Geophysical Society of Houston

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The Changing Economics of 3D Prestack Seismic Imaging in Depth

Philip S. Schultz, Vice President, Development
Advanced Data Solutions, Inc.

Prestack depth migration has long been regarded as a specialty product, to be tried only in extreme situations of severe lateral velocity variations. Until recently, it was never even considered as a possibility for 3D data, because of the high cost, poor turnaround time, unclear methodology, and the unpredictability of the outcome. The economics are changing quickly, and in dramatic fashion. Now, questions such as, "When does it make economic sense to do 3D prestack migration?" or "How can I tell to what degree the process will improve the data?" demand a new basis for evaluating cost versus benefit. The economics of seismic depth imaging have undergone, and continue to undergo, a consistent and relentless trend: the cost has fallen, the turnaround time has dropped, and reliability of the methodology has increased. The direction and intensity of the trend has been controlled by the convergence of four primary factors: hardware architectures and performance, software environments, seismic data quality, and imaging methodology.

We can now imagine reaching the situation where 3D prestack depth migration is the standard. But, how approachable is this process? Even though costs are going down, they are still not zero, and how will I know if there is sufficient benefit? Let's address the cost side first. Hardware costs are plummeting. RISC architectures are now supporting peak processing speeds over 700 Mflops on the desktop making some stages of parameter testing for prestack imaging truly interactive. Just two years ago the standard was 300 Mflops. Even more impressive is the cost of that compute power. In 1996, you paid less than $70 per peak megaflop versus $260 in 1994. At the same time, machine architectures of powerful numerical servers support parallelization using shared memory and truly parallel operating systems and compilers, making it commercially viable for software vendors to develop and to maintain both single processor and parallel versions of their software.

The evolution of software environments are often less well known, but are equally critical. Standardization of interactive graphics and user interfaces around the X/Motif toolkits has proven to be the linchpin in raising interactive systems to a new level of usability. This standardization, while of superficial benefit in unifying the "look and feel" of interactive applications, has had a more profound and subtle effect due to a relatively new generic feature within X/Motif allowing multiple interactive processes to communicate and exchange information in real time, while running concurrently. These inter-process communication tools in the X/Motif layers are found in the basic architectural layers of newer software systems, and they form the foundation for achieving high levels of usability and productivity with the new software. The results show themselves in reduced turnaround time for project completion.

On the benefits side, the methodology of imaging complex structures prestack in depth has enjoyed continuous improvement and refinement by practicing geophysicists dealing with important real-world imaging problems, such as sub-salt. Today, a well-tested and reliable approach to prestack depth imaging exists, and the methodology is driven by the interpretation and iterative refinement of the seismic velocity model in depth. The new methodology no longer supports the processing geophysicist acting in isolation and

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PLEASE READ ME

H.E.S.S. WILL NOT RELOCATE IN JANUARY.

ALL JANUARY GSH EVENTS WILL OCCUR AT THE OLD LOCATION.

GEOPHYSICAL SOCIETY OF HOUSTON

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Editors Note

I must apologize to all the members of the GSH for the late arrival of the newsletter in December. The delay was do to several factors: 1) Some late arriving GSH event information. 2) A little slower than normal turnaround time at the printer. 3) Lastly, very, very slow delivery through the mail system.

I will take full responsibility for the number of inconveniences it created. I should have been a little tougher on the deadlines and I should have moved the deadlines up further to anticipate the heavy holiday mail volume. I am torn at times to wait, or to go to print, without society information. I have always waited, I may have to change that thought. The delay was not do to waiting for Outlook 97 contributors.

Well, I certainly have heard from you and I still do want to hear from you. Call me, Fax me, E-mail mail. This is our society and newsletter, your participation will make it better for all of us. The topic next month is Borehole Technology.

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GSH Technical Breakfast

Tuesday, January 14, 1997:

The GSH Technical Breakfast will be held on Tuesday, January 14, 1997 on the north side at Mobil Exploration & Producing's Greenspoint Area Headquarters at 12450 Greenspoint Drive. Richard O. Lindsay of Diamond Geoscience Research will present "Pore Pressure Prediction from 3D Seismic". This presentation is expanded from Rick's Subsalt AVO Analysis paper, published in the Oil & Gas Journal's October 28, 1997 Applied Geophysics Issue.

