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2008 – Issue 5

Saudi Arabia oil & gas

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Inside

Drilling Symposium

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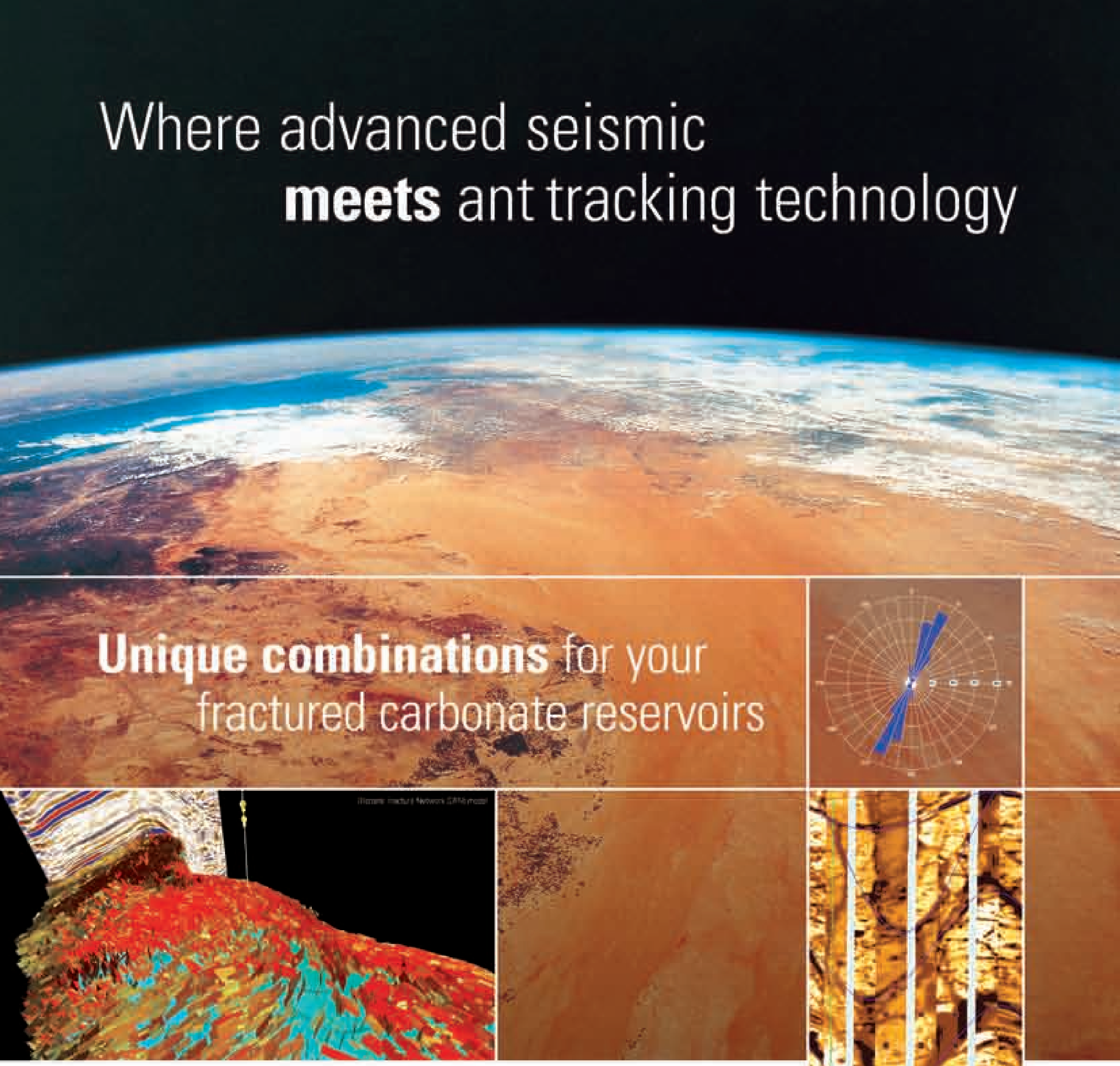
OGEP Meeting Review



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2008 – Issue 5

Saudi Arabia Oil & Gas

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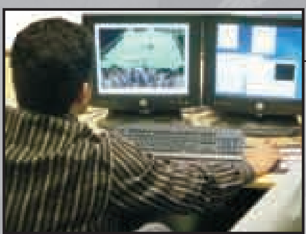

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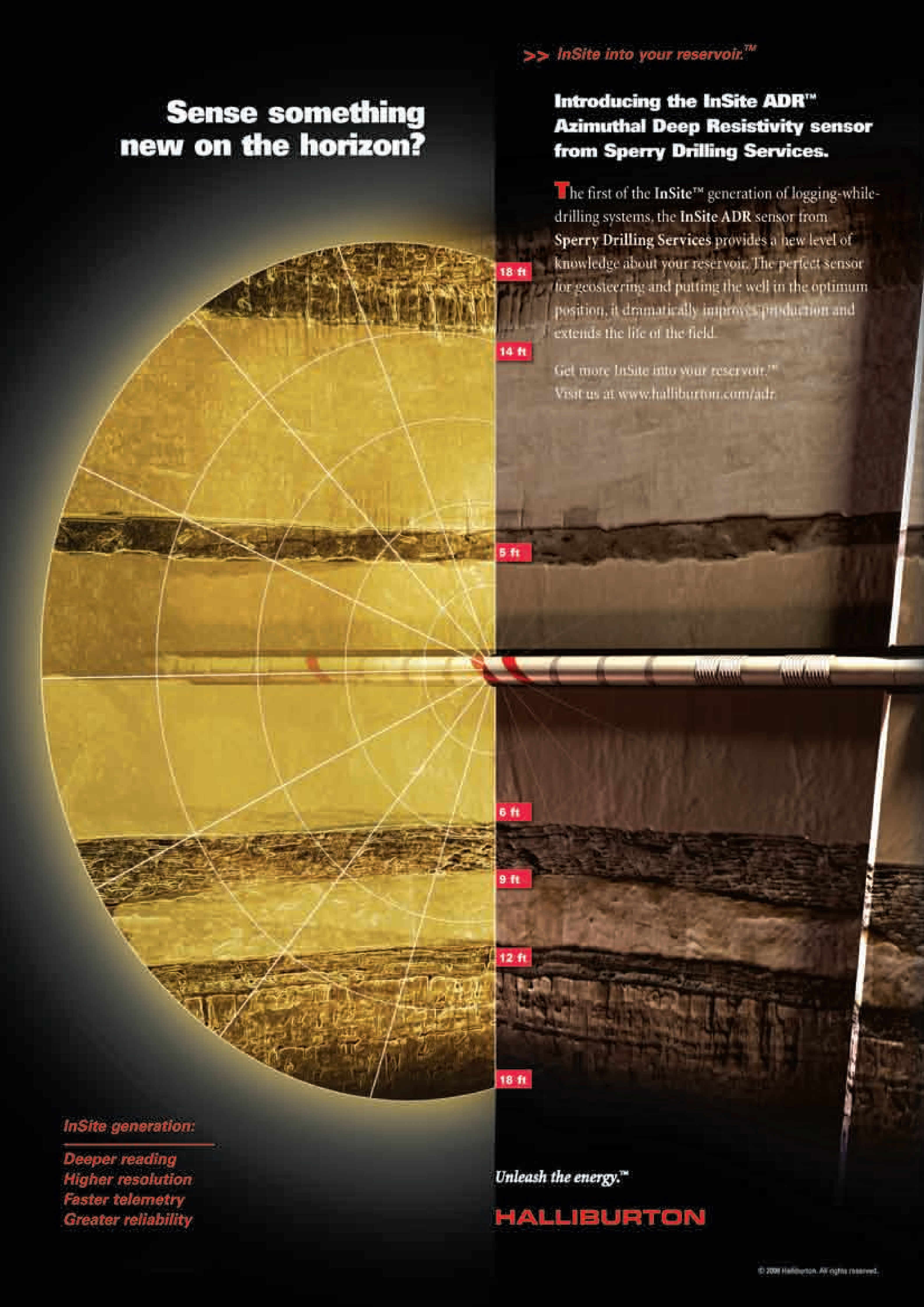
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NOTE FROM THE CEO

On behalf of EPRasheed's Signature Series, I am pleased to pen this note for issue 5 of our exciting publication Saudi Arabia Oil & Gas.

EPRasheed is an innovative Oil and Gas publisher that has a truly international and diverse workforce that hail from all over the world. We are the first oilfield publisher to think globally – ie to look strategically at global EP markets and invest time and money in developing innovative products and pioneering projects.

Founded in 2004 by Wajid Rasheed, EPRasheed focuses on select National Oil Companies and EP technologies worldwide (see www.eprasheed.com). Some of these markets are Saudi Arabia, Brazil, Norway and Trinidad and Tobago.

The EPRasheed Signature Series has taken shape over the past 4 years as we have interviewed over 100 senior execs ie Petrobras President Jose Sergio Gabrielli, Statoil (US) President Oyvind Reinertsen, Lisbeth Berge Permanent Secretary Norway Petroleum Ministry, Petrotrin President Operations Wayne Bertrand and countless technology, corporate and operations managers.

Saudi Arabia Oil & Gas - Technology

In the case of Saudi Arabia Oil & Gas – we see EP Technology as a foundation of certainty of supply and countering the doomsayers. The doomsayers do not have a geological (carbonate reservoirs) or drilling (geosteering) or completions (minimizing reservoir damage) or production (maximising reservoir sweep) background.

But they are good marketers. Oilfield technologists despite their importance are however not that good at marketing.

Technology is key to dispelling the historically recurrent Peak Oil claim. Technology is a basis for calming markets as it enables new reserves to be found and produced. Therefore, our interest lies in technology at all stages of its development - from solving well, field and asset challenges to run data and applications analysis to laboratory R&D projects exploring fundamental concepts.

Kingdom of Saudi Arabia Leads in Oil and Gas

The Kingdom of Saudi Arabia is leading the region and arguably the world in terms of certain types of Oilfield technology development and uptake. Exemplifying this is Saudi Aramco which has some of the industry's most revolutionary technology and advanced software.

Think OSPAS, OCC, Geosteering, Event Solution and Extreme Reservoir Contact.

Furthermore the KSA's National Plan for Science and Technology and the recent OGEP conference highlight the growing trend toward RD.

Saudi Arabia Oil & Gas was the Official Journal of the very successful 1st OGEP Conference and Exhibition held in Riyadh in January which was held under the auspices of the Minister of Petroleum and Mineral Resources HE Ali Al-Naimi and organised by KACST.

Read more about OGEP in the in-depth feature on page 10. Another event of note was the Saudi Aramco Drilling Symposium organised by the KSA SPE in Dhahran further details are to be found on page 42.

These events provide a rare glimpse of future technologies – Nanotechnology, the e-Field, 4D-Seismic and super-fast processing and Real Time Geosteering. The possibilities are constrained only by our imagination and vision.

Let's consider how countries such as Norway and Brazil have reached production in 'incredible' conditions. By using complex subsea tie-ins and floating production systems in Arctic and Ultra-deepwater plays reaching near 3,000m water depth, we see a remarkable increase in bookable reserves and production.

Imagine how much more can be done for less harsh environments such as Saudi Arabia?

We look forward to your comments – ultimately our readers' guidance will help make Saudi Arabia Oil & Gas a success.

So pick up your pen - write to:

wajid.rasheed@eprasheed.com

Enjoy the magazine.

"EPRasheed's aim is to consider global EP Markets in a strategic manner and foster balanced coverage and commentary on the International Oilfield and key EP technologies. Saudi Arabia Oil & Gas intends to help bring together local Saudi experts and international people to remove barriers and promote interaction."

Wajid Rasheed

Founder EPRasheed and Saudi Arabia Oil & Gas

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OPEC 3rd Su

OPEC Press Office & EPRasheed Staff

King Abdullah Hosts OPEC Summit Opening Ceremony

The Custodian of the Two Holy Mosques, King Abdullah bin Abdulaziz Al Saud, hosted a glittering opening ceremony for the Third OPEC Summit at the King Abdulaziz International Center for Conferences in Riyadh. Heads of State and leading dignitaries and officials from the OPEC member states gathered for only the third such event in the organization's 47 year history.

He also thanked the heads of OPEC countries, pointing out that this summit is of great importance for being convened in Riyadh.

He said that OPEC has spared no effort in preserving the interests of its members by ensuring the stability of oil markets and securing stable oil supplies, adding that the organization achieved its objectives through the precise predicting mechanism of the level of consumption in the medium and long term.

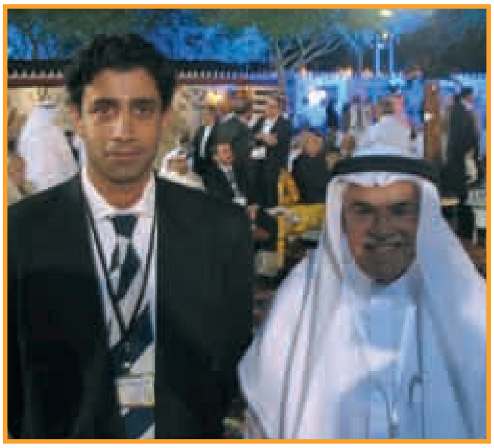
Both President of Venezuela, Hugo Chavez, and OPEC Secretary General, Abdullah bin Salem Al-Badri, thanked The Custodian of the Two Holy Mosques King Abdullah bin Abdulaziz on his patronage of the Summit. The Minister of Petroleum and Mineral Resources, Ali bin Ibrahim Al-Naimi, introduced former OPEC secretaries general, the current secretary general, distinguished researchers and prominent journalists, who have all contributed to the service of OPEC, to King Abdullah bin Abdulaziz.

Photo: OPEC

King Abdullah greets dignitaries at the Summit opening ceremony

Right to left: Dinner at the King Fahad Cultural Center with HE Dr. Francisco Parra*, HE Dr. Alvaro Calderon*, Kamal Field Economic Advisor for Iraqi Government, HE Rilwanu Lukman* HE Dr. Abderrahman Khene*, Wajid Rasheed

*ex OPEC Secretary Generals



Right to left: HE Ali Al-Naimi and Wajid Rasheed CEO & Founder EPRasheed at the King Abdulaziz Historical Centre Riyadh

HE Ali Rodriguez Araque ex OPEC Secretary General and Wajid Rasheed

mmit Riyadh

Al Naimi Media Briefing:

Photo: OPEC

HE Ali Al-Naimi, Minister of Petroleum & Mineral Resources of Saudi Arabia during the Final Press Conference, III Summit, November 18, 2007

As part of a major news media program, hundreds of journalists from around the world also visited Saudi Arabia for the Third OPEC Summit, many of them enjoying their first visit to the Kingdom. From specialist oil industry publications to regional newspapers and from the world's largest television stations to newswire agencies, the media spotlight was firmly on Saudi Arabia during the event. In addition to specially arranged tours around the country to visit the Kingdom's major oil and petrochemical facilities, visiting journalists were also able to attend a number of significant press events in Riyadh as part of the Summit program.

One such event was a far-reaching open 'Q&A' session, with His Excellency Ali Al-Naimi, the Minister for Petroleum and Mineral Resources for the Kingdom of Saudi Arabia. In the hour-long meeting, the minister took questions from journalists on topics as varied as the Canadian Oil Sands, inventories, investments costs, the world's developing economies, the environment, and world peace, as well as those on pricing and OPEC related issues.

Group photo of OPEC invited media and Saudi Aramco staff on the steps of the Saudi Aramco Exhibit in Dhahran

OGEP Meet

KACST & EPRasheed Staff

Saudi Meeting discussed future of oil and ga

HE Ali Al-Naimi responds to questions during OGEP Exhibition

In cooperation with the Ministry of Petroleum and Natural Resources, KACST organized the first Saudi meeting for oil and natural gas exploration and production technologies (OGEP 2008) which was held in the King Faisal Conference Hall in Riyadh from 6-8 January.

The meeting was held under the auspices of His Excellency Mr. Ali Naimi, Minister of Petroleum and Natural Resources. It was called to help develop modern and advanced technologies in upstream operations that will support an industry that is of economic importance for Saudi Arabia, which is the world's largest producer of oil and also holds a ¼ of all world reserves. The Kingdom also holds the world's fourth largest gas reserves.

OGEP's theme was "Towards Local Research and Development" and the meeting focused on technologies currently used in oil and gas exploration and production as well innovations to improve oil and gas recovery. Consideration was also given to natural gas as Saudi Arabia needs to benefit from its available resources. It is known that higher rates of oil recovery, even a few percentage points, can mean significant economic progress, as this means additional revenues worth billions of dollars.

Various parties from the government, business and institutions that have investments in oil and natural gas gathered for the meeting. They discussed issues of upstream technologies and how more EP technology could be further developed.

ing Review

as exploration and production technologies

Turki AlSaud VP KACST Research Institutes addresses the OGEP audience

Scientific topics dealt with advanced upstream research and technology, especially the application of innovative oil and gas technologies such as drilling techniques, geophysics of oil and natural gas reservoirs, the geology of Rub Al Khali (the empty quarter), description and management of oil and gas reservoirs, seismic exploration technology, field studies, applications of nanotechnology and smart fluids, reservoir simulation, and increasing local content of R&D and technology.

Eighty local and international speakers participated in the two-day meeting, some of whom are international authorities on seismology, oil reservoirs and scientific research. A number of world experts on the use of nanotechnology in the oil industry were also present.

The majority of the speakers were experts from the local organizations, including KACST, Saudi Aramco, and the gas exploration companies, King Fahd University for petroleum and minerals, and King Saud University. International speakers came from the Netherlands, the United States, the United Kingdom and Turkey.

The list of participating organizations includes a large number of oil and gas companies, such as the south Rub al Khali Company limited (SRAK), EniRepSa GAS Ltd, LUKOIL Saudi Arabia Chevron, Al Khafji Joint operations, and Abu Dhabi National Energy Company (TAQA).

HE Ali Al-Naimi, KACST President Mohammed Al-Suwayail and Turki AlSaud, VP KACST Research Institutes

Left to right: Dr. Abdulaziz Al-Majed Director Center for Petroleum and Minerals, Research Institute KFUPM and Dr. Abdulaziz Laboun, Professor of Geology King Saud University

Dr Mohammed Al-Suwaiyel and HE Ali Al-Naimi seated with other senior delegates

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Dirk Smit

The organizers of the meeting, the first of its kind in Saudi Arabia, hope that it will be the nucleus for other similar meetings. They propose that it be held every two years for the purpose of promoting and developing the oil and gas industry in general, and the development of local oil and gas technology in particular.

The meeting activities included field trips for the participants, who visited some geological sites in the Riyadh area, and sight seeing tours to The National Museum at King Abdul Aziz Historical Centre, and the old city of Ad driyah, the historical birth place of the first Saudi state.

A technical and service exhibition was also held in conjunction with the meeting, which gave both operating and service companies the chance to demonstrate their capabilities, expertise and technologies. Exhibitors included large operating companies as well major service companies and smaller sized companies as well. The exhibition represented both academic and professional institutions such as the DGS and SPE Saudi Arabia section. Manufacturers working in the exploration and production of oil and natural gas, and the provision of various services of supplies, export and import, transport, maintenance and safety for industrial installations were also present.

Saudi Arabia Oil & Gas Magazine was the official publication of the event and was present at the exhibition.

An online site for the meeting was established at www.oilandgas.org.sa


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OGEP Exhibition

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HE Ali Al-Naimi inaugurates the OGEP Exhibition with the ribbon cutting ceremony

Opening address HE Ali Al-Naimi

Dr. Muhammad Saggaf, Prof. Larry Lake and Dr. Tariq AlKhalifah hibition OGEP Exhibition OGEP Exhibition

Coverage of select companies receiving awards

HE Ali Al-Naimi awards Saudi Aramco Business Line Head Amin Nasser

HE Ali Al-Naimi awards SRAK CEO Patrick Allman-Ward

HE Ali Al-Naimi awards Arabian Pipes Dr. Al-Mansoor

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Dr. Mohammed Al-Suwaiyel President KACST

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Sulaiman Al-Sulami and Abdullah Al-Dabil

Mahmoud Hedefa and visitor

The purpose of the Dhahran Geoscience Society (DGS) is to help provide for the technical and professional development of its members -- in geology, geophysics, and related sciences, especially in exploration and development of petroleum and mineral resources within the Arabian Peninsula. The Dhahran Geoscience Society is affiliated with the American Association of Petroleum Geologists (AAPG), the Society of Exploration Geophysicists (SEG), and the European Association of Geoscientists and Engineers (EAGE).

Activities of the Dhahran Geoscience Society include regular monthly dinner meetings, field trips to local and out-of-Kingdom locations, technical seminars, special projects, and publications. Membership includes subscriptions to the society's monthly newsletter "The Oil Drop", and a quarterly geoscience journal. The society is a co-sponsor of the regional "GEO" conferences.

The Dhahran Geoscience Society was pleased to be part of the First Saudi Arabia Conference on Oil and Natural Gas Exploration and Production Technologies (OGEP), which was held in early January in Riyadh. The conference was opened by His Excellency, Mr. Ali I. Al-Naimi, Minister of Petroleum and Mineral Resources for Saudi Arabia. Mr. Al-Naimi visited the DGS booth during the conference, and indicated interest in the society. After the conference, the DGS sponsored a structural geology field trip to two outcrops in the Riyadh area.

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Dr. Sami Al-Neaim Saudi Aramco

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OGEP Conference

Dr. Muhammad Saggaf Saudi Aramco and Wajid Rasheed

Right to left Dr. Abdulaziz Laboun, King Saud University and Omar Al Misned Associate Professor KACST

Technology Abstracts

Facies and Stratigraphy of the Dibsiyah and Sanamah Members of the Wajid Sandstone in Southwest Saudi Arabia

By Jean Loup Rubino, et.al, Total, SRAK, Saudi Aramco, Shell

Recent field investigations in the Wadi Ad-Dawassir area provided new insights on the stratigraphy and sedimentology of the Dibsiyah and Sanamah Members of the Wajid Sandstone Formation, Saudi Arabia.

