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A Direct Hydrocarbon Indicator Method and Results of a Demonstration of Capabilities in Abu Dhabi*

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Search and Discovery Article #40895 (2012)**

Posted March 31, 2012

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

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Abstract

Today's earth scientists have a sophisticated array of imaging tools to focus their exploration efforts. Downhole geophysics, and 2D and 3D seismic imaging are some of the tools most often used by petroleum explorationists to find and exploit hydrocarbon resources.

Unfortunately, no single technology has the current capability to answer all of the questions posed by the exploration professional; each offers its own unique view into the subsurface and, when used together in a complementary fashion, helps build a more complete picture of the petroleum system and/or the reservoir. As the challenge of finding and efficiently exploiting our petroleum resources continues to mount, so, too, has the need to advance and improve these mainstream technologies in order to maintain acceptable levels of risk.

Surface geochemical techniques have been used to explore for hydrocarbons since the late 1920s. These techniques look for the presence and effects of minute levels of hydrocarbons that migrate through the imperfect seals that cover every reservoir and migrate either as macroseepage via faults or as microseepage vertically through the reservoir overburden (Klusman, 1993, Coleman *et al.*, 1977). Some of these early techniques were crude and included soil analysis, active soil gas sampling and analysis, iodine mapping, and counting microbial populations. Unfortunately, exploration results using these early geochemical techniques were often disappointing, the result of a host of complicating factors such as:

- heterogeneous soils (matrix, moisture, organic content, permeability);
- in-field and laboratory sampling error and loss effects;
- limited data range (usually only C1 to C6);
- use of indirect indicators (e.g., microbial populations as indicator of hydrocarbon presence and amount);

- failure to use statistical methods to demonstrate correlation of measured signal to charged reservoir rather than more widespread petroleum system sources.

This poster provides a brief overview of the application of a modern surface geochemical technique, which overcomes the limitations of prior methods. A brief summary of a recent demonstration of the capabilities of this technology near an oil and gas field in Abu Dhabi is presented.

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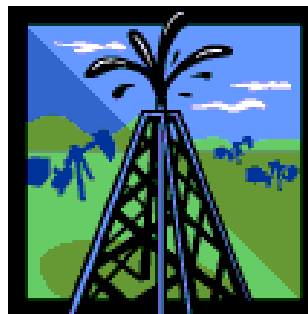
"Amplified Geochemical ImagingSM" Services

A Direct Hydrocarbon Indicator Method & Results of a Demonstration of Capabilities in Abu Dhabi

Prepared for:
GEO 2012, 10th Middle East Geosciences Conference and Exhibition
Bahrain
4th -7th March, 2012

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شركة أبوظبي للعمليات البترولية البرية (أدكو)
Abu Dhabi Company for Onshore Oil Operations (ADCO)



Outline

- Overview of Amplified Geochemical ImagingSM Technology
- Results of UAE Demonstration Project
- Questions



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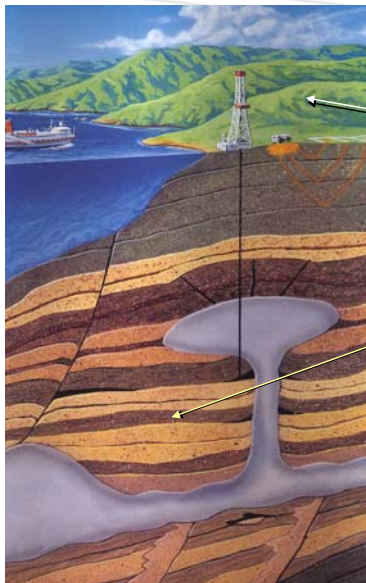


Presenter's Notes: The field of medicine provides a good analogy to the challenges in oil & gas exploration:

- Medical professionals rely on a host of sophisticated non-invasive imaging technologies (CAT, PET MRI, X-ray, etc.) to diagnose and treat disease deep in the human body.
- Good imagery allows surgical procedures to be targeted and increasingly precise to:
 - reduce surgical trauma or complications,
 - speed patient recovery,
 - minimise long term medical costs
 - Ultimately achieve a higher rate of successful patient outcomes

Petroleum Exploration's Challenge

Interpreting the Unseen - Mainstream



- **Surface Geology**
 - Aerial photos / Satellite
 - Geologic maps

- **Subsurface Analysis**
 - Gravity
 - Magnetics
 - Seismic reflection
 - Wells – Petrophysics - Logging
 - SR Geochemistry/Basin Modeling