Mobil is providing a full hot breakfast, which will be served in Mobil's second floor meeting room from 7:30 till 8:00 am, with our speaker beginning at 8:00 am. Mobil deserves the society's thanks and appreciation for hosting the complimentary hot breakfast and the facilities for another GSH Technical Breakfast.

January Technical Luncheon

Speaker:
Norman S. Neidell

Date: Monday January 20
Time: 1:30 A.M.
Register and cash bar
12:00 P.M.
Luncheon and Talk
Location: HESS,
3121 Buffalo Speedway
Cost: $17 to registered members.
$22 to guests and walk-ins.
Reservations: Please make reservations through the GSH/HGS automatic phone line 917-0218, by Friday, January 17 at 12:00 P.M. Reservations made after that time will be charged the walk-in price of $22.
Luncheon Topic: Beyond Nyquist - Huygens-Type Wavefield Imaging Extending Resolution Beyond Sampling Theory Norms.
Speaker: Dr. Norman S. Neidell
Co-authors: Mr. E.R. Prince *(Zydeco Exploration, Inc.)*

Professor G.H.F. Gardner *(Emeritus, Rice University)*

Professor E.A. Robinson *(Columbia University)*

Dr. Elmer Eisner *(Consultant)*

Bruce Meadours
Wavefield Image, Inc.

Maggie Smith
Wavefield Image, Inc.

Abstract:

Principles of multichannel signal theory have been misapplied to wavefield imaging giving rise to guidelines and paradigms which unnecessarily limit attainable image resolution. Properly addressing the wave equation in terms of sampling and wavefield reconstructions, where space-time variable linkage is maintained throughout computations, allows full access to the wavefield sampling information content. Resulting wavefield images can achieve resolution beyond that predicted following Nyquist criteria as applied to the individual variables. Additionally, resolution achieved can be outside the range of wavenumbers and frequencies characterizing wavefield sources.

Such apparent paradoxes arise from confusing coordinates of the wavefield sampling with those of the image space. For example, it is only a wave equation and an appropriate velocity function which relate the four independent variables necessary to describe a wavefield sampling (x, y, z, t), to the three independent variables (x, y, z), which describe some attribute of the propagation medium. Note that the variable t does not appear at all in the image space.

Since all of these coordinate relationships are complex and often non-analytic, no direct formulations currently exists which can rigorously assess information content transferred between the two domains using Fourier transform methods. Also, supposed "safeguards" such as anti-alias filters and limiting digital samplings in deference to Nyquist criteria can be recognized not only as being in error, but usually as well remove information from the wavefield sampling thus having an overall negative effect.

Examples of extended resolution imaging using seismic reflection data are shown in support of the theory offered. It is further recognized that most

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imaging applications acquire significantly more data than needed to achieve particular levels of resolution. Methods as described here should offer lower overall cost while attaining higher resolution imaging for a variety of applications. Future applications for wavefield imaging will be guided by rules and axioms which embody the actual physical relationships underlying the imaging process.

Geophysical Society of Houston - Reservoir Geophysics SIG

The Reservoir Geophysics Special Interest Group is an interdisciplinary forum for the discussion of reservoir geophysics topics of interest to geophysicists and geologists, and expanded interchange with the reservoir engineering community.

Date:	Monday, January 13, 1997
Time:	4:00 p.m.
Place:	Texaco EPTD 3901 Briarpark (Corner of Briarpark and Westpark) Conference Room A
Cost:	No charge
Topic:	An Event Specific Seismic AVO Method
Speaker:	Thomas Hu, Texaco EPTD
Organizer:	Tien-when Lo, RC Squared Consulting

An Event Specific Seismic AVO Method
Thomas Hu, Texaco EPTD

Seismic amplitude versus offset (AVO) detects potential hydrocarbon accumulations by examining prestack reflection amplitude at different source-to-receiver offsets. The trend of AVO variations at different surface locations serves as a direct indicator to changes of rock properties and/or subsurface fluid content. This information can be used as one of the tools to help geophysicists identify anomalies in building prospects and delineating reservoir boundaries.

