Geophysical Society of Houston

VOL. 33, NO. 5 NEWSLETTER JANUARY 1999

I N S I D E

GSH Meetings

Notice to members:

Joan Henshaw, our office manager, has been diagnosed with Hodgkin's lymphoma. She began her chemotherapy treatment on Thursday, December 17. Please keep her in your thoughts and extend her your best wishes. In the meantime, please understand that the office will be understaffed at times.

I know that we all will send our best wishes to Joan.

SEG 1999 Spring Distinguished Lecture

Dr. David H. Johnston
Date: January 19

Time:	Register and Cash Bar 11:30 a.m.; Luncheon and Talk 12:00 noon
Location:	NewHESS Building, 5430 Westheimer Formerly the Carlyle Restaurant located on the north side of Westheimer between Chimney rock and Yorktown
Cost:	$20 for pre-registered members; $25 for walk-ins and guests
Reservations:	Call 713/917-0218 or Email: reservations@hougeo.org

4D Seismic: Can a Difference Make a Difference?

4D seismic reservoir monitoring (time-lapse seismic) has the potential to significantly increase recovery in existing and new fields. Changes in fluid saturation, pressure, and temperature that occur during production induce changes in the reservoir's density and compressibility that may be detected by differencing repeated seismic data. As a result, seismic data can be used to help monitor and predict the inter-well position and movement of reservoir fluids, locating bypassed oil, avoiding premature breakthrough, optimizing infill well locations, and evaluating EOR pilots prior to full field implementation.

However, most published seismic reservoir monitoring examples have been demonstration projects and the impact of the technology on reservoir profitability has not been well established. The cost of reservoir monitoring must be recovered through increased production rate, added reserves, and/or reduced operating costs. Locating fluid saturation fronts allows optimization of the recovery process. Better placement of infill and development wells, elimination of dry holes, balancing injection and production rates, and more accurate workovers can decrease costs and increase recovery. Although studies suggest that the potential economic impact is great, the acceptance of 4D seismic data in our industry remains limited — similar to the situation with 3D seismic data 10 to 15 years ago.

Indeed, there are many issues associated with the application of time-lapse seismic data. Two of the most significant technical issues are the repeatability of the seismic data in the non-reservoir portion of the data volume and the robustness and credibility of the seismic difference within the reservoir. In principle, estimates of dynamic reservoir properties, obtained over the entire field area from 4D seismic data, can be used to optimize reservoir management. However, because of non-uniqueness, the process of inferring dynamic reservoir properties from seismic data is hardly trivial. What then, is the likelihood that action will be taken based on seismic monitoring data that will result in an increase in the economic value of a field?

These issues are examined using several case studies. Seismic monitoring has become an integral part of the enhanced oil recovery technology at Imperial Oil's Cyclic Steam Stimulation Cold Lake Field in Canada. Seismic monitoring surveys

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GEOPHYSICAL SOCIETY OF HOUSTON

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Issue ....March 1999
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Issue ....April 1999
Deadine .... February 18, 1999

Issue ....May 1999
Deadline ...... March 18, 1999

Issue ....June 1999
Deadline .... April 15, 1999

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provide definitive images of the fluid saturation fronts in the reservoir, where about 50% of the oil has been bypassed. These images were used to drill 46 deviated steam injection wells, three horizontal wells (which serve as injectors and producers), as well as to model and monitor new pilot processes. Early oil production data from the infill pilots indicate a significant improvement in oil rate. New reservoir technologies are being developed to attempt to capture the bypassed oil as identified by the seismic data.

An example from the Gulf of Mexico Lena Field looks at the application of 4D seismic data in a mature setting. The legacy seismic data over the field were not acquired or originally processed to maximize repeatability. Sequentially increasing the level of sophistication in the seismic re-processing effort, quantifying and reporting the results at each step establishes the costs and benefits in achieving a robust seismic difference. However, the acquisition of the repeat survey was not necessarily timed to optimally map reservoir changes or impact development decisions. While the interpretation of the seismic difference has yielded infill-drilling opportunities, rig availability and other operations constraints may limit action.