Source: Modified from AAPG, The Quest For Energy
http://www.aapg.org/slide_bank/armenrout_john/index.shtml

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 The Ministry of Oil



Presenter's Notes:

- Just like Medical professionals, so too the exploration professional relies on ways to image what normally cannot be seen.
- Surface mapping
- Mainstream Subsurface technologies
- Often overlooked....surface geochemistry
- Surface geochemistry:
 - Has a long and mixed history of use since late 1920s
 - Is often overlooked and under utilized.
 - However, developments in material and polymer science, analytical instrumentation and computer technology have allowed significant improvements over the past 15 years making Amplified Geochemical Imaging technology an invaluable component of the exploration and exploitation process.
 - Not limited by trap type....structural or stratigraphic traps can be imaged by geochem

So, where does surface geochemistry fit in?

Petroleum Exploration's Challenge

Interpreting the Unseen - Mainstream



- **Surface Geology**
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 - Magnetics
 - Seismic reflection
 - Wells – Petrophysics - Logging
 - SR Geochemistry/Basin

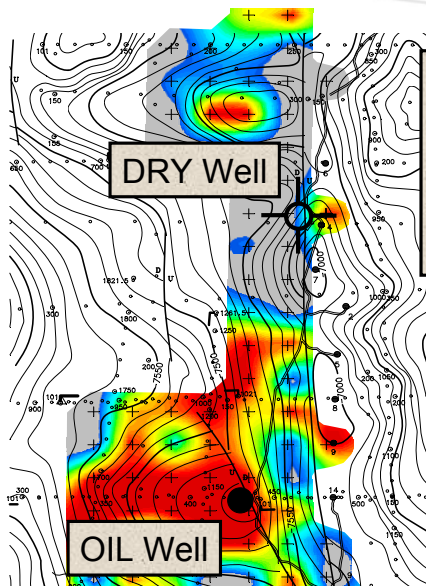
Mod - **Surface Geochemistry**

Goal

- Understand the Petroleum System
- Build Energy Reserves
- Limit Risk & Increase Success Rates
- Reduce Finding & Exploitation Costs

Source
<http://www.gore.com/surveys>

Benefit of Adding Surface Geochemistry to Exploration Programmes



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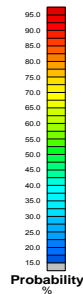
Answer Fundamental

Questions:

- **Frontier Acreage:** Is my concession prospective (evidence of a petroleum system)?
- **Exploration:** What is the charge potential in my concession or in defined leads? Reduces drilling risks
- **Field development:** What are the extents of the field and/or bypassed pay?

Onshore & Offshore Capability

Direct Hydrocarbon Indicator



الجمعية الوطنية للعلوم الجيوساينسية
The National Geoscience Center



Presenter's Notes: The short answer: It can be used at any stage in the exploration and exploitation process!

- Frontier
- Exploration
- Field development

With the right technology they can be used in ONSHORE and OFFSHORE environments and, when properly applied, can yield direct evidence of hydrocarbon charge.

Various “Microseepage” mechanisms have been proposed:

- 1) Diffusion - gradient movement of dissolved gases
- 2) Aqueous transport - movement in ascending water
- 3) Continuous gas phase flow

Favored mechanism:

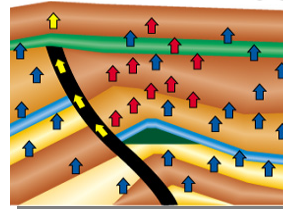
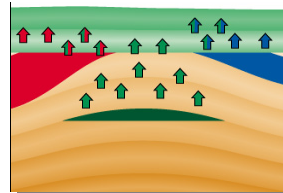
- 4) Microbuoyancy - transport in buoyant microbubbles
 - Direct surface projection of reservoirs
 - Migration in the absence of faults
 - Rapid changes in surface anomalies as production starts

Klusman, R.W., and M.A. Saeed, 1996, Comparison of light hydrocarbon microseepage mechanisms, *in* D. Schumacher and M.A. Abrams, eds., Hydrocarbon migration and its near-surface expression: AAPG Memoir 66, pp. 157-168.

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**“Vertical
Migration
Mechanisms”**

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الجمعية الجيوساكنة
الشرق الأوسط



Presenter's Notes: All surface geochemical techniques rely on one fundamental concept; that hydrocarbons migrate to the surface in measurable amounts...even through perfect seals.