Whereas similar amplitude versus offset analysis methods exist in the industry, the method discussed herein, XAVO, is more robust and flexible. It analyzes AVO effects specific to interpreted horizons. These event specific target amplitudes are normalized by amplitudes extracted from another reference horizon. The normalization process helps minimize amplitude variations caused by changes in the overburden and makes a "true" amplitude recovery preprocessing less critical. This method has been proven successful in many parts of the world.

The method has been implemented on a workstation, migrated from a program originally running on a mainframe. The client/server XWindows environment enables users to interactively scrutinize data quality, edit out noisy picks, and visualize results in multiple windows simultaneously. The add-in automatic analysis modules, easy-to-control graphical user interface and event-driven processes greatly increase user efficiency.

Data Processing SIG

Date:	Wednesday, Jan 15, 1997
Time:	Social, 4:30 pm Presentations, 5:00 pm
Location:	Texaco Auditorium 4800 Fournace
Cost:	NO CHARGE Please call 917-0218 no later than Monday, Jan. 8, 1997 to make a reservation
Topic:	Migration from Topography
Speakers:	Alfonso Gonzalez Western Geophysical Xianhuai Zhu, Burke G. Angstman, and David P. Sixta Union Pacific Resources
Organizers:	Dave McCann & Joe Keliher, Texaco
Parking:	Enter the employee parking gate on Fournace, just west of the Texaco Station at Loop 610. Security guard will direct you to drive across the parking lot, past the 10 story building to the 6 story building. Auditorium is on the first floor of the 6 story building.

Seismic Imaging in Mountainous Areas
Alfonso Gonzalez
Western Geophysical

Abstract:

Careful consideration should be given to the special problems of seismic imaging in the presence of irregular topography. Imaging algorithms have particular requirements pertaining to the reference datum where sources and detectors are located. Understanding these requirements is important if the fidelity and resolution of the seismic data is to be preserved. The cost of 3-D wave equation datuming, the correct procedure to change datums, is still too high to apply routinely to data; therefore, we bring data acquired in regions with irregular topography to a planar horizontal datum with static corrections. Refraction and residual static corrections simulate a layer replacement process with the objective to simplify the complexities of wave propagation near the surface. By understanding the interplay between layer replacement with static shifts and a particular imaging algorithm, it is possible to define datum surfaces that minimize travel time errors. This is particularly true with 3-D prestack depth migration because much of the layer replacement process traditionally left to static shifts can be done more accurately by the migration. It is not always a good strategy to define a single processing datum for the entire imaging process. The datum does not even need to be planar. In this study I review different imaging processes and recommend a processing strategy in mountainous regions. NMO works best if applied from a locally horizontal time surface. DMO is particularly sensitive to the reference surface. Even in the constant velocity case, changing the datum destroys the simplicity of the 2-D DMO elliptical operator and can bring tridimensionality and asymmetry to the operator. Travel time errors in DMO are minimized if applied from a smooth

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surface that follows the time average of the original topography; otherwise, raytracing and an accurate velocity model are needed to define an exact operator. I discuss strategies to obtain an optimum datum for DMO. Optimum datum surfaces for time migration depend on the type of migration algorithm. In 3-D depth migration, static shifts should be applied only to correct the rapid variability of velocities and topography near the surface. 3-D depth migration can accurately process the longer wavelength variations associated with both the topography and the near surface.