New field developments allow planning of time-lapse acquisition to have the greatest impact on field economics. In one such example, seismic modeling based on reservoir flow simulation illustrates that significant seismic differences associated with fluid saturation changes should be observed even within a few years after first oil. An engineering study of the impact of early field-wide production data afforded by 4D seismic shows the potential to improve reservoir description by identification of by-passed oil volumes. This can result in improved reservoir simulation models and performance prediction, reduced probability of dry holes, and reduced operating cost through more efficient injection/production strategies.

Seismic monitoring is a maturing technology and its impact on reservoir management is far from proven. As with the development of 3D seismic technology, industry experience through case studies will establish the costs and benefits of 4D seismic technology.

SEG 1999 Spring Distinguished Lecturer
David H. Johnston

David H. Johnston is a Senior Research Specialist for the Exxon Production Research Company (EPR) in Houston, Texas. He received a BS degree in Earth Sciences from the Massachusetts Institute of Technology in 1973 and a Ph.D. in Geophysics in 1978, also from MIT. He joined EPR in 1979 and has held assignments in rock physics research and seismic reservoir characterization. He is currently group leader for time-lapse seismic research and is responsible for the development and worldwide application of the technology.

Dr. Johnston is active within the Society of Exploration Geophysicists (SEG) and the Society of Petroleum Engineers (SPE). He was Secretary/Treasurer of the SEG in 1990, Chairman of the Development and Production Geophysics Committee from 1987 to 1988, and Chairman of the Interpretation Committee from 1991 to 1992. He has served on SEG, SPE, and OTC technical program committees.

In addition to a number of published papers in Geophysics and other technical journals, Dr. Johnston was co-editor of the book Reservoir Geophysics, published by the SEG in 1992 and co-editor of the SEG Reprint Series volume on Seismic Wave Attenuation published in 1981. He has presented numerous papers on rock physics and reservoir geophysics including keynote addresses at several conferences. Dr. Johnston was awarded the Best Presentation by the SEG in 1993 and was an SPE Distinguished Lecturer from 1992 to 1993.

GSH Technical Breakfast

The January GSH Technical Breakfast on Wednesday, January 13, 1999 will be hosted by Don Herron at BP. A complimentary continental breakfast will be served 7:00 to 7:45 am, speaker 7:45 to 8:30 am. Speaker: Paul Ware (Unocal). Topic: The Problem of paleo-Oil-Water-Contacts in Seismic Identification of Hydrocarbon Accumulations. Please make reservations by noon Monday, January 11. Event code 607.

Summary

Paleo-oil-water-contacts ("paleo-OWC") have been reported in recent years in the literature. Identification of bitumen-stained sandstones in outcrop, for example, is relatively easy. In this paper I show an example from Greenland where the intrusion of Tertiary dolerites has thermally altered oil that had been trapped in a Jurassic reservoir1. Similarly, cores can identify residual oil below present-day OWCs in accumulations where there has either been a seal failure, change in hydrodynamic regime or subsequent regional tilting2. Considerably less common is the recognition of paleo-OWCs by geophysical means. This paper demonstrates one such case and suggests that this phenomenon may be more widespread than previously thought and may, in fact, be responsible for some of DHI/AVO's "Famous Failures" in the past.

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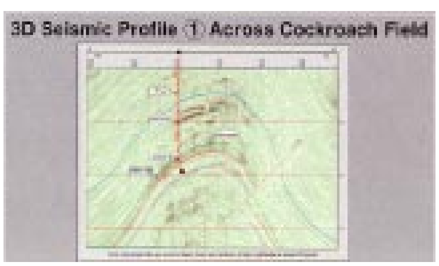
In the Tertiary basin presented in this paper, amplitude variation with offset (AVO) modeling has shown a classic Rutherford-Williams relationship of porosity and fluid fill to AVO response. The relative responses of stack amplitude and AVO crossplot to changes in porosity, bed thickness and water saturation at one well were modeled. In each case, the in-situ values of two of the variables were kept constant while the other was varied. Changes in porosity have a greater effect on stack amplitude than thickness or water saturation. This is especially evident in the AVO crossplot response. Additionally, it was found that high GOR oil sands in this basin actually gave higher amplitude responses than gas sands4.

