[PS]3-D Seismic Effective Integration Role in the Development of a Giant Offshore Field in Abu Dhabi, United Arab Emirates*

Raed El-Awawdeh[1], Haitham Al Junaibi[1], Jie Zhang[1], Kenneth Brantferger[1], and Gary S. Kompanik[1]

Search and Discovery Article #40900 (2012)**
Posted April 9, 2012

*Adapted from poster presentation at GEO-2012, 10th Middle East Geosciences Conference and Exhibition, 4-7 March 2012, Manama, Bahrain

[1]Zakum Development Company, Abu Dhabi, U.A.E. (raed.t.el-awawdeh@exxonmobil.com)

Abstract

During recent carbonate seismic interpretation projects of recently reprocessed 3D seismic data of an offshore field in Abu Dhabi, U.A.E., several carbonate intervals were mapped using post-stack Band-Pass frequency filtered amplitude and multi-attribute seismic volumes. Interpretation results of main reservoirs and overburden intervals played a major and an effective role in current and future drilling operations, project planning, and reservoir development scenarios.

Several examples from recent drilling, and reservoir and aquifer characterization projects will demonstrate how 3D seismic integration in field development can be critical for designing horizontal and highly deviated wells, planning disposal wells, and ultimately enhancing overall reservoir recovery through improved seismic based next generation geologic models.

Initial seismic processing and interpretation results and learnings were incorporated in latest reprocessing and reinterpretation strategy, where effective value of information methods were implemented in incorporating seismic impact on a major producing field. The paper will discuss briefly these methods but mainly concentrate on several reservoir/aquifer specific seismic impacts on field development and drilling activities examples from various locations within the field. Specific reservoir simulation examples will demonstrate seismic direct supporting role of well history match.

GEO 2012
10th Middle East Geosciences Conference and Exhibition

3D Seismic Effective Integration Role in the Development of a Giant Offshore Field in Abu Dhabi, United Arab Emirates

Raed El Awawdeh, Haitham Al Junaibi, Jie Zhang, Kenneth Brantferger, Gary S. Kompanik, - **Zakum Development Company, Abu Dhabi, U.A.E.**

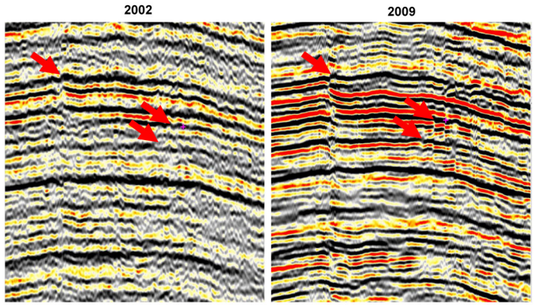
Abstract

During carbonate seismic interpretation projects of recently reprocessed 3D seismic data of an offshore field in Abu Dhabi, U.A.E., several carbonate intervals were mapped using post-stack Band-Pass frequency filtered amplitude and multi-attribute seismic volumes. Interpretation results of main reservoirs and overburden intervals played a major and an effective role in current and future drilling operations, project planning, and reservoir development scenarios.

Several examples from recent drilling, and reservoir and aquifer characterization projects will demonstrate how 3D seismic integration in field development can be critical for designing horizontal and highly deviated wells, planning disposal wells, and ultimately enhancing overall reservoir recovery through improved seismic based next generation geologic models.

Initial seismic processing and interpretation results and learnings were incorporated in latest reprocessing and reinterpretation strategy, where effective value of information methods were implemented in incorporating seismic impact on a major producing field. The paper will discuss briefly these methods but mainly concentrate on several reservoir/aquifer specific seismic impact on field development and drilling activities examples from various locations within the field. Specific reservoir simulation examples will demonstrate seismic direct supporting role of well history match.