Overthrust Imaging with Tomo-Datuming: A Case Study

Xianhuai Zhu, Burke G. Angstman, and David P. Sixta
Union Pacific Resources

Abstract:

Prestack imaging of 2-D seismic data in overthrust areas containing both highly-variable near-surface velocities and rough topography can be accomplished by using iterative turning wave tomography followed by wave-equation datuming (or tomo-datuming) and prestack depth migration. In tomo-datuming, shot records are redatumed from the topography to a flat datum using velocities estimated from tomography. The main advantage of tomo-datuming over tomo-statics (tomography plus statics corrections) and/or refraction statics is that instead of a vertical time shift, tomo-datuming projects raypaths, obeying Snell's law. Since turning ray tomography provides a more accurate near surface velocity model than that from refraction statics, tomo-datuming appears to have better reconstructed diffractions and reflections and therefore, better images after migration. In the prestack depth migration, input shot records have been redatumed to a flat datum by the wave extrapolation without applying imaging conditions, such that errors in travel-time calculations associated with the raypath distortions near the surface can be reduced and conventional Kirchhoff depth migration algorithm can be more effectively applied. Case studies with synthetics and field data examples show that tomo-datuming is especially helpful when strong lateral velocity variations are present below the topography.

Interactive Workstation SIG Meeting

Date:	Thursday, January 16, 1997
Time:	4:30 PM
Place:	British Petroleum, 3rd Floor; British Petroleum is located at 200 Westlake Park Blvd; this is between the Katy Freeway and Memorial Drive just east of Highway 6. Please park in the BP parking garage which is located to the west of the BP building. The Visitor Parking Entrance is on the west side of the garage.
Cost:	No charge; however, please reserve a place by calling the GSH Office (713-917-0218) no later than noon Tuesday, January 14. Seating is limited. A meeting of the SIG Committee will be held at 3:30 PM prior to the presentation. All committee members are urged to attend.
Topic:	Symposium-Data Management of Interactive Interpretation Workstations
Speakers:	Don E. Robinson, General Manager, Panther Technologies Larry Godfrey, Consultant to Samedan Oil Corporation

Abstract:

The speakers will address the data management of interactive interpretation workstations from several points of view. First, problems in your data which should be addressed prior to loading and interpretation- how errors in data loading can impact the interpretation results. Examples of some of the pitfalls of data loading will be presented, and how they can be recognized and avoided.

Secondly, a look at data loading and data management using five of the commercially available workstation software packages. The experience derived from loading the same 3D project on each of the five software packages will be discussed. The project consisted of a 3D trace volume and well information. The outcome of the exercise produced interesting conclusions and recommendations which will be presented.

Lastly, time will be available for discussion by the audience of data management issues. Be sure and join us. This is a topic which should be of interest to both interpreters and data managers. If you have specific comments on data management and loading issues, this will be a good forum to express them.

Potential Fields SIG

Date:	Thursday, January 16, 1997
Time:	5:30 - Social Hour, 6:30 - Dinner, 7:30 - Talk
Location:	HESS, 3121 Buffalo Speedway
Cost:	$20.00
Topic:	Reflectorless Laser Rangefinding Systems for Gravity Terrain Corrections
Speaker:	Carlos L.V. Aiken, PhD University of Texas at Dallas
Reservation:	Chuck Campbell, ACCEL Services, Inc. campbell@neosoft.com, or 713-993-0671

Abstract:

Reflectorless laser rangefinding systems developed by the military have an ability to receive reflections from many types of materials for most angles of incidence and most compositions, making it possible to map terrain for gravity terrain corrections in the inner zone interval where it is usually done by sight estimations. There are several systems produced especially for the commercial market including the Laser

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Atlanta Optics Advantage Rangefinder, the Laser Technology Criterion, and the Leica Vector Binocs. Our experience has been with the Laser Atlanta system from Western Data of Houston. They all have built-in inclinometers and stand-alone compasses which, along with the laser rangefinder, is a device similar to a total station, measuring distance, azimuth and inclination for three dimensional positions with accuracy sufficient for terrain modeling (and many other applications). The Laser Atlanta records on a PCMCIA card while the others have internal memory. All these lasers can integrate with portable computers with software such as Condor Earth Technologies PenMap and ESRI's ARCVIEW GIS software to display data for real time quality control (very important) and to perform other operations. In a Nevada gravity survey the 1:24,000 30 minute topo grid was used for calculating outer terrain corrections and laser mapping for terrain within 50 meters of the station. There is a question as to what pattern of terrain sampling could be expeditiously accomplished so as to not slow a gravity survey and yet be sufficient for terrain corrections. Should one sample along radial lines or break lines or some other pattern? Experiments have been done with various patterns in various terrain environments.

