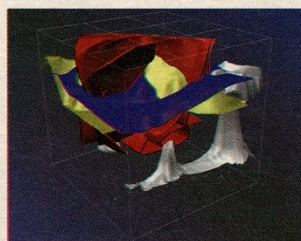


EXPLORER

MAY 1994



0476651
H. ROICE NELSON JR.
WALDEN 3-D INC.
P.O. BOX 382
BARKER TX 77413-0382

Seismic, geophysical and geochemical databases were integrated to create a 4-D (x, y, z and time-lapse) data cube to visualize fluid flow in the Eugene Island area of the depobasin. The sequence goes clockwise from the upper left corner. "Trails" of seismic amplitude anomalies indicate the presence of hydrocarbon migration pathways extending downward into deep, hard geopressure. The complex amplitude anomaly network is thought to originate from three main source areas of turbiditic sands, ponded among vast vertical salt columns. Isotherm overlays on structure show hot spots that occur in tandem with pronounced pressure gradient bulges. Modeling of the fluid flow needed to produce these coupled anomalies requires a transient fluid burst up the Red fault zone within the last 10,000 years.

Graphics courtesy of Engineering Animation

Finding a Field of 'Streams'

Fluid Flow Concept Could Boost Reserves

By LOUISE S. DURHAM
EXPLORER Correspondent

Just when you thought you had heard it all, now there's talk that the practice of drilling into reservoirs in order to produce oil and gas may become passé.

Before you scoff, take a look at a cutting edge project down Gulf of Mexico way at Eugene Island Block 330.

Some erudite folks are testing a theory there that it may be possible to tap into and produce hydrocarbon "streams" as they migrate upward from deep source rocks toward shallower reservoirs—a concept that could revolutionize the way operators select well locations.

And, if successful, it could increase the undiscovered hydrocarbon reserve base in the Gulf by as much as a few billion barrels.

The project is being spearheaded by the Global Basins Research Network (GBRN), which was organized in 1989 as an Internet research consortium of

geographically distant and separate academic institutions.

The group's lofty goal is two-fold:

□ To image and tap into active, or dynamic, hydrocarbon pathways.

□ To identify the mechanisms that cause hydrocarbons to burst out of geopressured confines and begin upward migration.

It has attracted the interest of a dozen oil and gas companies—mostly majors—and several communications and service companies, which have joined forces with the organization.

The success of a subsalt concept resulted in 82 exploration companies bidding \$277 million at the Gulf of Mexico lease sale for the chance to try their luck seeking big payoffs. Story on page 4.

Basic to the GBRN methodology is the analysis of dynamic, time-dependent phenomena, which transcends the usual subsurface observations (stratigraphy and structure) and instead homes in on the visualization of physical and chemical influences of fluids as they move through

See **Streams**, page 14

President's Column

Cooperation An Aid to All

By DON TOBIN

One of AAPG's major endeavors this year has been to expand and strengthen our cooperative efforts with other associations to effect a more harmonious and productive relationship among the principal earth science organizations.

There has been some effort toward these goals in past years, but to a lesser extent compared with the purposeful and determined resolve to achieve the mutually supportive working relationship that we are now attempting.

See **President**, page 8

Streams

from page 1

the rock.

Quantification of changes in pressure, temperature, geochemistry and seismic amplitudes over time in a given area provides the clues to detect the presence of active hydrocarbon migration routes.