The four offshore structures (Cockroach, Louse, Tick and Flea) that are presented are located within an area 25km x 85km. All have amplitude anomalies within late Tertiary sediments between one and three seconds (all times are TWT). Four profiles are shown. Profile 1 is a 3D line that crosses the Cockroach structure.



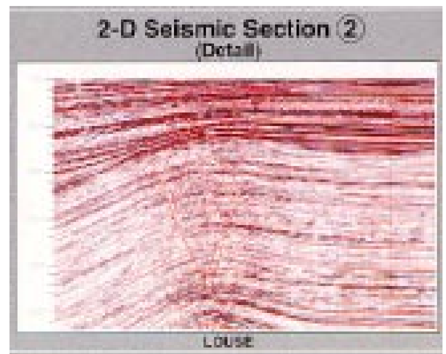
Amplitude anomalies are seen at 1.9 seconds (gas) and 2.3 seconds (oil). An amplitude extraction over a 45msec window around the main reservoir shows structurally conformable high amplitudes, with a hint of a secondary sub-concentric "corolla" or "bath tub ring" of high amplitudes, in the south-central part of the figure. A mud volcano obscures the data to the southeast. Absorption and scattering due to a shallow gas cloud in the northwest covers 40% of the reservoir. Fortunately, despite this, both the inner, structurally conformable anomaly and outer "corolla" can be distinguished. To the southeast of this, the corolla or "bathtub ring" becomes more obvious. The inner amplitude anomaly corresponds to the present-day OWC, and has been penetrated by wells. The outer ring is asymmetric. Note the position of the two wells on the southern flank.

The logs for these two wells show that the upper well penetrated the present day OWC. The lower well penetrated a flushed zone. The outer "bathtub ring" corresponds to the paleo-OWC.

Both regional tilting and a seal failure have occurred. A thick, hydrocarbon-bearing shale underlies this structural trend. Pliocene compression, plus sedimentary loading of the shale on one flank of the structure, initiated argillokinesis and uplift, which created a linear sill. This, in turn, caused further asymmetric loading, and steepening of the northern flank. Finally, the diapir rose to a level at which explosive ex-solution occurred within the shale and dissolved gases penetrated through the overlying formations. Hydrocarbons then leaked to the surface, either directly through the mud volcano diatremes or via faults that became active at this time, until the migration conduit was sealed by fine clastics. An amplitude anomaly remains at the position of the paleo-OWC.

Satellite radar data reveal the presence of oil seeps over many of the structures in the basin. As an interesting sidelight, this has been popularly misinterpreted to mean that the underlying reservoirs must themselves contain oil. Unfortunately, biomarker data shows that oil sampled by UNOCAL from a mud volcano onshore is stratigraphically older, but less mature, than that trapped in reservoirs around the flanks. Thus, a given structure may leak to the surface marginally mature oil directly sourced from the vertically underlying Oligocene source rock. But Pliocene reservoirs in that same structure may contain catagenic gas, which has migrated laterally from a deeper kitchen area.

Profile 2 crosses both Cockroach and Louse, which is the southernmost of a series of structures parallel to Cockroach. Amplitude anomalies can be seen between 2.5 and 3 seconds TWT at Louse. A CMP gather at the Louse structure shows a marked Class 3 (low normal incidence reflectivity, high gradient) AVO response. Exploration wells found that, although higher amplitudes were restricted to the highest part of the structure, the main reservoir was wet and there was non-commercial gas, with some questionable liquids, at a deeper level. In detail, Profile 2 shows Louse to be highly faulted.