Environmental Applications S.I.G.

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This Special Interest Group focuses on the best available commercial applications of *non-intrusive* geophysical methods (air, water and land-based).

SITE CHARACTERIZATION based on INTEGRATED non-intrusive geophysical methods offers:

- appropriate and cost effective delineation (area and *depth*) of anomalies before core drilling.
- fewer and/or better placed core holes to characterize waste/contamination.
- fewer and/or better placed monitor wells to monitor changes.
- lower risk for successful remediation and monitoring programs.

BIMONTHLY MEETING: Thursday January 23, 1997
Time: 4-6 PM
Host Company: B P Exploration (Don Herron)
Location: BP Plaza, 200 Westlake Park Blvd (near Eldridge and Memorial), 3rd floor. Visitor parking no charge. Check in with receptionist.
Cost: NONE. Open to the public.
Program: Stephanie Hrabar, PG (KY), CFE, CPG phone 713/ 683-0638.

- Kerry Campbell, CPG, Manager of Geology and Geophysics at Fugro-McClelland Marine Geosciences, will discuss *Site characterization in the marine environment-active and buried faults, geotechnical properties, and other engineering concerns prior to drilling wells.*

- Bill Kardos, PG (CA): Safety Message.

FORMAT: Exhibits and posters will be posted and may be reviewed before and during the session. Presentations are followed by an informal dialogue with the audience. Session ends promptly at 6 pm.

NEXT MEETING: Special 2-day forum *LOOKING INTO THE EARTH*, Friday and Saturday 21-22 March, Host Company: Texaco EPTD, 3901 Briarpark (corner of Westpark and Briarpark)

Day 1 features two case studies and technology exhibits:

Case 1) A proposed disposal facility for radioactive waste 40' into sediments near the town of Sierra Blanca, Hudspeth County, Texas.

Case 2) A proposed hazardous waste disposal facility within the Boling salt dome in Wharton County, Texas. Secured Environmental Management, Inc. is the permit applicant, and it has approved the participation of their geophysicist of record H. Roice Nelson, Jr.

Contact Mr. Nelson (713/579-0172 or E-mail: rnelson@walden3d.com) to see the 3-D seismic reflection data on a computer workstation and/or download some of the 3-D seismic reflection data. Geological information in permit application TNRCC #34819 is at the Houston TNRCC office. Request the file from Valerie at 281/767-3502 one day before you go to review or copy the report.

Day 2 features field demonstrations of non-intrusive geophysical methods to characterize the underground geology: Seismic reflection and seismic refraction with acoustic (sound) sources, ground penetrating radar (electromagnetic source), electromagnetic/conductivity, resistivity, magnetic, . . . and one invasive tool, the cone penetrometer.

$35 REGISTRATION is for both days and includes lunch.
Make check payable to GSH/FORUM.
Mail check to GSH/FORUM c/o P O Box 925809, Houston, TX 77292-5809.
Friday seating is limited and based on receipt of check. Walk-ins are not guarenteed a seat on Friday.
Saturday field demonstrations will happen regardless of weather (if weather poor, we will be under cover).

NAME: ____________________

ADDRESS: ____________________

PHONE: ____________________ FAX: ____________________

Environmental Applications S.I.G.