Two types of seepage:

1. Macroseepage (from discrete geological features, high volume, visible, offset from source, requires conduits)
2. Microseepage (molecular scale, detectable only through sensitive sampling and analysis, vertical, rapid, along grain boundaries)

Bottom line:

- Microseepage migration is now a well documented phenomenon. This is the focus of this technology.
- It is a complex process that is not perfectly well understood
- With so many sources, how do we know which hydrocarbons derive from an accumulation and which derive from more pervasive background sources?
- Reliance on the measurement and distribution of a few compounds or other parameters is not enough and requires certain assumptions that may not be valid in the area of interest.

Some Challenges:

- **Skepticism**
- **Data collection**
 - Sensitivity (ppt to ppb)
 - Consistent and reproducible
 - Reduce field sampling and/or lab preparation error
- **Natural signal variability**
- **Signal measurement**
 - Wide range (C_2 - C_{20}), high sensitivity (nanograms – 10^{-9} g)
- **Interpretation of the data**
 - What is the source of the measured geochemical signal?
 - Developing a valid the model that is predictive of actual charge

Passive sampling systems and multi-variate statistical modeling techniques are well suited to gathering and interpreting the available surface geochemical signal.



Presenter's Notes: Some challenges in surface geochem sampling:

- Multiple source contributions to the measured signal
- Signal variability...soil matrix/moisture effects, local ecosystem variations (plants, environment etc)
- Signal collection
 - Have high sensitivity
 - Reduce sampling loss or error
 - Reduce sample handling and preparation in the laboratory – which can contribute to further loss

Adopt an empirical approach with no assumptions:

- Measured signal is a mixture contributed from multiple sources
- What components of (or contributions to) the measured signal actually correlate to oil or gas reservoir charge?
- Use of multivariate statistical model approaches can help “deconvolve” these complex signal contributions.

Passive, adsorbent-based, systems are well suited to this task



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*A Direct Hydrocarbon Indicator Method
and*

Results of a Demonstration of Capabilities in Abu Dhabi

A Pilot Survey

Southern Abu Dhabi, UAE

Survey Objectives

Assessment of surface “Amplified Geochemical ImagingSM” technology in the vicinity of a known field in southern Abu Dhabi:

1. Validate Technology:

- Demonstrate ability to image existing oil field boundaries

2. Prospectivity Assessment:

- Help de-risk several seismically defined prospects/leads south of the field
(NOTE: location and size of leads withheld from GORE)

Background

Geological Setting:

- Lower Cretaceous period:
 - Abu Dhabi part of a broad carbonate ramp on the southern Tethyan margin with a local intrashelf basin.
 - This regional carbonate system hosts many of the giant oil fields in the Middle East (Melville et al., 2004).
- The XY oil field:
 - High-API oil was discovered in 1965 with subsequent exploration leading to discovery of other hydrocarbon-bearing zones, including gas (Melville et al., 2004).
 - Thamama Group reservoir is a layered carbonate system.
 - Multiple stacked reservoir zones

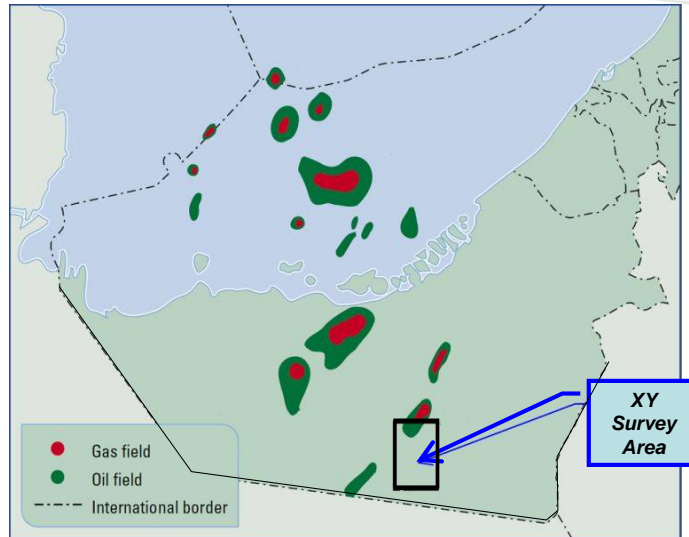


Presenter's Notes: The Lower Cretaceous (Thamama Group) reservoir is a layered carbonate system, characterised by cyclic deposition of alternating high-energy skeletal-peloidal packstone-grainstones and low energy skeletal wackestones-lime mudstones.