Structural modeling has shown little tectonic movement through most of the Pliocene. The faulting occurred in Latest Pliocene time, which corresponds to the onset of mud diapirism at Cockroach. The same structural loading that steepened the reverse-faulted northern flanks at Cockroach caused extensive normal faulting at Louse (where faulting decreases with depth). If hydrocarbons ever filled the main reservoir, they leaked out at this time.

Further along trend, the Tick structure also shows structurally conformable amplitude anomalies on Profile 3 at deeper levels, but not at the shallower main reservoir level.

From the drilling results, we know that these are hydrocarbon related, whereas the (non-structurally conformable) high amplitudes seen at 1.2 seconds and 2.1 seconds correspond to porous sands. Note the lack of younger faults at Tick: the structure was relatively unchanged by the Latest Pliocene tectonics that affected both Cockroach and Louse, so entrapped hydrocarbons did not leak

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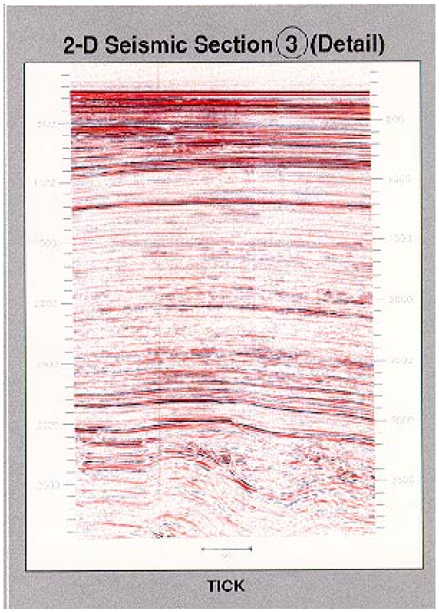
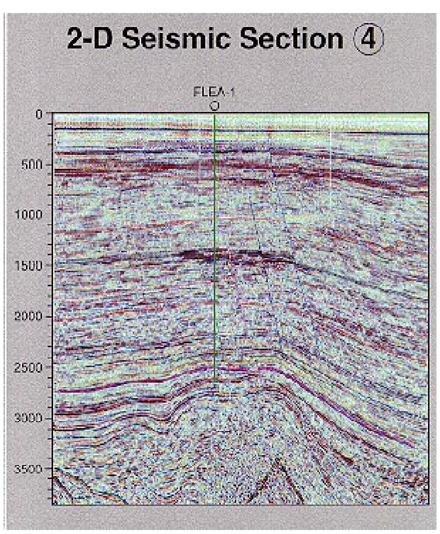


to the surface.

The final structure to examine is Flea, at the northern end of the trend. Profile 4 shows amplitude anomalies at 1.5 and 2.5 seconds.

Both are structurally conformable and highly faulted, with the shallower anomaly also showing a stratigraphic component on 16-bit data due to channeling. On 8-bit data, the amplitudes are still structurally conformable but do not have sufficient detail to show the channels. However, on drilling, both levels showed only residual gas: the hydrocarbons had leaked out.

Thus, a typical structure in this



basin could have a multiplicity of false positive and false negative DHIs. First, scattering associated with a shallow gas cloud could obscure the amplitude anomaly associated with either the top of the reservoir or OWC (or GWC). Second, velocity affects due to the shallow gas could obscure the fact that an amplitude anomaly is structurally conformable, even on 3-D data. Third, 8-bit data do not show stratigraphic components of trapping. Fourth, porosity - rather than fluid fill - is the primary driver of amplitude response in this area so that porous beds could be mistaken for pay. Fifth, leakage of hydrocarbons due to mud volcanism or recent faulting could leave behind a paleo-OWC that may not be distinguishable on the seismic from the real OWC, if one still exists. Although the study area may be unique in having all these effects simultaneously, there is reason to suppose that many basins around the world could exhibit one or more of these problems, which could mean the difference between a “Great Success” and a “Famous Failure”.