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SIG at Texas Recycles Day Fair

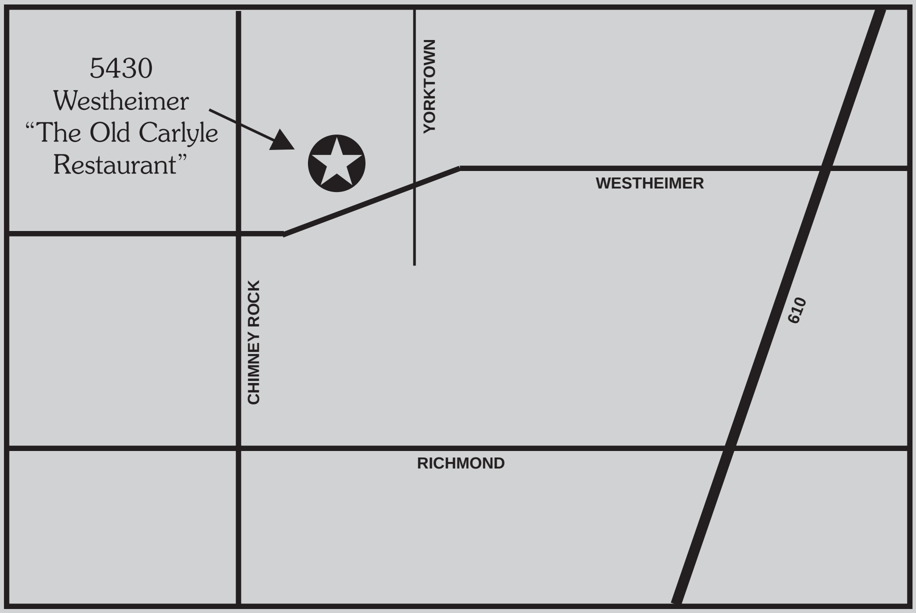
On Friday 15 November the Environmental Applications SIG joined more than 60 environmental groups, oil and gas companies, recycling and waste management businesses, and city, state, and federal agencies at the Texas Recycles Day Fair. The fair was held from 10 am until 2 pm at the reflection pool at City Hall. It was presented by the City of Houston Solid Waste Management Department/ Recycling Division and benefited the Houston Corporate Recycling Council Scholarship Fund.

Stephanie Hrabar and Claire Bresnahan represented the Environmental Applications SIG. They distributed information and talked to interested parties about matters such as the

- distribution of nearly 300 landfills in Harris County.
- geophones that record reflection and refraction data to locate buried landfills and characterize sites.
- high resolution reflection data to characterize the near surface geology.
- commercial applications of non-intrusive geophysical methods and computer workstation technology featured at the SIGs spring forum titled *LOOKING INTO THE EARTH* .
- GSH Bulletins and membership applications.
- fact sheet about the GSH and Environmental Applications SIG meetings that are open to the public.

PLEASE READ ME!

HESS is relocating beginning in February. All GSH activities starting in February will occur at the new location



Upcoming Meetings and Conferences

Subsalt '97

Subsalt Technology Conference, January 28 -30, 1997. The conference is sponsored by Offshore Magazine, and will be held at the George R. Brown Convention Center.

For more information contact Dena Trochesset at the following address:

PennWell Conferences & Exhibitions
3050 Post Oak Blvd. Suite 205
Houston, TX. 77056
713/963-6252

Landmark Worldwide Technology Forum

On February 12-14, 1997 Landmark Graphics will hold its annual World wide Technology Forum at the Adam Mark Hotel in Houston, Texas. Keynote speakers at the Worldwide Technology Forum will be Dick Cheney, President & CEO of Halliburton and former U.S. Secretary of Defense under the Bush Administration; and Daniel Yergin, President of Cambridge Energy Research Associates and Pulitzer-Prize winning author of "The Prize: The Epic Quest for Oil, Money, and Power. "

For further information about Worldwide Technology Forum registration, visit the Landmark Web site at http://www.lgc.com. Or e-mail at forum@lgc.com. Or phone at 281/560-1000.

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specifying parameters in the time domain. To image the seismic data efficiently in depth, there is a fundamental requirement for geological input at such an early stage in the processing sequence that velocity models for seismic depth imaging today are often built only in the depth domain.

