranging from the shelf to water depths greater than three thousand (3000) meters. A two thousand seven hundred and seven (2707) square kilometer 3D seismic survey exists entirely within the contract area, acquired by PGS in late 1998. This survey revealed the presence of major structural anomalies and thicker than normal Tertiary sediments.

Offshore Togo thus represents an area of untested plays on the transform margin of equatorial West Africa. The play of highest interest consists of Late Cretaceous shelf / slope / submarine fan sandstone reservoirs, sourced by underlying mature, source rocks deposited during the Late Cenomanian to Early Turonian worldwide oceanic anoxic event. These reservoir targets are associated with transpressional antiforms, creating migration focus and large trapping geometries. The influx of thick Late Cretaceous and Tertiary clastics associated with the paleo and present day Volta River drainage ensures adequate burial of the source rock to peak oil generation levels, and there are a number of direct hydrocarbon indicators in the contract area.

Work by Togo Hunt Oil Company has identified several prospect and leads, involving Early to Late Cretaceous, and Tertiary reservoirs in a number of differing trap styles and geometries.

Mohamed Nabil Sultan¹ (1) Geoscience Consultant, Cairo, Egypt

Gulf of Suez / Red Sea Structure Evolution and Hydrocarbon Potentiality

Tectonic events, which shaped the Red Sea, Gulf of Suez and Gulf of Aqaba as Parts of the North East African Rift System, are studied. The growth history of the area has been influenced by four forces since the Late Eocene, these forces were responsible for its structure evolution.

The hydrocarbon entrapment within the Gulf of Suez area, proved to be mainly controlled by the fault pattern, as manifested by most of the fields mapping. This is most probably the same case as in the similarly tectonised Northern Red Sea province.

The main structural trends NE-SW to NNE-SSW and NW-SE, are significant and most of the hydrocarbon accumulations are directly or indirectly related to the intersection of these structural elements. The NE-SW trending structure elements are cross-faults along which the Gulf of Suez as well as the Red Sea have been opened. Cross-faults are difficult to be interpreted in the subsurface, where they laterally displace the blocks and are also masked by the thick Miocene sediments. However, some examples using details seismic interpretation reveals cross-faults in the subsurface are presented in this study.

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Delivering a Sustained Improvement in E&A Performance

No Abstract Requested

Pavel Syngaevsky¹, Sergey F Khafizov² (1) Numar (A Halliburton Company), Houston, TX (2) TNK (Tyumen Oil Company), Moscow, Russia

NMR Application for Development Optimizing in Shaly Reservoirs

Samotlor Field - one of the biggest oil fields in the World, was discovered in 1965 and put on production in 1969. Despite the big amount of core recovered during exploration and early development stages many questions related to petrophysical characterization and geological models still go unanswered. Particularly this is the case with the reservoirs of ÄÄ1(1-3) group which are characterized by a high level of heterogeneity, that is recognized at two scales. All that turns the pay zones with sedimentary structures described as "Ruabchek" into extremely complex target for interpretation. In 2000-2001 an interpretation of new cores, magnetic-resonance imaging logs and re-interpretation of NMR formation fluid measurements were performed. The main goal was to identify and characterize production potential of pay zones formed under various depositional sequences of tidal plains and deltas, and optimize wells completion in shaly formations.

The possibility of successful measurements of the following parameters: current and residual oil saturation, total and effective porosity, permeability and shaliness was proven based on processing of multi-frequency NMR data. Combined interpretation of MRIL materials, core data and modern depositional environments description allows us to identify and quantitatively characterize the following facies: lagoon tidal flats, tidal sands, low and high tidal plains, coastal bays, point bars and various channels. For the first time in West Siberia Basin TNK applied MRIL-C/tp for 78-degree borehole. Data obtained during one pass gave a sufficient amount of petrophysical information about structure and reservoir properties of several targets.

Ali Mohamed Taha¹ (1) Geisum Oil Company, N/A, Egypt

Pre and Post Simulation of Shagar Reservoir in North Geisum Field, Egypt

North Geisum is located in the southern entrance of the Gulf of Suez, Egypt. The field started oil production in April, 1995. One year after, peripheral two water flooding injectors were implemented in the field. A Two - phase integrated reservoir study was performed on the two main sand reservoirs (Shagar and Rahmi). The first phase was basically intended to understand the different complications in both characteristics and performance of each reservoir. In this pre-modeling phase, all conventionally known reservoir engineering approaches were applied, including the pressure and production performance calculations (material balance), aquifer strength, and decline curve analysis.

In the simulation phase, a geostatistical technique to integrate the 2D seismic data, geological interpretation, petrography, and log data were used and a representative model was eventually developed.

Another technique was applied via the hydraulic zonation (FZI) in order to define the distinct zones with similar fluid flow characteristics within the reservoir and to predict the permeability in the uncored wells. This is based on core analysis and application of a methodology developed by Jude Amaefule and others.

This paper addresses the importance of applying the classical reservoir engineering approaches/techniques before performing the costly full field reservoir simulation work.

Ernesto Taia¹, Virgilio Pinto¹, Simao Jose¹, Guy Delorme² (1) Sonangol P&P, Luanda, Angola (2) Chevrontexaco Overseas Petroleum, Luanda, Angola

Large Angle AVO in the Presence of Strong Shale Anisotropy: Understanding Angle Dependant Reflectivity to Help Locate Thick Turbidite Reservoir Sands in the Lower Miocene of Block 14, Offshore Angola

Turbidite channel reservoir sands in the Lower Miocene of Block 14 can be difficult to detect on near to mid-offset range data because many of the sands have weak to moderate positive acoustic impedance contrasts relative to the encasing shales. Excellent images of the reservoirs can however be obtained when AVO attributes derived from the full offset range of 400 to 4000 meters are used.

To retain the very long offset data an anisotropic moveout correction had to be used in the data processing since the tertiary shales are strongly anisotropic. This anisotropy causes the reflections on the CDP gathers to be severely over-corrected at the very long offsets when simple hyperbolic moveout corrections are used.

To understand the expected AVO behavior of the reservoir sands a simplified anisotropized Zoeppritz equation was used to calculate angle dependant reflectivity from which models were derived that tie the real seismic with remarkable accuracy. Model analysis led to the development of a seismic attribute aimed specifically at revealing thick sands based on their expected AVO behavior. By subtracting -90 degree phase near angle data from -90 degree phase very large angle data a seismic trace is obtained which closely mimics a Gamma Ray curve.

The technique has been calibrated against Block 14 well penetrations and has been used to locate drilling targets. Stunning images of subtle channels that were difficult to detect on the conventional seismic data (0 to 30 degrees) are now obvious from amplitude maps derived from this "Pseudo-Gamma Ray" data.

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Structural Analysis of Recent Hydrocarbon Discoveries in the Berkine Basin: Characterization and Process-Based Predictive Modeling

Over 3 billion barrels of recoverable oil have been discovered in the Berkine Basin of Algeria since 1990. One component of exploration success has been the identification of faults that provide migration pathways and structural closure. Understanding the timing, vertical and lateral continuity, and hydraulic behavior of these faults is fundamental to understanding the hydrocarbon system. We have developed a procedure for predicting vertical fault continuity in layered rock, and have successfully applied it to understand the distribution of hydrocarbon types in this basin. The technique integrates documented rheological heterogeneity with a three-dimensional effective stress model to predict the presence or absence of faulting in specific depth ranges under applied tectonic loads. The calculated mechanical threshold where discrete fault segments should link together to breach regional seals corresponds to the documented onset of vertical migration, confirming our predictive model. Our approach provides a mechanical rationale supporting the interpretation of downward dying and vertically segmented faults in areas of ambiguous seismic data, and suggests a robust method for evaluating gas risk in this dominantly oil-producing region. As a corollary, these results illustrate that Andersonian or kinematic models force unrealistically complex interpretations. Advances in structural characterization using continuum mechanics have yielded insights on local fault patterns and their relationship to regional tectonics that are inconsistent with such traditional interpretation techniques. This further suggests a simplified tectonic model for the Berkine Basin can adequately capture the kinematic fault history and the variability in structural style, but with far fewer tectonic events.