The Dibsiyah member forms the lower part of the Wajid Sandstones. It is 150m thick and rests uncomfortably on basement. The lowermost part consists of a thin fluvial conglomerate overlain by fluvial-dominated sandstones. Above, the main part is fully marine and intensively bioturbated. The depositional cycles are interpreted as third to fifth order sequences, in turn organized in a larger transgressive second order cycle as shown by the increasing size of tidal bedforms and upward increase of bioturbation. The lack of chronological data does not allow a comparison with other Cambro-Ordovician formations of Saudi Arabia. However, because both Sajir and Risha Members display similar depositional trends, we propose to correlate it to one of the Saq Formation members defined in Northwest Saudi Arabia. This would mean that the base Sanamah Member glacial erosion could have removed the entire Qasim Formation there.

The Late Ordovician Sanamah Member is split into three stratigraphic units displaying considerable variations in thickness and lateral facies changes. The lowermost Unit 1 consists of deformation and basal tills overlain by thick outwash deposits recording high sedimentation rates. Its top is marked by an iron-cemented horizon overlain by Unit 2. This unit consists of red heterogeneous rainout tills passing upwards to coarser melt-out tills, outwash sands, and gravity flow deposits. Its top is also marked by an iron-cemented horizon overlain by Unit 3. The latter displays comparable characteristics to Unit 2. In places, the base of both Units is characterized by discontinuous beach sands marking the onset of each sedimentation cycle. Its top is characterized by an erosional surface, which could represent a base Silurian or pre-Khusayyayn unconformity.

Integrated Geology and Geophysical Evaluation to Constrain Glacial Paleo-Topography, Sarah and Qasim Formations in the South Rub AlKhali Basin

By Geoff Pike, SRAK

The glacial topography of the Ordovician Sarah and Qasim Formations in the South Rub AlKhali Basin is an important factor for prospectivity assessments as it influences reservoir distribution and hydrocarbon migration. Analogue models are known from North Africa and Arabian outcrop areas but little attention has as yet been given to subsurface implications for hydrocarbon exploration in the South Rub AlKhali Basin. Within the exploration areas of the South Rub AlKhali Company in the Kingdom of Saudi Arabia, indications for such topography can be seen on 2D seismic lines. Additional integration of well and potential field datasets and actual geometries measured in outcrops allow to construct a 3D model of glacial topography for the South Rub AlKhali Basin. This 3D model can be used to assess the likelihood for a variety of trapping configurations that may be prospective for hydrocarbon exploration.

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~ Tsunami Migration 2D/3D PSDM
~ Calibrated Inversion of PSDM Data
~ Integration of Tomographic Velocities

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Technology Abstracts Technology

Development of New Retarder Systems to Mitigate Differential Cement

By Mohammad Al-Arfaj, Saudi Aramco

When cementing liners, the cement must develop compressive strength at the top of the liner before drilling is resumed. In other words, if drilling is paused in order to acquire the compressive strength at top of the liner this will result in excessive delays on cement (WOC) time which can exceed 24 hours. Cement slurries with conventional retarders often achieve acceptable thickening times under dynamic conditions. However, these cement slurries do not produce rapid compressive strength under static conditions. The aim of this study is to develop retarder systems for cements that are exposed to BHST of 400 °F at the bottom of liner (BOL) and 330 °F at the top of the liner (TOL).

More than ten retarders including lignosulfonate, ethylene glycol, and aromatic polymer derivatives were evaluated to provide extended thickening times for extreme high temperature cement slurries, while having minimal effect on compressive strength development. The lab studies included comparison between various retarders and their performances of thickening time, compressive strength development, free water, fluid loss, rheology, and gas migration control.

Two new retarded systems were developed. The first system is used for non-latex cements for wells that do not show indications of gas or fluid flow. The second cement system includes latex and is recommended for cases where there is potential for gas flow. The new retarder systems were effectively applied in the field. The article will address lab studies that led to the development of the two new retarders, discuss field application and summarize lessons learned.

Trial of Low Frequency Technology for Deep Gas Exploration in a Frontier Area

By Rob Habiger et. al., Switzerland

A growing number of Low Frequency Surveys at different oil and gas field locations throughout the world have established the possible relationship between micro-tremors and presence of hydrocarbons. These narrow-band, low frequency (from ~1Hz to ~10Hz) micro-tremor signals can be used as a direct hydrocarbon indicator (DHI) for the optimization of decisions, including well placement, during exploration, appraisal and production phases.

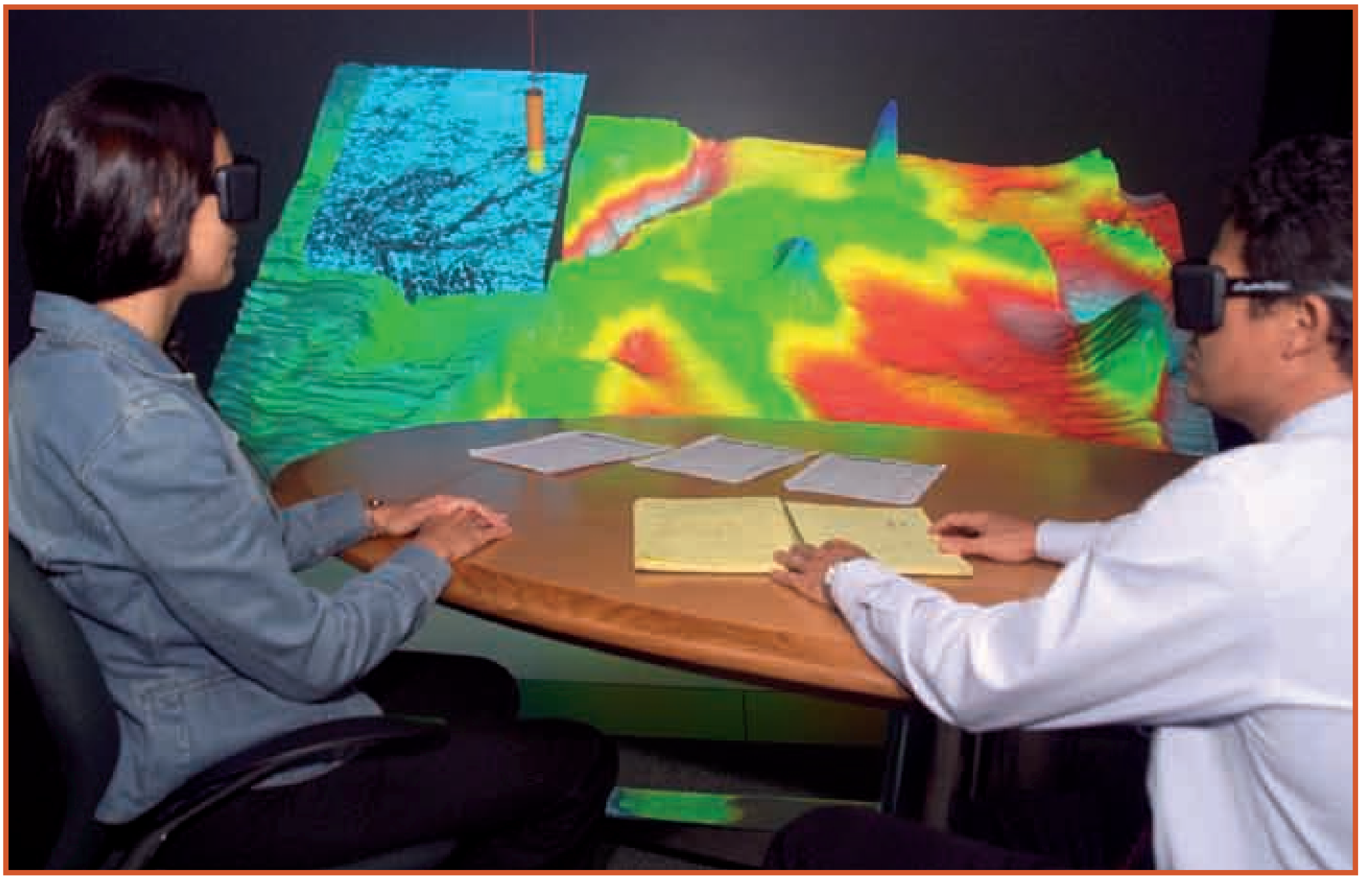
This article describes a Passive Low Frequency seismic survey pilot project conducted on a prospect located in EniRepSa Block C (Saudi Arabia). The block covers a large area of approximately 52,000 km^2 in the central sector of the Rub al Khali basin.

The low frequency data was acquired across east-west lines over a prospect by using seismometers at the surface. No active source was involved in these measurements. The acquisition strategy consisted of three synchronized parallel lines using a 10-stations acquisition spread. Station recording time was 22.5 hours on average, plus 72 hours for a permanent monitoring station (3 full days), and station separation ranged between 2.5 and 5 Km. The logistical support for this low frequency survey was supplied by a conventional seismic acquisition crew operating in the area for EniRepSa.

The main challenges of the project are the depth of the targets (around 5,000 meters) and the possible presence of shallower oil bearing levels in the structure which may interfere with the Paleozoic main gas objectives.

The aim of the project is to assess if Low Frequency Passive Technology can be used for DHI application in deep gas.

Abstracts Technology Abstracts



An Example of High Productivity Single Vibrator 3D Acquisition

By Jean-Jacques Postel, CGGVeritas

It is becoming increasingly accepted that wide-azimuth 3D acquisition is the best way to improve imaging of complex and subtle traps. It is also claimed that high-density point source/point receiver acquisition constitutes the ultimate seismic acquisition technique. Clearly, both techniques require a considerable increase in equipment and density of both source and receiver points. How much is still a matter of debate. Currently most 3D vibroseis crews use two fleets of vibrators in flip-flop mode. The productivity depends on the sweep length and the time it takes to move from one VP to the next. The slip sweep technique is an attractive way of optimizing productivity to a level that can keep the cost of increasing source density within reasonable limits. The productivity increase with this technique is linked to a new parameter called the slip time (the minimum time interval between two consecutive SPs). In the real world, nothing is free and the price to be paid is that the data can be severely contaminated by harmonic noise due to the use of long sweeps combined with a very short slip-time. To overcome this problem, a method of harmonic noise reduction known as HPVA (High-Productivity Vibroseis Acquisition) has been developed. This method consists of estimating the harmonic noise in the vibroseis signature so that it can be subtracted. Several crews are now routinely using this technique with three to four fleets of vibrators. Recent 3D tests with 12 fleets of single vibrators also show very promising results which will be presented. Combined with a densification of the source grid, single-vibrator acquisition can bring either an improvement in data quality or an increase in productivity and opens the road to affordable dense, wide-azimuth seismic acquisition in desert environments.

Technology Abstracts

Isharat -1 Multi Azimuth VSP

By Pieter Van Mastrigt and Abdulmohsin Al-Dulaijan, SRAK

On its first exploration well SRAK successfully acquired a multi-azimuth VSP. In addition to zero offset data, 4 azimuths were acquired at a considerable offset from the wellhead > 3km.

Acquisition of this VSP data involved manufacture and mobilization of dedicated equipment and was hampered by considerable logistical challenges, resulting from the remoteness of the well location, multitude of suppliers, tool failures and timing, all of which has resulted in invaluable learning on VSP operations.

After processing of the data and integrated evaluation we observe an improved understanding of the seismic to well match, and in particular a better handle on the presence of multiple systems in the surface seismic.

This is of considerable importance as these multiple systems mask part of the objective sequence and a better understanding yields an improved outlook on removal of the unwanted energy.

Imaging results within a very large VSP aperture remain challenging, however, after careful review, we find hints as to how the source rock sequence may have been deposited.

In this article we will discuss the design, acquisition, processing, and evaluation of the data and derive the important learning for future VSP programs in this environment.

Also discussed are the design, acquisition, processing, and evaluation of the data to derive the important learning for future VSP programs in this environment.

Efficient High-Resolution Seismic Data to Model Near-surface

By Tariq AlKhalifah, KACST

Accurate correction for topography and near surface complexities of surface seismic data from the Arabian Peninsula requires accurate modeling of the near surface and a proper algorithm for the correction to make use of the model. Refraction and residual static based modeling though help improve results, have fallen short of what is required in complex regions in the area. In fact, almost all the existing near surface correction methods require an accurate near-surface velocity model, which is, in some cases, impossible to estimate from conventional low resolution seismic data in which near surface inhomogenieties falls within the near field region of our wave propagation. Through numerical modeling we show that a reasonably accurate shallow velocity model can be obtained from applying conventional horizon-based velocity analysis on shallow high resolution seismic data. The model proved to be effective in correcting the conventional deep seismic image using either the simple static shifts or wave-equation datuming.

We also present a novel idea to acquire high resolution shallow seismic data in a cost-effective way. The novelty of the approach is in the spacing of the receivers in which we use conventional acquisition configurations to acquire the high resolution data with minimal additional cost. We investigate the resolution limits achieved from conventional configurations. A real experiment in the Riyadh region shows the possible resolution limits obtainable using this approach.

Isharat multi azimuth VSP

Piet van Mastrigt

South Rub Al-Khali Company Limited

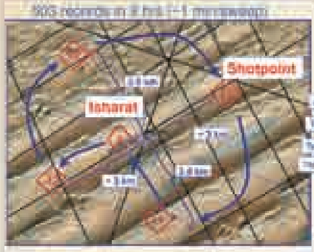
Acknowledgement: A. Al-Dulaijan; K. Saadawi

Did SRAK succeed to combine an optimal well tie with high resolution lateral coverage?

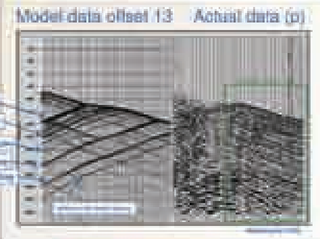
1.) Acquisition

Where? – location map

What? - well schematic

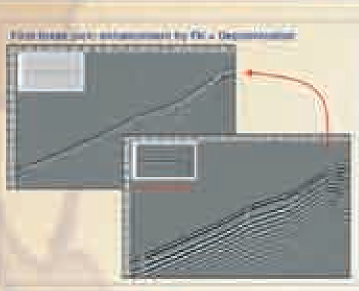


How? 0 and >3 km offset source



Expectation? Prior modeling

2.) Processing

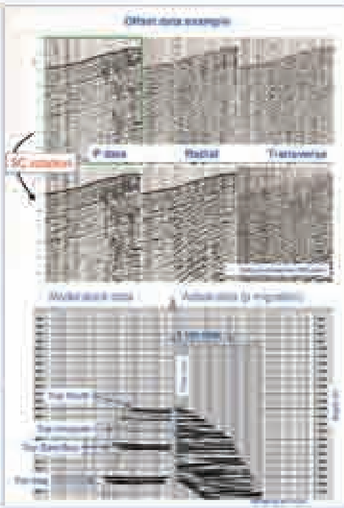


Processing 0-offset:

- First Break picking
- Residual Upcoming Wavefield Enhancement
- VSP downwave deconvolution
- Corridor mute and stack

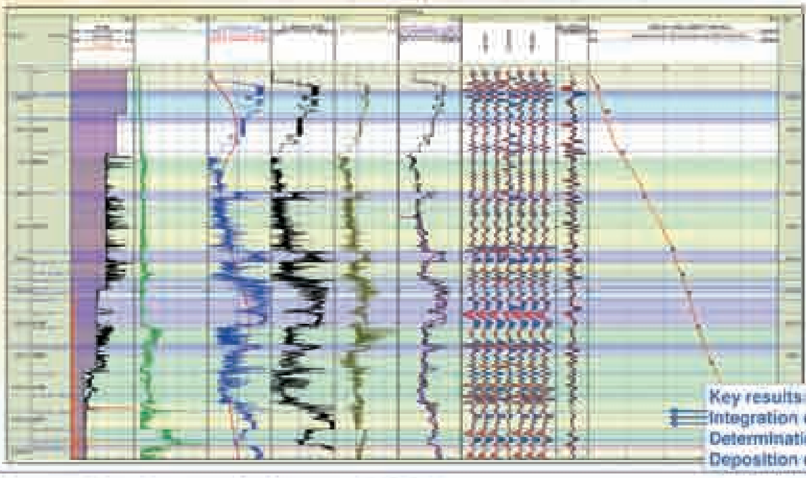
Processing offset data:

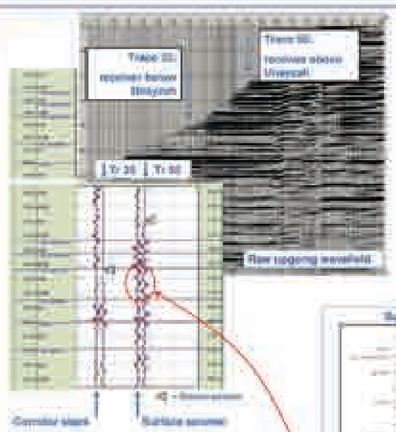
- 3C rotation
- Wavefield separation
- Parametric wavefield decomposition
- VSP downwave deconvolution

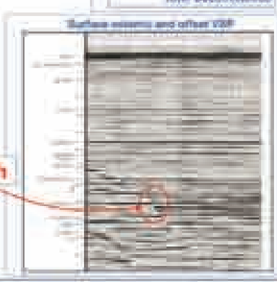


Key: integration of all info – enhanced fb / uphole / seismic picks / water well data.

3.) Results





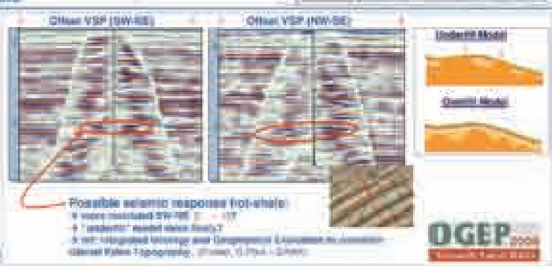


Multiples are generated in Unayzah

Key results:
- Integration of well & seismic data
- Determination of multiple generator
- Deposition of Hot-shale

Conclusions Isharat VSP

- Experiment successful for 0-offset, useful time-depth data through multiple casings (5).
- Offset data > 3 km pushing the limits. Prior modeling of acquisition parameters key.
- Processing after integration of all relevant data yields excellent time/depth tie. (integration of VSP / up-holes / enhanced first breaks / water well)
- Zero offset part invaluable for well tie and detection of multiple generating system.
- Multi offsets exhibit weak tie with seismic. Qualitative conclusions only. (multiples/deposition)



OGEP 2006

Technology Abstracts **Technology**

Reservoir Protection in ESP Completions

By Mohammad Athar Ali, Schlumberger

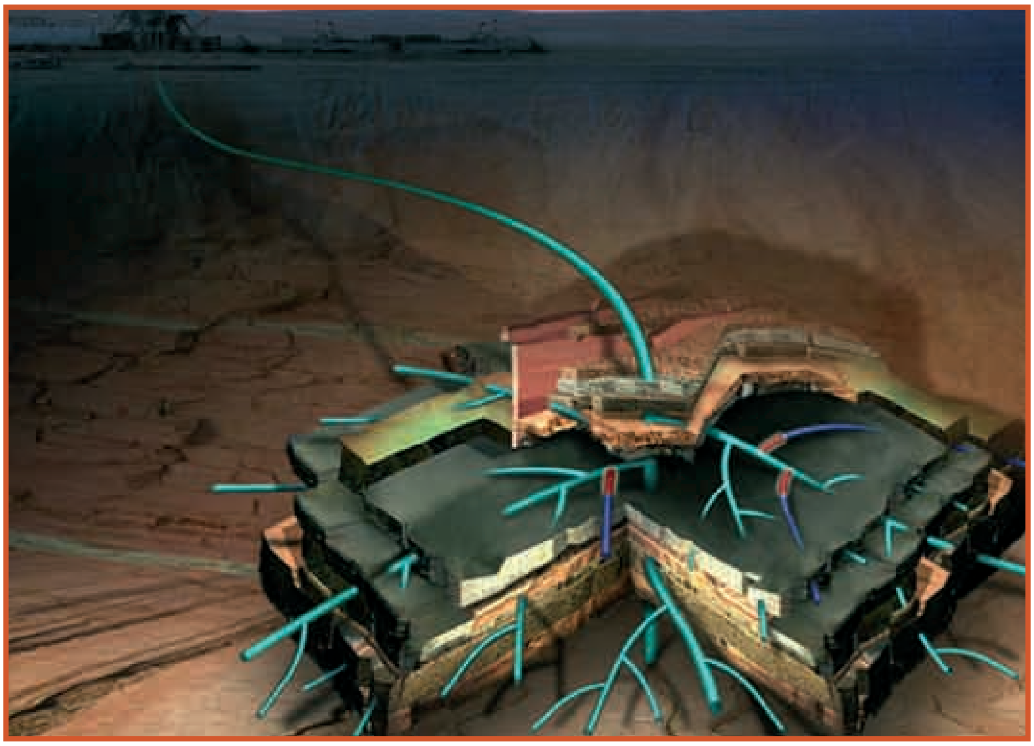
Electrical Submersible Pumps play a key role in producing from oil wells that are incapable of producing naturally at commercially viable rates. ESPs are commonly used in wells which cannot lift the oil to surface due to low reservoir pressure, high water cut, and high back pressure from surface facilities or a combination of all three. As more and more large oilfields around the world are maturing ESPs will be essential to maintain production for these brown fields.

Run life of ESPs varies anywhere from a few months to a few years but almost all ESP completions have a much shorter life as compared to the productive life span of the well. This requires periodic workover of all ESP completions. Over the life of a well as many as 10 or more workovers may be performed to replace ESPs.

Most workover techniques require "killing" of the well with completion fluids which damage near wellbore permeability and therefore production potential of the well. This can be detrimental to the wells which already have low reservoir pressure.