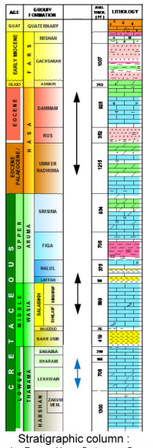
3D Seismic Data Quality – Seismic Processing



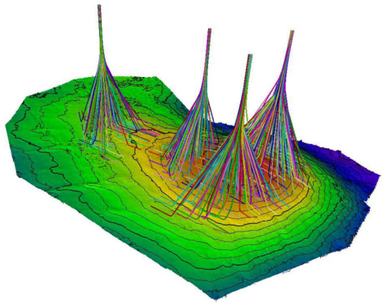
Seismic reprocessing comparison of 2002 vs. 2009 TWT seismic section showing data quality and fault throws at various reservoir intervals

Seismic reprocessing comparison example from northern area of the field showing clearly data improvement, where amplitude balancing, fault imaging improvement, providing higher confidence in horizon / fault interpretation, and identifying new faults with significant throws.

The key objective of this presentation is to show the effective integration of 3D seismic data learnings and range of uncertainties that impact the development of a giant offshore field in Abu Dhabi, U.A.E. The effective integration role of 3D seismic in current and future well planning, drilling activities, and during seismic to simulation modeling process.



Stratigraphic column :
Overburden Eocene-Upper Cretaceous Secessions
Lower Cretaceous Reservoir Targets



Future Artificial Island Based Well Trajectories
Relative to Reservoir Target Horizon

Carbonate Field 3D Seismic Reprocessing & Interpretation

Seismic data reprocessing strategy took into consideration the following steps to meet field development objectives. Processing flow was designed to be "physics based" to tackle data issues related to hard water bottom and complicated overburden (Reilly et al., 2008); and avoid "filters" that remove fault offsets. Apply consistent strategy for overburden issues, and produce multiple volumes for interpreters to use for different purposes.

Seismic reprocessing strategy took into consideration major field development activities planned with over 200+ wells in the next five. A Value Of Information (VOI) analyses was conducted to demonstrate business. Key drivers for VOI included increasing individual well productivity / recovery, identifying new drill well opportunities.

Value of Seismic Derived Subsurface Information Example

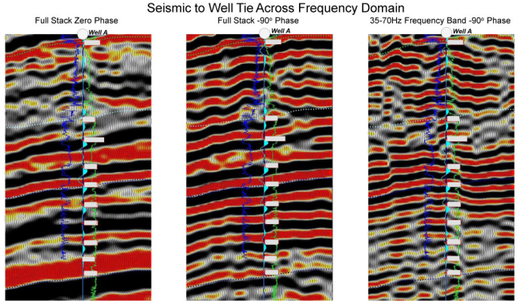
Possible Reservoir Management Outcomes (Assumption: 9 Rig Case-205 wells)	Area	Planned Wells in Area	Outcome C.O.O.	Increased C.O. Detection	Outcome Impact: Avg. IP BBLS/Day	Outcome Impact: Avg. Well: $M	Total Risked Impact: NPV $M
-Identify better locations relative to complex faulting	NE Crest / Flank	20	20%	40%	100	10.0	16.2

saving on well cost by preventing re-drills, and improving models for field development.

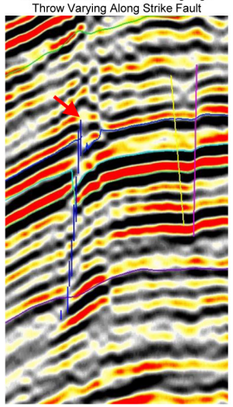
Seismic Interpretation strategy was also implemented to understand limitations of horizontal and vertical seismic resolution, impact of overburden geology, extensive QC of geophysical logs for well-seismic ties, use different data sets, workflows and tools for horizon interpretation versus fault interpretation, careful tracking of fault throws and confidence levels for modelers, and lineaments for well planning.

Frequency filtering techniques were implemented to better identify semi-vertical faults with varying throws across major reservoirs, where due to large reservoir thickness variations, well ties to different frequency seismic data was required.