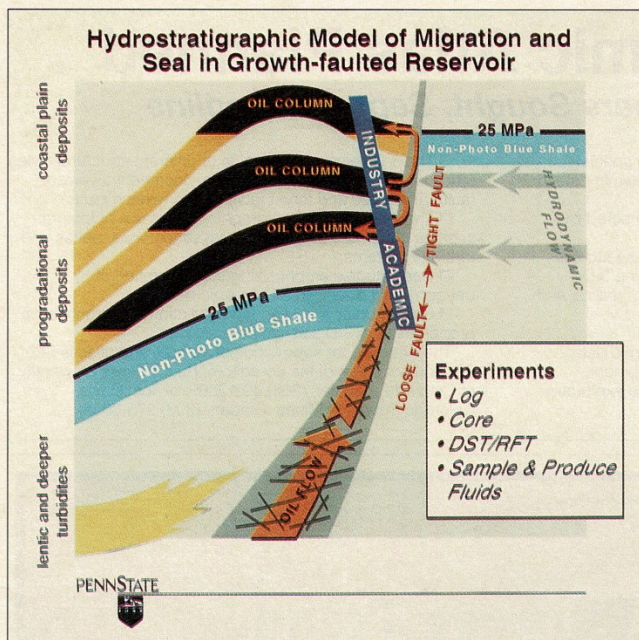
The research group looked at basins worldwide in search of a study area with a strong migration signal. The Gulf basin, with its active sea floor seeps and vast available data base, was determined early on to be the primo locale for a migration phenomena study.

Finding Fault

Eugene Island Block 330, site of the initial field test, is a Pleistocene producing behemoth that has coughed up more than one billion barrels of oil equivalent since production began in 1972.

It occurs as an anticlinal structure on the downthrown and low pressure side of an arcuate NW-SE-trending, pressure sealing growth fault. Dubbed the "A" fault or "Red" fault, this feature serves as the plumbing system for fluid movement in the field.

Peculiar things are happening here; the oil/water level is static, and the pressure has been increasing since 1987, according to Jeff Nunn, Louisiana State University geophysicist and GBRN co-director. The field is depleting at an unusually slow rate, and Nunn points out, "So far, it's produced 103 per cent of the estimated reserves."



Graphics courtesy of Beth Bishop and Peter Flemings, Penn State University

A sketch of the Eugene Island 330 drilling program, designed in part to address how secondary migration of hydrocarbons is occurring through the fault zone in the shale-prone and geopressured section beneath the "non-photo blue" shale.

One plausible explanation for this production anomaly is that initial reserve estimates may have been conservative, perhaps in part because they failed to take into account the reserves that were present in some of

the silts or shaly sands that, owing to their inherently high irreducible water saturation, show a low resistivity reading on the logs.

An inadequate understanding of these intervals could have eliminated

significant reserves – something GBRN scientists continue to investigate.

But substantial clues for dynamic hydrocarbon replenishment have been identified here. Organic fingerprinting of the oil produced at Eugene Island shows geochemical variances over time from the same perforation depths in the same wells that suggest evidence for refilling of reservoirs.

Adding intrigue to the scenario are isotherm overlays on structure that show the 400,000-year-old producing reservoirs to be four times hotter than expected. These hot spots, in tandem with pronounced pressure gradient bulges, are centered over the area's major oil fields.

Modeling of the fluid flow needed to produce these coupled anomalies requires a transient fluid burst up the Red fault zone to have occurred within roughly the last 10,000 years.