While in some cases the damage may be easily removed by stimulation treatment, in most cases it may not be possible to restore the original production potential of the well. Also the additional cost, time required to perform the stimulation treatment and resulting deferred production make it desirable to protect the reservoir from damaging workover fluids during ESP replacements. "Prevention is better than cure".

This article describes the use of an innovative completion design which incorporates a Mechanical Formation Isolation Valve in ESP completions. This has made it possible to completely isolate reservoir from upper ESP completion during workover operations. Thus protecting the reservoir and eliminating the need of remedial stimulation treatments after each workover.



Abstracts

Technology Abstracts

Seeing The Invisible: Predicting Fluid Paths With an Innovative New Seismic Attribute

By Khalid Al-Hawas and Saleh Al-Dossary, Saudi Aramco

Natural fractures and faults in the subsurface play an important role in fluid flow and accumulation. Therefore, identifying and mapping the distribution of fractures and faults systems is critical to understanding the fluid dynamics within a reservoir.

Although fractures and small-throw faults are not easily identifiable using conventional 3-D seismic techniques, their orientation and intensity can often be inferred using seismic attributes such as coherence and seismic curvature.

This case study will demonstrate how seismic curvature was used to map small scale fractures in a Saudi Arabian oil field which has been affected by premature water breakthrough. Premature water breakthrough is an increasing concern to all the geoscientists and engineers involved in developing the field. Curvature illuminates subtle fracturing that was difficult to detect with conventional seismic amplitudes. Using curvature allows geoscientists to map, for the first time, small-scale fractures believed responsible for bringing water prematurely to the top of the reservoir. The integration of image logs, zones of lost fluid circulation, production test and well test data has increased our interpretation confidence and helped optimize the placement of future horizontal wells.

A Practical Approach to Determine Permeability from Wireline Measurements

By Ahmed Al-Harbi et. al., Saudi Aramco & Imperial College

Permeability is a crucial input to any simulation effort to forecast production. It is available from different sources: core, nuclear magnetic resonance (NMR), wireline formation tester (WFT) and drill stem test (DST). These sources are different in many aspects: the type of permeability they measure, e.g. absolute or effective, the scale of measurement in the vertical and the lateral directions and the degree of inconvenience caused by the data acquisition process in terms of operational constraints, costs, safety issues, etc.

Much effort has been invested by the industry to be able to use the most cost effective tools, NMR and WFT, for permeability measurement as a substitute for the less convenient ones: core and DST. Results of these efforts are still mostly qualitative.

This work is a summary of the senior author's MSc thesis which reviewed the different sources of permeability and their limitations using field data from, an oil bearing, clastic reservoir that included core, NMR, WFT and DST. All these data were analyzed and interpreted for permeability evaluation. The objective of the study was to develop an approach for calibrating the static NMR permeability log with the WFT dynamic data and to compare the results with the traditional approach of calibrating with cores. Permeabilities from both approaches were upscaled for comparing with DST-derived permeabilities.

It was found that the upscaled WFT-calibrated NMR permeabilities match the DST permeabilities as satisfactorily as the upscaled core-calibrated NMR permeabilities.

OGEP Cultural Vi

isit to Addiriyah

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Left: Mr. Al-Shammari, Mr. Al-Homaidan, Mr. Al-Eisa, Mr. Al-Khonaizi from Ministry of Petroleum and Mineral Resources, Dr. Al-Enezi from Saudi Aramco

Dr. Paul McElfresh, Baker Hughes (Oil tools)

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Mazen Alyousef, Hashim Almalki and Abdulaziz Alasbali

Dr. Eissa Shokir of King Saud University and Dr. Hazim Abass, Saudi Aramco

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From right to left: Mazen Alyousef of KACST, Dr. AbdulRahman Al Quraishi and Dr. Eissa Shokir of King Saud University.

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Russell Croley of Halliburton and Tom Davies of Colorado School of Mines et al perform a light hearted dance

Group photo at the entrance to Addiriyah

IPTC - Awards
"Excellence in Project Integration"

Society of Petroleum Engineers (SPE) & EPRasheed Staff

The IPTC Awards recognised project teams that have made significant and unique achievements in managing and directing an integrated oil or gas project from discovery to delivery.

2007 IPTC "Excellence in Project Integration Award Recipients

Anadarko Petroleum Corporation & Enterprise Products

The Independence Project

Anadarko Petroleum Corporation & Enterprise Products

With the development of the infrastructure necessary to bring previously economically inaccessible ultra-deep Gulf of Mexico reserves to market, the Independence Project is an industry solution to the problem of stranded reserves. Given the complex technological and commercial elements, it took unprecedented cooperation among partners and subcontractors to complete the world's deepest natural gas processing facility.

The Independence Project, the Gulf's largest natural gas processing facility with capacity of 1 billion cubic feet of natural gas per day, is located in the ultra-deepwater Eastern Gulf of Mexico and is comprised of three major components: the Independence Hub platform, the Independence Trail export gas pipeline and the Independence Subsea infrastructure. Enterprise Products Partners LP and Helix Energy Solutions own 80% and 20% respectively of the Independence Hub Platform and Enterprise owns and operates 100% of the Independence Trail export gas pipeline. Anadarko Petroleum Corporation operates the Independence Hub platform and is the main producer and owner of the subsea infrastructure along with Devon Energy Corporation, Eni Exploration & Production Inc. and StatoilHydro. The massive project spans 142 blocks or about 1,800 square miles (over 4,600 square km) in waters up to 9,000 feet (2,745 m) deep and accounts for 10% of all natural gas production from the Gulf of Mexico.

Total E&P Angola

Angola Block 17 Rosa Development

Total E&P Angola

Discovered offshore Angola in 1998 by TOTAL, operator for a consortium of the "prolific" Block 17, the Rosa field is located at a distance of 16 kilometers from the spread-moored Girassol FPSO. Water depth in the area is about 1,350 meters. The Rosa Development Scheme is a long sub-sea tie-back of Rosa development wells to the existing Girassol FPSO which has required a huge upgrading for that purpose in order to cope with combined daily production of 270.000 barrels.

By its size and scale, together with the use of innovative technology associated to flow assurance constraints and the unprecedented challenge of the offshore hook-up works on a live FPSO in SIMOPS conditions, where safety was the key word, Rosa is a full cycle time Project.

The excellence in management by Integrated Project Teams was the key to success in particular for the offshore works on the FPSO, for which over 3.000.000 man-hours have been expended over 23 months without a single Lost Time Injury.

Brunei Shell Petroleum Co. Sdn. Bhd.

Champion West Project

Brunei Shell Petroleum Co. Sdn. Bhd.

Brunei Shell Petroleum (BSP) company Sendirian Berhad's most recent development phase at Champion West is a forerunner of several SmartField® projects expected to be in operation in the near future. Novel well designs in combination with implementation of key technologies, remote downhole and surface production operations using real time monitoring and optimisation allows cost effective recovery from the field. Only with the unique "Smart Snake Well" engineering concept and by installing Brunei's first SmartField® platform, the economic development of these oil reservoirs was made possible. Integration of tools, data, models, and team work allowed the project to break new grounds for the industry and realise increased value for all shareholders.

IPTC Award - Excellence in Project Integration

Saudi Aramco

Haradh Increment III

Saudi Aramco

Haradh is part of the super giant field Ghawar, the largest field in the world. Haradh was developed in three different Increments. Haradh Increment-I came on stream at 300 MBOD in the second quarter of 1996. The Increment was developed exclusively using vertical wells. Haradh Increment-II came on stream in the second quarter of 2003, again at a rate of 200 MBOD. This Increment was developed using horizontal wells. Haradh Increment-III came on stream in the first quarter of 2006 also at 300 MBOD. Many milestones and achievements were recorded in various aspects during the development stages of Haradh Increment-III project. The project spanned a period of 21 months, completed 5 months ahead of schedule and established several firsts for the company. The project entailed the engineering, procurement and construction of the gas-oil separation plant to receive 300,000 barrels of Arabian Light crude oil per day and 140 million standard cubic feet per day of associate gas.

BP

The ACG Programme - A Production Line of Integrated Project Delivery

BP

Developing facilities as a production line of similar concepts, supported by a collaborative environment has delivered real value to AIOC and BP. Benefits have been realised in numerous areas culminating in projects delivered on, or ahead of schedule whilst providing significant cost savings, in what could be considered a high risk environment. Key enablers of this strategy have been standardisation, the common understanding of an integrated team and the support of the supply chain. Repeat delivery of equipment and materials has seen real cost savings in a sector that has experienced significant inflationary pressure over the same period. Familiarity of repetitive hardware delivery in parallel with a consistent design and fabrication process has fostered an environment that has nurtured a developing talent within Azerbaijan. This has supported a successful local content programme producing a sustainable future for the AIOC, Baku, and Azerbaijan.

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From the Aramco Newsroom • From the Aramco Newsroom

NOCs, IOCs Make Most of Each Other's Strengths

More than 3,000 people from more than 70 countries participated in the Dec. 4-6 International Petroleum Technology Conference (IPTC), titled "A Changing World - Interdependence, Innovation and Implementation."

Delegates to the conference, hosted by HH Sultan ibn Saeed Al-Mansoori, Minister for Government Sector Development, gathered to address energy in the modern world.

Abdullah Al Saif and Tony Hayward share thoughts on the NOC & IOC plenary session

Abd Allah S. Al-Saif took part in a panel session and was a keynote speaker at the International Petroleum Technology Conference (IPTC).

A number of Saudi Aramco executives and subject-matter experts contributed papers and presentations, including a panel session in which Abd Allah S. Al-Saif, senior vice president, participated.

Al-Saif discussed the relationship between national and international oil companies (NOCs and IOCs) in terms of the technical cooperation needed to exchange expertise. He also noted the growing need to build cooperative relationships in the industry.

He said there are three types of national oil companies: those that are fully self-sufficient, those that rely significantly on technical contractors, and those that are self-sufficient in some areas but rely on technical contractors for others.

"The manner in which NOCs and IOCs partner depends on the unique needs of the individual NOCs. NOCs wish to utilize an optimum arrangement that makes best use of the parties' strengths," said Al-Saif.

He said most national oil companies already have relationships with IOCs.

Al-Saif also said that the nature of its business makes Saudi Aramco reliant on its human and material resources to develop the technologies required to operate and to solve technical problems. He stressed that all national and international oil companies need to develop their human resources because markets do not always provide qualified employees.

He stressed the importance of finding ways to encourage students to enroll in majors that the oil industry needs, such as petroleum, geology and geophysics engineering. He also called for international collaboration to guarantee political stability in oil producing areas around the world.

Al-Saif concluded by encouraging the industry to avoid procrastinating on improving its infrastructure.

"If the industry does not deal with this problem I'm afraid that it would encourage governments to impose more red tape and more regulations, for which consumers would eventually pay," said Al-Saif.

Fahad A. Al-Moosa, vice president of Northern Area Oil Operations, received an award from Saudi Aramco for the company's leading role in the management and operation of the smart fields in the Haradh GOSP-3 expansion. Smart fields contributed to a decrease in operating costs while increasing the efficiency and productivity of the fields.

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Drilling Sympo a First for Saudi

By Karam Yateem, Saudi Aramco

Andrew Gould

With rising hydrocarbon prices and increased exploration and production activities by major oil companies, the atmosphere was right for Saudi Aramco's First Drilling Symposium, which was held earlier this month at an al-Khobar hotel.

More than 500 representatives from drilling contractors, service companies, universities, research and development centers, and national and international oil companies came together under the theme "Drilling Technology, Pushing the Envelope" Dec. 1-2, 2007 to share their knowledge and ideas through presentations, posters and a panel discussion.

After a welcome from steering committee spokesman Dr. Jamal AlKhonaifer, symposium chairman Saud S. Al-Otaibi opened the gathering, saying the timing could not have been better, given the excitement in the drilling industry. "In the last few years, the drilling industry has made quantum leaps in the use of new technologies on many fronts, in the drilling rigs and in the types of wells drilled.

"What makes it more exciting," he said, "is not only has the quality of work improved but also the quantity." He said the world's rig count has increased by more than 60 percent in the past five years and that Saudi Aramco's rig

Huda M. Al-Ghoson, Director of Human Resources Policy & Planning of Saudi Aramco, a participant of "The HR Challenge – Bridging the Gap" Panel Discussion.

sium Aramco

A look at the audience. Front row, from left to right: Abdulla A. Naim, VP Exploration, Abd Allah S. Saif, Senior VP, Khalid A. Falih, Executive VP Operations, Andrew Gould, President & CEO of Schlumberger, and Amin H. Nasser, Business Line Head of E&P.

activities have increased almost threefold in three years. Among the keynote speakers was Saudi Aramco senior vice president Abd Allah S. Al-Saif. In a presentation titled "Saudi Aramco Responds to the Call to Deliver," Al-Saif outlined the world's energy outlook and some of the challenges in the global oil market.

"These days," he said, "the oil industry is overwhelmed, to say the least, with issues such as prices, cost, peak oil, safety, environment, and security of supply and demand."

He said that rising demand - along with a decreasing supply from other producers, geopolitical tension, misconceptions about resources, and environmental concerns - have led Saudi Aramco to intensify its effort to meet the global demand.

"By the end of 2009, we will have a sustainable capacity of 12 million barrels per day, compared to 10 million barrels per day in 2004," he said after listing some details of those efforts.

In the longer term, Saudi Aramco's goal is to increase the discovered resources and increase the recoverable portion of those resources. "The role of drilling and service companies is essential to accomplish these objectives," he

Abd Allah S. Al-Saif receives a token of appreciation from Saud S. Al-Otaibi, symposium chairman.

Dr. Ali Ghalambor receives a token of appreciation from Saud S. Al-Otaibi, symposium chairman.

Group pose with Mr. Zuhair Al-Hussain, Executive Director of Drilling & Work Over and members of programme/technical/organizing committees.

said, adding, "Our rig count has grown from less than 50 rigs in 2003 to about 130 rigs in 2007."

Collaboration with academia, and drilling and service companies is an important part of the plan. Under a new approach to collaboration, the company is "identifying current needs and then collaborating with the service companies to develop appropriate tools to address these needs."

Andrew Gould, chairman and CEO of Schlumberger, in his keynote speech titled "Lowering Cost Through Drilling - The Ultimate Recovery Tool," said, "Drilling is a profession that requires men and women of strong character. They demand clear instruction and clear communication. They are often called upon to make difficult and dangerous decisions with insufficient data in rapid time frames."

Another speaker, Dr. Ali Ghalambor, American Petroleum Institute endowed professor and department head of petroleum engineering at the University of Louisiana at Lafayette, talked about challenges from economical, safety and technical points of view.

Zuhair A. Hussain, executive director of Drilling and Workover, said the symposium was a great opportunity for employees to hear from regional and international leaders in the drilling industry.

The industry overcame many challenges in the past and will continue to "push the envelope," especially in the use of new technologies to save time and money, he said.

Also featured at the symposium were 15 technical sessions and a panel discussion on HR challenges.

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KACST's Seismic Analysis Center focuses on processing technology to compete with giants

By Tariq Alkhalifah and Hashim AlMalki, King AbdulAziz City of Science and Technology (KACST)

The development of a Seismic Analysis Center (SAC) at King AbdulAziz City for Science and Technology started in early 2004. At that time, it was recognized that despite the vast amount of oil in the Kingdom of Saudi Arabia and the large amount of seismic data being acquired, no seismic processing centers existed outside of Saudi Aramco. This fact gained importance with the Ministry of Petroleum and Mineral Resources (MoPM) awarding concessions to four newly developed gas exploration, and hopefully production, companies in the Rubaii Alkhali region. The center development stage included the purchase of required hardware and processing software. Most importantly it required the training and hiring of high quality processing professionals. During the preparation stage, SAC developed methods to integrate third party software to our in-house developments. We forged an agreement with LMKR in Dubai to help train Saudi graduates and assess us in the initial processing.

Vision

In April 2006, we officially inaugurated the center's operation with a vision to be a leading solution provider for seismic processing in the region. From the start the focus has been on high-end processing and solution development. We offered the capability to process and image 3-D seismic data as well as study and develop new seismic processing and imaging algorithms, with emphasis on algorithms that can be useful for seismic processing problems in the Arabian Peninsula.

This means the SAC can both modify existing methods as well as develop new methods that meet the needs of day-to-day seismic data processing problems faced in this region. The ideas and experiences gained at SAC are used for applications such as reservoir characterization, shallow reflection seismics, processing in complex regions, and many other useful endeavors.

All such applications are geared to increase the recovery of natural resources from the Earth's subsurface in this region, a task of great importance and now part of the objectives spelled out in the Saudi strategic plan for Oil and Gas technology. The objectives of the center are directly related to the need of solving the technical seismic challenges that will face the regions' oil and gas industry in the future.

Mission

Our mission is to provide advanced local processing of seismic data through:

- Our advanced hardware capabilities.
- State-of-the-art software solutions.
- Highly trained professionals with R&D experience.

We recognized early on the importance of the near surface, and thus, made solving this problem a priority. We developed Straight Ray Datuming (SRD) to efficiently datum the data. We also initiated several projects to solve the near surface

using high resolution seismic data as well as Radar electromagnetic data to map the Sand cover.

SAC today

SAC hopes to have very close ties with our clients and with funding entities in general. The ties include regular communication, sharing of information, and providing reports and assistance to these entities.

Personnel

The center relies first and foremost on the talent and dedication of its professionals. Professionals with special interest and experience in seismic processing primarily form SAC personnel. These include Geophysicists with B.Sc., MS, and Ph.D. degrees. All professionals usually perform and participate in tasks at SAC in accordance with their capabilities. Ph.D. members develop new seismic processing algorithms, new ideas, and reports. MS and BS members of the center are responsible mainly for processing the data and application of these algorithms, data acquisition, as well as assisting the Ph.D. members in the application parts of their reports. The center also benefits from the assistance of a part time computer administrator, with the responsibilities of looking after the computer hardware at the center. The center also includes a director among the Ph.D. holders with the responsibilities of a regular Ph.D. member, as well as, the job of performing all the necessary director responsibilities. Director responsibilities include communication with our clients and sponsors and outside communication in general. The director is also responsible for organizing meetings, communicating with visitors and responding to the general needs of the center with regard to hardware, software or personnel. The center also benefits from the help of a full time secretary with tasks ranging from preparing letters, organizing reports and serving the publication and reporting needs of the center's participants.

The Lab

The majority of work performed at SAC is accomplished through a powerful 96 processor Linux cluster. There is also an 8-processor server, which is capable of handling 3-D prestack data. The network has three graphical specialized computers that are connected to the main server as well as the Linux cluster through an advanced network. These computers are used to handling extensive graphical problems, like visualizing 3-D models using programs like GOCAD. The rest of the machines are Linux-driven PC's, which are provided to every person in the center for development purposes. Since the Linux machines have X windows as part of the package, Linux users will be able to display all images obtained using the main server machine on their local machines. Practically all storage tapes are handled at the center. In addition, as needed, the center will update its computer capabilities with state of the art parts so that the center can remain capable of coping with the continuous advancement in geophysics.

The Software

To develop processing algorithms that can easily communicate data with each other we must establish a consistent and practical data format. There are many to choose from; some of which are free and others which are commercial. For 2-D processing, as well as simple 3-D processing, we will use Seismic Unix; a free seismic processing package developed by CWP at the Colorado School of Mines, Golden, Colorado. This package is used by many academic institutes around the world, and has a lot of unique advantages, the biggest of which is its simplicity. It operates using Unix-type commands. The output of a process can be either stored in a file or piped to another command. The parameters of a command can be fed through the command line or read from a file, referred to as a parameter file.

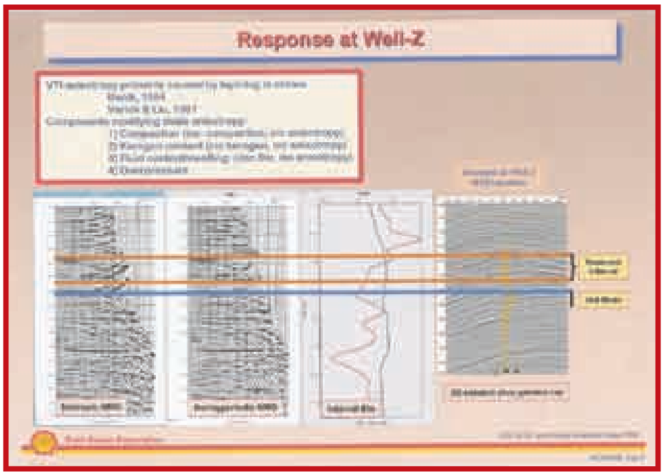
For heavy 2-D and 3-D applications, we use Promax; a commercial seismic processing package developed at Landmark Geophysical. An important feature of this processing package is the ease in developing new algorithms using the package libraries. Promax includes applications from a simple gain all the way to full 3-D prestack migration and velocity analysis. It is flexible in reading most types of data formats including SEGY, SEGD, SU, and others. Thus we will have the flexibility of moving data from Promax to SU and back. We also intend to use any contributed software from companies.

For near surface applications we have GLI3D, which is at the forefront of refraction static's model building and is used to improve our near surface handling capabilities.