One effective way in which the benefits of prestack 3D depth migration can be predicted is to evaluate two key questions regarding the data and processing: First, "Can depth migration bring any benefit?", and second, "Has anything been lost in the stacking process?" For prestack depth migration to be of any benefit (in 2D or 3D) the answer to BOTH questions must be "yes." We often answer the first question simply by depth migrating the data poststack, and comparing the result to the time domain migration. At an early stage, the velocity model is usually still in need of refinement, but it can be described precisely enough so that the poststack depth migration gives an indication of potential gain from depth migration. In the example, Figures 1 and 2 show poststack time and depth migrations from a 3D land dataset in the Wilcox trend. Two features are worth noting. First, the rotated fault blocks stepping up to the right starting from about 14500 feet of depth in Figure 2 and from about 3.1 seconds in Figure 1 are imaged more clearly in the poststack depth migration. Second, two events on the upthrown side of the fault at about 12000 and 13000 feet of depth, and in the range of cdp numbers 275 to 310, raise the question on both Figures 1 and 2 of whether they are broken by a near-vertical fault near cdp 295, or whether this apparent faulting is an artifact caused by the faulted high velocity Wilcox layer above. The comparison of Figures 1 and 2 give evidence that depth migration has real benefits to bring to this data. Has anything been lost in the stacking process for this data? Performing a test of the prestack 3D depth migration to output a single migrated line often can resolve this question quickly. In this case, the same line 3D depth-migrated prestack, as seen in Figure 3, shows a clearer image of the system of rotated fault blocks. Now look at the two events under the fault. Was the apparent minor faulting real or an artifact of the fault shadow? The prestack 3D depth migration image gives evidence that the events are actually continuous, and the apparent faulting was indeed an artifact caused by a velocity distortion in the fault shadow. In this case, using prestack 3D depth migration brought a clear benefit. In some cases, it doesn't. The way to find out whether your data will improve with prestack depth migration to use the "staged approach" the prestack depth imaging. Doing so allows you to answer the two key questions posed above without spending time and money unnecessarily. You can stop at any point where the answer is "no." The sequence normally followed in the staged approach is as follows.

1) Do a 3D poststack depth migration and compare the result to 3D poststack time migration to determine if depth migration can bring any benefit. If yes, proceed to the next step; if no, you can stop.

2) Do a swath 2D prestack depth migration from the 3D dataset or a full aperture 3D prestack depth migration into a single output line. Compare this result with the poststack 3D depth migration, to determine if anything has been lost in the stacking process. If yes, proceed to the next step; if no, you can stop.

3) You have now established that 3D prestack depth migration will bring a benefit. Do prestack 3D depth migrations into key lines or a target subvolume to confirm that the improvement is as you expected from your previous analysis. Stop if no, or if the key line or subvolume image is sufficient for your needs.

4) You are now ready for full volume 3D prestack depth migration. By this time, the velocity model has matured through all the above steps, and the migration should be good quality.

Before the end of 1997, you may find your group having to justify why you did NOT prestack depth migrate your 3D seismic data. Using the staged approach will provide you that justification.

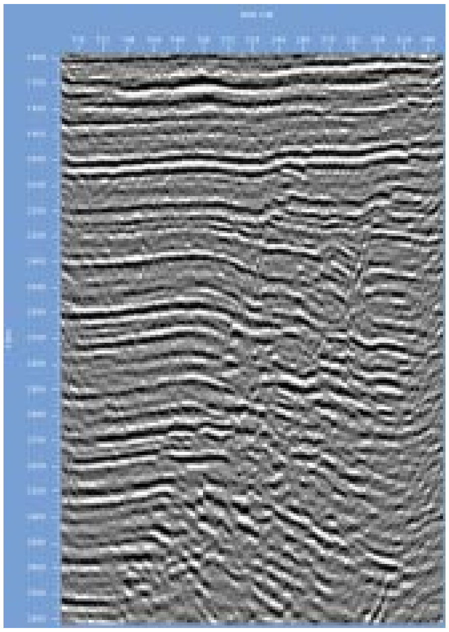

Figure 1. Inline section from a poststack 3D time migration from a 3D land survey in the Wilcox trend.