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Using Expert Systems Technology as Knowledgebase and Learning Systems in Hydrocarbon Exploration Programs

Searching for hydrocarbon is a very sophisticated scientific process. Over the years, large wealth of knowledge and experience have been accumulated and passed from one generation of explorationists to the other. Advancement in computing technology played a key role in automating these processes and capturing of the exploration data. Advancement in application integration and visualization technology enabled the explorationist to get more out of the exploration data. However, as the volume of data is getting larger and larger, the technology is getting more and more sophisticated and the active explorationists generation is getting older, the need to capture their knowledge and experience in a systematic approach and made their knowledge accessible to future generation exploratioist is highly needed.

For many years, the oil industry has been attempting to utilize the Expert System technology to capture the knowl-edge of their experts to make it accessible for younger generation. Many success and failure stories have been reported in the literature.

In this paper, a survey of the industry attempts in building Expert System applications is given along with the some insight for each approach and some of the analysis of their success or failure drives. A highlight of some of the current active research in this area will also be presented. The paper will be concluded with recommendation of a new approach to tackle this old dream using the latest advancement in computing technologies.

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Jurassic-Early Cretaceous Sedimentary Patterns of a Central-Northern Portion of Western Desert Area

An integrated sedimentological, biostratigraphic and rock microcharacterisation methodological approach applied in the Central-Northern portion of Western Desert, allowed to draw a lithostratigraphic and genetic scheme of the Alam el Bueib, Masajid, Khatatba and, partially, Ras Qattara s.l., Jurassic to Early Cretaceous formations.

A detailed palynozonation provided the stratigraphic framework of the Hettangian-Early Aptian succession.

Regional sedimentological cross-sections, highlighting the basin-modifying tectonic activity at the top of Masajid Formation, framed the sequence stratigraphy of the area. The more detailed results have been obtained for the Alam El Bueib Formation, where four main depositional sequences bounded by unconformity surfaces have been recognised basinwide. The sequences are constituted by deltaic depositional systems showing a South (sandy entry point) to North (shaling out of some sandstone levels into shelfal deposits) progradational pattern. In some high areas (Mirach and Qattara Rim) the lower sequences are reduced or not deposited, while, toward South-East, the same pattern is shown by the uppermost sequence.

Rock microcharacterisation was performed in order to point-out the petrographic and pore network variables that determine the efficiency of the sedimentological facies. Quartz overgrowths precipitation resulted to be the main factor controlling reservoir quality, as, following the burial/thermal history, it may fill partly or completely the pore space. The pattern of quartz precipitation is thus the key issue for reservoir quality prediction.

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New Oil in a Mature Basin: The Edfu Discovery, Suez Rift, Egypt

Advances in 3D seismic processing coupled with a detailed fault-seal evaluation allowed us to identify and test a new lead in a proven structural trend in the Gulf of Suez, Egypt. The Edfu prospect was interpreted as an up-thrown, 3-way closure on a normal-fault bounded block south of Ramadan Field and west of the giant El Morgan Field. The Nubia Sandstone, which contains approximately 3 billion of the 9 billion barrels of oil produced in the Gulf of Suez, was the main target. Many Gulf of Suez oil fields consist of this trap-reservoir combination, however exploration of this play type had limited success in the last 10 years.

Previous work (vintage 1980's and early 1990's) utilized 2D seismic data and post-stack migrated 3D data. Recently, we have reprocessed our 3D data using multiple removal techniques and pre-stack depth migration. As a result, the Edfu prospect emerged from what had previously been mapped as a structural low.

Our regional evaluation determined that seal was the dominant failure for other wet Nubia structures, so a competent seal was required to trap significant oil volumes. Detailed seismic mapping showed the Nubia in the footwall was fault-juxtaposed against Eocene carbonate and Miocene shale in the hanging-wall. Petrology, petrophysics and shows analyses confirmed that these zones should be good sealing facies. The Edfu well found oil in the Nubia and other horizons, and was our first discovery of this kind in the Gulf of Suez in 13 years.

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3D Multiple Elimination in the Gulf of Suez: Acquisition Design for Optimum Processing Results

The Gulf of Suez (GoS) is a very mature basin, and is acknowledged for the poor quality of the seismic data. Free surface and interbed multiples are the most severe problems from a host of geophysical effects that mask primary events on GoS seismic data.

BP Egypt established an in-country applied-research project (the GoS Demultiple Project) to identify, evaluate, develop and apply techniques to significantly improve seismic data quality on a very timely basis, and to assure the continued development of a high quality prospect portfolio.

A 2D test program in 2001, provided zero-offset data which gave substantial imaging improvements by allowing optimized application of 2D Surface-Related Multiple Elimination (SRME) software, in the relatively shallow water (~60m) GoS, in addition to further advancements such as low frequency adaptive subtraction.

Further work on source comparisons, and acquisition aspects, led to a novel 3D survey design for attenuating GoS multiples, with the prime tenet of acquiring data that would meet the 3D sampling requirements of SRME algorithms.

The survey design includes:

- An optimized source to emphasize the low-frequency primary bandwidth
- A multi-azimuth component to aid in illumination and multiple removal
- Near offset recording to provide pre-critical data for SRME, and
- Adequately sampling the multiples in 3D for application of full 3D and sparse inversion 3D SRME, and interbed multiple elimination software

Modeling indicates that the number of streamers, the streamer separation and the sail line spacing play an essential role in improving the applicability of 3D SRME algorithms.

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An Integrated Approach to Basin Analysis

An integrated approach to basin analysis

We present a methodology and the initial results of its application in the characterization of the processes involved in the development of sedimentary basins. The methodology combines the advanced seismic data analysis techniques and numerical basin modelling tools to resolve the basin (de)formation processes. The basin target horizon is represented in terms of its seismic properties, including reflection and transmission coefficients. The information on seismic properties is integrated with the information on the distribution of geomechanical parameters. The careful analysis of the integrated information should result in the quantification of the relation between the stress distribution within a basin and the seismic response.

The methodology consists of three phases. The first phase involves the conventional seismic data interpretation. In this research the data was gathered from the sedimentary basins of extensional tectonic settings and passive continental margins. The basins of the Norwegian Continental Margin and the North Sea were selected because of intensive hydrocarbon exploration and exploitation in these regions. After the conventional seismic data interpretation, some portions of the basin and the adjoining areas were investigated in detail. The selected portions were simplified and synthetic geological sections were constructed. The second phase involves the seismic modelling of the constructed cross-sections by comparing various ray tracing and finite difference modelling techniques. Both acoustic and elastic wave modelling were included. The synthetic seismic data were analysed by considering the established relationships between the seismic properties and the material parameters. The stress field and the deformations were predicted on the modelled cross-sections by using finite element modelling techniques. Travel-time and amplitude information from seismic modelling were used to improve the quantification of stress field-seismic response relation.

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Common Reflection Surface (CRS) Processing in Complex Geology – An Alternative to Prestack Depth Migration?