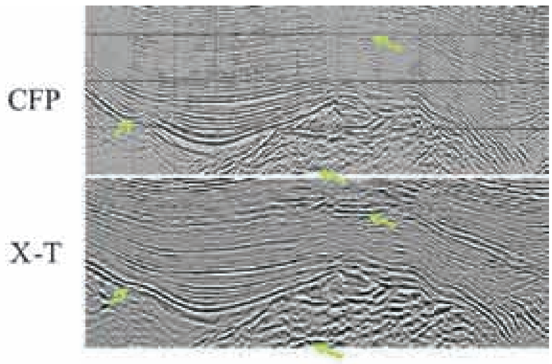
SAC Case Studies

SAC during its development and after the actual inauguration has worked on many problem solving projects, including those requiring development of algorithms that are dedicated to solve particular problems in various data, and lately most of the development has concentrated on solving the near surface for Land data. In the following we provide a list of our problem solving experience:

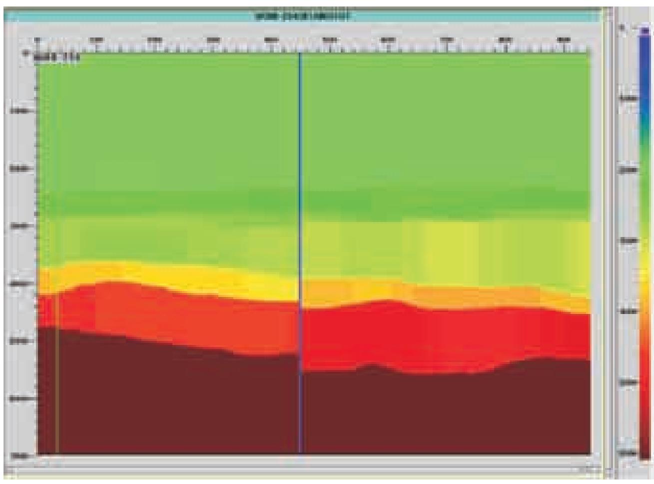
• Anisotropic processing project for Shell:
As part of the project we equipped Shell with conventional anisotropic processing code and velocity analysis algorithms. The approach was applied to many data from West Africa and was used to interpret lithology, specifically the shale-sand content.



• Prestack 2-D TAU migration and velocity estimation project for Saudi Aramco, Saudi Arabia:
As part of this project we installed the prestack 2-D TAU migration code and processed many data with the code such as the two 2-D Midyan (Red Sea, Saudi Arabia) crossing lines in which images ended up superior to those obtained using conventional methods or even using the CFP method.

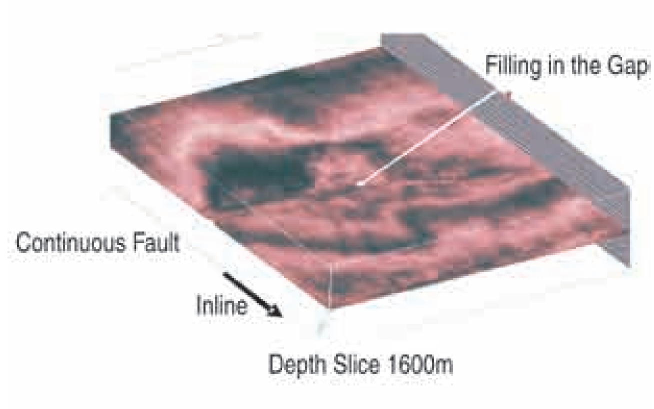


• Prestack 2-D and 3-D anisotropic migration for Eni, Italy:
As part of this project with equipped Eni with 2-D and 3-D anisotropic migration and velocity estimation capabilities and we applied the method on mainly 2-D lines from offshore West Africa and Brazil with excellent results. Eni later managed to process and show 3-D results using the codes.

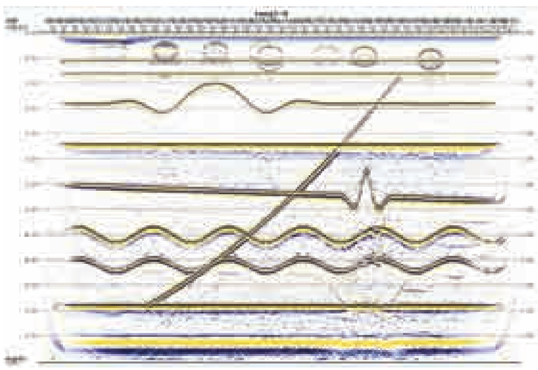


• Prestack 3-D TAU migration and Velocity Analysis: Application to data from the Mandous Field, Abu Dhabi:
Using prestack 3-D τ (a depth variant) migration with velocity model building on the Mandous test data set

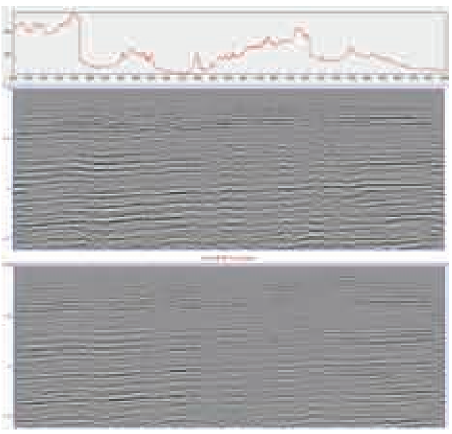
we managed to image the shallow Gas attenuated area in reservoir area. We managed also to obtain a rather accurate velocity model that agreed with the well data and managed to image the fault reflection in the middle of the affected region.



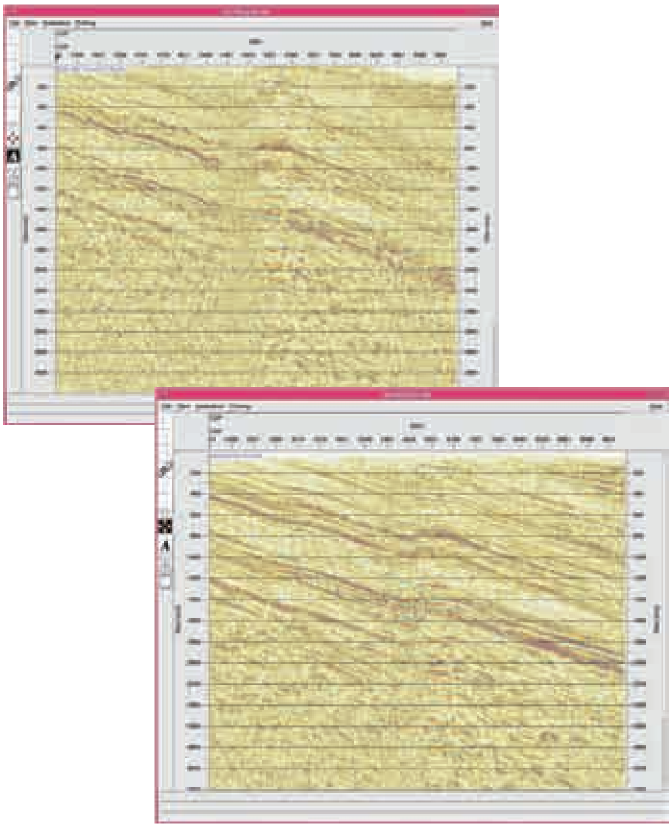
• Prestack 3-D TAU migration and velocity estimation project for Saudi Aramco, Saudi Arabia:
As part of a project, we equipped Saudi Aramco with 3-D prestack TAU migration and velocity analysis capability that they are currently using as their main prestack depth migration software. The project lasted for about 2 years and many from Saudi Aramco contributed to the development and integration.



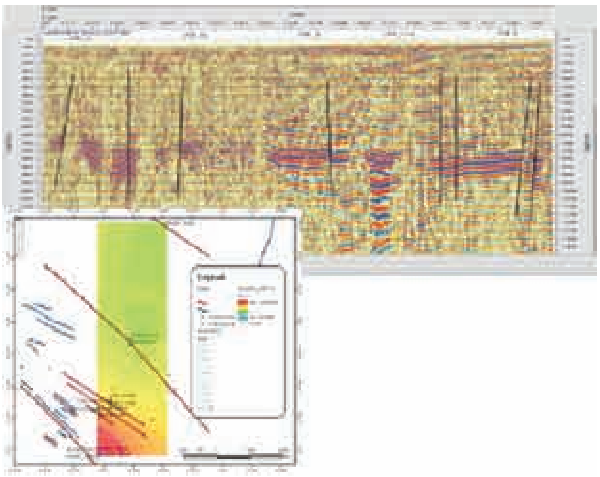
• Application of SRD on a Saudi Aramco Dalim 2-D test line:
Using Straight Ray Datuming (SRD) as opposed to statics we managed to obtain superior results compared to others as was shown at the MADRID EAGE 2005 special workshop on the data, and as a result Aramco is pursuing the SRD code.



• Reprocessing of 2-D Seismic data project for Saudi Aramco:
The objective of this reprocessing was to enhance the data quality for seismic interpretation by emphasizing especially on Static Solution and applying our proprietary tools. The comparison below shows how results in the middle complex area considerably improved through our processing.



• Processing of 2-D High resolution Seismic data project for Alyanboo Hydrogeologic consultancies office and GTZ:
The main objective of this project was to image the subsurface structure from the basement interface in the region in some selected areas, which is expected to be at depths between 500 meters and 1 km.

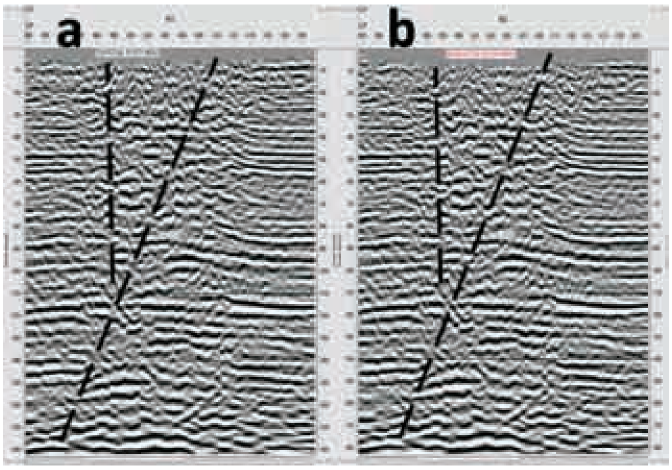


Our approach at SAC is to treat the seismic data set individually and as if it were our only project.

• Application of SRD on 2-D lines:
Application of Straight Ray Datuming (SRD) on lines from Aramco and SRAK for test purposes with full reports on all applications.

• Processing of 2D seismic test lines for Enirepsa:
Using 2-D prestack TAU migration and velocity analysis we managed to get a depth image of the section.

• Using high resolution seismic to correct for the near surface
A project for Saudi Aramco, in which we test the feasibility of using high resolution seismic data to estimate a near surface model. Below is a comparison between advanced refractions statics and using the near surface model obtained from high resolution seismic data. In previous results it would have been impossible to estimate the faults locations.



Challenges

One of our biggest challenges as a new processing center, other than the obvious ones related to startup issues, is the liberal policy associated with data processing in the Kingdom. Unlike neighboring countries, no quota exists on how much data should be processed within the Kingdom, as opposed to outside the Kingdom. Though this might be a reasonable policy in a free market, it is hard for a newly developed center to compete with international companies with long histories of cooperation and collaborations, and even relations, with the oil companies. We might compete on the quality of the result, but we will fall short in the exposure and experience departments and in the capability of business interaction and presentations. This liberal data policy will not help in the local technology content efforts nor will it help in the quality of results. Though the major service providers in seismic processing may offer quality in process, they usually do not deliver quality in results, because they deal with data in a bulk matter and we feel that each dataset requires its own processing touch.

Bulk processing versus hand crafted

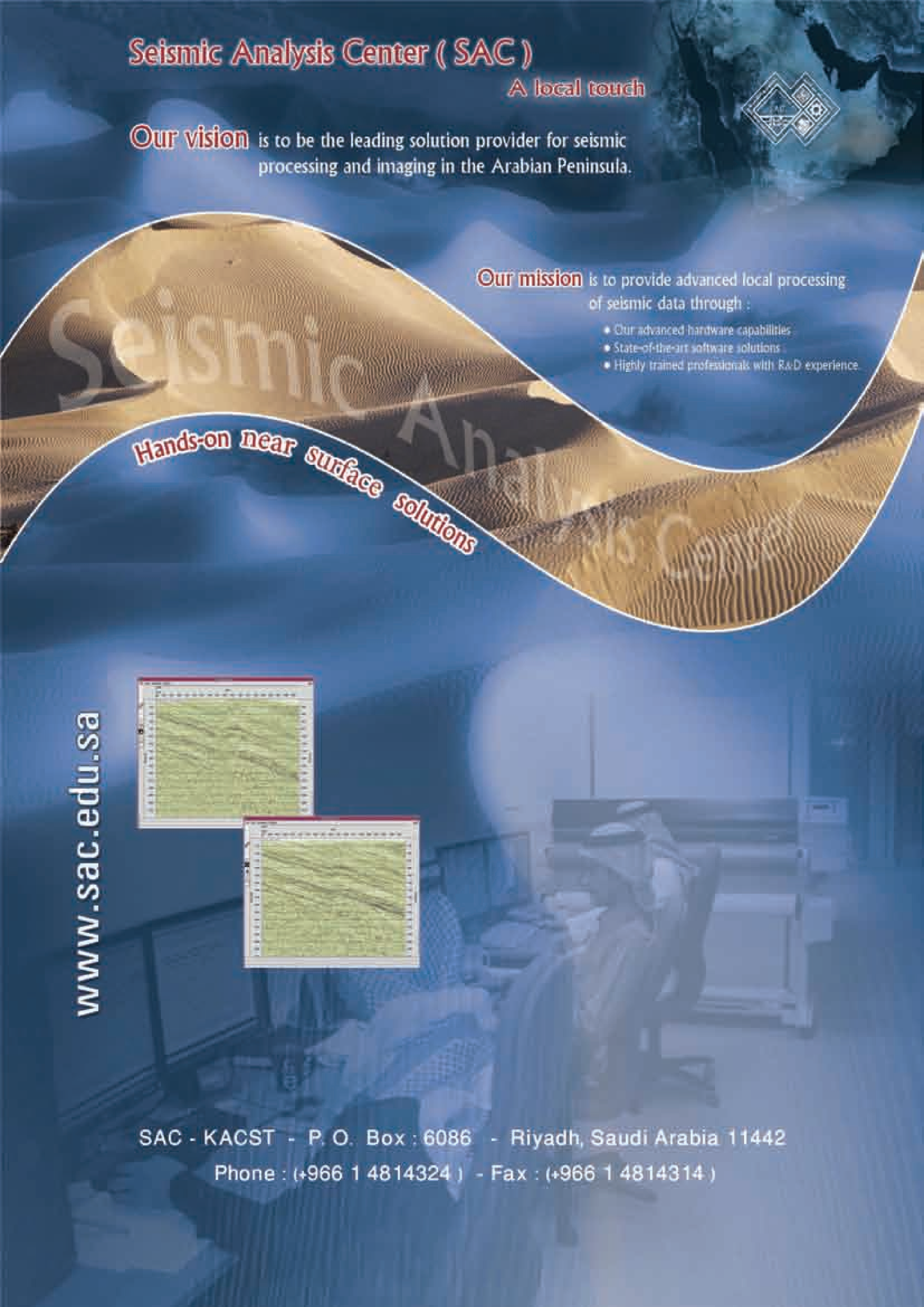
Many of the major service providers deal with all seismic data (good quality or poor, complex area or low relief) in a bulk mentality, not giving the data the care and attention it requires. Each data set is unique in its makeup, method of acquisition and the impact of the subsurface geology on it. The bulk mentality may work on a big portion of the data but not on all the data, especially not those that come from areas that have special problems.

Our approach at SAC is to treat the seismic data set individually and as if it were our only project. This allows us to apply the care the dataset deserves. Our approach usually is based on providing solutions uniquely geared for the problem even if that requires utilising our coding and software development capabilities, because in the end what matters is the quality and accuracy of the final image.

What is next?

We plan to continue developing our methods and techniques to help solve local problems and challenges, and continue to pursue technology projects.

We think that quality at the end will prevail especially since quality might mean the difference between drilling a $60 million-dollar dry hole and hitting it big with returns that far exceed the cost. Quality comes from focus, from an R&D mentality, and from providing a fit-for-purpose solution. As we apply our methods on more data, we expect a longer track record in our capabilities and greater benefits for our customers.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New Iterative Approach Makes Compelling Case for Reservoir Modeling

By Sumon Bhattacharyya

Reservoir modeling has long been a best practice as a practical component of ongoing field management in the oil and gas industry. A revolutionary new dynamic workflow is now possible, saving time over existing approaches and allowing operators to keep up with drilling schedules. New operational data and revised interpretations, such as a new well or a recently discovered fault, are easily incorporated into the model at any point in the workflow in a matter of minutes. Real-world use has shown a 3-5x speed up in modeling and maintenance tasks. To top it off, the new technique runs on both Windows®-based as well as Linux-based computers, reducing the potential cost and learning curve.

The Need for Modeling

The objective in building and maintaining a reservoir model is, of course, to be able to predict the future performance of the field. Drilling rates are at an unprecedented level, generating large volumes of data that, if incorporated into a model, could yield a greater understanding of the subsurface. This in turn could yield improved drilling programs and advanced warning of operational challenges. With the increased focus on efficiently exploiting existing fields, modeling is taking a lead role in identifying opportunities.

Modeling helps answer such questions as:

1. Are there 'hidden' reservoirs that were missed?

2. What impedes flow?

3. What is the best way to leverage secondary recovery techniques?

4. How can overall recovery be optimized?

5. What downstream facilities will be needed in the next few years?

Sumon Bhattacharyya is a Senior Geological Modeling Consultant at Fugro-Jason, working with clients ranging from independents to large oil and gas companies. His expertise includes G&G Interpretation and reservoir modeling especially in Thrust Fold belts. He has been with Fugro-Jason for nearly 2 years and has over 14 years experience in the oil and gas industry.

Bhattacharyya started his career working as a Mining Geologist. Subsequently he worked with GeoGraphix (a Landmark Company) and was a certified Support Specialist, Technical Consultant and Trainer for GeoGraphix. He later worked at Schlumberger, serving in various technical, sales and managerial positions. Before joining Fugro-Jason, Bhattacharyya was working as a workflow consultant (seismic to simulation) for Schlumberger. His job responsibilities included working on client projects and recommending the best workflows for seismic through to simulation. He was also responsible for internal and external training as well as assisting in business development.

Bhattacharyya holds a Bachelors of Science (Honors) Geology and a Masters of Science (Applied Geology). He is also a fellow of Geological Society of London.

6. What surface facilities will be needed to deal with extra water, higher gas mix, cutover to other wells, and other operational changes?

7. Is there a risk of 'surprise wells'?

By interpreting data from well logs, cores, seismic and other data, geologists, engineers and geophysicists can develop a better understanding of how the reservoir functions and can simulate flow over time. An early model can help determine the initial drilling program. Ongoing models that take into account each drilling cycle can drive adjustments and tune operational logistics as the field matures.

Operational Obstacles

Clearly, there are compelling arguments in favor of geologic modeling. However, until recently the associated techniques and technologies have not been able to keep up with the quickening pace of new data acquisition. As a result, many fields are modeled infrequently, updated rarely and operational logistics tend to be driven by reactive rather than predictive decision-making.

Various problems in the traditional modeling workflow have typically prevented even the largest oil and gas companies from keeping models up to date with current data. First, a lot of effort has been required to ensure that flow simulations match production data. This manual intervention, usually needed to accurately model the geological heterogeneity between wells, is time consuming and can be expensive.

The second problem stems from the need to update the model with new wells or changes in the structural and stratigraphic definition. The process has simply been too time consuming, or required too much specialization to be practical. In fact, in most cases so much time and effort is involved that information from a new well cannot be added to the model and new simulations run before the next well must be drilled.

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Figure 1 - Linear Workflow commonly used to generate reservoir models.

These workflow problems introduce a tremendous burden into the modeling process. As a result, even in large fields operated by the national and major oil companies, modeling has often been infrequently applied. Some fields go as much as three years between modeling efforts. This choice, based on economic realities at the time, forces a reactive stance at the field level. When the unexpected is encountered, it is handled in the moment. As time goes by, the unexpected is compounded and the subsurface is more and more uncertain.

Changing the Workflow

The traditional, linear approach to modeling had the advantage of stepping the user through the workflow. However, it made updating the structural or geologic model a lengthy process. Each discipline passed its results to the next. There was no looking back and no consistency checking. Unconnected steps make updating the simulation model quite difficult.

To be effective and useful to everyone, the workflow must be dynamic, allowing changes or additions to the model at any time. Now technology exists that enables this iterative approach, automatically recording the workflow as the reservoir model is initially built and providing the framework for the model to be updated when any input is modified or any modeling parameter is changed. Iteration is a choice and can happen anywhere in the workflow. By taking advantage of this new approach, exploration and production managers can improve their drilling programs, production yield and predictive planning accuracy.

Linear and dynamic workflows are contrasted in Figures 1 and 2. The linear workflow shown in Figure 1 moves steadily from left to right. Although iteration is technically possible in the early stages of interpretation and structural modeling, and in the late stages of flow simulation and well planning, generally the workflow assumes a one-way path.

In contrast, the iterative workflow shown in Figure 2 assumes that iteration may be desired at any stage in the workflow. This workflow allows interactive, dynamic updating of new data and ideas at any position in the workflow. This approach increases accuracy and reduces the time involved in both building and updating the model, making modeling far more attractive as a living workflow.