XY Field: Elongate, faulted anticline measuring about 30 kilometres in length by about 10 km. wide. Axis oriented NE-SW.

Background

Petroleum System Setting – XY Area and Main Regional Oil Fields



MAP SOURCE: http://www.slb.com/~media/Files/resources/mearr/num1/united_approach.ashx

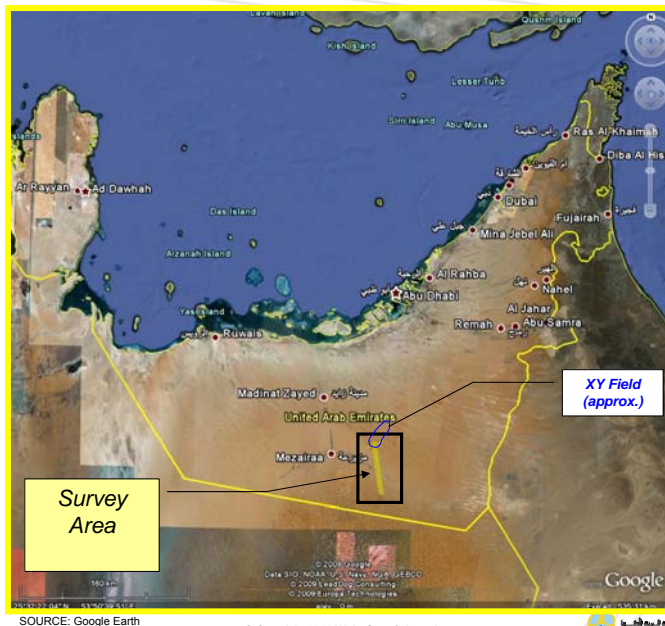
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Presenter's Notes: Main regional Oil and Gas fields, Timeline: Actual duration of project: 4 months (mobilization to report)

Regional Setting & Survey Area Location



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SOURCE: Google Earth

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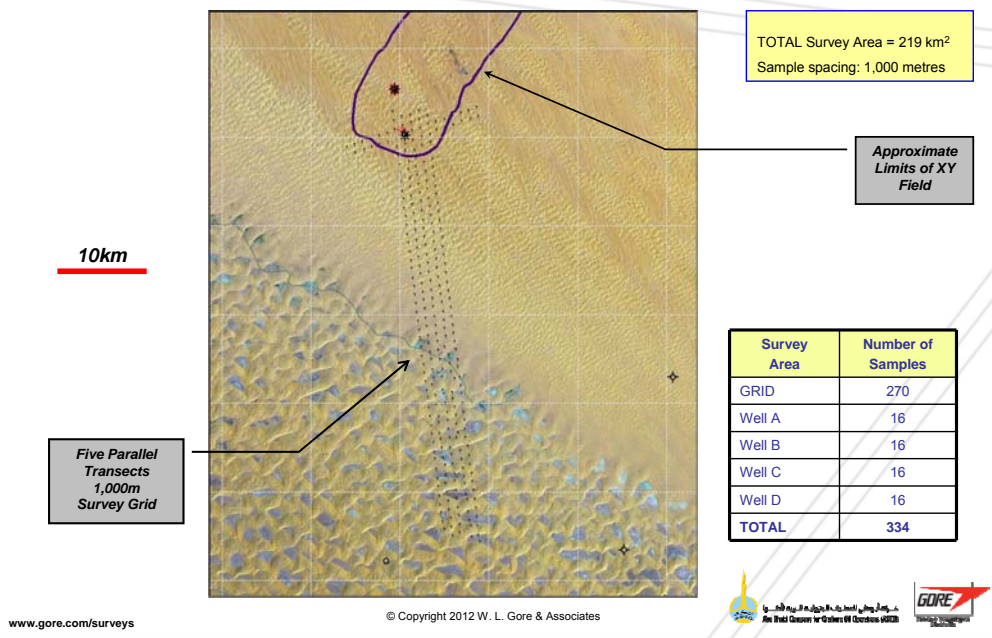
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The United Arab Emirates Ministry of Oil



Presenter's Notes: The survey area centered about 155 km. SSW of Abu Dhabi

- Narrow (4km wide) fairway that extends about 50 km in a southerly direction from the southern end of ADCO's giant XY oil field.
- Medium to very large desert dune topography.
- Salt sabkha flats in the region of the Liwa Oasis.
- Survey area virtually devoid of vegetation (with exception of farms and settlements in the Liwa Oasis)