In conclusion therefore, structures in the area of interest are known to leak crude oil and gas. Even if amplitude anomalies are present, the presence of active mud volcanoes and/or young faults may be clues as to recent leakage. Amplitude anomalies that are not structurally conformable may be due to porosity, not fluid fill. Even for structurally conformable amplitude anomalies, residual hydrocarbons can give similar amplitude effects to commercial accumulations. Shallow gas clouds can mask any distinction between paleo-OWC and present-day OWC.

Conclusions

- Structures in the area of interest are known to leak crude oil and gas
- Even if amplitude anomalies are present, the presence of active mud volcanoes and/or young faults may be clues as to recent leakage
- Amplitude anomalies that are not structurally conformable may be due to porosity, not fluid fill
- Even for structurally conformable amplitude anomalies, residual hydrocarbons can give similar amplitude effects to commercial accumulations
- Shallow gas clouds can mask any distinction between paleo-OWC and present-day OWC

Acknowledgements

Thanks to the companies who own the data presented. My apologies for the name changes that were necessary to preserve the confidentiality of the data. Thanks also to Carl Burgess, my co-author on the original paper that was presented at the AAPG International Convention in Rio de Janeiro.

References:

Exhumed hydrocarbon traps in East Greenland: analogs for the Lower-Middle Jurassic play of NW Europe, Rice & Whitham, AAPG Bulletin, February 1997

Petroleum Migration, Alteration, and re-Migration within Troll Field, Norwegian North Sea, Horstad & Larter, AAPG Bulletin, February 1997

Modeling the AVO response in the South Caspian, Paul Ware, Keith Wrolstad & Zhiming Li, Society of Exploration Geophysicists Convention, Dallas, 1997.

Using a detailed model of AVO response in the successful pursuit of Hydrocarbons in the South Caspian Basin, by Tai-Lin Hong, Michael Harkness, Paul Ware, Dennis Yanchak and Nicholas Bassett, ASEG, Baku, 1998

The relationship of accretionary wedges and mud volcanoes: some global examples from the Caribbean and Eastern Indonesia by Paul Ware, ASPG, Baku, 1995

Biography:

Paul L.G. Ware is Senior Geophysical Advisor at Unocal New Ventures in Sugar Land. He has lectured and presented posters on geophysics and geology for the SEG, EAEG, GCAGS, Houston Geological Society, Indonesia Petroleum Association, Azerbaijan Society of Petroleum Geologists, Azerbaijan Society of Exploration Geophysicists,

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Society of Petroleum Geophysicists of India and at Texas A&M University. He has also had papers published in “First Break” and “Geology”. He received a BS in Geophysics with Geophysics from Bath University in 1976.

SIG ANNOUNCEMENTS

POTENTIAL FIELDS SIG

Location:	HESS building, 5430 Westheimer, Houston
Date:	January 21, 1998
Topic:	Southeast Asia Gravity and Magnetics Interpretation: a Tour of Significant Basins and Regions
Speakers:	Richard Gibson and Dale Bird
Cost:	$20.00
Contact:	Mike Kowalski, Chair - GSH Potential Fields Group, at 713-432-6828 (kowalma@texaco.com) by Tuesday, January 19 for reservations. Please honor this reservation if you make it. We must start billing no-shows!

Abstract

Recent high-quality satellite-derived free air gravity data and magnetic data compiled by the Geologic Survey of Japan are interpreted to provide a regional plate tectonic framework for planning hydrocarbon exploration. Interpretation includes: regional detail of rifts, depocenters, carbonate buildups and platforms, and major structures and accommodation zones; distribution of volcanics and depth to magnetic basement; as well as definition of oceanic fracture zones and their interaction with prospective continental margin areas. The study area is 100* to 120* East by 3* to 23* North, or about the same size as the entire Gulf of Mexico or North Sea.