Building the Model

Realistic models are achieved by creating a framework using both seismic and well data. Porosity and lithology information derived from the seismic data can be

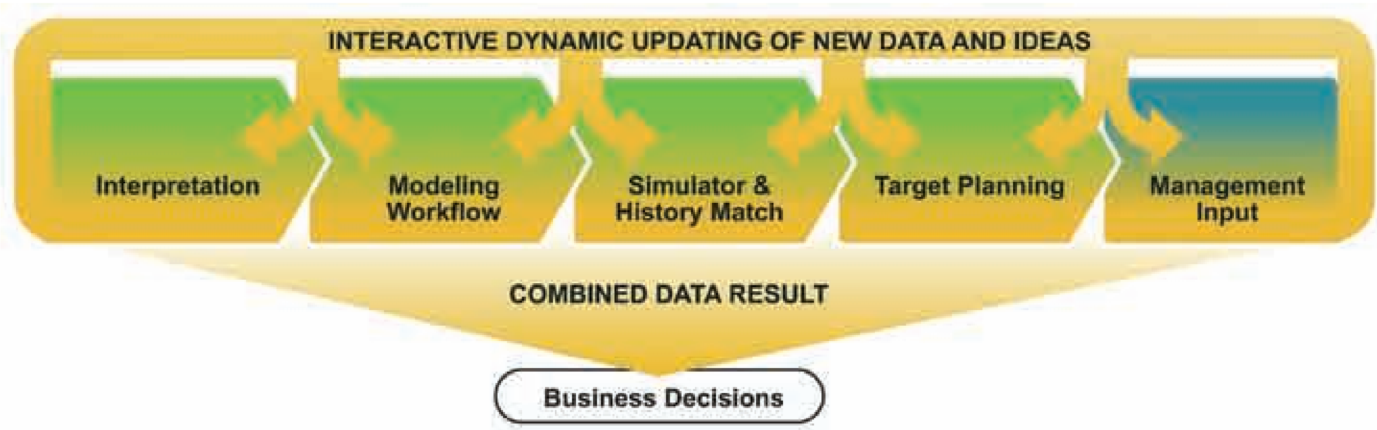

Figure 2 - Iterative Workflow enabling changes at any time at any point in modeling.

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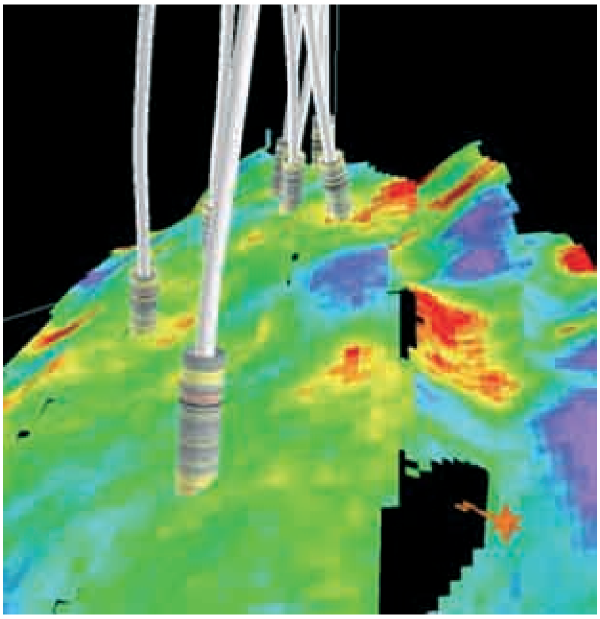

Figure 3 - Fine-scale model.

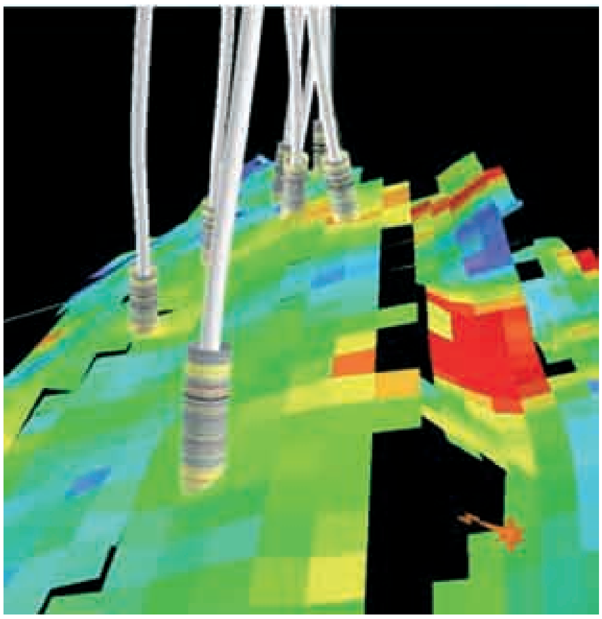

Figure 4 - Upscaled model.

combined with the well data in the initial geological model. Models which are built with and robustly honour both the seismic and well information typically require dramatically less intervention to obtain satisfactory history matches with the production data, and any changes needed are usually a result of the coarseness introduced in the upscaling process. The resulting model is kept current by including ongoing operational data as it is acquired.

The first step in modeling is gathering well logs, cores, a geological interpretation, and other operational data. A geological model is then built from this data, based on a corner point grid (CPG) or a hexahedral grid. Geologists and engineers review this model to ensure it matches conditions observed in the field.

Next, seismic data is used to provide cost effective, laterally extensive field measurements because it provides better horizontal resolution. Techniques for acquisition and processing have evolved over the past few years, leading to better quality seismic data. At the same time, the volume of data acquired has skyrocketed, making it difficult for companies to take advantage of the data in a timely fashion.

The biggest challenge to date has been to transfer this information from seismic to the right location in the corner point grid. This is partly because the seismic data is captured in a different geometry and scale than the corner point grids. Technology is now available to correctly sample the seismic derived properties into corner point grids. This information can then be used as a trend for modeling reservoir properties.

Seismic inversion also creates a 3D representation of the stratigraphy and lithology of the field, which is then combined with the geological model to create a new model that honors all the data in the field. The resulting grid, quickly built from the combination of geologic information and seismic data, can then be updated and upscaled as required. Engineers can use the upscaled model, as shown in Figures 3 and 4, to run flow simulations or for in-fill drilling decisions. This process is now far more integrated and substantially faster than ever before.

Updating the Model

The seismic-to-reservoir model workflow is recorded automatically as the first version of the model is built. It can then be modified and updated in minutes, via a simple drag and drop interface, every time new information is available. Geologists can import horizons from any source, create a geological model including seismic, upscale the results and analyze the reservoir over time using any simulator. Any input can be modified; any parameter changed. Figure 5 shows how a fault can be added, repaired, and truncated against surfaces.

Fast updating of three elements is key to this new approach:

1. **Structure.** When a geologist adds a structural feature, certain characteristics are implicit and automatic. For example, if a new fault is dropped into the workflow and it crosses a horizon, the fault horizon interface is automatically adjusted. This modularity removes much of the need for manual intervention.

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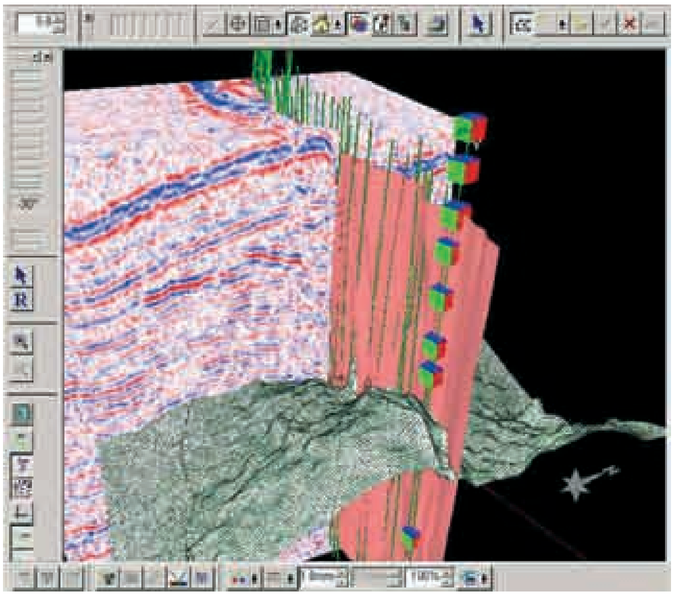

Figure 5 - New fault added, repaired and truncated against surfaces.

2. **Data.** New operational data can be added to the model at any time. The effect of the new data is essentially immediate because after adding the new data, the previously recorded workflow is rerun with the additional inputs.

3. **Recorded Workflow.** Every step of the workflow is automatically recorded, requiring no training. The geologist or engineer can revisit any decision or parameter in the workflow at any time. All changes are immediately reflected in the model.

Significant time-savings enable geologists and engineers to run multiple scenarios and simulations, resulting in a greater understanding of the reservoir behavior in a fraction of the time previously required.

Supporting Operational Logistics

The value of ongoing modeling to ongoing operations is tremendous. For example, preventing the drilling of one dry well or re-routing a well to target the highest porosity zones through ongoing modeling can save millions of dollars. Anticipating the needs of surface and downstream facilities can save substantially more than that.

Consider the case of a new fault discovery. This will likely have an effect on flow and may drive the need for an additional well. If the new condition could be quickly incorporated into the reservoir model, the operator could determine the best course of action to preserve or enhance the field's production. Similarly, if the gas flow from a field is increasing, modeling can help predict the downstream facilities needs and timing.

A common complaint when modeling infrequently is that the realities in the field no longer match the predictions of the model. A quick way to improve field management, then, is to incorporate new field data as quickly as possible into regular modeling and simulation. In the past, models were not able to keep up with the volume or pace of data acquisition and got out of sync. With the new approach, this is far less likely to happen.

Dealing with Uncertainties

While models provide insight into the subsurface, many uncertainties remain. A great deal of this uncertainty is removed by starting with the most detailed initial model that honors all input data. When modeling itself is a less time consuming process, multiple scenarios can be modeled and simulated, further reducing uncertainty.

Still, even the most thorough model can miss an uncertainty that results in a 'surprise well'. With the ability to update the model, geologists can quickly incorporate the 'surprise well' into the model, speeding reaction time from months to weeks. This same capability makes it easier to model a wide range of uncertainties, reducing the risk of further 'surprise wells'.

Scenario Modeling

Accurate models created and updated in a fraction of the time previously required can help improve operational logistics and overall field production. An iterative workflow opens the possibilities for in-depth analysis without significant time and effort, yielding:

- Fine scale interpolation between closely-spaced wells
- Estimation of uncertainty to assess risk
- Generation of lithotype (e.g., high, medium and low porosity carbonate) volumes
- Estimation of porosity (key in carbonate fields) from seismic impedance
- Integration of high vertical resolution well data with low vertical, high lateral resolution seismic
- Inputs for reservoir flow simulation

Geologists and geoscientists can then investigate various options for production wells and explore multiple models and interpretations. When dealing with large fields, the significantly reduced time investment makes a compelling case for keeping reservoir modeling in step with data acquisition.

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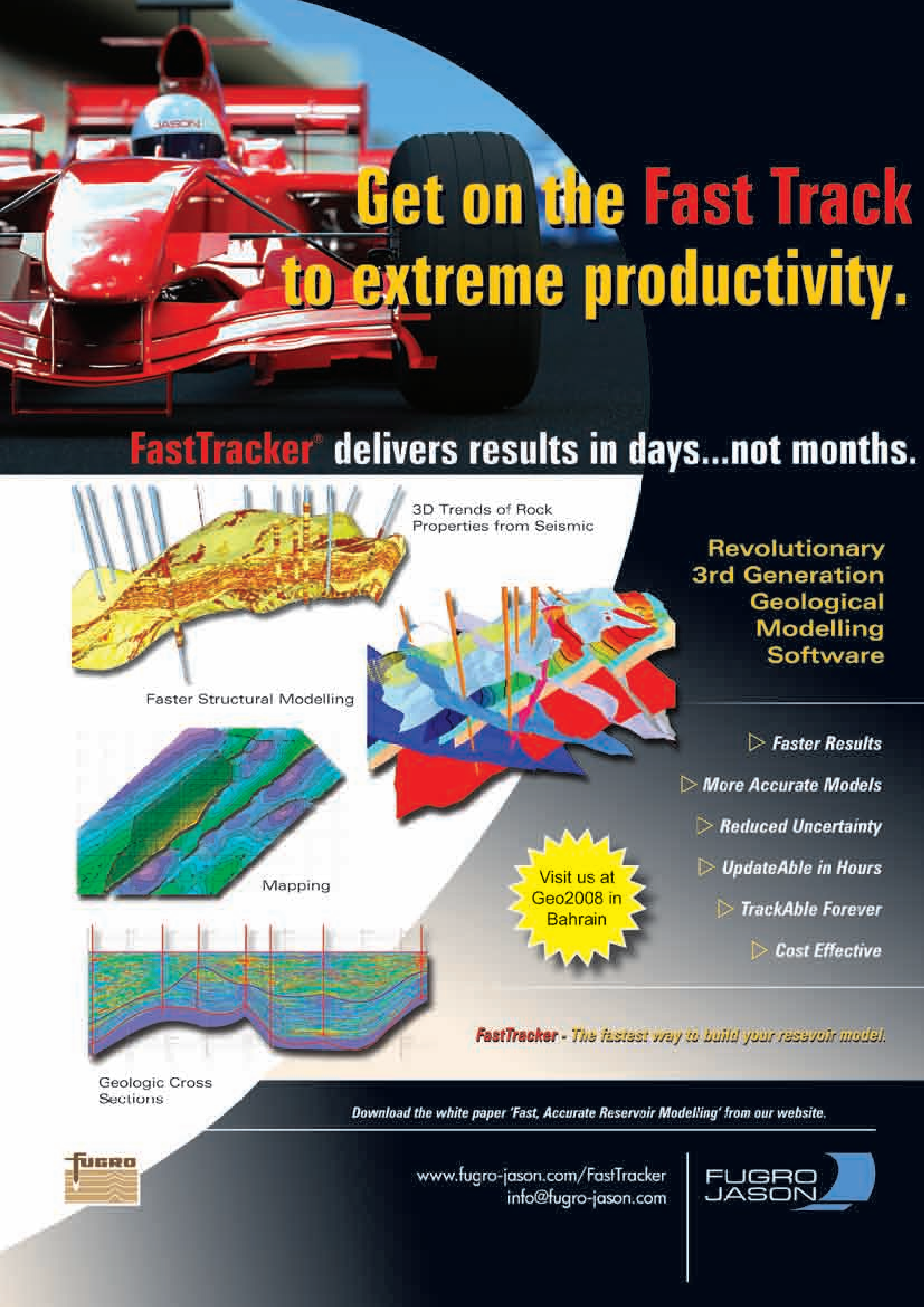
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Remote Data Management Services: Opportunities and Challenges

Introduction

The market focus on business process optimization has increased during the past few years. Vendors are entering the outsourcing market at all levels, seeking differentiation. In addition, "offshore" delivery of services via global delivery models is changing the competitive landscape.

Power lies in the simple and effective transfer of information from its source to the place where it can create most value. Remote Data Management Services is one such way to achieve this objective. Remote Data Management Services require robust, high performance information capabilities, platforms, and processes. This model can be very effective in providing high quality, and competitively priced services to clients worldwide. By outsourcing this service to experts, clients are able to realign internal resources to concentrate on core business activities.

Remote data management is one of the components of an integrated global delivery model. It allows organizations to have full control over enterprise data as the applications and the data hosted on those applications stays within the control of the organization.

Global Delivery Model

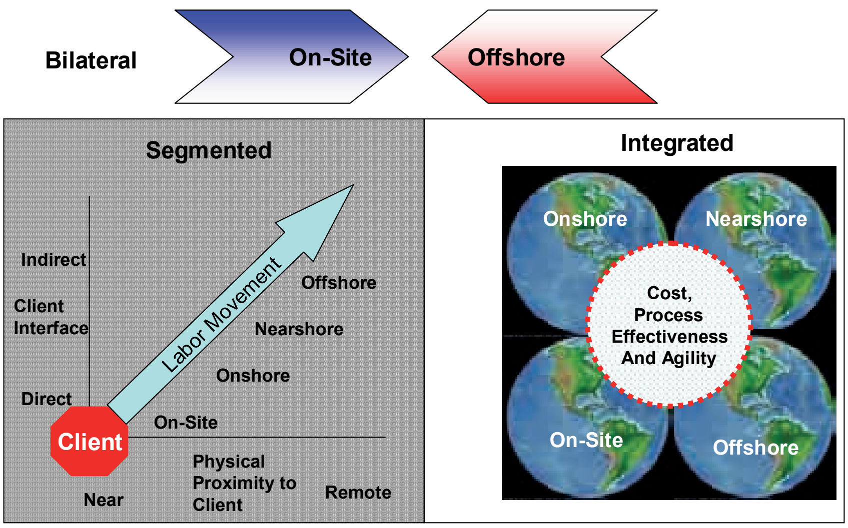
In the future, global sourcing will be business as usual and leading organizations and leading service providers will perfect an integrated, dynamic service delivery model that optimizes labor/resources globally (on-site, onshore, near-shore and offshore).

Remote Service Provider – Support Model

Remote Services deliver the benefits while avoiding the pitfalls of Application Service Provider (ASP). There is no argument about who is hosting whose licenses. The hardware investment is preserved – with the potential of moving to a lower cost platform at the right time. The data and applications stay in the same place avoiding performance problems.

Remote Service provides a very user-centric approach which uniquely combines IT and Application Support as one service. It also allows the organization to

How GDMs Are Envolving: From Bilateral to Segmented to Integrated Approaches



- appropriately allocate the work load on its onsite staff by utilizing them for more business critical activities and push tasks that are not very time critical to the remote service provider.
- use process, technology & emerging economies to deliver services.
- add or subtract services as required (Pay Per Use).

Incase of application support encompassing various sites located worldwide, remote data management services can add benefit to the organization by replicating the best practices performed at one site to all others as all sites are virtually placed aside and knowledge transfer can take place quickly. Resource utilization can improve; it is very scalable and provides substantial cost reduction.

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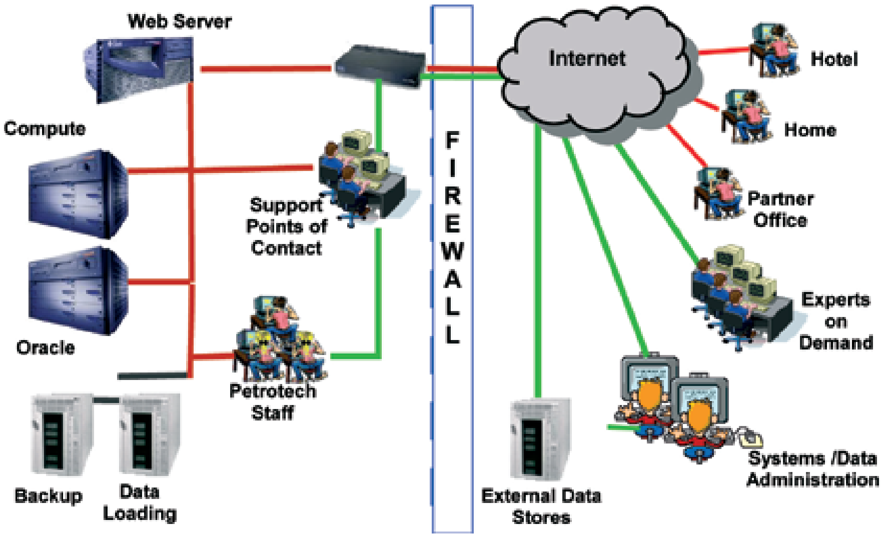

The organizations can adopt "Follow the sun" service delivery via the offshore center and depending on the criticality of the job, either the onsite, regional, or the off-shore center can take over the assignment.

Globalized Resources Pool

The trend toward a global resources pool has been emerging for more than a decade, and has changed the choices for enterprise buyers and Enterprise Service Providers. However, most organizations are at the very beginning of the learning curve for using global sourcing effectively. Most organizations that have used global sourcing have done so for the Resources-intensive applications services layer, with the objective of doing the same work at lower cost. There are significant potential cost benefits for appropriate tasks if the exercise is managed well. However, organizations need to learn new sourcing knowledge and skills to succeed with global sourcing. They need to build management competency to operate globally, learn about new provider options and begin to learn through carefully selected projects.

With remote data management services, the organizations can fast track the learning curve of its resources as the knowledge acquisition and transfer can take place at a rapid pace due to continuous sharing of procedures followed at various locations and also rotation of resources from one site to another. The replication of expertise to new staff can help an organization grow while meeting the service delivery standards.

Utility Computing (On-demand Services)

Remote Data Management Services is a simple, manageable and very cost effective step towards a world where the organizations can utilize a high level of service from anywhere in the world and only pay for what they use.

A truly globalized market is evolving, which translates into organizations accepting the realities of a global workforce, an expanding network of global delivery centers and a global lineup of competitors — some familiar and some new. On the horizon for each of the main platforms of outsourcing is utility computing, which has been popularized as on-demand services.

Today, most utilities (on-demand services) have focused on efficiency and cost savings. However, focus is beginning to shift to more strategic uses of sourcing. As outsourcing evolves, project scope must expand and mature.

Drivers and Inhibitors for Remote Data Management Services

There are a large number of drivers and inhibitors that can affect an enterprise's decision to establish remote data management services. Some of these drivers are grounded more in the "home country" dynamics (for example, regulatory issues); others are more a factor of the business' dynamics (for example, cultural diversity in the organization), while some are affected by the offshore country's dynamics (for example, the IP/security environment).

It is, therefore, important to focus sufficiently on all three aspects of this evaluation, as opposed to the tendency of just one (the typical offshore country evaluation).

Remote data management services demands;

- High Quality as a pre-requisite in services.
- Established documentation of processes and procedures
- Established effective escalation controls
- Established SLA's that fully reflects the range and type of work undertaken
- Monthly metrics reporting to client

Offshore providers are seeking to excel in a fiercely competitive part of the market, and more-traditional providers are keen to ensure that they are keeping pace with these up-and-coming players. Unfortunately, while many providers are trying to establish a mature "business as usual" position for their GDM, the market keeps changing. The past "cost driven" requirements of buyers are beginning to develop into demands for balanced business benefits. Fully integrated GDMs that are able to deliver an increasing range of services using the best skills, from the right location, at the right time and the right price are becoming a necessity. In addition, the drive toward the use of utility services will place increasing pressure on providers to move their emphasis from labour-intensive approaches to increased automation.