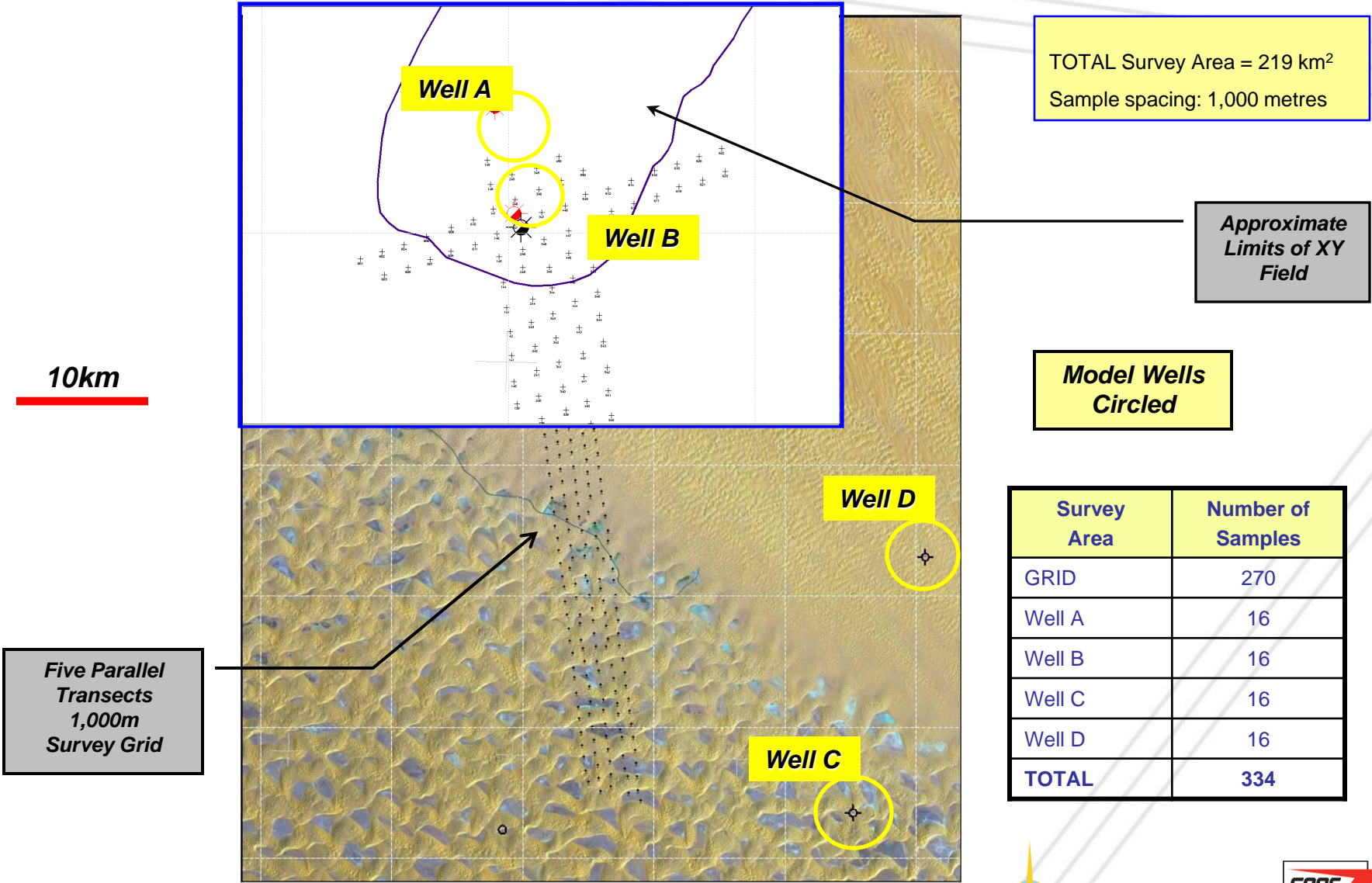
Survey Location and Model Sites



Presenter's Notes:

- Design generally comprised five parallel transects one-kilometre apart and oriented generally N-S.
- Along each transect, grid samples were spaced at intervals of 1km.
- Samples were also installed along two parallel transects aligned more or less perpendicular to the main fairway. They cross the SW and SE margins of the XY oil field and extend "off structure".
- Samples were installed at two hundred seventy (270) grid locations within a narrow fairway measuring roughly 50km long by 4km wide.
- The fairway extends in a southerly direction from just inside the southern margins of the giant XY oil field and reportedly crosses several structural prospects or leads located south of the XY field (locations unknown to GORE).
- Total survey area coverage is approximately 219 km².
- Sixty-four (64) samples were used to acquire geochemical model calibration data from a total of four well sites (regional analogues, including oil, gas & condensate, and background sites).
- All grid and model samples were installed by one field team
- Good access to the survey area: existing blacktop roads to ADCO's XY oil field, and to Liwa Oasis. 4-WD vehicles essential for transit throughout the survey area.
- Field work completed in 6 weeks including a short administrative delay. Entire duration of project: 4 months

Survey Location and Model Sites



Model Site Information

MODEL WELLS

	STATUS	Comments
Well A †	Gas & Condensate producer	Multiple stacked reservoirs containing either oil or gas & condensate
Well B †	Gas & Condensate producer	Multiple stacked reservoirs containing either oil or gas & condensate
Well C	Dry/Background	TD in Lower Cretaceous Thamama zone G.
Well D	Dry/Background	TD in Middle Jurassic at ~10,901 (sub-sea). Several horizons with residual oil shows interpreted to be either palaeo-oil column (remigrated) or migration pathway

† Wells A and Well B each produce gas and condensate.

However, these well sites exist in a stacked petroleum reservoir system that also includes multiple oil-bearing horizons.



Presenter's Notes:

- Although the model sites were BOTH gas & condensate producers, the signal we measured actually incorporates oil phase contributions.
- Therefore, the sum total of all hydrocarbon conditions vertically below these two sites represents the “sweet-spot” of the model

Analysis and Processing – General steps

- **Sample Preparation**
- **Laboratory Analysis**
- **Data Pre-Processing**
 - reconciliation & fitness for use
 - S/N
 - PCA and outlier analysis
 - analysis of system variance
- **Geochemical Model Development (DA)**
- **Mapping of Results**

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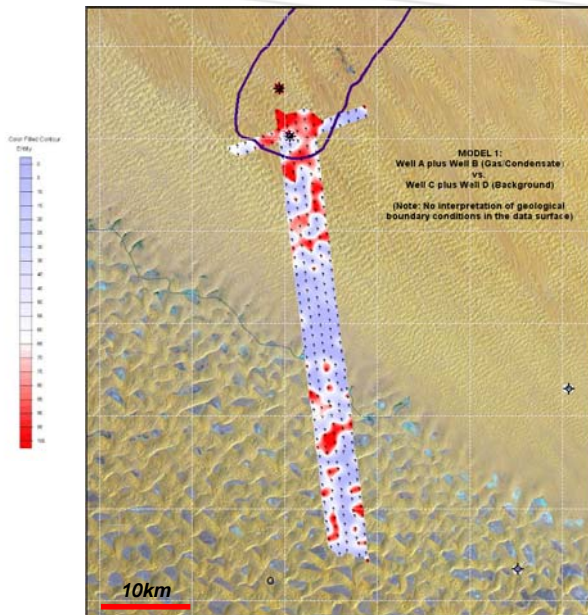
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Presenter's Notes:

- Preparation – includes randomisation
- Laboratory Analysis
 - GC/MS – 85 compounds (C₂ to C₂₀) - results reported to 0.01 nanograms
 - Calibration Standards & QC samples & duplicates (30% of total project samples)
- Data Pre-processing
 - Sample Reconciliation
 - Fitness for Use Analysis (*Passed*)
 - Signal to Noise processing of mass data
 - Data Transformation Using Principal Component Analysis (PCA)
 - Removes redundant compound-compound correlations
 - Isolates principal signal patterns in data (predictors)
 - Identify and Remove Outliers (redo PCA if necessary) – *No Outliers*
 - Assess System Variance (instrument drift, team-team effects) – *None found*
- Geochemical Model Development
 - Evaluate model calibration data for reasonable signal content
 - Discriminant Analysis (DA) Classification
 - Model calibration data sets define group classes (model end-members)
 - Determines which predictors (data patterns) best separate the end-member sets
 - DA assigns class membership to each unknown grid sample - % probability of match
 - Method precision – prediction of duplicates (87%)
 - Map model probability values & benchmark with other G&G