Happy Trails

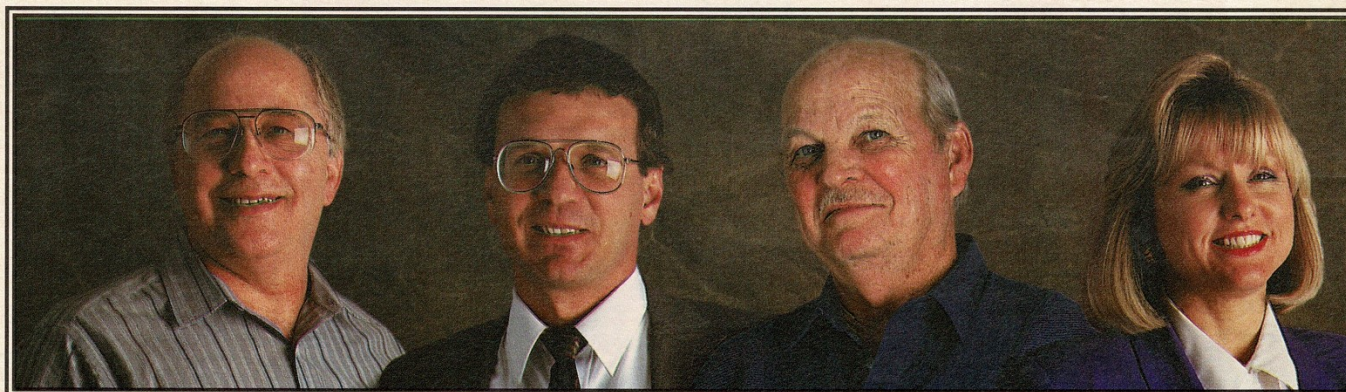
The argument for active migration is enhanced by data acquired from 3-D seismic surveys, which indicate "trails" of seismic amplitude anomalies in several Eugene Island blocks.

These "trails" connect to the Red fault zone either directly or, in some instances, indirectly by means of an antithetic fault that intersects the Red fault at depth.

GBRN scientists believe that at least seven separate observed amplitude anomaly trails indicate the presence of migration pathways that extend downward into the deep, hard geopressure.

continued on next page

Lately, We've Developed Quite



Ed Rudder, Gulf Resources Corporation

Mark Ziegler, The Vector Companies, USA

Don Earney, Bandera Petroleum Inc.

Carolyn King, Global Natural Resources

When it comes to 3D seismic interpretation, the market leader is Landmark. But many small and medium size independents believe we're beyond their reach because of our longstanding, high visibility relationships with the majors and large independents.

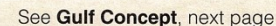
Not true. Landmark has the flexibility and resources to provide even the smallest inde-

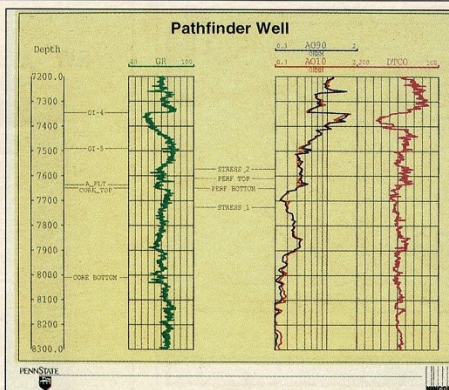
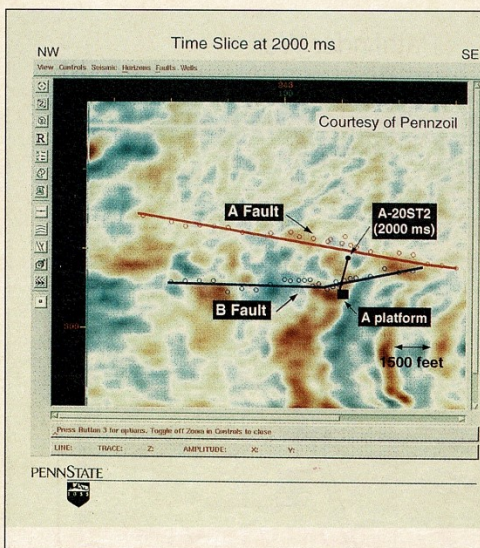
pendents with just what the majors have—complete 3D software solutions backed by comprehensive service and support. And if you think we're just talking, take a look at all the independents who've come on board lately—and the many who've used us all along.

These days, 3D's not just the leading tech-

nology, it's an investment for success. You need 3D seismic to minimize drilling risk, optimize drilling location, control costs and raise investor capital. Landmark's unparalleled 3D capabilities can help you do just that. All you have to do is call for information, or request a free videotape titled, "Independents Talk About the Landmark 3D Solutions."