Imaging in complex geology environments faces numerous problems like rapid lateral changes, discontinuous reflectors, a high noise level, and multiple contamination. Reliable velocity models often cannot be defined, neither in time nor in depth, since primary reflections are hardly visible in the prestack data, or cannot be discriminated from multiples.

Macro-model independent imaging could represent an approach to reduce these difficulties. The Common Reflection Surface (CRS) stacking technique offers several advantages with respect to the conventional NMO/DMO processing:

- No velocity model is required. However, available velocity information may be used as a constraint.
- The CRS stacking parameters are automatically determined from the seismic data for each point of the stack. This local adaptation optimizes the image of strong structure and velocity changes.
- The hyperbolic stacking surfaces extend across several CMP locations. The resulting high fold leads to a strongly increased signal-to-noise ratio.
- The CRS method assumes subsurface reflectors that are characterized by local dip and curvature. This leads to an enhanced imaging of curved and dipping structures.

Application examples show an improved image of complex geology by the CRS method in comparison to conventional imaging. Poststack depth migration of the CRS stack produces a high-resolution depth section, that can be superior to prestack depth migration results in data environments, that do not allow a reliable velocity model building.

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Rodinia to India: Signatures of Time and Space on Sediments of East Coast Basins of India and Its Significance on Hydrocarbon Potential

The structural grain of India is a result of welding of Early and Middle Proterozoic mobile belts, which were wrapped around Archaean nuclei of Karnataka, Jeypore-Bastar and Singhbhum. This anisotropic basement could not withstand the stresses and split along paleosutures during initial rifting from Gondwanaland, the same way as the contiguous Zambezian type basement. These incipient sutures started receiving sediments from nearby elevated provenance through numerous minor fluviodeltaic systems, overlying the glaciomarine/glacio-fluvial prerift (Permo-Carboniferous) sediments. The subsequent block movement along these paleosutures has given rise to different sub-basins separated by ridges, accommodating up to 8000m of sediments in some areas. During the final phase of rifting a volcanic episode - the Deccan Trap capped rift sediments.

By an estimate, 62% of the world's total hydrocarbon occurrences fall between Pennsylvanian-Turonian age, hence these sediments attain great significance from exploration point of view.

Nine rifted Basins considered along the east coast of India are, viz., Cauvery, Palar, Pennar, Pranhita-Godavari, Krishna- Godavari, Mahanadi, Bengal, Surma valley (Bangladesh) & Assam. These basins have recorded the signatures of various tectonic episodes that the Indian plate has undergone on its journey from near South pole to the present day position. These are indicated and very well decipherable on the basis of sedimentation patterns copied on seismic investigations and drilled wells records.

In the paper, authors have correlated these signatures with distinct stages of rift evolution and basin building mechanism. The sediments accumulated during these phases attain significance as fossil fuel deposits, as worldwide analogues are available where due to increase in geothermal gradient during rifting; source rock is adequately matured to generate commercial hydrocarbons. A comparative analysis of contemporaneous petroleum systems of NW Australia, E. Africa, & Madagascar was considered to understand the structural settings and identify the future thrust areas for hydrocarbon exploration in the East Coast basins of India.

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Anisotropy: Who cares?

Abstract

The reservoir characterization process increases the confidence level on the description of the rock and fluid properties which make up the constituents of reservoirs, both clastic and carbonate. With the increasing resolution of seismic observations and with the use of multi-component acquisition & processing technologies, there is a growing awareness that the assumption of isotropy is often violated. Thus, methods which allow the proper imaging and reservoir characterization, in the presence of anisotropy, are highly desirable.

In the presentation we will show using synthetic and real data examples various seismic data processing technologies which incorporate anisotropic parameters and aim to correct the kinematics and dynamics of the seismic wave propagation in anisotropic media. Time imaging algorithms operating in the pre- or post-stack domain will show the effect of incorporating not only the NMO velocity for horizontal reflector ($V(0)_{NMO}$) but also the anellipticity coefficient η (eta). Depth imaging algorithms, however, will depict that the above two parameters are not sufficient to properly position the structures at the correct spatial and depth locations. In this paper, we will demonstrate that for a proper prestack depth migration methodology, one needs to incorporate Thomsen's parameters ϵ (epsilon) and δ (delta) in addition to V_0 in order to obtain the correct travel times required during a PSDM procedure.

Also, traditional AVO theory breaks down in the presence of anisotropy. We will demonstrate the use of more sophisticated AVO algorithms in the description of anisotropic reservoirs, as well as isotropic reservoirs with anisotropic overburden.

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Petroleum System Analysis in the Central Alborz Basin, Iran -Geochemical Characteristics of Oil Seepages and Source Rocks-

Geochemical analyses on oil seepages in the Central Alborz Basin reveal that the seeps belong to two distinct oil families, and thus two different types of source rocks possibly exist in this region. These two types of seep oils are correlated to the Jurassic coal and the carbonate rocks of unknown age.

Biomarker analyses by GC/MS and GC/MS/MS show that the first family is characterized by high concentration of C29 steranes and lack of C30 marine steranes. High diasteranes/steranes ratio also suggests that clastic input was significant. Hence it can be correlated to terrestrial source rocks. Lack of oleanane proves that the source rock was not younger than the Cretaceous. As the biomarkers extracted from the Jurassic coals and shales, which are thought to have been a part of deltaic sediments, are very similar to those of the seep and the hydrogen index of these rocks are plotted between 100 and 250, it is interpreted that the Jurassic rock is the source of the oil seepage.

The second family is characterized by high concentration of C27 and C30 steranes, high C29/C30 hopanes ratio and irregular distribution of homohopanes. These characteristics point to a marine carbonate source rock, which may have been of Cretaceous or younger age as evidenced from the high concentration of 24-norcholestanes and 24-nordiacholestanes, and from the occurrence of dinosteranes.

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Intergration of Vertical Seismic Profiling in 3-Dimensional Modeling: A Co-Dynamic Approach to Better Reservoir Characterization and Imaging in the Niger Delta

The growth Fault system that characterised the potential Niger Delta hydrocarbon reservoirs have defined the architecture of the geological structures of the Agbada formation that serves as the most valuable hydrocarbon formation as being complex. With irregular simple roll-over anticlines associated with fault fronts and diapiric structure of clay-shale compositions confirmed in the offshore region, only 3-dimensional modeling has produced a picture of this complexity.

Conventionally, data for 3-Dimensional modeling has been from surface seismic technology, however the intergration of data acquired from Vertical Seismic Profiling have yeilded higher resolutions and thus allows for better imaging of objects within the vicinity of the well bore that could not otherwise be defined by surface seismic techniques.

Concisely, this paper will focused on the co-dynamic effect of VSP on 3-Dimensional modeling as it applies to acquiring better reservoir characterization and imaging in the Niger Delta, giving a general overview of this technique. The paper will tend to shy away from detailed discussion on VSP data processing, but highlight the value of the technique as well as the field procedures involved.

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Regional Hydrodynamic Assessment of the Memouniat Formation in the Murzuq Basin, Libya

The Murzuq Basin has a relatively simple tectonic history, complex facies distribution in the Memouniat carrier beds/reservoir horizons and an active groundwater flow system. A hydrodynamic analysis was used to risk areas of hydrocarbon flushing and trap-fill preservation as well as to predict oil migration pathways. The Memouniat can be broadly divided into four geographic regions defined by characteristic hydrodynamic systems:

- A low flux of formation water migrating to the centre of the Murzuq Basin most likely driven by erosional rebound and dilatation of the Tan ezzuft shales;
- A high flux of formation water from the high elevation Ordovician outcrops on the west side of the basin across the northern rim to low topography discharge in the northeast;
- A ridge of high hydraulic head originating at Ordovician outcrops on the northern edge of the basin; and
- A trough of low hydraulic head north of the inferred Memouniat shoreline draining northward into the Ghadamis Basin.