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Seismic Technologies

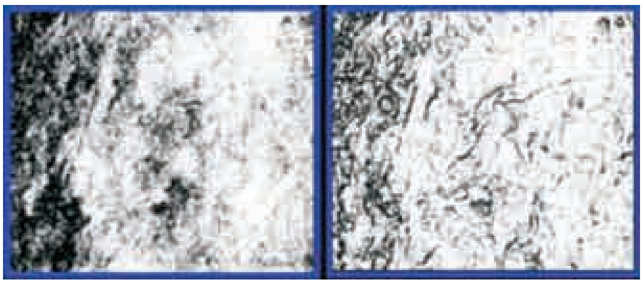
Oil and gas are usually found where two different types of rock meet at great depths. Such areas are "out of sight" to those searching for these valuable hydrocarbon reserves. But where the eye can't see, sound can.

Geophysicists "look" into the earth by various means, and one of the most effective is known as seismic reflection, in which sound waves are thumped into the earth and detectors listen for the echoes. These sound waves are generated by massive vibrating plates suspended from trucks, such as those seen on Dhahran roads lately.

The sound travels deep into the earth and then is reflected back from rock formations to the surface, carrying geological information in the form of sound signals. In processing these signals for mapping the earth's interior, scientists find that not all the reflected energy is useful. The signals are often obscured by a lot of unwanted noise.

Think of signals as words you can't understand because you are in a noisy place. You can turn down the volume of the music playing, close the window, turn off the coffee grinder, tell the children to stop squabbling, until eventually the words become discernible to your ear. Supercomputers can be used to remove as many unwanted noise sources as possible, but signals, unlike words, can be degraded in the process.

The result is that the edges between rock types - or "discontinuities" - that geophysicists are looking for, become blurred, something like slurred words.



Applying EPS on seismic data presents dramatic results. Two subsurface maps for the same area are shown. The image at left is generated without applying EPS, but it is applied on the image at right. Geoscientists can see more and interpret better by using the image at right. In this way, EPS and the scientists who have been using it for the past five years have helped Saudi Aramco find new oil and gas deposits to meet the world's growing energy requirements.

From left, Mohammed Alfaraj, Maher Al-Marhoon, Yi Luo and Saleh Al-Dossary came together to produce Edge Preserving Smoothing, or EPS, a technology that sharpens geophysicists' view of hydrocarbon reservoirs and has now received a U.S. patent.

Scientists from the EXPEC Advanced Research Center (EXPEC ARC) joined forces with colleagues from other Saudi Aramco sister organizations to respond to that problem. Geophysicists Yi Luo (EXPEC ARC), Saleh Al-Dossary (EXPEC Computing Center), Maher Al-Marhoon (Exploration) and Mohammed Alfaraj (EXPEC ARC) invented Edge Preserving Smoothing (EPS), a noise-reduction technique that removes certain types of noise without damaging the edges of the signal. In November, the Intellectual Assets Management Group, which worked with the inventors on a patent application, learned that the invention had been granted Patent No. 7,136,079 by the U.S. Patent and Trademark Office.

EPS avoids smearing the edges of major discontinuities by choosing from among multiple overlapping "windows" of the signal instead of smoothing the whole. The window with the minimum variance or distortion is then subjected to smoothing with a filter.

As one of the inventors explains, "EPS works by selecting the most homogeneous window from a suite of candidate windows containing the analysis point."

The result - a much clearer picture of the wealth that lies hidden beneath our feet.

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Pore Network Modeling: A new Technology for SCAL predictions and interpretations

By V.S. Suicmez, SPE, Saudi Aramco; M. Touati, SPE, Saudi Aramco

Abstract

There have been recently substantial advances in Pore Scale Physics Discipline. These advances can now be used for the benefit of special core analysis (SCAL) measurements and interpretations. This article is devoted to explain these improvements from two perspectives: (i) Pore scale imaging and network extraction (ii) Fluid flow modeling applied on the extracted networks in order to predict some key petrophysical properties (capillary pressures, relative permeabilities).

We use either thin sections or X-ray microtomography (micro-CT) to analyze rock cuttings of sandstones from Saudi Arabian oil and gas fields. These cuttings are a few mm across and are imaged with a resolution of 3 to 12 microns. Hence, the details of the three-dimensional pore space can be clearly seen. A maximal ball algorithm[1,2] is used to extract a topologically equivalent pore-throat network: the largest inscribed spheres in the pore space representing the pores, with throats representing the connections between them.

In parallel to this algorithm, thin section images are utilized to build 3D equivalent images, reproducing porosity by a similar spatial variation of the grain sizes obtained from the thin sections. This has been done through the so called process based technique[3] which is based on honoring the geological depositional mode of the rock.

The final aim is to input these network models into pore-scale fluid flow simulators to predict macroscopic properties such as relative permeability and capillary pressure. Blind tests are envisaged to compare the measured petrophysical properties and their corresponding numerical estimations.

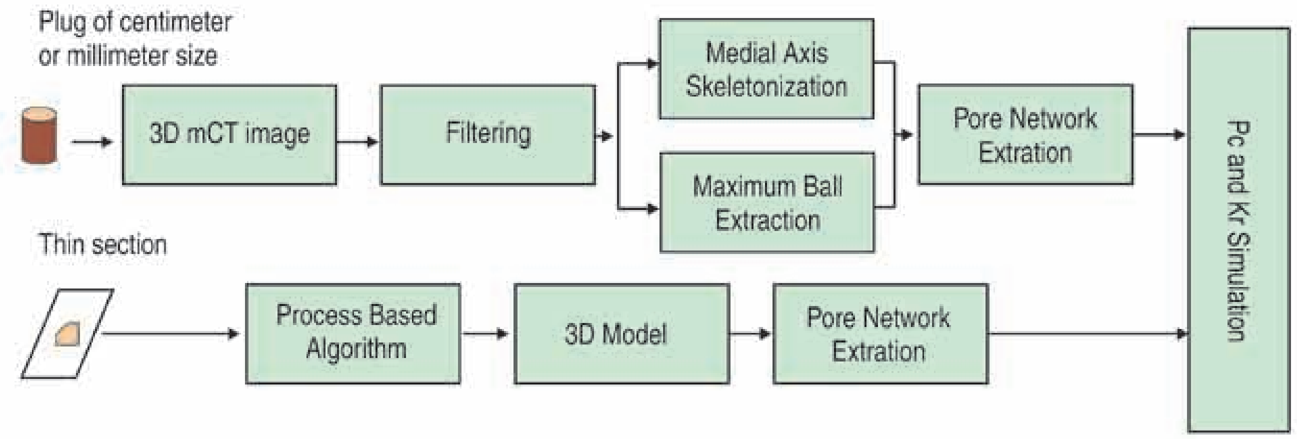


Figure 1 - Steps of the pore network modeling from 3D or 2D imaging to petrophysical properties estimation.

This acts as a valuable complement to special core analysis, enabling predictions of properties – such as three phase relative permeabilities and the impact of wettability trends – outside the range probed experimentally.

Introduction

Obtaining the SCAL data can be very expensive, and even more importantly acquiring, analyzing and integrating the data may take a long time. In order to prevent this expense and even more importantly the wasted time due to the long and tedious SCAL procedures, numerical simulation techniques were developed and deployed in the last few decades.

With the availability of more efficient numerical modeling algorithms and super-fast computing resources, there have been significant advancements in the specific area of "pore-network modeling". Pore-scale modeling which combines an accurate description of the pore space with a detailed analysis of pore-scale displacement physics is a useful tool for understanding multiphase flow in porous media. From a practical perspective it can be used to make predictions for situations that are difficult to study experimentally. Some of the previously conducted studies[4] show that even for rather complex displacements – such as WAG flooding – this approach is able to make accurate predictions while revealing the subtlety of the influence of pore-scale displacement on macroscopic behavior.

In short, the main advantages of such developed procedure for pore network extraction and multiphase fluid flow modeling, are as follows:

• It takes only a few hours of computing time to obtain multi-phase flow properties while it may take a few weeks and even months to get the same properties measured in the lab.

• It is possible to virtually change some input parameters such as initial water saturations, Swi, interfacial tensions, IFT's, and contact angles to conduct sensitivity studies for different fluid and rock systems. It is a well known fact that these parameters are not constant throughout the reservoir, but instead quite varied especially in the transition zone.

In the course of this article, we will first discuss and compare two of the recently developed pore-network generation algorithms (i) Maximum ball algorithm[1,2] and (ii) Process-based technique.[3] Once we obtain the pore/throat network which is representative to the pore space of the real reservoir rock, we can then conduct multiphase fluid flow simulation in order to obtain the macroscopic transport properties such as relative permeabilities and capillary pressures (see Figure 1).

Pore Space Reconstruction

Utilizing pore-network modeling technique and solving multiphase fluid flow equations to predict transport properties not only require a detailed understanding of displacement mechanisms at the pore level but also an accurate and realistic characterization of the structure of the porous medium. Although there have been significant advances in describing the geometry of pore space and several techniques were already introduced in the last few years, we will limit this article with the two recently developed promising approaches; maximal ball algorithm and process-based technique.

Micro-CT Imaging and Maximal Ball Algorithm

We extract pore networks from direct micro-CT images. A micro-CT scanner at Imperial College London and a synchrotron tomographic scanner at ELETTRA, a national laboratory in Trieste, Italy, have been used to image sandstone and carbonate samples (Figure 2). The micro-CT scanners output three-dimensional (3D) arrays of reconstructed linear X-ray attenuation coefficient values (CT numbers), which can be viewed as gray scales in image processing software. The raw images are filtered to smooth the image, reduce noise and improve the contrast between grain and void. We use the median filter which replaces the gray scale value of a voxel by the median value of the nearest 26 surrounding cells. A threshold value is then chosen to binarize or segment the gray scales into two phases: solid and void. The effect of image processing is seen in Figure 3.

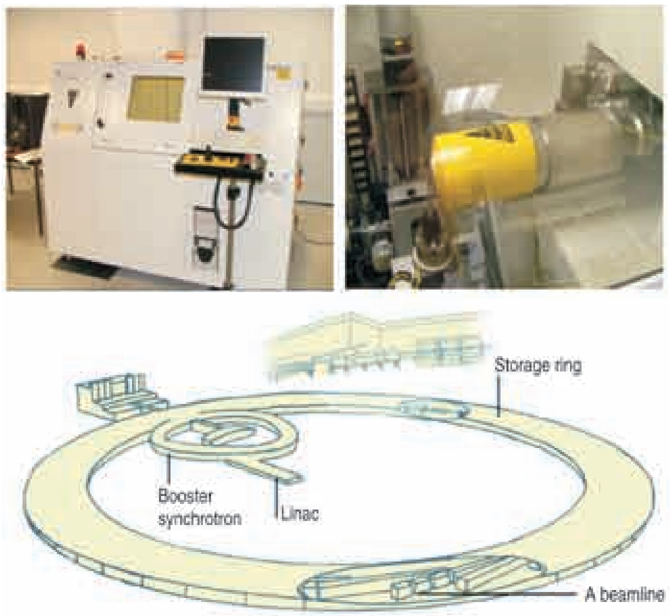
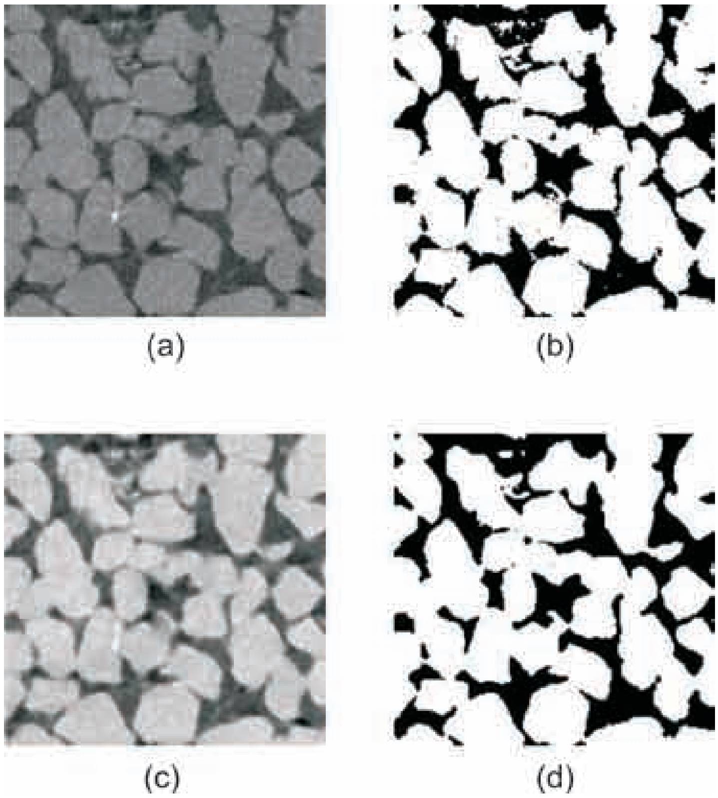


Figure 2 - Micro-CT scanner at Imperial College London and X-ray tube (left), in this scanner and the sample stage. Synchrotron (Above).



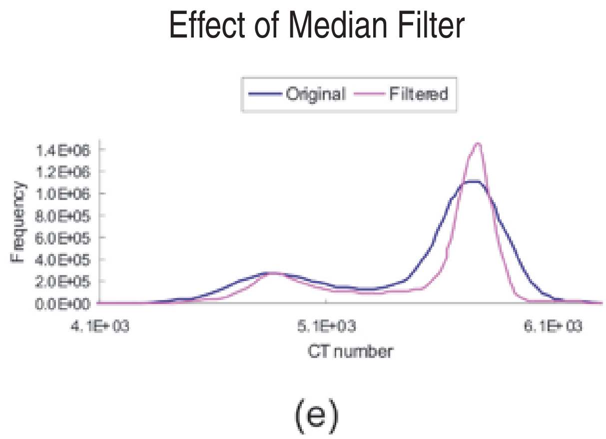


Figure 3 - (a) Cross section of the raw image of a sandstone sample (b) segmented image of the raw image (c) median filtered image (d) segmented image of median filtered image. Comparing (b) and (d), we find the median filter preserves the integrity of the grains and the pore space. The side length of the four cross section images is 0.75mm; (e) shows the effect of median filtering on the gray scale histogram and where the threshold value is set. The two peaks representing two phases (void and solid) are more distinguished after filtering.

Once we obtain the 3-D representation of the void and solid using the micro-CT technology, maximal ball algorithm is used to construct the largest spheres centered on each void voxel that can just fit in the pore space. A maximal ball is one of the spheres not completely enclosed by another. The concept of maximal balls was first introduced and used by Silin et al.1 to study the morphology of 3D pore-space images. A maximal ball that does not overlap any larger sphere defines a pore. Throats are defined as chains of smaller balls connecting pores. The maximal ball method easily and unambiguously identifies pores, but the construction of throats is more tedious, as there may be several different ways to connect pores by overlapping smaller spheres.

Validation of Maximal Ball Algorithm

Ten rock samples of Saudi Aramco have been scanned and fourteen images were obtained using industrial and synchrotron micro-CT scanners. In order to obtain suitable samples for imaging, we drilled cylindrical specimens from the larger cores before scanning. The resolution of 3D images varies from 3 to 12 microns corresponding to specimen diameters ranging from 2 to 8 mm.

Pore networks have then been extracted from two sandstones (named as S1 and S2) and one carbonate sample (named as L1). Cross-sectional views as well as the full 3D representations of the micro-CT images are shown in Figures 4 and 5 respectively. The sandstone sample S1 has measured porosity and permeability of 16.4% and 906 mD. We drilled a 10 mm long, 8 mm diameter cylindrical specimen from the core plug and used a subset of the image (with a bulk volume of 1.73 mm^3) for pore network analysis. The resolution of the image was 8µm. The porosity measured on the image was 16.8% and the permeability was computed using Lattice-Boltzmann simulation as 1400 mD. As the image analysis results were in good agreement with the experimentally measured data, the subset of the image was considered as a representative elementary volume (REV) of the sandstone, S1.

The second image (from sandstone sample S2) was obtained at a resolution of 5µm and is representing a volume of 0.42 mm^3. And the last image (from limestone L1) has a resolution of 3µm. It represents a volume of 0.1 mm^3.

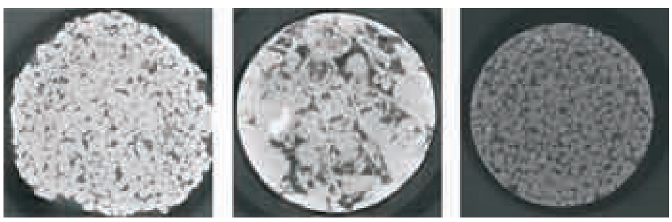


Figure 4 - Cross sections of micro-CT images of Saudi Aramco core samples. The image resolutions are 8 µm, 5 µm, and 3 µm respectively. Each image is 512 voxels across.

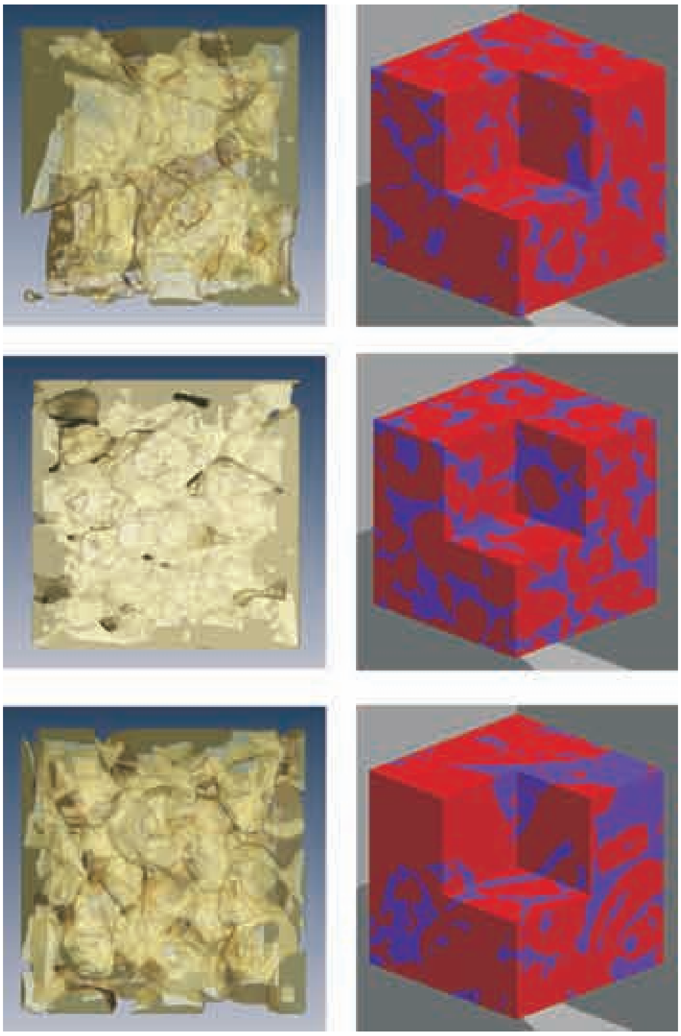


Figure 5 - Transparent view (left) and cutaway view (right) of the 3D micro-CT images. (a) S1, (b) S2, (c) L1.

Properties	Samples		
	S1	S2	L1
Porosity (%)	16.8	25.2	29.8
Number of pores	442	279	347
Number of throats	1018	631	1265
Avg. coordination number	4.71	4.59	8.6
Max. coordination number	14	12	32
Avg. pore radius(µm)	25.0	19.0	22.3
Max. pore radius(µm)	87.7	59.7	117
Avg. throat radius(µm)	19.2	13.1	19.3
Max. throat radius(µm)	78.5	37.2	88.9

Table 1 - Properties of pore networks extracted from Arabian reservoir samples

We extracted pore networks from these three samples and list the properties of the networks in Table 1. Since the minimum size of pores and throats is always the resolution value of the image, we don't list them in the table. We find that the sandstones have average coordination numbers between 4 and 5, which is in agreement with other analyses of granular media.[3,5] However, the vuggy carbonate has higher coordination numbers and a wider distribution of pore and throat sizes than the sandstones, which is also another expected result.[5] Figure 6 illustrates the extracted networks from S1, S2, and L1 samples.

Process-Based Network Generation

The process-based technique generates a model porous medium by simulating the packing of grains. The technique was first introduced and used by Øren et al.[3] and based on the simulation of the geological processes that the rock has been formed. The only input for this technique is a thin section image. Using image analysis techniques, sizes of the grains are recorded and deposited to form a 3-D porous medium. In addition to sedimentation process, compaction and diagenesis mechanisms are simulated to obtain a more accurate description of the porous medium in three dimensions. Medial axis algorithm[6,7] is then utilized, which uses a thinning algorithm to erode the pore space from grain surfaces until the medial axis – lines with branches denoting the centers of the pore space – is found. Pores are located at branches in the medial axis, while throats are connecting the pores. The size of the pores and throats can be determined by the number of steps of erosion from the surface of the grains. The medial axis mathematically preserves the topology of the pore space. However, the intrinsic sensitivity to the irregularity of pore space results makes the unambiguous identification of pores that may encompass several branches of the medial axis, difficult[7]. Generally, medial axis based algorithms readily capture the interconnectivity of the pore space but pore identification is tedious.

In this section, we will present the results of 3 blind tests that have been recently conducted on three Saudi Arabian sandstone samples. Thin section images were obtained for these samples to be tested through the process-based modeling approach (see Figure 7). In parallel to this study, the samples have undergone complete routine (RCAL) and a few special (SCAL) core analysis studies.

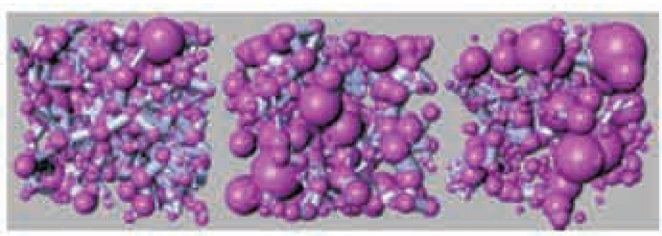


Figure 6 - Pore-throat networks generated from micro-CT images using maximal ball algorithm.