Basins interpreted include: Beibu Wan, Hoang Sa, Malay, Mekong, Nha Trang, Outer, Pearl River, Sabah, Sokang, Song Hong, Tarakan, Thai, West Natuna, and Yang Ghe. Other important regions interpreted include the Baram Delta, Luconia Platform, McClesfield Bank, Paracel Islands, Reed Bank, and Spratly Islands areas.

In addition to interpretation maps, nine mega-regional modeled cross-sections are used to support the interpretation. The presentation is interactive utilizing ArcView* GIS software.

Biographies

Dick Gibson was trained as a geologist and mineralogist at Indiana University and the University of California at Davis. After four years of mineralogical analysis of kidney stones, he started his oil industry career in 1975 with Aero Service Corporation in Houston. At Gulf Oil’s Technical Services Center he performed geological interpretations of gravity, magnetic, and seismic data from around the world, and helped teach Gulf’s in-house gravity and magnetics school. He was Director of Gravity and Magnetics for Everest Geotech, Inc., (Houston and Denver) from 1984-89, and since 1989 he has had his own consulting firm, Gibson Consulting, in Golden, Colorado. He teaches an industry short course in gravity and magnetic data interpretation that has been taught in Los Angeles, Bakersfield, Houston, Midland, Bloomington (Indiana), London, Denver, and Dehra Dun (India), and he also teaches field geology for students and explorationists in courses at Indiana University’s Geologic Field Station in Montana. His specialty is tectonic interpretations of continent-scale gravity & magnetic data sets, and for the past year and a half he has focused on interpreting satellite derived gravity for hydrocarbon exploration.

Prior to founding Bird Geophysical, Dale Bird established and managed an affiliate office in Houston for Aerodat Inc., an international airborne geophysical survey company. His 16 year career also includes: Chief Geophysicist for World Geoscience Inc. (Americas), another international airborne geophysical survey company and Geophysicist with Marathon Oil Company, Digicon Inc., and Aero Service Division of Western Atlas International Inc. Dale served in the US Army, 1st Military Intelligence Battalion, as an Image Interpreter specializing in interpretation of various imagery formats. He is the current Chairman of the SEG Gravity and Magnetics Committee, and served as Chairman of the Potential Fields Group and Editor for the GSH. Dale earned BS and MS geophysics degrees and is currently a PhD candidate (geophysics) at the University of Houston.

Near Surface SIG

January Meeting

Date:	Wednesday, January 13, 1999
Time:	5:30 pm
Location:	Fugro Building, Room 160, 6100 Hillcroft (corner Hillcroft and Gulfton, 1 blk. south of Hwy 59)
Cost:	None
Speaker:	Robert C. Gauer Coda Technologies, Houston

Topic:

Transition Zone Geophysical Case Study, Little Dauphin Island Drilled Crossing Program Gulf of Mexico, Nearshore Alabama

Presentation to the Houston Geophysical Society January 13, 1999 by Robert C. Gauer, P.E., P.G.
Coda Technologies, Inc.
9800 Richmond Avenue, Suite 480
Houston, Texas 77042 USA

ABSTRACT

A geophysical investigation was conducted for the Little Dauphin Island drilled crossing phase of the Aloe Bay Pipeline Project located in the Gulf of Mexico near the coast of Alabama. Little Dauphin Island is a US National Wildlife Refuge and, as such, a water-to-water drilled crossing was planned

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from Dauphin Bay to Mobile Bay underneath Little Dauphin Island. The purpose of the geophysical program was to determine soil stratigraphy information beneath the US Wildlife Refuge for guiding the directional drill crossing program.

The geophysical program was performed concurrently with a geotechnical study and consisted of electrical resistivity, frequency-domain electromagnetic, and time-domain electromagnetic surveys combined with a series of borehole geophysical logs. The geophysical logs were used to calibrate resistivity sounding data by providing measured depths and resistivities of clay and sand layers at drilled crossing entry and exit locations in water depths up to about 20 ft. Geophysical borehole logs and a suite of surface geophysical surveys were performed at each drilled crossing entry and exit locations. Further non-intrusive, surface geophysical surveys (resistivity and electromagnetic methods) were conducted on the ground surface of Little Dauphin Island and in shallow, brackish water (up to about 5 ft deep) adjacent to the island for assessing the subsurface stratigraphy along the proposed pipeline alignment.