These flow systems together with source rock and carrier bed distribution, control the migration pathways of liquid hydrocarbon within the Murzuq Basin. Estimated hydrodynamic tilts were compared to the structural slope to risk oil charge and trap-fill preservation. The flow systems observed here have had an impact on the distribution of liquid hydrocarbon within the Murzuq Basin, and they are most likely linked to the adjacent Ghadamis and Sirte Basins.

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New Frontiers for Deep Water Exploration: Senegal-Guinea Bissau Joint Exploration Zone

For many years ENI has focused much of its exploration interest and investments in the offshore of West Africa, with an activity which is gradually moving from conventional to deep water areas. One of the latest acquired exploration Permits is "Cheval Marin"; it lies in territorial waters that are jointly managed by the Senegal and Guinea Bissau Governments.

The "Cheval Marin" permit is located in the Casamance sub-basin, geologically belonging to the regional Mauritania-Senegal-Gambia-Bissau (MSGB) Basin. A thick sedimentary section aged from Paleozoic to recent is present, including pre, syn and post-rift sequences.

The exploration activity in Senegal and Guinea Bissau has been so far focused only on the platform domain, with many exploratory wells drilled onshore.

The analysis of the well data samples shows the presence of an efficient petroleum system, whose oil generation has to be mainly referenced to the Cenomanian-Turonian source rocks; this sequence can be correlated to the "black shales" found on DSDP-367 well, located just over 200 km to the west of the Permit.

Halokinesis phenomena related to the presence of a Triassic evaporitic sequence, led to the formation of structural closures that increase the possibility for the generated hydrocarbons of being locally trapped.

The main target is represented by the Cretaceous sedimentary series, deposited on a slope environment during the post rift phase.

The deep water domain of the Casamance sub-basin constitutes a fully unexplored area that can be considered as an emerging frontier area with high potential and moderate risk.

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Fast-track, Data-driven Interbed Multiple Removal: Application to the Gulf of Suez

Removal of multiples from seismic reflection data is an essential pre-processing step before seismic imaging in many marine environments. Surface-Related Multiple Elimination (SRME) has proven to be a valuable tool to remove free-surface multiples, multiples that have propagated down- and up the water layer more than once. This paper discusses the application of SRME to remove multiples generated by internal surfaces.

There are two generic strategies to tackle interbed multiples: model-driven methods, that make use of statistical assumptions and/or a priori information about the subsurface (local 1D assumption, detailed velocity- and/or reflector information), and data-driven methods, that use the measured data itself to predict and subtract interbed multiples.

Although conventional, model-driven approaches have been applied successfully, the reliability of the inherent assumptions and the user-provided priori information, as well as the level of user-interaction required makes these methods less suitable for large 3D production processing.

The approach taken here is an extension of the SRME method and requires only the identification (i.e. picking) of the multiple generator. Then, through a double convolution of muted common receiver- and common shot gathers, 2D internal multiples can be predicted. Through least-squares subtraction, these predicted multiples are subtracted from the input data.

An optimised processing strategy leads to efficient removal of either interbed multiples that are generated by a (chosen) internal reflector, or interbed multiples that have crossed a (chosen) pseudo boundary during wavefield propagation.

Application to a data set from the Gulf of Suez leads to encouraging results.

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The Role of Leadership in Exploration

No Abstract Requested

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Use of Seismic Attributes and Acoustic Impedance in 3D Reservoir Modelling: An Example from a Mature GOS Carbonate Field (Ras Fanar)

Discovered in April 1978, Ras Fanar Field in the Gulf of Suez of Egypt has produced approximately 91 MM STB oil, from Middle Miocene coralline algal carbonates which are informally known as the "Nullipore Facies" and to a lesser extent the South Gharib Formation. The field lies some 2 Km offshore east of Ras Gharib and produces from a NW-SE trending structural trap bounded by a major fault system to the SW and tilted to the NE. The depositional setting of the reservoir comprises a narrow 4-5 Km wide carbonate ramp which extends eastwards from Ras Gharib Field to Ras Fanar Field. In previous interpretations the carbonate Nullipore Facies was interpreted as eroded and subsequently on-lapped by South Gharib sediments along a single unconformity. The current geological model allows for both lateral and vertical facies transitions between the Nullipore carbonates and South Gharib evaporitic-siliciclastic-carbonate units. Several phases of upward-shoaling deposition and erosion are evident. Periods of erosion coincide with high porosity layers within the reservoir resulting from karstification and solution collapse brecciation. Diagenetic overprinting of the original facies was intense therefore a petrophysical-based modelling procedure was adopted.

This paper presents a simple but effective 3D reservoir modelling workflow which used absolute acoustic impedance (AI) data and its relationship to effective porosity as a deterministic 3D modelling parameter ("porosity-facies") rather than the more traditional facies based approach. Implicit in the modelling workflow was the assumption that the 3D distribution of the resulting "porosity-facies" could be interpreted using a geological model which conformed to a "modern" sequenced-based approach to reservoir zonation and the model-derived vertical and horizontal "porosity-facies" trends were reflected in the actual evaporitic-carbonate facies transitions seen in the Gulf of Suez today, as well as nearby outcrop analogues.

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Physical Modeling of Salt Tectonics in the Eastern Nile Deep-Sea Fan

The present-day setting of the eastern Mediterranean includes the combined influences of thick-skinned, crustal-scale tectonics and thin-skinned, gravity-driven spreading of the Messinian evaporites and their Plio-Pleistocene overburden. The west and north parts of the Nile deep-sea fan show salt-related structures typical of those found on other salt-bearing passive margins. In contrast, the structural pattern of the east part of the fan is drastically different. The eastern part comprises a long (>200 km) NW-SE deformation corridor trending obliquely with respect to the slope direction. Along dip, the corridor exhibits a structural progression typical of salt-bearing passive margins, including small distal buckle folds, mid-slope minibasins surrounded by salt ridges, and proximal normal growth faults. Less typical is the corridor's being bounded by narrow, NW-SE fault zones underlain by narrow salt ridges. We used physical models to test whether such pattern was caused by the presence of NW-SE dormant or active subsalt relief or of a bathymetric high (the Eratosthenes seamount) acting as a buttress during spreading. Model results clearly indicate that the presence of a passive subsalt relief and/or of a buttress, rather than that of an active subsalt relief, has caused this peculiar structural pattern. Early gravity spreading caused radial thin-skinned extension and the formation of minibasins and NW-SE and ENE-WSW salt ridges, a pattern also enhanced if basement steps are present. Later, buttressing by the seamount opposed further northeastward extension. The salt and overburden spread northwestward, reactivating the NW-SE salt ridges as strike-slip zones bounding the corridor.