15150 MEMORIAL DRIVE • HOUSTON, TEXAS 77079-4304 • 1-800-946-8700 • 713/560-1192





To the left, time slice at 2000 ms, showing the A and B faults and the position of the A platform. Above, the type log showing the locations of the major sands (OL-4 and OL-5), as well as the location of the various experiments.

Gulf Concept from previous page

dynamic hydrocarbon replenishment concept, and results are looking good.

With \$10 million in the GBRN pockets, courtesy of the U.S. Department of Energy's advanced oil recovery program (which industry participants will match dollar for dollar with goods and services), the research group kicked in on its part of the "Pathfinder" well at 7,300 ft. and took the drillbit down an additional 700 feet.

"We drilled into a low seismic amplitude target within the fault zone, seeking a spot where the fault was tightest," said GBRN co-director Roger Anderson, senior research scientist at Columbia University's Lamont-Doherty Earth observatory.

He explained that the intent was to explore what it would take for deep oil to get through the tight spot in the fault zone, rather than to find the optimal place to produce.

Numerous oil and gas bearing cores were recovered from the Red fault. The test zone was a shale on shale contact, which nixes the probability that the hydrocarbons were

sourced from nearby sands. High resolution resistivity imaging logs showed the high-angle fault zone dipping as expected and cut by natural vertical hydraulic fractures, Anderson said, confirming that the fault zone had, indeed, been isolated.

The target area was perforated over a 40-foot interval and frac-packed, which involved opening the formation and pushing what is basically a gravel pack back into the fracture.

Besides encouraging higher rate production by providing a larger cross sectional area for fluid flow, this completion technique maintains

longer-term well productivity because the fines, which tend to plug gravel packs in the small cross sectional area of the wellbore, take longer to plug the fracture pack's large surface area.

Flow rate from the highly permeable propped zone maxed out at roughly 200 bbl/day, but the flow couldn't sustain itself, and the fracture system closed. Pennzoil senior petroleum engineering advisor Dick Ellis likens the effect to "sucking through a straw in a super thick milkshake."

Without sufficient pressure control at the surface to draw down easily, the pull on the formation became increasingly more pronounced, while fluid production declined.

Over time, the proppant sands apparently became embedded in the fracture walls, impeding the permeability of the zone until ultimately only the low intrinsic permeability of the shale matrix remained.

While team members found that they could reopen the fracture network by pumping into the fault zone at a rate of a few hundred psi, the fractures would tighten as soon as the pressure dropped.

The Great Migration

Anderson speculates that one method to make such faults producible might be to perforate over greater intervals to create larger hydraulic fractures than the 70- by 30-foot fracture made at the Pathfinder well.

Other strategies he contemplates to activate production from fault zones include deep injector wells to sweep

continued on next page

Z&S: 'The Dipmeter and Borehole Image Specialists'



INTERPRETATION SERVICES

There's more to dipmeter and borehole image interpretation than identifying dip patterns. Simply take a glance at any reservoir analog outcrop to be convinced. As the leading, independent, specialists in this field, Z&S have considerable structural and sedimentological experience to draw upon. By integrating our long standing experience in core description and core based facies analysis, we can add yet a further dimension to interpretation. Over the past decade, we have established an unrivalled reputation for providing the highest quality services available.

DIPMETER PROCESSING

- From all dipmeter tools (including the Schlumberger HDT, SHDT, FMS, FMI and OBDT, Western Atlas Hexdip and Halliburton six arm).
- From all service companies (including Schlumberger, Western Atlas, Halliburton, BPB, Computalog and Digital logging).
- Reprocessing of any historic or archived dipmeter data.

BOREHOLE IMAGE PROCESSING

- From Schlumberger FMS & FMI resistivity Microscanners.
- From all digital borehole televiwers.

CORE IMAGE PROCESSING

- Digital imaging and goniometry.

WELL PLANNING ADVICE

- Dip and image tool performance by formation and mud type.
- Application of dip and image tools in specific environments.