XY Oil/Gas & Condensate-Like Probability Distributions (2-Way model 1)



Geochemical Map:

- Warm colours – high probability values (positive anomalies)

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**Presenter's Notes:** Geochemical Model for XY Area

The mapped results reveal several key features

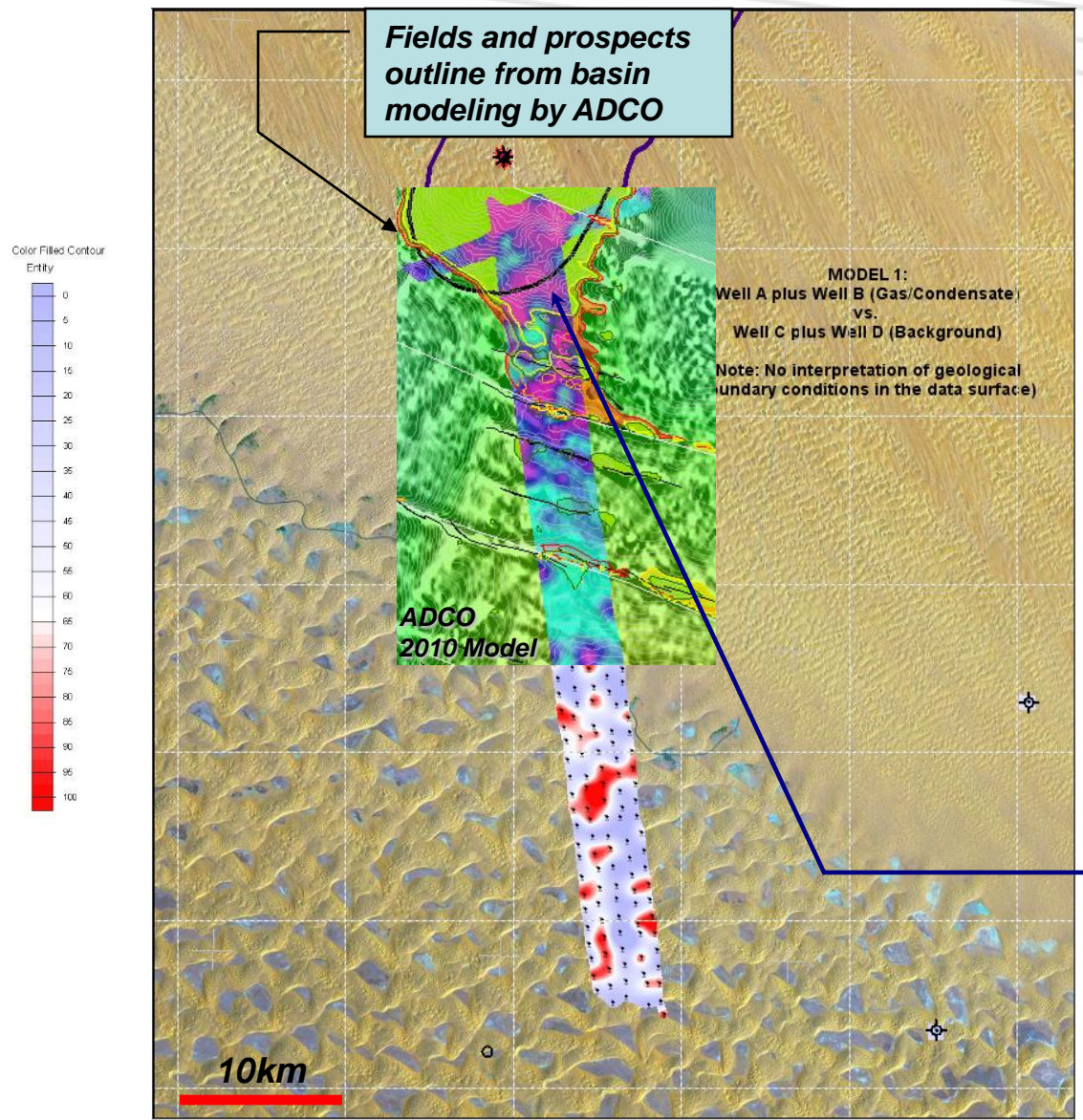
- Model yields anomalous response across the existing XY field - **establishes the geological validity of the model.**
- The models yield several moderate size geochemical features outside the XY field - Highlights prospective regions and areas that do not appear prospective.