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Multicyclic Depositional History Of Middle Eocene-Early Oligocene Carbonate Sequence Of Panna-Bassein-Heera Block, Western Offshore India: Implications for Exploration and Production Strategy

Middle Eocene to early Oligocene platform carbonates (>700m) of Bassein and Mukta Formations harboring number of discovered oil and gas fields around Bombay High is a complex carbonate sequence with cyclic depositional and diagenetic imprints and vertico-lateral thickness/facies variations. Discovered hydrocarbons in the uppermost porous layers of carbonate sequence lead to hitherto accepted model of single phase Middle/Late Eocene unconformity related reservoir development. However, number of hydrodynamic fluid anomalies encountered necessitate alternative solution. Chrono-stratigraphically constrained log correlation across platform area has revealed the heterochronous character of reservoirs in different structures. Eight distinctive stratigraphic units are identified depicting the transgressive-regressive cyclic sedimentation during Middle Eocene-Early Oligocene. Four hydrocarbon bearing units within Middle Eocene are identified as Neelam pay (Youngest), Bassein Pay, Heera Pay, and B-lower Pay (Oldest). Additionally charged middle Units form Mukta Pay. It implies existence of multiple phases of hiatus-diagenesis related porosity generation and stratigraphically controlled hydrodynamic fluid draining systems, which better explains fluid distribution.

It has significant implications for hydrocarbon exploration strategy. An interplay of porosity generation vis-à-vis structural disposition of respective layers seems to govern the hydrocarbon accumulation. Three set of faults genetically related to rifting and rotational shearing further influence the fluid migration and accumulation. Lateral extent of discovered pay units may be tracked down in structurally favorable areas to locate hitherto untested oil and gas pools.

Spatial traceability of identified units on reconstructed seismic sections and chronostratigraphic constraining of carbonate depositional cycles by biostratigraphic information and eustatic sea level curves establishes their stratigraphic validity.

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A New Loose Sand Coring Technology Resulted in Longer Core per Run with excellent core quality

A new technique is used to core and recover unconsolidated sand from shallow and Deep water offshore Mediterranean wells using the positive full closure Posiclose Ver2 core barrel. This technology when combined with unique designed CMP107FD core head tremendously improved the length of the core runs and increased the recovery rates. The new design also resulted in reducing the number of trips which positively impacted the drilling cost reduction.

Before the new developments, Posiclose were limited in the number of core cut and the recovery was almost +/- 30-40ft per run. With specially designed core head, revised coring parameters and enhanced mud properties multiple and successful 90 ft runs in several wells were achieved. This paper contains three different case histories, compares between the new and previous technologies and highlights the cost savings.

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Case Histories of Successful Conformance Control Treatments in the Gulf of Suez, Egypt

Every field is unique in its response to conformance control treatments. In the Gulf Of Suez (GOS) a couple of conformance jobs were successfully completed. This paper presents two case histories involving a water shut-off treatment in an oil producing well and an injection profile modification treatment on a water injection well.

A new, organically cross-linked polymer system was used to obtain deep penetration that could sustain long term results in these GOS wells. The job design phase included modeling of reservoir cool-down to optimize polymer gel times and gel strengths. Appropriate placement techniques and key modifications in the traditional conformance control program were implemented to achieve very successful results following the treatments.

In the oil producing well, water production of over 3000 bpd was shut off and an incremental oil production of over 680 bpd is being realized from the treated zones. The incremental oil reserve from this production is 1.5 million barrels.

The results from the treatment of the injection well showed a remarkable improvement in the water injection profile of the subject well. Prior to the treatment 10% of the perforations took about 47% of the injected fluid, and the rest of the fluid was distributed over 90% of the perforations. After the treatment the same 10% of the over-swept perforations took only 5% of the total injected fluid and 95% of the fluid went to 90% of the perforations.

Several lessons were learnt from these treatments. This paper details the key factors that allowed these jobs to be successful.

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Historic Shelf Play Revisited - Offshore Gabon

The Ompoyi discovery well, drilled in February 2002, tested at 6300 bopd, revitalising interest in the Eocene-Palaeocene Ozouri play, offshore Gabon. The well targeted a large structural closure (13 km²) and encountered a 110 m oil column and no OWC.

The salt induced structure had been originally recognised on a coarse 2D grid and unsuccessfully drilled in 1982. The original well failed due to reservoir absence, at that time assigned to stratigraphic variation. 3D seismic subsequently revealed that outside a crestal graben area, the Ozouri reservoir was present over the entire structure.

The Ozouri formation is regionally extensive, and can reach a thickness of 450 m. It is frequently oil bearing above salt induced structures, although its potential has often been overlooked by exploration programs focusing on Upper Cretaceous clastic objectives. The Ozouri Formation, broadly analogous to the Monterey Chert Formation of California, is characterised by highly variable lithologies, generally relying on natural fracturing to give good productivity. The Ompoyi discovery is located in an area where the Ozouri is a primary reservoir target due to a favourable depositional, diagenetic and structural history. Exploration continues for analogous structures in this trend.

In these days of technology driven deepwater exploration, Ompoyi is a salutary example of how basic geological work and a reappraisal of drilled structures guided by modern 3D can discover low cost reserves in the West African shelf regions.

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Lower Paleozoic Marine Source Rocks and Hydrocarbon Kitchens in the Tarim Basin, China

Exploration activity has increased significantly during the past 10 years in the Tarim basin, which is largest and least explored petroliferous basin in China. Although oils-source rock correlation have proved that petroleum may be mainly originated from Cambrian and Ordovician marine strata, the distribution of effective source rocks and evolution of hydrocarbon kitchen are still controversial in past years because the lower Paleozoic strata occur over the entire basin and its maximal thickness exceed 12000m in the interior of basin. According to more than 1,5000 rock samples geochemical screen analysis, the prime organic-rich interval exist in lower Cambrian and upper Ordovician, the former distribute in anoxic environment, the latter distribute in the slope with high productivity. Based on a detailed organic facies, oil-source correlation, organic maturity and thermal history reconstruction by organic geochemical and petrological techniques and Basin Modelling System, two lower Paleozoic hydrocarbon kitchens have been identified, the first is lower Cambrian euxenic source rock, located in the Awarti-Majaer depression, the second is upper Ordovician carbonate mud mound source rock, located in the slope of Tazhong uplift and Tabei uplift to Majaer depression. The hydrocarbon in the gigantic Silurian tar sandstone and residual reservoir were derived from Cambrian source rock, the hydrocarbon in the Carboniferous and Devonian reservoir were from Ordovician source rock in recent 100Ma.

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North African Rift Systems: Comparison of Cenozoic Red Sea and Triassic/Jurassic High Atlas of Morocco

The Cenozoic Red Sea and Mesozoic Atlas continental rift systems have similar lengths, widths and rift tectonic frameworks. They each contain early rift continental beds and evaporites, were flooded by marine waters, and exhibit a facies mosaic representing marine environments that were controlled by local rift tectonics and global eustatics.

Whereas sediments in the modern Red Sea are still accumulating in the syn-rift stage, those of the Mesozoic rift were inverted to form the continuous mountain belt now represented by the almost east-west ranges of the Moroccan High Atlas, Algerian Saharan Atlas, and Tunisian Atlas.

Post-Mesozoic tectonic inversion in the Central and Eastern High Atlas of Morocco exhibit exposures of the Late Triassic dry-rift continental facies and superb outcrops of the Jurassic wet-rift marine facies. The Jurassic facies are limestones and marls, controlled mainly by fault-block tectonics and Toarcian eustatic sea-level rise, and secondarily by hundreds of cycles of deposition that respond to a hierarchy of higher-frequency sea-level fluctuations. The cycles are exhibited in paleoenvironments that represent sabkha, shallow-platform, platform edge with reefs, platform margin with olistoliths, deep basins with turbidites, and isolated platforms with sponge-algal buildups.