PROCESSING SERVICES

A major constraint to dipmeter and image interpretation is simply the amount of time it can absorb for key personnel. Why not let Z&S take some of the strain? By applying our experience to the processing of your data, we can provide you with quality assured results ready for interpretation. Z&S are uniquely qualified to provide this service since we can process *any* dipmeter or borehole image data. Furthermore, our software is designed to cater for new logging tools as and when they are introduced. Z&S guarantee value for money and no hidden costs.

DATA MANAGEMENT

- Log quality control, data recovery and audit.
- Dipmeter database construction and maintenance.

STRUCTURAL STUDIES

- Faulting, folding and unconformities.
- Integration with seismic.
- Fracture and breakout analysis.

SEDIMENTOLOGICAL STUDIES

- Facies analysis.
- Depositional modelling and palaeotransport analysis.
- Reservoir description.

CORE STUDIES

- Core logging, facies analysis, petrography and reservoir quality assessment.
- Probe permeability.

All processing is accomplished using INCLINE or IMAGE in conjunction with the RECALL database. Developed by Z&S, these systems have become recognised as industry standards. All Z&S software is fully transportable across all UNIX and VMS platforms and is available for rental, lease or purchase.

"Integrating Geology and Petrophysics with Software Engineering"

Telephone: LONDON (44) 81-202 2433 • ABERDEEN (44) 224 822555 • HOUSTON (1) 713 789 3038 • STAVANGER (47) 51 52 29 65 • COPENHAGEN (45) 35 36 03 33

continued from previous page

oil up toward producing wells; wellbore orientation parallel to the fault plane to expose a greater surface area; and going after high seismic amplitude targets.

As to what's triggering the upward hydrocarbon movement, Anderson said it's likely that the formation pressures increase until the fracture-closing stresses in the fault zone are periodically overcome, and large volumes of fluid are released out of the geopressed chambers to migrate into the fault plane prior to the ensuing pressure drop which causes the fault to tighten once again.

LSU's Nunn emphasizes that these transient fluid bursts are episodes that may continue for years, perhaps decades.

Analyses of the 340 feet of core retrieved from the Red fault, along with the array of physical and chemical data obtained in situ during the Pathfinder's logging program, will be rolling in during the next couple of years, and optimism is high over the possibility of drilling additional test wells in other locales.

Declaring Victory

While the Pathfinder data may pose more questions than answers, success can be defined in many ways. Anderson notes that DOE's underwriting marked the first time an academia-based project was able to test its modeling and data visualization results directly with the drillbit.

And the federal agency is happy. "We already consider the project to be a success from the standpoint of the scientific data acquired and DOE's reason for going in, which was to test the concept and collect data to confirm the validity of the geochemical evidence and the seismic amplitude anomalies," said Edith Allison, DOE project manager at the Bartlesville, Okla., office.

She also said that the agency hopes this ultimately will be a catalyst for industry to increase Gulf production.

While there may have been a tad of trepidation by some participants about entering a field test jointly run by industry and academia, all's well that ends well.

"We were pleased with how smoothly everything went," said Mike Osborne, Pennzoil's senior vice-president for North America. "It was like clockwork. The scheduling went well and the coring, logging and other evaluations went extremely well."

Columbia's Anderson would like to see this kind of academia-industry linkup become a trend in the oil patch, noting that when a company is in a production mode, there's little time to think about what is discovered.

He suggests that universities are as natural as the R&D labs of the future. Thirty-five scientists will have worked on the Pathfinder over a three-year period.

And they're eager to spread the word about their dynamic hydrocarbon migration research. Pennsylvania State University, in conjunction with the University of Colorado, organized a special poster session on the GBRN effort for the June 1994 AAPG annual meeting in Denver. Eighteen posters have been accepted for what the Penn State team says will be the largest single poster session at the meeting. □

Denver Poster Session to Highlight Eugene Island Drilling Program

A poster session dealing with the U.S. Department of Energy/Global Basins Research Network drilling program involving Eugene Island 330 in the Gulf of Mexico will be offered during the AAPG annual meeting in Denver.