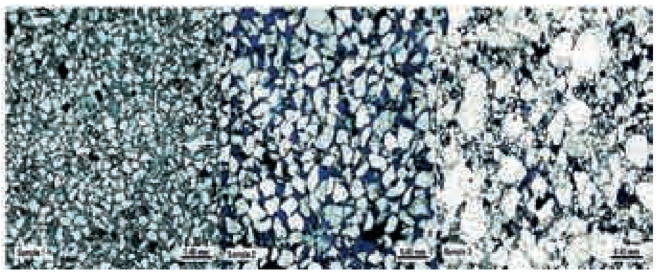


Figure 7 - Thin section images of the three Saudi Aramco sandstone samples which were selected for the blind study in order to test the validity of the process-based modeling technique.

The output properties that were targeted for comparison are the porosity, permeability and capillary pressures.

Descriptions of the thin sections reported for the three samples are as follows:

Sample 1: Fine-grained (0.08 - 0.12 mm) quartz, well sorted, angular. Ovoid patches of carbonate cement up to 1 cm across. Visual porosity estimated to be around 25%.

Sample 2: Fine-grained (0.20 - 0.24 mm) quartz, well sorted, angular to subangular. Estimated visual porosity is between 25 to 30%.

Sample 3: Bimodal with fine & medium grained (0.08 - 0.12mm & 0.34 - 0.40mm) quartz. Visual porosity is estimated to be 8 - 10%.

Scanning electron microscope (SEM) images were then generated for each thin section to build a numerical 3D model from which porosities and permeabilities are estimated. The values of the estimated porosities and permeabilities (with the corresponding error margins) as well as the experimentally obtained ones are reported in Table 2.

	SAMPLE 1	SAMPLE 2	SAMPLE 3
Measured Porosity (%)	30	34	19
Predicted Porosity (%)	31.5 - 32.1	28 - 30	14.2
Measured Permeability (md)	1265	1789	139
Predicted Permeability (md)	1800	1944 - 3428	9.4 - 15.4

Table 2 - Comparison of the experimentally measured and predicted porosity and permeability values.

As can be seen from Table 2, the results obtained through the numerically generated 3D images were comparable with the experimental data. Pore networks were then constructed from the 3D images using the medial axis algorithm. 2D slices of the numerically constructed 3D models as well as the pore-throat networks are presented in Figure 8 below.

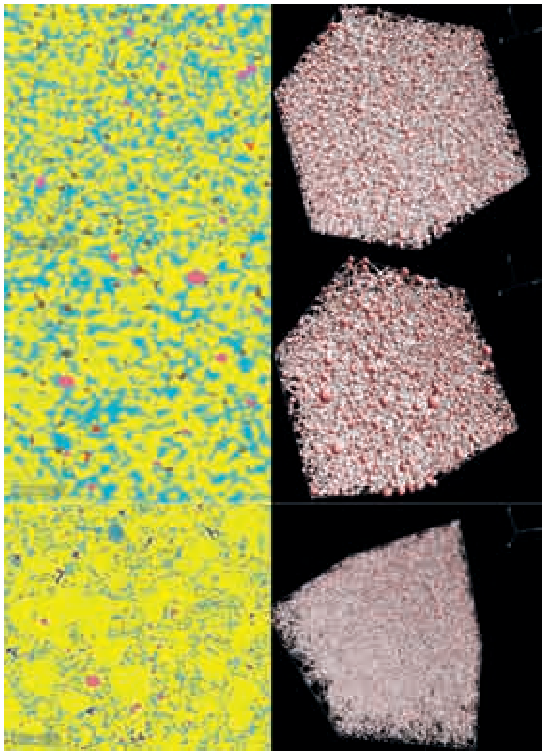


Figure 8 - A 2D slice of the 3D Model (left) and the corresponding pore-network (right) for samples 1, 2 and 3.

Some of the key characteristics of the numerically constructed rock networks are shown below (see Table 3). Nodes stand as pore-bodies while links are representing the pore-throats. Coordination number is the number of links that are connected to a node element. Note that, statistics are concordant with the porosity and permeability trends of the samples. For example, sample 3 with the lowest pore/throat radii as well as the lowest average coordination number has also the lowest porosity and permeability values. Sample 1 and 2 with similar pore/throat radii and coordination numbers have similar porosity and permeabilities.

	SAMPLE 1	SAMPLE 2	SAMPLE 3
Number of Nodes	55048	56448	65137
Avg. Node Radius (µm)	12.6	14.7	7.2
Number of Links	125116	121009	120243
Avg. Link Radius (µm)	6.6	7.7	3.0
Max. Coordination No.	34	53	21
Avg. Coordination No.	4.6	4.4	3.8

Table 3 - Key properties for the pore-throat networks constructed from Saudi Aramco sandstone samples through the so called process-based methodology.

Fluid Flow Simulation

Valvatne and Blunt[8] developed a mixed-wet, two-phase pore-network simulator in order to predict the key petrophysical properties such as relative permeability and capillary pressures. The fluids are assumed to be Newtonian, incompressible, and immiscible. The displacements at the pore scale are assumed to be quasi-static and capillary dominated. A displacement is defined as a change in the configuration of an element (pore or throat) in order to satisfy capillary equilibrium conditions. Each displacement has a threshold capillary pressure associated with it. In other words, displacement is carried out only if the invading phase reaches the required (threshold) phase pressure. At a certain phase pressure, all possible displacements take place until there is no more available displacement, which means system is relaxed and capillary equilibrium conditions are satisfied. The analytical computations of the threshold pressures have already been discussed in the literature.[3,8]

We use the model developed by Valvatne and Blunt[8] in order to predict the mercury/air capillary pressure data as well as the water/oil relative permeabilities during waterflooding using the rock networks generated from Saudi Aramco samples. Figure 9 and 10 compare the mercury/air capillary pressure curves for the experimentally measured and numerically estimated data for sample 1 and 2. The interfacial tension between mercury and air was assumed to be 480 mN/m during simulations. Although the match between the predictions and measurements were not perfect, the results were

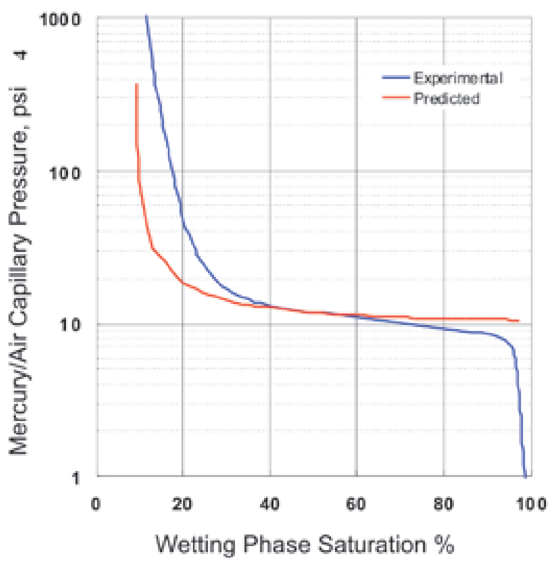


Figure 9 - Experimentally measured and numerically predicted capillary pressure curves for sample 1. Note that interfacial tension between mercury and air is assumed to be 480 mN/m during our simulation.

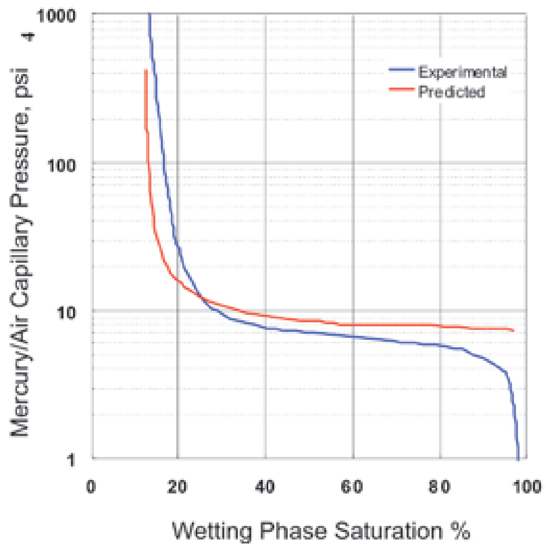


Figure 10 - Experimentally measured and numerically predicted capillary pressure curves for sample 2. Note that interfacial tension between mercury and air is assumed to be 480 mN/m during our simulation.

reasonable considering the fact that the only available input was a single thin-section image while constructing the representative rock networks.

We then simulate a water injection cycle in order to predict water/oil relative permeabilities. Unfortunately we currently do not have experimental data to validate our findings. However, we are planning to conduct steady-state relative permeability measurements to test our simulation results. Figure 11 compares the predicted water/oil relative permeability curves for a water-wet (oil/water contact angles were distributed between 30 and 60 degrees) and a neutrally-wet (oil/water contact angles were distributed between 70 and 120 degrees) system for the rock network of sample 1. The interfacial tension between water and oil was assumed to be 35mN/m.

The results confirm that water/oil relative permeabilities have strong dependence on the system's wettability (see Figure 11). In a water-wet medium, oil is the non-wetting phase and prefers to invade the larger pores and throats. Thus oil relative permeabilities are significantly higher in a water-wet system. However, it is also shown that the residual oil saturation is lower for a neutrally-wet medium as the oil layers do form and stable throughout the displacements. This is a similar conclusion which was reached by Janahundran and Morrow[9] after conducting a series of experiments with media of varying wettabilities. We are planning to conduct a series of two-phase steady-state relative permeability measurements to validate these results.

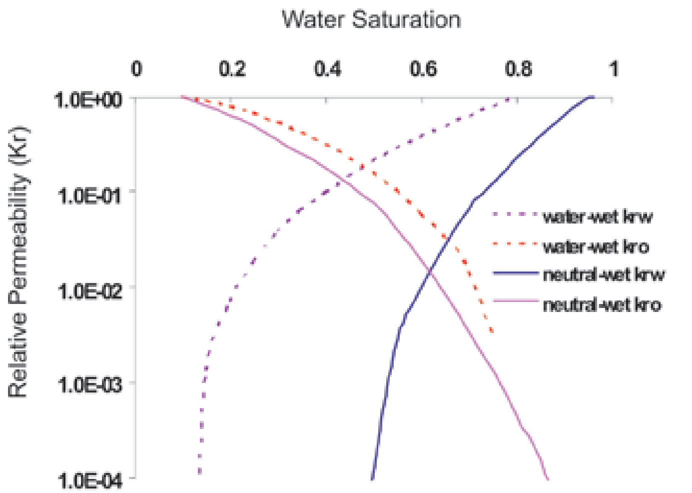


Figure 11. Comparison between oil/water relative permeabilities for a water-wet and a neutrally-wet medium. The simulations were conducted on the rock network of sample 1 and water/oil interfacial tension was assumed to be 35 mN/m.

Conclusions

We first described two recently developed pore-network generation techniques, maximum ball algorithm and process-based method. We were able to generate pore-throat networks that are representative to the real rock samples. We then simulated two-phase fluid flow through the rock networks (obtained by process-based technique) in order to test the predicted mercury/air capillary pressure data with the experimental counterparts. The results are encouraging. Considering the fact that the rock network is constructed from a single thin section image, predictions were in reasonable agreement with the measured data. We then simulated a water injection cycle after the primary oil invasion to see the effects of system's wettability on water/oil relative permeabilities. Oil relative permeabilities were higher for a water-wet system, however residual oil saturation was estimated to be lower for a system of intermediate wettability which is in line with previously conducted experiments[9].

Overall, pore-scale network modeling that combines an accurate description of the pore space with a detailed analysis of pore-scale displacement physics is a useful tool for understanding multiphase flow in porous media. From a practical perspective it can be used to make predictions for situations that are difficult to study experimentally.

Acknowledgments

We would like to thank Numerical Rocks Company, Trondheim, Norway for providing us with the Saudi Aramco sandstone network data used in this work which were obtained through process-based technique. We are also thankful to Saudi Aramco management for giving us permission to publish this work.

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Digital Projectio Control Room M

By Abdulmajeed A. Al-Abdulhadi, Saudi Aramco

Abstract
This article will give a brief history of control room mapboards, starting from posted printed paper drawings, through tiled mapboards and ending with video walls, including the advantages and disadvantages of each format. It highlights the important role of the mapboard in command and control centers. The article reviews the latest technology of control room projection systems and video walls, including important design criteria. The article concludes by sharing the experience of developing and installing one of the largest command and control center video walls in the world, in the Saudi Aramco Operation Coordination Center (OCC) in Dhahran, Saudi Arabia.

Introduction
Mapboards
Mapboards are usually the most dominant visual feature in a control room, which in addition to their valuable functions can provide a strong and positive aesthetic aspect of the control room environment. The word "mapboard" is derived from the words "map" and "board," which reflects the original form of information sharing between dispatchers in a control room; where drafted drawings were posted on a wall to highlight the current operation status. Paper was replaced by electronic and computerized mapboards.

Role of the Mapboard in the Control Room
Despite the rapid increase of computer based systems for network monitoring and controlling, dispatching, and service restoration activities; the need for mapboards in control room environments to display an overview of the system configuration – usually in real time, was required to show the "big picture" related to the operation network. The mapboard is the rallying point at which key personnel take decisions, especially in emergency situations. A mapboard provides an easy way for groups to discuss emergency scenarios, involving a huge operation network, while monitoring the situation.

History
Mapboards initially started by posting drafted drawings on walls, followed by printed drawings attached over steel board with magnetic symbols such as arrows to mark up the drawings. This method was hard to use because with time the drawings became obsolete, due to changes in the operation and physical deterioration of the drawings. This situation was the driving force to have a system that does not deteriorate and allow for small changes to keep the mapboard network up to date.

The mosaic tiled mapboard was a revolutionary move for command and control centers. It consisted of a frame structure which carried matrix grids. Tiles, multicolor LEDs, and digital counters were mounted over these matrix grids. The tiles were colored to form the operation network diagram. The multicolor LED and the digital counters were used to show the system data.

The main advantage of the mosaic tiled mapboard over the traditional posted drawings was the capability of showing the system data as part of the whole network diagram.

Later the mosaic tiled mapboard was enhanced by mounting CRT monitors, which were later replaced by projection systems. Demand grew because of the increased rich information that computer systems delivered through projection systems. This technology eventually led to video wall systems.

The advantages of the video wall over the mosaic tiled mapboards are flexibility, easy maintenance, quick display updates and excellent visualization.

n Revolutionizes ap-Boards

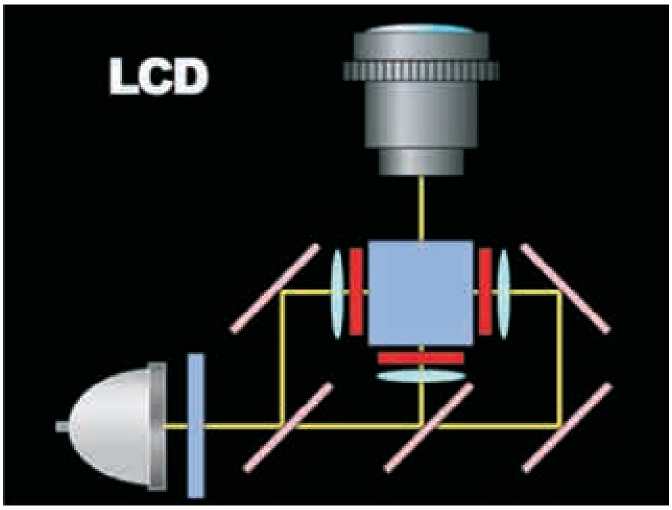

Figure 1 - LCD Projection

Video walls evolved from low quality CRT-based projection systems to state of the art digital projection systems, which revolutionized modern control centers. The digital system provides clear images on wide screen displays, with all the flexibilities and attributes of modern PCs. In the following sections we will go over the details of modern video walls.

Video Wall Mapboard

Main Components

Video walls consist of several stacked rear projection modules with a dedicated projection controller, which is a dedicated computer, controlling these modules to make them work as one display with a huge number of pixels equivalent to the sum of the individual projection modules pixels. For example, a 2x2 video wall of an SXGA projection module will have a resolution of (2560x2048) pixels. The modules are mounted on a frame structure that shapes the video wall. Each of these modules consists of a projector, screen and mirror. The projectors are usually designed for 24/7 operation, with no "burn-in effect" from displaying static information for long periods of time[1, 2].

Projector Types

Currently there are two common digital projector technologies that can support the command and control center's 24/7 operation rear projection systems. These are the Polysilicon Liquid Crystal Display (LCD) projectors and the Digital Light Processing (DLP) projectors.

The LCD uses three polysilicon panels to process each primary color (RGB). The LCD panels work as a light on/off switch for each pixel, see Fig.1. On the other hand, DLP use micro mirror reflection to switch on/off each pixel. DLP can use a single chip or three chips to process the primary colors (RGB), see Fig. 2. Single-chip DLP process the lights sequentially through a rotating color wheel to get the RGB, while the three-chip DLP processes the colors in parallel like the LCD. The disadvantage of the three-chip DLP is its high cost, but it delivers superior pictures and is currently used for digital cinema. Single-chip DLP is usually used in command and control center projectors.

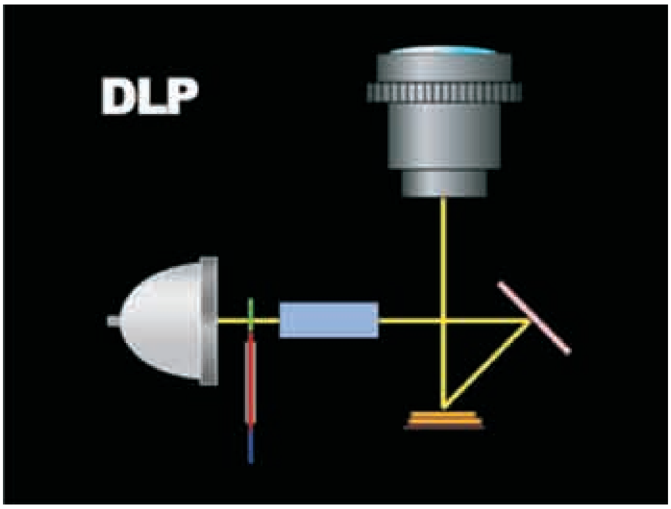

Figure 2 - DLP Projection

A screen is an imaging optical element that receives light from a light source and redirects it towards the viewer so it can be seen. In the case of rear projection, the optical element receives light from the projector and redirects this light towards the viewer.

Comparing both technologies, the LCD and the DLP, shows that:

• LCD projectors support resolution up to UXGA (1600 x 1200), whereas DLP currently supports resolution up to SXGA+ (1400 x 1050);

• DLP has a more active area, because it has a narrower pixel border, which will result in a more fluid image;

• LCD panels require alignment to converge the three-color images to one image, while a single-chip DLP does not require alignment;

• DLP uses DMD™ the Texas instrument proprietary chip, which has a lifetime of more than 100,000 hours, while the LCD lifetime is less than 70,000 hours;

• Because of DMD™'s reflective nature, DLP maintains its color stability over its lifetime. LCD panels are refractive and heat is generated in the panel's organic materials which deteriorate over time, resulting in a loss of brightness, which is perceived as a color change;

• DLP delivers higher contrast ratio (500- 600:1);

• DLP does not have the "burn-in effect" which affects LCDs due to the projection of a still image for a long time;

• LCD is subject to temperature and humidity conditions, while DLP is not. Because DLP is a reflective technology, heating and temperature do not affect the device's performance and reliability. LCD is a refractive technology, where light passes through the panel and gains heat;

• Single-chip DLP has the "Color Breakup Artifact," which is caused by the sequential processing of the three colors. The perception of this phenomenon is color separation on the screen, which could be noticed if the viewers move their eyes quickly. Technology is evolving to minimize this artifact by faster and different colorwheels. LCD and three-chip DLP does not have this artifact because colors are processed in parallel;

• DLP is gaining momentum over LCD because of the expected large market for digital cinema.

Both projection technologies can use two different types of lamps in their illumination unit, the Xenon lamps and the Philips Ultra High Performance UHP™ lamps. The Xenon lamps are very bright, which makes it suitable for open area events such as concerts. The deficiencies of this type of lamp are its shorter lifetime and it being more expensive then UHP™. Although the UHP™ lamps are less bright than the Xenon lamps, they are the best lamps for command and control centers. The UHP™ lamps are available with different power levels; 100 W, 120 W and 150 W. Higher power lamps are brighter than the low power lamps, but have shorter average lifetimes. For example, the 100 W lamp's average lifetime is 8,000 hours, while the 120W lamp's average lifetime is 6,000 hours. Lamp replacement is the main cost of ownership of video walls; therefore, it is very important to carefully select the required lamp type and power.

Screen Types

A screen is an imaging optical element that receives light from a light source and redirects it towards the viewer so

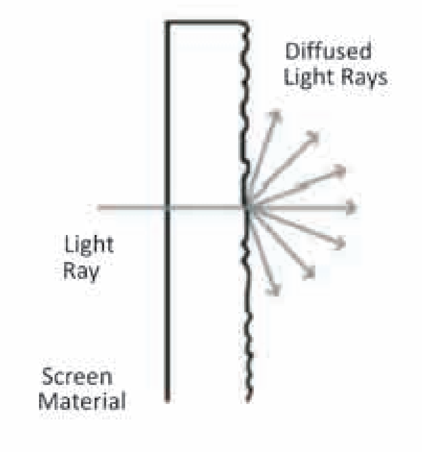

Figure 3 - Diffusion Screen

it can be seen. In the case of rear projection, the optical element receives light from the projector and redirects this light towards the viewer.