Each of these facies produces hydrocarbons in various rifts and other carbonate habitats worldwide. The High Atlas of Morocco is thus an inverted rift whose exposed formations can be compared to those forming in the modern Red Sea, as well as a model for understanding hydrocarbon accumulations in syntectonic formations preserved in subsurface rifts and other dynamic carbonate environments around the globe.

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Improved Sensitivity and Quality Assessment of Oil Shows in Development Drilling - Strategies for Oil-based Mud Systems

The objective of this paper is to define best practice strategies for detecting oil shows in development wells that are drilled with oil-based mud. Technology extensions include quantification of respective end-member signals and predicting crude oil quality. The workflow design includes: planning and preparation, analysis, and interpretation. Specific elements include:

1. Examination of mud logs, well logs, drilling reports, and physical samples;
2. Development of systematic analytical modules for rock cuttings, core material, pristine drilling fluid components and resultant mixtures, and associated fluids (e.g., flow tests if available);
3. Integrate results and define best practice; and
4. Maintain critical elements of the successful protocol for future operations.

Specific analytical tools and/or modifications to existing procedures will be outlined for Rock Eval pyrolysis, TEGC, quantitative GC, and quantitative GC-MS SCAN acquisition. Interpretive techniques of chemometric data processing and improved visualization tools aid in the workflow design. The resultant best practice applied to Gulf of Suez and Western Desert petroleum systems demonstrate that the methodology is rapid and low-cost, yet highly sensitive and capable of quantifying oil properties to impact well-site decisions in near real-time.

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Petroleum Systems of the Giant Oil Fields in Val D' Agri Region, Southern Apennines, Italy

The geology of Italy is ranked as one of the most complex and least understood in Europe. This presentation focuses on the hydrocarbon resources in Val D' Agri region within the Southern Apennines Thrust belt (SATB). The buried Apulian Platform contains both source rock and reservoir zones. A positive correlation is established between the produced oils and source rocks within the Cretaceous sequences. The carbonate reservoirs include karsted vuggy intervals, as well as extensively developed fracture systems, which provide flow rates in the range of 3,000 to 12,000 bo/d from oil columns 600 to 1000 meters thick. The entire producing complex is sealed by the overlying Neogene sequence.

The combination of tectonic regime and reservoir character contribute to an unstable oil column. This disequilibrium condition is described as compositional grading, and is a process whereby an oil fractionates heavier components toward the base (12°API) and volatiles toward the top (54°API). This compositional grading is consistent with thick oil columns within fractured reservoirs and its formation is promoted by a reduction in pressure and temperature as illustrated by 2-D basin modeling results. The influx of late charge volatile hydrocarbons (CSIA data) further reduced oil column stability. Determination of reservoir compartmentalization with molecular methods requires advanced geochemical analysis and chemometric processing due to the oil quality overprint. Despite the technical challenges, these fields will yield over a billion barrels of oil to rank them among Europe's largest onshore accumulations.

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Integrated Reservoir Characterization Studies in the Khalda Concession, Western Desert, Egypt

The Bahariya Formation is a complex succession of mixed clastic-carbonate deposits of Cenomanian age that formed on a broad, tidally-influenced ramp on the southern margin of Tethys. It is a principal oil reservoir in the Western Desert of Egypt. Over the past twelve months, reservoir characterization studies of Bahariya producing fields along the Khalda Ridge (Salam, Hayat, Yasser and Kenz fields) have resulted in a more complete understanding of the Bahariya depositional system as well as a number of successful infill drilling locations. The studies include full integration of depth-converted seismic, wellbore and production data within a sequence-stratigraphic framework and the extensive use of geologic modeling for data visualization and sand mapping.

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Sequence Stratigraphy and Sedimentology of the Bahariya Formation, Khalda Concession, Western Desert, Egypt

The Bahariya Formation is a complex succession of mixed clastic-carbonate deposits of Cenomanian age that formed on a broad, tidally-influenced ramp on the southern margin of Tethys. In the Khalda area it records the punctuated transgression of the Tethys margin, overlain by shallow-marine carbonate sedimentation of the Abu Roash Formation. Detailed core studies combined with regional correlation indicate a complex interplay between relative sea-level change and sediment supply.

The Bahariya Formation is divided informally into two members. The Lower Bahariya formation (400-800 feet thick) is the principal reservoir unit, a relatively sand-rich succession of fine- to medium-grained sandstone and mudstone. Sedimentary structures, ichnofacies assemblages, and stratal geometries indicate the unit was deposited in an estuarine to shallow-marine environment with strong tidal influences. Reservoir-scale sequence stratigraphy of the Lower Bahariya is complex due to the presence of multiple erosion/onlap surfaces (marked by carbonate cementation and *Glossifungites* trace-fossil assemblages), abrupt lateral facies changes, and a complex diagenetic overprint.

The Upper Bahariya varies from about 130 to 300 ft thick and consists mostly of thin (2-6 m), sand-poor parasequences that can be correlated regionally. Parasequence boundaries are typically cemented, burrowed, and overlain with mudstones. Sedimentary structures, ichnofacies assemblages, and stratal geometries indicate deposition in mainly low-energy, restricted marine settings. Very-fine grained sandstones occur mainly in the upper 75 feet, mostly as thin bayhead distributary-mouth bar and shoreface deposits, but occasionally as isolated channel-fills. Upper Bahariya sandstones thicken into sand-rich deltaic deposits up to 150 feet thick in the southwestern Shushan Basin.

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Wavelet-Consistent Reprocessing of Multi-Environment 3D Seismic from Abu Dhabi

A vibroseis survey was reprocessed jointly with an adjacent transition zone survey. Data of high temporal and lateral resolution, and of good structural and stratigraphic accuracy is required here for mapping of subtle faults and improved reservoir characterization. Accurate statics solutions and reliable wavelets are critical - here 6ms false structure can make the difference of an oil well or one in the water. The older data has laterally variable bandwidth, phase and structural errors, resulting from inadequate statics and from unsatisfactory matching of source- and receiver types.

Consistent data character requires good wavelet corrections for the various source-receiver combinations. In our reprocessing, partly-deterministic and partly-statistical (PDPA) zero-phasing dealt with these issues. Well-proven deterministic phase corrections were applied to the vibroseis data. A statistical deconvolution ("PSW signature") was used for zero-phasing the impulsive-source data and removing the hydrophone ghosts. This route avoids ad-hoc phase matching of overlapping parts of the data. Our method was validated using numerous comparisons of pre-stack and stacked data.

All data were zero-phased before first-arrival picking and refraction statics, ensuring consistency between statics-related and zero-phasing-related time shifts. This avoids structural errors resulting from lateral phase variability. Phase-corrected impulsive-source first arrivals were found consistent with those for zero-phased vibroseis.

This approach for matching the various data types yields a consistent data character across the combined surveys. The easier correlation of first-arrival data and absence of any post-statics space-variant phase corrections is expected to improve the structural accuracy.

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Structural Style and Growth History in Saudi Arabia

Most of the hydrocarbon fields in Saudi Arabia are basement-cored uplifts. These structures are compressional, typically low relief, bounded by steep frontal fault, and backthrust in some cases. The most common trap type is four-way closure, although subcrop-trap, fault-trap, and stratigraphic trap are becoming increasingly important.