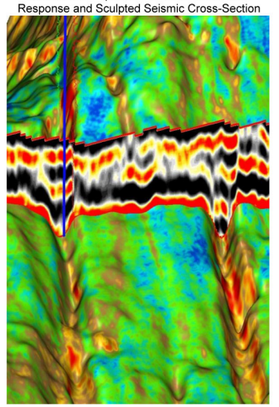
Seismic to Well Tie Across Frequency Domain



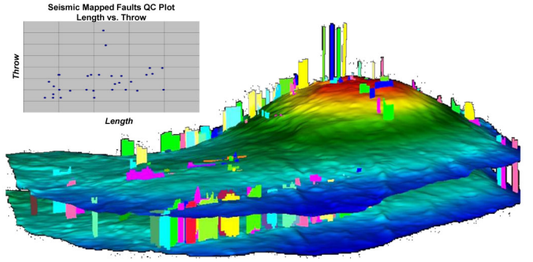
Seismic Cross-Section Showing High Throw Varying Along Strike Fault



Overburden Fiqa Channel Seismic Attribute Response and Sculpted Seismic Cross-Section

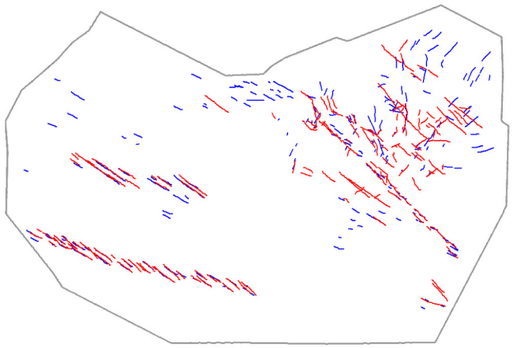


Interpretation of 2009 reprocessed seismic data resulted in a new and different structural framework, which will impact field development decisions. Details of major fault throw variations along strike were recorded and quality check plots of seismically mapped faults were used to track each fault's length versus throw to compare to 2002 interpretation results.

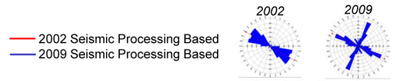


Three Dimensional View of Major Faults Across Reservoirs

Seismic interpretation of faults from 2002 versus 2009 reprocessed seismic significantly changed in the north-east area of the field, where many of the 2002 seismic based fault interpretations were not identified on the 2009 reprocessed seismic data. Final fault interpretation of 2009 seismic data resulted in low throw versus length fault ratio and north-east striking fault sets.



2002 vs. 2009 Seismic Based Fault Interpretation at Reservoir Intervals

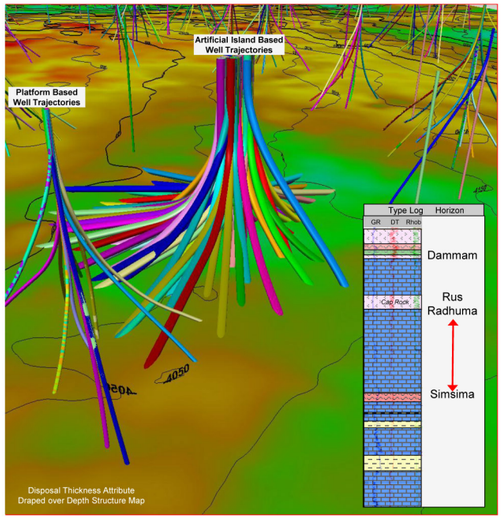


Fault Strike Comparison

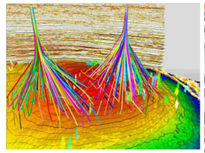
GEO 2012
10th Middle East Geosciences Conference and Exhibition

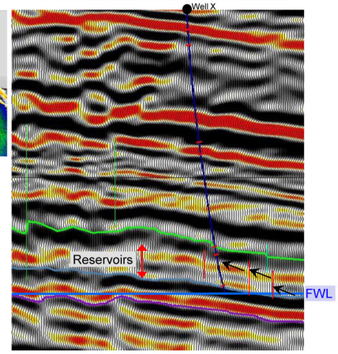
Integration With Development, Drilling, and Production

Additional value of effective 3D seismic integration with drilling was realized while supporting artificial island-based drilling well planning and initial island locations relative to shallow geologic hazards such as karsts. Ability to map hazardous faults, and karsts at overburden intervals, provided high confidence structural geometries to plan for future fluid disposal injection wells at various geologic zones, and reservoir long extended reach well planning.