The 17-poster session will be on display Monday afternoon, June 13.

Among the poster titles are:

□ The Adventures of Drilling and Conducting Experiments Through a Major Fault Zone in Eugene Island 330, Offshore Louisiana, Gulf of Mexico.

□ 4-D Seismic Interpretation Technologies and Their Application to the Eugene Island 330 Field.

□ The Role of Salt in Restraining the Maturation of Sedimentary Basins.

□ Effective Stress, Porosity and Abnormal Pressure.

□ Modeling Fluid Flow Along Lister Growth Faults in the Eugene Island Block 330 Field.

□ Effects of Basin Evolution on Regional Fluid Flow and Temperature History in the Gulf of Mexico, Offshore Louisiana.

PETROLEUM EXPLORATION OPPORTUNITIES IN MAURITANIA

ACREAGE OFFERING

THE DIRECTION OF MINES AND GEOLOGY

INVITES BIDS FOR

THE COASTAL BASIN

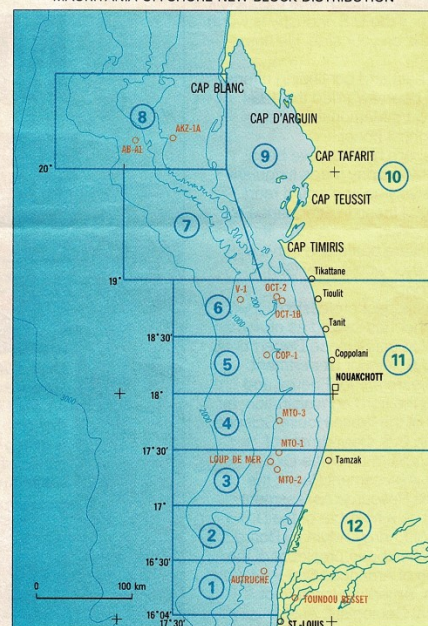
(mainly offshore)

and THE TAOUDENI BASIN

(onshore)



MAURITANIA OFFSHORE NEW BLOCK DISTRIBUTION



A FOLLOW-UP REPORT on the coastal basin (see map)

is now available for sale at price of US\$ 10,000.

All data acquired since 1985 are interpreted and presented in a 68 page large format Atlas (A2) to complement the **PETROLEUM POTENTIAL REPORT** issued in 1985.

A PROMOTIONAL BROCHURE (28 pages, 9 figures, 3 tables)

summarizing infrastructure, hydrocarbon potential, legal and contractual aspects is available free of charge upon request by interested petroleum companies.

QUALITY ENGINEERING ORIENTED PROSPECTS WANTED

Leede Exploration is actively soliciting high quality prospects emphasizing petroleum engineering aspects in conjunction with geological and/or geophysical data. Prospects should be supported by all available technical data and should have one or more of the following characteristics:

1. Development drilling;
2. Enhancement by stimulation;
3. Bypassed pay;
4. Secondary recovery;
5. Cost effective enhanced recovery.

Principals only should contact:

Leede Exploration
2100 Plaza Tower One
6400 S. Fiddler's Green Circle
Englewood, Co. 80111
Vic Hein-Mgr. Engineering (303)721-8000

ENQUIRIES should be addressed to:

Direction des Mines et de la Géologie (D.M.G.)

B.P. 199
Nouakchott - MAURITANIA

Tel: 222.2.532.25
Fax: 222.2.532.25

BEICIP-FRANLAB

Exploration Production Division
232, av. Napoléon Bonaparte
92500 Rueil-Malmaison - FRANCE

Tel: 33.1.47.08.80.71
Fax: 33.1.47.08.41.85