We quantitatively assessed growth history of each structure by adapting the concept of growth index, which is a numerical ratio of strata thickness in trough over crest. Every structure was given a set of four numbers (starting from 1 indicating no growth), each indicating the severity of one of four orogenic deformation: Carboniferous (Hercynian Orogeny), Early Triassic (Zagros Rifting), Late Cretaceous (First Alpine Orogeny), and Tertiary (Second Alpine Orogeny) time, respectively. Maps of structural growth indicate that most of the structures have persisted from Carboniferous to Holocene. The maximum principal horizontal stress in Late Cretaceous seems to be oriented NW-SE direction and was responsible for maximum growth of some of NE-SW oriented structures such as Abqaiq, Harmaliyah, Shaybah, and Tuhman. The Central Arabian Arch has long been a strain compartment boundary where the strongest deformation occurs and persists, and where most E-vergent structures are located to the north and most W-vergent structures are to the south.

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Exploration Geostatistics; Methods, Workflows, and Examples

Exploration risks in mature basins can be reduced through analysis of pre-existing data. The integration of this data with the spatial component using a geostatistical approach can provide valuable insights for both close-in exploration as well as conventional exploration leads. Currently, far less attention has been paid to the use of spatial modeling over larger geographic scales such as those used to define exploration "leads" or "plays." However just as geostatistical practice had to evolve when it moved from mining applications to reservoir studies, further evolution is needed to move to investigations that may involve hundreds to thousands of wells and more than 100,000 km².

The data sets used are more varied, incorporating not only well, core, and seismic data from numerous fields, but also other forms such as gravity, magnetic and seismic data, as well as oil and water chemistry, pressures, decline curves, etc. Non-stationarity is the rule rather than the exception and efficient removal of this over large areas can be a problem. Furthermore, complex structural settings over large areas can also create modeling problems. For intracratonic basins such as those in the Middle East, the problem is minimized in that the tectonic style is dominated by intersecting far-field vertical wrench faults of relatively low vertical separation. With such a model in mind, an exploration geostatistical workflow overcoming these issues can be constructed.

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Hydrocarbon Seepage Generation and Migration in the Southern Province from the Gulf of Suez, Egypt: Insight from Biomarker Characteristics and Source Rock Modeling

Active hydrocarbon seepage in Gebel El-Zeit area, southern Gulf of Suez province is associated with the Quaternary outcrop sediments. The oil seepage occurs in faulted zones on the western flank of the East Zeit Basin. The biomarker properties obtained from Gas Chromatography-Mass Spectrometry (GC-MS) proved that the hydrocarbon seepage possesses geochemical characteristics rich in tricyclic terpanes and extended hopanes with few diasteranes, typical characteristics of oils derived from marine siliciclastic source rocks with angiosperm land plants input as indicated from the higher proportion of oleanane index of 32.65% and low gammacerane index of 6.28%. The maturity parameter based on $[20S/(20S+20R)]$ -C29 aaa cholestane to the hydrocarbon seepage was found to be < 0.5 ; to indicate that the seepage was generated at relatively low grade thermal maturity. The hydrocarbon seepages correlate with the biomarker properties of Miocene crude oils, which were possibly derived from marine siliciclastic syn-rift Lower Rudeis shales rich in Tertiary angiosperm land plants. The incipient oil generation window is believed to have been generated at vitrinite reflectance in the range $R_o = 0.60-0.85$ at 3-4 million years before present (Mybp). The source rock distribution allows for extensive lateral and vertical migration through faults that reach the surface. Oil expulsion and migration began during Middle Miocene and still continuing at present in Gebel El-Zeit area. Hydrocarbon seepages may have also migrated from leaking accumulations.

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Stages of the Structural Evolution of the Red Sea - Gulf of Suez Rift, Egypt

Rift basins are potential oil provinces because they offer the structural and lithologic elements necessary for generation, accumulation and entrapment of oil. Fieldwork in the Red Sea area shows that rifts formation generally evolves through three distinct structural stages. 1) A reactivation stage, where deformation is dominated by reactivation of pre-existing fabric, dismemberment of the crust, and setting up its regional geometry, e.g., the formation of accommodation zones, which are controlled by Precambrian shear zones. Rift shoulders are defined in this stage by exploiting pre-existing fabric resulting in their characteristic zigzag pattern. Minor block rotation and local faulting perpendicular to rift axis occur at this stage. Movement on pre-existing faults controls locations and direction of sediment input points. 2) A linking stage where rift-perpendicular faults propagate along strike linking earlier reactivated faults via a system of relay ramps and transfer faults, which influences deposition of synrift sediments. Further displacement on faults allows fault block rotation and footwall uplift. 3) A mature stage, where the rift fault system reaches its maximum structural development forming through-going, basin-ward coastal faults that are generally perpendicular to the extension direction. Displacement on intra-rift faults increases while extension becomes focused along the rift axis. The rift reaches its greatest depth at this stage and deposition of reservoir-quality synrift sediment is minimal.

In the subsurface, it is expected that fault complexity is higher in blocks bounded by long, rift-perpendicular coastal faults, and that vertical stacking position of synrift sediments varies vertically and laterally according to rifting stage.

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An Integrated Approach to Optimizing a Large Asset-Static Modeling

The paper explains a new methodology to construct 3D static models of old fields. Massive amount of seismic and borehole data (167 wells), few core data, and engineering data were used to construct a 3D static model for Bakr-Amer field in the Gulf of Suez. This 14-km long field represents the central segment of a large NE tilted fault block. It produces oil from eight reservoirs made up of reefal limestone, fractured limestone and quartzose sandstone. Several problems were encountered while applying the well-known static model construction process (poor resolution of seismic data, old and missing well logs, and inadequate core data). After constructing the framework of the model, geostatistical approaches (Sequential Gaussian Simulation and CoSimulation) were used to populate the property model with petrophysical data (porosity, permeability, and water saturation) for each reservoir. This integrated approach led to the construction of the first reliable static model of the field. Drilling results of new wells confirmed the static model accuracy and validated the approach. The static model was also used to calculate the OOIP and to construct the dynamic model of the field. The flow simulation coupled with economical evaluation (described in a separate paper) was successfully used to optimize the field performance and increase the production rate.

This integrated approach can be used to construct reliable static models for fields with poor seismic data. The paper also suggests ways to overcome poor and/or missing data problems.

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An Investigation on Hydrocarbon Indicators in The Nile Delta

Significant gas reserves were discovered in the sedimentary section of the Nile Delta of Egypt. Gas bearing sands of different depositional systems were encountered in the Miocene and Pliocene sediments. Seismic amplitude anomalies have been associated with the Upper Paleocene deltaic sands of El Wastani formation, the Middle and Lower Paleocene sands of Kafr El Sheikh formation, the Upper Miocene fluvial channel sands of the Abu Madi formation, and the deep sand beds encountered in the steep dipping tilted fault blocks of Sidi Salim and Qantara/Teneh formations of Middle and Lower Miocene age.

This paper addresses the validity of seismic direct hydrocarbon indicators for the gas bearing sands of the Nile Delta. The data was processed using high resolution, well log data guided techniques. Several 2D dynamite lines and data from five wells were re-processed. Well log data was optimally edited through an integrated log analysis routine. The seismic processing sequence and the processing parameters were optimized by using 'Well Driven Seismic Processing'. The seismic resolution was maximized through a calibrated processing sequence, including post-stack space adaptive wavelet processing and inversion. Pre- and post stack seismic attributes were compared for discriminating between high seismic amplitudes due to hydrocarbon occurrence and lithological variations.

This study highlights the possibility of having significant hydrocarbon reserves in the on-shore Nile Delta that have not yet been discovered.