Exploration programme decisions generally improve as the amount of geological information increases, and involve risk reduction strategies that require integration of qualified data from geological and geophysical sources.

Many of the organic compounds detected and quantified using passive geochemical sampling, are thermogenic in origin and thus part of the regional petroleum system.

The model-derived geochemical anomalies are based on the distinction between complex geochemical signatures (using pattern recognition techniques) over reservoir and background areas rather than measurement of individual or compound suite intensities. Surface geochemical data offer an additional layer of information to better constrain assessments of hydrocarbon prospectivity or petroleum charge potential.

XY Oil/Gas & Condensate-Like Probability Distributions (2-Way model 1)



Geochemical Map:

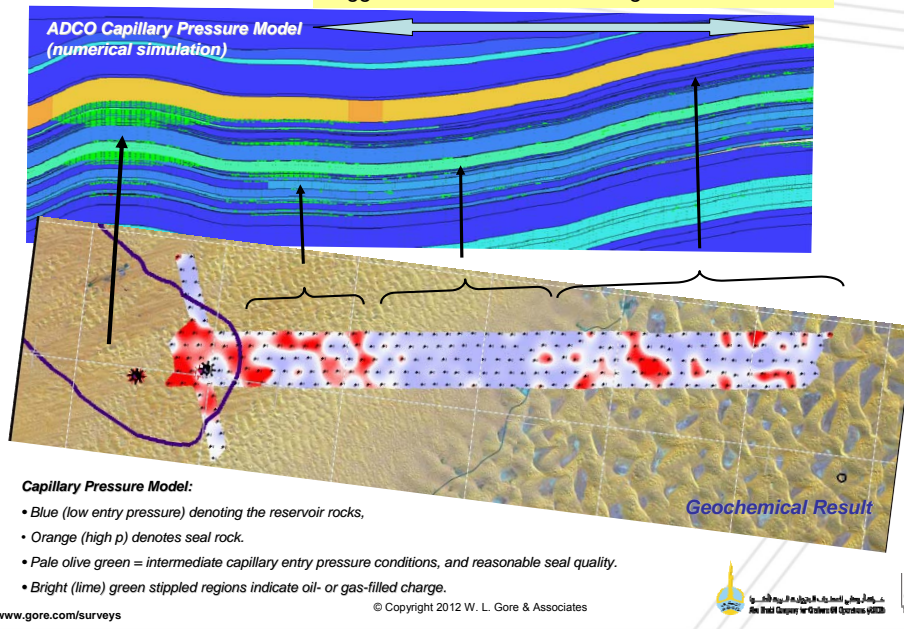
- Warm colours – high probability values (positive anomalies)

Basin Model/Seismic Overlay:

- Green depth map with edge filter applied (enhance fault visualisation)
- Yellow, Orange and Red polygon (with green fill): Basin modeling results taking into account different fault sealing capacities

GORE Geochemical & Basin Modeling suggest extended field delineation potential

Exploration, which is still in evaluation stage, suggests similar distribution to geochemical result.



Presenter's Notes: The coloured section is a capillary pressure model (result of numerical simulation).

- Blue (low entry pressure) denoting the reservoir rocks,
- orange (high pressure) denotes seal rock
- Green (pale olive green layer for example) indicated some intermediate capillary entry pressure conditions, and presumably reasonable seal quality.
- Bright (lime) green stippled regions indicate oil- or gas-filled charge.

Summary & Conclusions

- ✓ **Robust Geochemical Model Developed**
- ✓ **Survey objectives achieved**
 - ✓ Imaged XY Field – proof of capability and model validation
 - ✓ Identified possible southerly extension to field
 - ✓ Highlighted other prospective and non-prospective areas
 - ✓ ADCO basin modeling is consistent with the geochemical imaging results
 - ✓ Can help focus future activity



Presenter's Notes: Geochemical Model

- Predicted distribution of hydrocarbon charge in the southern portion of the XY field consistent with known field boundaries. This is geological validation of the geochemical model results and proves effectiveness of technique.
- Several regions of anomalous response outside the XY field
- Results adequate for focusing new exploration activity
- Integration with other G&G required
- Technique to be used as complementary technology – NOT a stand-alone exploration tool.
- The sampling density was reconnaissance scale and is not sufficient for siting a new well.
- Follow-up high resolution geochemical survey data acquisition may be appropriate as part of any future drilling decision in these areas.

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Thank you.

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