Well X Observed High S_w - Possibly Reservoir Layers Are In Communication with FWL Through Faults



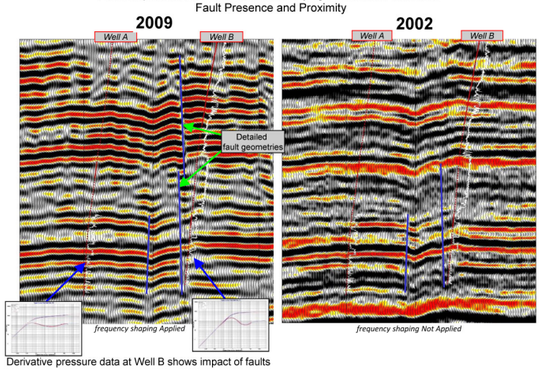


Well Location Relative to Faults and FWL

Island based drilling requires detailed and extensive fault interpretation at reservoir intervals to better understand fault fluid behaviors as observed at Well X example.

Improvements of seismic data from 2009 reprocessing and interpretation of frequency filtered 3D seismic data sets was successful in identifying faults responsible for production anomalies, where proximity and presence of these faults was supported by pressure data taken at both Well A and B.

2009 Reprocessed Seismic Data Identifying Production Anomalies
Fault Presence and Proximity

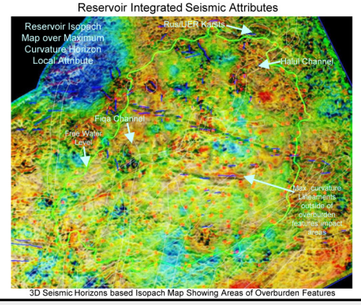


Derivative pressure data at Well B shows impact of faults

An integrated multi-seismic attributes analysis approach was used to build confidence in a 3D seismic based isopach maps modifications for production history matching model. Due to overburden seismic velocity pull-ups and push-downs imaging effects at reservoir surfaces, limits of each geologic feature responsible for any seismic velocity anomaly was identified and posted during the isopach maps modifications to ensure confidence in data. Seismic based isopach maps were used to modify Kh in certain areas of the field where more geologic details representing patchy high to low energy carbonate depositional environment geometries were more evident from seismic based maps. Well marker based isopach maps in this case under-estimated reservoir thickness in several areas between wells.

In same area of interest, several seismic attributes were utilized for fault interpretation to account for sub-seismic tuning small offset faults, where linear features on maximum curvature were identified and provided as possible high Kh areas for simulation team.

Reservoir Integrated Seismic Attributes



3D Seismic Horizons based Isopach Map Showing Areas of Overburden Features

Integration With Reservoir Simulation Modeling

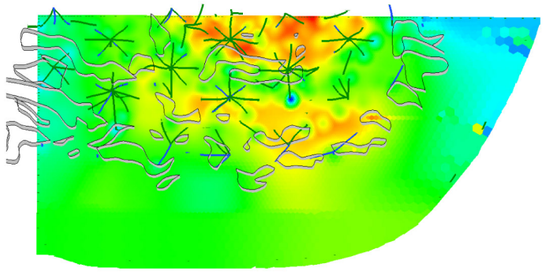
Within a 4 million cells static model which was initialized and turned dynamic, pressure matches were unachievable with the existent Kh map generated from well test permeability values adjusted to core permeabilities. After comparing pressure and injection rates provided by aquifer injectors / flank producers, clear compartmentalization effect was observed where aquifer injectors did not provide expected pressure support to flank wells.

Further investigation was carried out to find out a reasonable representation of this phenomena to enhance the quality of the simulation model. Three major assumptions came into play; Kh, a possibility of sub-seismic fracture corridor which could provide sealing effect, or a digenetic cementation deterioration in permeability that occurred across the wells due to the tilt in oil water contact.

Multiple FMI logs analyzed at reservoir interval where this phenomenon was observed exhibited a low to rare fracture occurrence within reservoir interval, which ruled out fractures as a cause. The digenetic cementation was plausible due to regional experiences within Abu Dhabi basin, but lack of conventional cores within the field limited further investigation.

Investigation of possible Kh relationship was then taken into consideration; where either k or h had a major role of reducing the connectivity, and support.

Seismically derived reservoir thickness maps were compared to well marker derived thickness values; which resulted in multiple regions with differences of 20 to 30 feet, which resulted in significant reduction in Kh between aquifer injectors and flank producers. Map example below shows polygons created to display regions of difference within the mentioned range.