Generally, screens can either spread out the light evenly or direct most of the light more intensively, in a narrow cone towards the viewers. In the older dim projectors, high gain was necessary even if it results in a poor viewing angle, while the new projectors are bright and allow for a wide viewing angle. Screen choice depends on many parameters such as the followings:

• Brightness of the image;

• Viewing angles or the angles under which the image is seen with an expected quality;

• Position of the operators relative to the wall;

• Room lighting conditions;

• Screen size and display wall size;

• Contrast;

• Image uniformity;

• Light loss;

• Type of materials used.

Let us define some of the used terminologies to understand the differences between screens.

<u>Screen View Angle</u>
Viewing angle is the full angle at which the screen is still viewable with a good level of image quality. Screens have two viewing angles, horizontal and vertical.

<u>Screen Gain</u>
Screen gain is the factor at which the screen amplifies the received light toward the viewers. Screen gain is reversely proportional to the viewing angle from the center of the screen, which means that the screen's clarity will drop as you go away from the center of the screen vertically and horizontally.

<u>Half-Gain Angle</u>
Half-gain angle is the angle at which the screen gain is half the gain at 0°, which is the center of the screen. This half-gain angle results in half of the straight projected light output, which is applicable for both directions horizontal and vertical.

Screens
A screen must have at least one image forming surface. Different types of imaging layers are on the market, of which the most applicable types for rear projection are listed below.

<u>Diffusion Screens</u>
A diffusion screen diffuses each incident light ray and diffuses it to the public (Fig.3). Diffusion screens have symmetric gain curve and equal half angles. The main advantage of diffusion screens is that they often have large half-gain angles, which ensures a viewable image under an extreme viewing angle. This characteristic makes it applicable for multi-screen walls.

<u>Lenticular Screens</u>
Lenticular screens consist of an optical structure with vertical "cylindrical" lenses (Fig.4). Lenticulars are normally used in conjunction with fresnels (single or double element screens) and the lenticulars spread out the light horizontally, while limiting the viewing angle in the vertical direction.

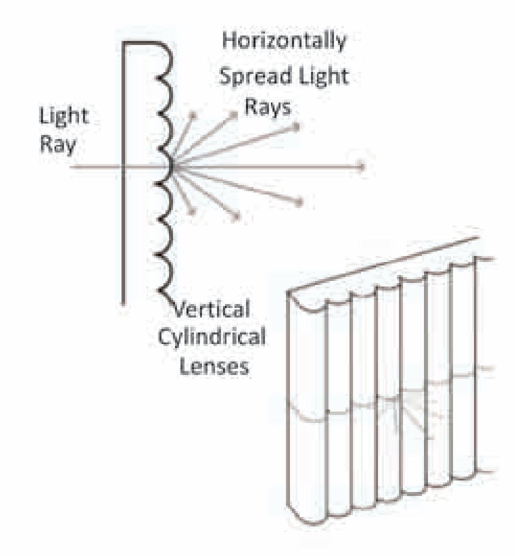

Figure 4 - Lenticular Screen

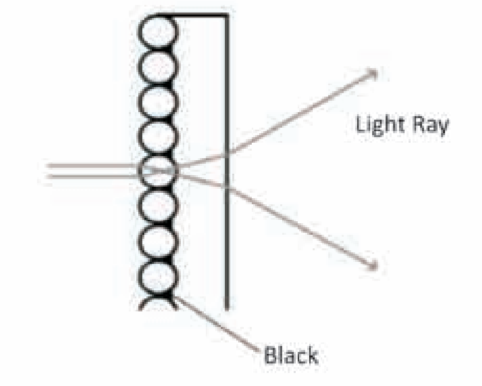

Figure 5 - Beaded Screen

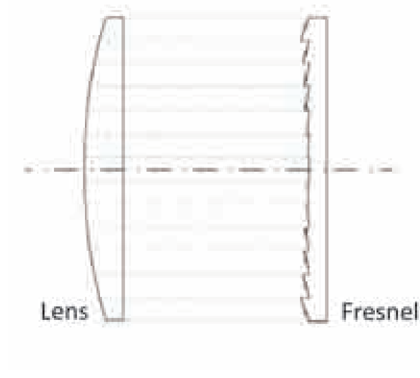

Figure 6 - Fresnel Screen

Bead Screens

The screens consist of a layer of microscopic spherical beads, embedded in a black resin (Fig.5). The beads will give the screens symmetric gain comparable to diffusion screens while maintaining a high contrast. Usually these screens have superior quality for video wall applications, especially if they are combined with fresnel screens.

Fresnel Screens

A fresnel is an optical surface, performing as a lens, which redirects the cone shaped light from the projection engine into a bundle of parallel light rays (Fig.6). A fresnel must always be combined with an image forming layer, such as diffusion or beaded screens.

Single Element Fresnel Screens

This type of screen typically has a fresnel structure facing the projection engine and an imaging forming layer for example diffusion or lenticular facing the viewer (Fig.7). Single element fresnel screens have the advantage of redirecting incoming light rays from the projection engine to parallel light bundles, which then can be diffused in the diffusion layer to form the image. The disadvantage of such a screen is the light-loss as demonstrated around the perimeter in the figure. Light-loss around the perimeter of the screen results in a hotspot.

Single element fresnel screens are often not a good solution for rear projection, but they may be the only solution beside diffusion screens, for large screen sizes.

Double Element Fresnel Screens

This type of screen consists of a fresnel screen element with the fresnel facing the viewer and a separate image forming screen element (Fig.8). By this method we eliminate the hotspotting and carry on the advantages of a single element fresnel screen. Double element screens are difficult screens to handle which requires complicated suspension on the structure to maintain the integrity between the two elements. Also both elements may act differently to environmental conditions.

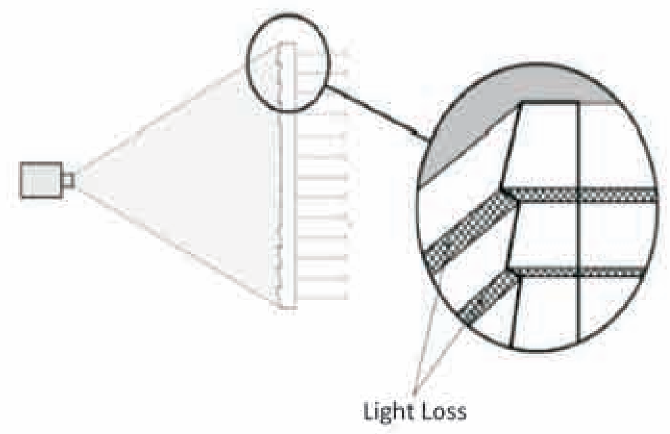

Figure 7 - Single Element Fresnel

Combined Fresnel Screens

A fresnel-diffusion combined single element screen will produce a screen with a higher gain than a non-fresnel diffusion screen. A fresnel-lenticular combined single element screen will increase the screen horizontal gain and

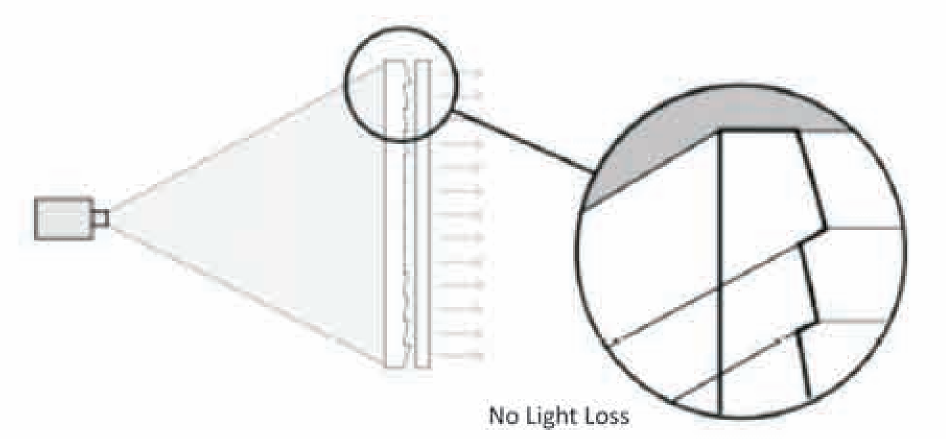

Figure 8 - Double element fresnel screen

limit the vertical viewing angle. Both combinations will lead to a severe hotspot from light loss if the focal length is incorrect.

To overcome the hotspot issue, use a double element fresnel screen combined with lenticular screen, instead of a single element fresnel screen. The drawback of this solution is the complexity of the mechanical suspension system.

A good combination is the fresnel screen with beaded type screen, which will give a large viewing angle (depending on the type of beaded front element screen) and moderate half-gain angle in both directions with sharp image and high contrast. The drawbacks of this combination are the limited dimensions which do not exceed 80 inches, and the difficult mechanical suspension system. This combination is also the most expensive[1, 3, 4].

Wall Structure

A video wall is a matrix of screens working in harmony as one display. Determining the size and location of the display wall adheres to constructional, functional, financial and ergonomic constraints. A control room is always a compromise of several requirement issues. Choices and compromise are getting more difficult in the process of a display wall design, for example, high gain with wide viewing angle, brightness with contrast, and high resolution with speed.

There are two types of structures, open structure and enclosed (cubical) structure. In the open structure the projector and the mirror are not part of the frame structure mounting the screens, which leaves the screens, the projector lens, and the mirror exposed to dust and environment impact. On the other hand, in the enclosed structure the projector, the mirror, and the screen are mounted together on one cubical frame structure that is enclosed as one unit and protect all the parts from dust by filter, and keeps everything tuned with minimal impact from the environment.

The command and control center designer has the following guidelines:

- Size of screen;
- Size of wall;
- Screen mounting;
- Wall shape;
- Height of total wall;
- Position from wall.

Screen Size

The screen size is in relation to the size of the room, the size of the wall, and the function of the screen. For example, for large screen sizes, the operators have to sit further away to have a smooth image, which will require a larger control room. Also the screen materials could be a limiting factor on the screen size, for example the limitation of the beaded front element screen. Generally screen size depends on the following:

Screen Size	Pixel Format	PPI	Min. Distance to Screen in M (Resolving Distance)	Character Height in amount of pixels (mm)	Max. Distance to Read in M
				10	
19	XGA	67	0.43	3.77	0.72
50	XGA	26	1.12	9.77	1.87
67	XGA	19	1.53	13.36	2.55
67	SXGA	24	1.22	10.69	2.04
70	SXGA	24	1.22	10.63	2.03
84	XGA	15	1.91	16.68	3.19
84	SXGA	19	1.53	13.34	2.55
100	XGA	13	2.17	18.98	3.62
100	SXGA	17	1.74	15.18	2.90

Table 1 - Character size, viewing distance and screen size

• How much pixels per inch are needed?

• How many people have to see the screen?

• What is the budget?

• What is the total height of the room?

• What material is shown on the screen (data, graphics or video)?

• Where are the viewers located in the room or in the adjacent rooms?

The following table provides some guidelines for the required character size and distance with respect to screen size (Table 1).

Wall Size
Some people think the bigger the wall, the better the display, but this is not true. Besides the financial burden in constructing a wall, there is a running cost that includes: power consumption, environmental control and maintenance. Wall size depends on the following:

• How much total content is needed? Reflected by how many total pixels?
• How much has to be worked with by one operator, two operators, supervisors and managers, and visitors?
• What is the minimum/maximum distance from the screen?
• How many pixels per inch are needed?
• What is the aspect ratio of the wall and is a panoramic view preferred or not?

Screen Mounting
There are two approaches for mounting the screens on the frame structure. The first method is to glue the edges of each screen into the cubical frame structure, which makes the screen firmly bonded to the structure without leaving any room for the screen to stretch or shrink due to temperature and humidity variation. This leads to screens that could buckle and degrade the picture quality and affect the minimum gap (1 mm) between each screen. Any enlargement of the gap makes the screen matrix borders more noticeable. Some video wall manufacturers use a different technique to mount the screens loosely to the cubical frame structure, which leaves some flexibility for the screens to stretch and shrink. In this way the screens are stitched together to form one large floating screen. The advantages are smaller gaps between screens (0.2 mm), and a more sustainable system for environmental changes.

Curved or Straight
A curved wall is usually the best solution as all information is focused on the central operators (Fig.9). A curved wall will widen the half-gain angle intersection, which defines the area where the whole wall is viewable. For the best uniform view the operators should sit within this

Figure 9 - Straight / Curved

Figure 10 - Upward viewing angle

Figure 11 - Position from front

half-gain angle intersection. It is clear that the larger the wall, the farther the operator will have to sit to be within the combined half-gain angle. A curved wall will maintain the required viewing angle between the operators and each screen, which is less then 45 degrees. Text legibility is lost when operators look at a screen at an angle larger than 45 degrees.

Wall Height

The height is limited by the upward viewing angle of the operator which should not exceed 33 degrees. Limitations are also set by the screen vertical viewing angle, the construction of the wall, and the safety factors. The number of required vertical modules is determined by the required amount of vertical pixels (Fig.10).

The height of the first screen is another factor that should be considered, which will be determined by the number of operators' rows and the height of the local monitors.

Wall Position

The operator position from the wall should be at enough distance to see the whole wall with less than 33 degrees upwards vertical view and 60 degrees horizontal view (Fig.11). Table 2 lists the minimum required distance in meters for different screen sizes and wall configurations:

The maximum distance from the screen is dependent on the size of the content. As long as the fonts are big enough to read and the graphical symbols are large and sharp, the operators and the viewers can sit as far away as necessary[5].

Information Display

The actual returned value of the video wall is totally dependent on the information and how it is displayed. The following are guidelines to optimize the display of information:

Visibility

- Viewing distance in relation to size;
- Viewing angle;
- Absence of parallax and visual occlusion;
- Visual contrast;
- Minimal interference from glare;
- Adequate illumination.

Conspicuousness

- Ability to attract attention;
- Distinguish between background interference and distraction.

Legibility

- Pattern discrimination;
- Color and brightness contrast;
- Size;

Screen Sizes	50"	67"	70"	84"
1 Wide 1 High	1.30	1.78	1.85	2.22
2 Wide 1 High	1.30	1.78	1.85	2.22
3 Wide 1 High	1.73	2.37	2.46	2.96
4 Wide 1 High	2.31	3.16	3.28	3.94
5 Wide 1 High	2.98	3.95	4.11	4.93
6 Wide 1 High	3.46	4.74	4.93	5.92
7 Wide 1 High	4.04	5.53	5.75	6.90
2 Wide 2 High	2.60	3.55	3.70	4.44
3 Wide 2 High	2.60	3.55	3.70	4.44
4 Wide 2 High	2.60	3.55	3.70	4.44
5 Wide 2 High	2.89	3.95	4.11	4.93
6 Wide 2 High	3.46	4.74	4.93	5.92
7 Wide 2 High	4.04	5.53	5.75	6.90
3 Wide 3 High	3.90	5.33	5.54	6.66
4 Wide 3 High	3.90	5.33	5.54	6.66
5 Wide 3 High	3.90	5.33	5.54	6.66
6 Wide 3 High	3.90	5.33	5.54	6.66
7 Wide 3 High	4.04	5.53	5.75	6.90
4 Wide 4 High	5.20	7.11	7.39	8.88
5 Wide 4 High	5.20	7.11	7.39	8.88
6 Wide 4 High	5.20	7.11	7.39	8.88
7 Wide 4 High	5.20	7.11	7.39	8.88

Table 2 - Viewing Distance

To summarize, modern digital video walls are the future trend for command and control centers. Based on the operation type, the environment, and the location architecture, the right technology of projectors, screen type, and wall structure should be selected carefully to meet the intended purpose of the displayed information.

- Shape;
- Distortion;
- Illusory aspect.

Interpretability

- Making sense to the intended observer within viewing distance;
- Requirements for interpretation and extrapolation;
- Special learning[5].

Projection Controller

The projection controller is a dedicated computer, usually a PC with extra components from the hardware point of view, but from the software side it is like any PC, running standard off-the-shelf operating systems (OS) such as Windows XP™ or Linux; provided that the OS is certified by the vendor.

What differentiates controllers from each other is the flexibility of use and configuration, the type of supported inputs, management applications, remote control applications, and performance. The controller should be capable of projecting multiple video and RGB inputs, with the capability of scaling these inputs to fill the whole video wall with minimal picture distortion (pixelization). The users should be able to control the displayed content, remotely from their workstations, over the data network. Management software to control and report the status of the wall with information about the health of each cubical is vital, especially in large video walls and if the map-board is critical to the operation. The controller should be off-loaded by implementing as much as possible of the functionality at the hardware level.

For the controller to support a mission critical operation, it should be redundant in most of its parts: CPU, power supply, network interface and hard disks.

Project Experience In OCC Wall Setup

Saudi Aramco Operation Coordination Center (OCC) is one of the largest hydrocarbon and electric power distribution command and control centers in the world. Its video walls consist of five video walls. Three are configured as 8x3, and two are configured as 13x3. This adds up to 150 projection modules with each screen's size of 67 inches. The total length of the wall is 67 meters long and three meters high. The projectors are based on the SXGA DLP chip which has a resolution of 1280x1024. The 8x3 video wall resolution is 10240x3072, and the 13x3 video wall resolution is 16640x3072. Each of these walls is operated by different planners running different operations. These video walls are controlled by five projection controllers. The projection controller is capable of projecting four analog video sources, two RGB sources, and any PC installed applications. Each projection module has dual 120 W lamps. The dual lamps are configured in hot/standby mode, so if the hot lamp failed, the standby automatically takes over and the operation continues normally. The used screens are double-element fresnel screens combined with black beaded lenticular screens. The five video walls are connected to a UPS unit.

Conclusion

To summarize, modern digital video walls are the future trend for command and control centers. Based on the operation type, the environment, and the location architecture, the right technology of projectors, screen type, and wall structure should be selected carefully to meet the intended purpose of the displayed information.

Acknowledgements

I especially thank Mr. Gamil Ali for his continuous encouragement and technical comments that aided me in the completion of this article.

Saudi Arabia Oil & Gas Magazine would like to thank Saudi Aramco Journal of Technology for reprint permission.

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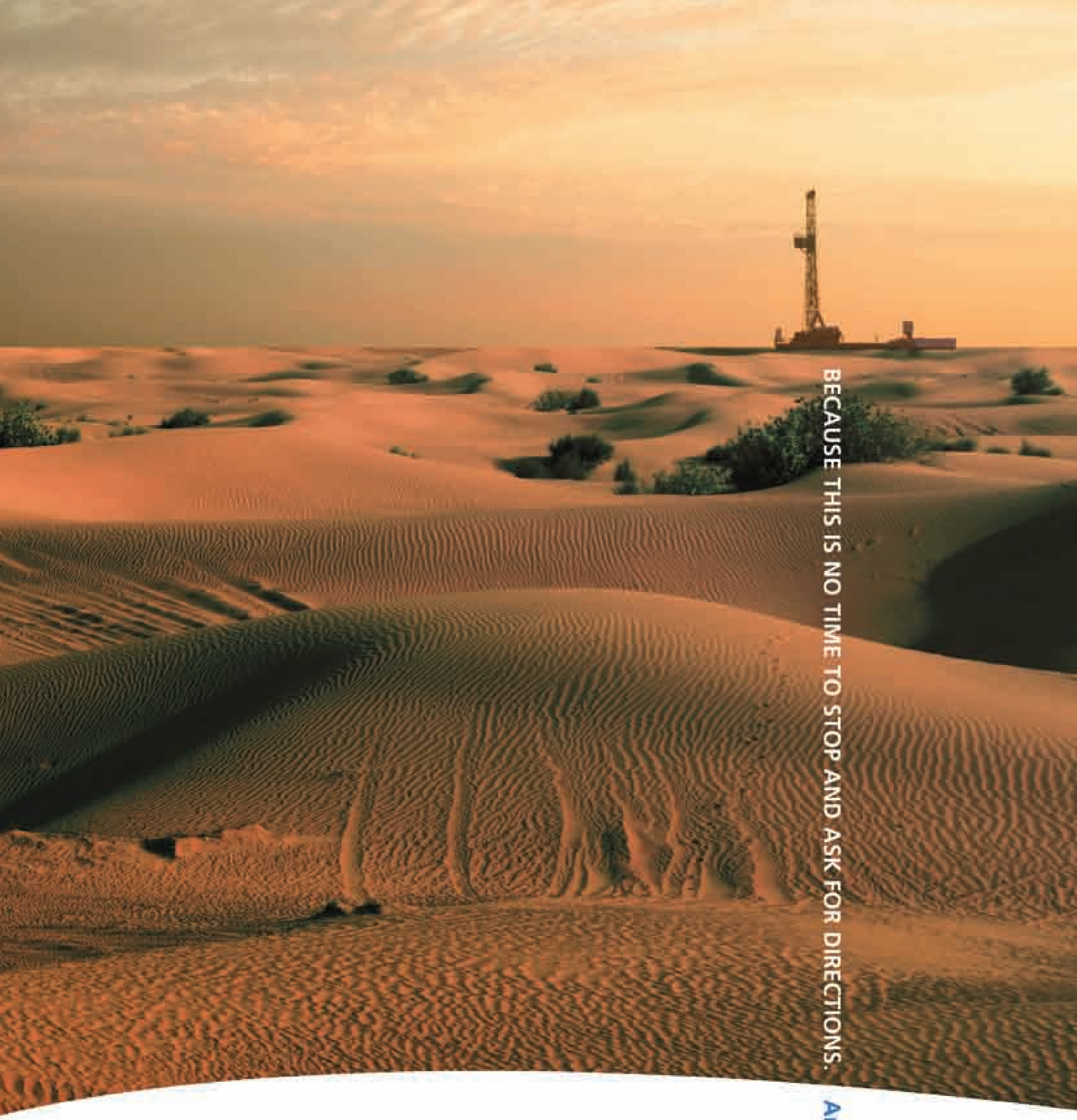
	* Saudi Aramco 75th Anniversary		* Petroleum in Carbonate Reservoirs

BONUS CIRCULATION

SPECIAL PUBLICATIONS



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BAKER HUGHES INTEQ

من أجلكم، فإن طاقتنا لا تنضب
TOTAL