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Impact of Transfer Faults on Basin Evolution, Sedimentation and Hydrocarbon Accumulation

The geometry of a basin could change in depth and width from a uniform to non-uniform configuration due to the presence of transfer faults, with intensive impact on depositional environments along the basin axis. The basin is being shallower and narrower close to the transfer faults. Relative to the above depositional environments could gradually pass laterally from terrestrial to shallow and deep-water environments along the basin axis. The synchronous activity of synthetic and antithetic faults could create either intrabasinal highs or highs at the basin margins. Transfer faults that cross-cut intrabasinal highs produce pathways for the sediment distribution at both sides of the intrabasinal highs. Submarine fans sandstone lobes might accumulate at one side of the high and fine-grained deposits on the other side. The above basin evolution, with the presence of intrabasinal highs and pathways, could influence the development of hydrocarbon traps and reservoirs. Distributary channels that discharge into the basin are perpendicular to its axis and shift axially at the basin floor. Examples are referred to from the Gulf of Suez, Corinth-Patras extensional basin and Pindos foreland in Greece, where the impact of transfer faults on basin evolution, depositional environments development along the basin axis, sediment distribution, and potential hydrocarbon fields are possible.

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Comparison between Fan Deltas Formed in the Gulf of Suez in Egypt and in the Gulf of Corinth in Greece

Fan-delta systems that have been studied in Egion and Evrostina areas in Gulf of Corinth in Greece, were formed in restricted and narrow sub-basins at the margins of the main Corinth basin, due to the presence of an intrabasinal basement high, are characterized by the absence of toe-sets, and termed Trapezoidal-type fan-deltas. Evrostina fan-delta system is characterized by an upward change from trapezoidal-type to Gilbert-type fan-delta system, when the prograding system overstepped the high. Fan-delta systems that have been studied in Gulf of Suez in west-central Sinai in Egypt, were formed also in restricted sub-basins at the margins of the main basin also due to the presence of a pre-rift basement high. These fan-deltas are characterized by the absence of toe-sets, when they started to form, and gradually passed upwards to Gilbert-type fan-deltas. Both studied examples in Greece and Egypt are characterized by the absence of toe-sets. The later is related to very restricted conditions reducing the space that is necessary in order to develop the toe-sets, and for this reason when the systems overstepped the intrabasinal highs change from trapezoidal-type to Gilbert-type fan-deltas. From the other hand in Egypt the absence of toe-sets is related also to the amount of sediments during the first stage of their development. In both settings it seems that the presence of intrabasinal basement highs was the factor that influenced the type and development of fan-deltas. Trapezoidal-type fan-deltas gradually pass upwards to Gilbert-type fan-deltas when the prograding systems overstepped the intrabasinal highs.

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Appraisal of a Supergiant: The Kashagan Field, North Caspian Basin, Kazakhstan

The Kashagan field is located on the North Caspian sea, offshore Kazakhstan and is one the largest discoveries made in the last several decades. The structure was successfully tested by the Kashagan-East1 and Kashagan-West1 exploration wells, which penetrated a significant oil column in late Devonian-Carboniferous platform carbonates. The Kashagan structure developed as an isolated carbonate platform and is approximately 75 km length and 35 km width. Due to its areal extent and complexity of the reservoir, further appraisal is required to determine the true size of the Kashagan resource. Challenges of the appraisal program include operating in shallow, ecologically-sensitive waters subjected to harsh winter and ice conditions.

The Kashagan appraisal program includes acquisition of a state-of-the-art 3D seismic dataset and a sequence of wells which are designed to assess the potential of the structure as rapidly as possible. Due to water depths that range from 3 to 8 m, approximately 1600 km² of OBC seismic data will be acquired and processed to better image the reservoir. Appraisal wells have been strategically located to test the geological model and to assess reservoir quality across the structure. Well logs, core data and vertical seismic profiles are also used to tie in the 3D seismic data set in order to correlate reservoir intervals between wells.

The Kashagan-East2 and Kashagan-East3 appraisal wells support the presence of a platform rim with enhanced reservoir quality and strengthen the geological model. Further drilling and integration with 3D seismic will allow for continuing definition of the resource.

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The Relationship Between Oil-Gas Reservoir Formation And The Accommodation Space Changes of Songliao Basin, China

Using upper Jurassic-lower Cretaceous of Songliao basin as research target, the relationship between the accommodation space changes and oil-gas reservoir of the lacustrine basin were studied by the ways of comprehensive explanation of geochemical, drilling and core data. During the deposition of the first member of Qingshankou Formation and the first-second members of Nenjiang Formation, increasing tremendously of the accommodation space resulted in wide distribution of good source rock in which the amount of organic carbon was high and the type of organic matter is well. The accommodation space changes caused by tectonic and climatic period changes controlled the characteristics of source-reservoir-seal combination, and formed some types of combinations such as lower source-middle reservoir- upper seal combination et al.. The accommodation space changes controlled the evolution of sequence and the distribution of system tracts, and it is best for oil and gas accommodation that base fan and slope fan of lowerstand system tracts.

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Recent Applications of Turning-Ray Tomography And Tomostatics

Turning-ray tomography and tomostatics have been applied to areas with rugged topography and strongly variant near-surface geology. I review the methodology of turning-ray tomography and tomostatics, and show how the near-surface velocities estimated from turning-ray tomography are used for static correction, wave-equation datuming and prestack depth migration. Questions frequently asked will be highlighted to show 1) when and where tomostatics will work better than conventional refraction statics; 2) limitations of tomostatics; and 3) key steps to run tomostatics. Quality controls will be illustrated to ensure the robustness of turning-ray tomography and tomostatics.

Turning-ray tomography and tomostatics enhance interpretation and are applicable to areas where refraction statics often fail, such as thrust belts, high-velocity basalt or carbonate outcrops, unconsolidated low-velocity sand dunes, marine trenches and shallow gas cloud regions. Although it does not always provide better-stacked images than those from refraction statics, tomostatics are at least as good as refraction statics. Interpreters often find the near-surface velocity profile very useful when they determine a drill site.

Synthetic and field data examples have shown that the resolution of estimating a near-surface velocity model is directly dependent upon the picked first arrivals. Picking the first arrivals via a virtual reality system significantly improves the consistency of input data for the subsequent velocity estimation.

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Image Enhancement Below the pre-Khuff Unconformity Using Pre and Post-Stack Multiple Attenuation

One of the primary processing challenges within Saudi Arabia is the attenuation of multiples. One source of multiples is the pegleg multiples generated between the Jilh and the Khuff formations. This paper discusses several techniques used to minimize this energy, the effect on the final stack and ultimately, the interpretation.

The attenuation of this energy is accomplished through several means: 1.) The optimization of the velocity analysis by using demultiplied input. 2.) CDP based pre-stack demultiple algorithms. 3.) An inner trace mute. 4.) An interpretation-driven post-stack demult.

No one process is adequate, but each provides incremental improvements in the attenuation of multiples. Taken together, the first three provide an optimized stack through data processing alone. The last step, a post-stack demult, requires multi-discipline cooperation between processing and interpreting explorationists. This step flattens the data on the Jilh horizon, making the assumption that the pegleg multiples will be parallel to this event. A very narrow, surgically applied FK reject filter is applied to the data below the Khuff, with the intent of removing only flat-lying energy.

The interpretation of the pre-Khuff data becomes crucial in the final process, as primary energy is also removed if it is parallel to the Jilh. This process works best where there is a difference between the dip of the primary energy and the multiple energy. Two examples are shown in this paper: first, a dramatic subcrop beneath the pre-Khuff unconformity, and second, the image of a deep pre-Cambrian graben that is barely visible on the non-demultiplied data.