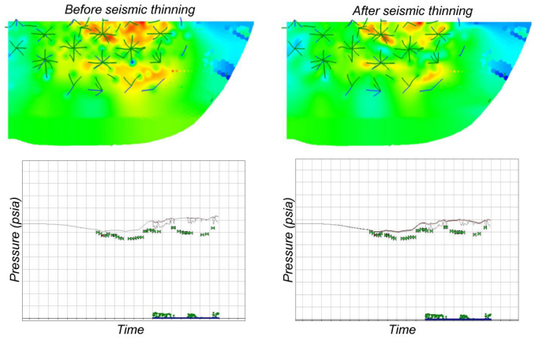


Seismic thinning on original Kh map

Acknowledgments

We acknowledge the help and support of ADNOC (Abu Dhabi National Oil Company) and ZADCO (Zakum Development Company). Island based well data loading and Geoscience support was provided by Audrey Reznik (ExxonMobil). Critical comments and directions were also provided by Gene Skeith (ExxonMobil secondee to ZADCO).

The polygons bounded the regions thickness were then provided to simulation team for trials and analysis, where each boundary polygon was modified to its respective Kh decrease in value. Maps and plot examples below show a well before and after applying the "seismic thinning" and the resulting improvement of the history match.



Adjustment to Kh and HM improvement

This exercise represents direct influence of integrating 3D seismic in modeling giant offshore field and eventually improving quality of dynamic model therefore boosting confidence in prediction runs for future field development plans.

Conclusions

Effective 3D seismic integration with development, drilling, and production modeling resulted in meeting technical objectives through improved seismic data quality where Pre-project estimate of business value from processing was achieved through an effective 3D seismic processing and interpretation integrated approaches, where both have direct impact on business realizations measured by the following:

- Increase individual well productivity and recovery
- Identify new drill well opportunities
- Save on well costs by preventing re-drills
- Improve geologic and simulation models driving field development

References

El-Awawdeh, R., Khouri, N., Neyadi, A., Shevchek, Z., Shebl, H., Edwards, H., Gombos, A., Johns, M., 2008, 3-D Seismic Evidence of Tertiary-Cretaceous Karsts & Collapse Disturbance from Offshore Oil Field in Abu Dhabi and Outcrop Analogs from Jebel Hafit, United Arab Emirates: Society of Petroleum Engineers, SPE 118006

El-Awawdeh, R., Khouri, N., Neyadi, A., Al-Suwaidi, M.H., Williams, M., Zhang, J., Al-Neyadi, A., Shebl, H., Edwards, H., Shevchek, Z., Gombos, A., Johns, M., 2010, 3-D Seismic Evidence of Tertiary-Cretaceous Karsts and Cretaceous Marine Channels from Offshore Oil-Field in Abu Dhabi and Outcrop Analogs from United Arab Emirates: Geo2010 Conference

El-Awawdeh, R., Zhang, Shevchek, Z., Khouri, N., Mirza, A., Harris, C., Reilly, J., 2010, Carbonate Enhanced Seismic Mapping Using Post-Stack Band-Pass Frequency Seismic Volume Filtering of Two Offshore Fields in Abu Dhabi, United Arab Emirates: Geo2010 Conference

Shevchek, Z., El-Awawdeh, R., Khouri, N., Sultan, A., 2010, Impact of Improved Seismic Data in a Mature Carbonate Production Setting, Offshore Abu Dhabi, UAE: Society of Petroleum Engineers, SPE 137194

Reilly, J., Shatilo, A.P., Shevchek, Z.J., 2010, The Case for Separate Sensor Processing: Meeting the imaging challenge in a producing carbonate field in the Middle East: The Leading Edge, SEG

Modavi, A., Al Muflehi, A.H., Tarmoom, I.O., Al Khatheeri, B.S., Noman, A.M., 2011, A Super-Giant Offshore Field Development Plan Change from Steel Structures to Artificial Islands, OTC 22015

Branferger, K.M., Al-Jenaibi, H.M., Patel, H., Al Harbi, A.S., Kompanik, G.S., Mubarak, M., 2011, A Team-Based Approach to History Matching a Long-History, Giant Carbonate Reservoir Using Sector Models and a Domain Decomposition Workflow, SPE 148386