An interpreted stratigraphic cross-section was compiled from geophysical sounding results that extended across Little Dauphin Island between the two end boring (drilled crossing entry/exit) locations. The resultant cross-section showed the consistent presence of an interpreted clay (low resistivity) layer established at the two end boring locations and interpreted as extending beneath the island. The interpreted clay layer targeted for directional drilling operations thinned and shallowed west of Little Dauphin Island, but thickened and deepened beneath Little Dauphin Island and east into Mobile Bay. The interpreted stratigraphic information was provided to the directional drilling contractor who used the information to successfully drill two parallel 5200-foot long water-to-water pipeline crossings beneath the US Wildlife Refuge.

Robert C. Gauer - General Manager (North America)
E-mail: rcg@coda-technologies.com

Education:

B.S. in Geophysics from Virginia Polytechnic and State University (Virginia Tech)

M.S. in Civil Engineering from The University of Texas at Austin

Qualifications:

Registered U.S. Professional Engineer, State of Texas Registered U.S. Professional Geologist, State of Tennessee

Thesis Title:

Experimental Application of the Spectral-Analysis-of-Surface-Waves (SASW) Method Offshore

Experience:

Served as a Nuclear Weapons Officer with the 25th Infantry Division Artillery (DivArty) in Hawaii for several years prior to joining Fugro in 1992. Worked at Fugro as a consulting Geotechnical Engineer with a special interest in applying geophysical techniques to engineering and environmental projects worldwide. Conducted consulting projects throughout North and South America, the Middle East, and the Gulf of Mexico.

Professional Memberships:

American Society of Civil Engineers (National Geophysics Committee Member), Society of American Military Engineers, Marine Technology Society, Society of Exploration Geophysics, Engineering and Environmental Geophysics Society.

Robert C. Gauer is responsible for all operational activities of the Coda U.S. office located in Houston, Texas. He specifically provides technical and sales support to Coda's North American customer base while actively pursuing marketing and business development opportunities. He ensures that Coda customers receive innovative, technically superior products backed by a network of responsive and reliable support staff.

Interpretation SIG Meeting

Date:	January 27, 1999
Theme:	Application of Co-Criteria SubVolume Detections and Volume Visualization within Multiple 3-D's Volumes in the same 3-D Space, a Gulf of Mexico Example
Place:	Pennzoil Building, 700 Milam 30th Floor Conference Room
Time:	4:00 PM
Speaker:	Gerald Kidd, Paradigm Geophysical Corporation, Houston, Texas

Abstract:

The study area consists of an approximately 4 sq.km. area on the west flank of a faulted anticline. The reserves are trapped within several zones in the Middle Pliocene section.

A reflectivity volume and its corresponding Acoustic Impedance (AI) 3-D volume (Data courtesy of Jason Geophysical) are "blended" together where both amplitude and AI values can be visualized in the same 3-D space. Both reflectivity cut off criteria and AI cut off criteria are utilized as a common denominator to control the "auto" detecting of amplitudes and the search for all similar occurrences. The ability to apply co-criteria cutoffs to filter through volumes of 3-D data independent of data type can be an efficient process to evaluate multiple attributes or related volumes in the same 3-D space. New technologies, workflows and methodology are emphasized.

Attendees are asked to please register with GSH office in advance, please check in with visitor's reception in lobby of Pennzoil building. Parking available at several sites including Wortham Center, Jones Hall.

JANUARY 1999

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
					1	2
3	4	5	6	7	8	9
10	11	12	13 Near Surface SIG Technical Breakfast	14	15	16
17	18	19 SEG Distinguished Lecture	20	21 Potential Fields SIG NEWSLETTER DEADLINE	22	23
24	25	26	27 Interpretation SIG	28	29	30

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