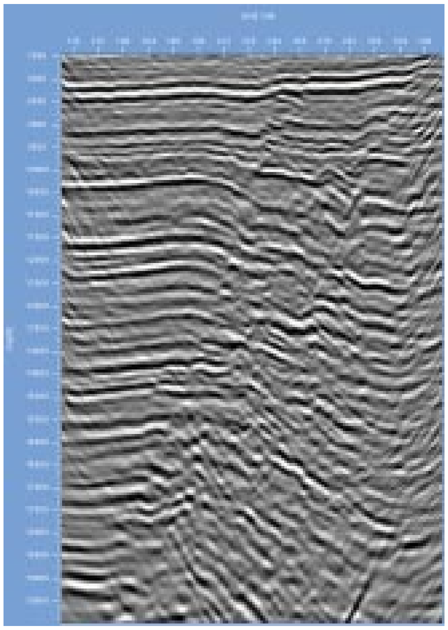

Figure 2. Same inline section from a one-pass poststack 3D Kirchhoff depth migration.

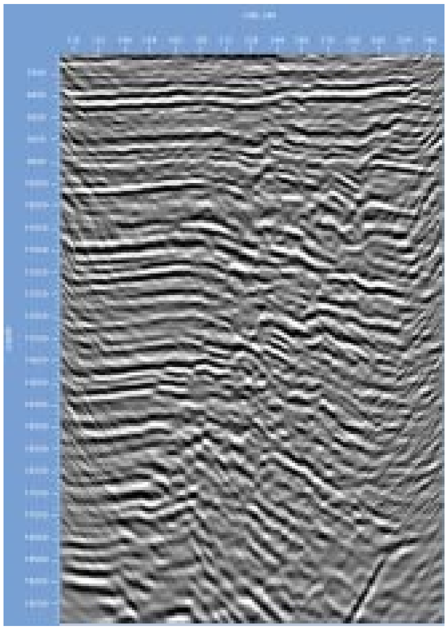

Figure 3. Same inline section from a one-pass prestack 3D Kirchhoff depth migration.

Interpretive Depth Imaging Leverages 3D Technology

Mark V. Lance
Landmark Graphics

Exploration has come a long way since the old story " …this is where the truck broke down, so this is where we drilled". Our industry has made great strides since the days of optimistically drawing time highs against faults from a series of 2D seismic lines. Blind luck and artistic impression have and continue to play their role, but in today's competitive E&P environment 3D seismic technology is the driving force in a successful E&P strategy.

Visionary companies are leveraging 3D seismic technology to create a competitive advantage. Wulf Massell, president of EPIC Geophysical in Houston states "The industry has realized that the information content in 3D data is so great that we must use a higher level of technology to extract more information from it". One of the emerging technologies that leverages more information from 3D data is interpretive depth imaging. Integrating this technology into the E&P work flow lowers risk and increases success ratio.

3D Prestack Depth Imaging

Acquisition, processing, and interpretation of 3D seismic data have emerged as the most widespread and successful technology for oil and gas exploration and development over the past two decades. The use of 3D data has given credibility to many exploration plays, opening the door to capital for drilling prospects that otherwise would be collecting dust in the filing cabinet. 3D seismic has had an impact on exploration and exploitation of reservoirs in complex structural and stratigraphic settings. Our industry's success has encouraged us to push exploration and development into increasingly complex areas.

For all the benefit 3D seismic data provides there are limitations to conventional 3D time domain data processing and interpretation methods. In complex structure or where the velocity field varies rapidly, the wavefront of seismic energy is distorted. Salt velocity adjacent to gulf coast sediment velocity or high velocity sediments thrust over slower velocity sediments are well known examples of this condition. Conventional time domain processes begin to fail. Ray paths bent by these large velocity contrasts are not accounted for by normal moveout correction and common midpoint stack assumptions in conventional time domain processing. These time domain processing steps filter out signal.

Time domain migrations assume a smoothly varying input velocity model and are unable to produce an image that positions reflectors accurately. In these and other complex situations time domain processing cannot reveal accurate information about the depth-velocity field or position reflectors properly. In very complex areas time domain processing can result in misleading images and in some extreme cases reflected signal cannot be imaged at all. In the Gulf Coast example we are left to only imagine what potential might lie beneath the salt (Figure 1).

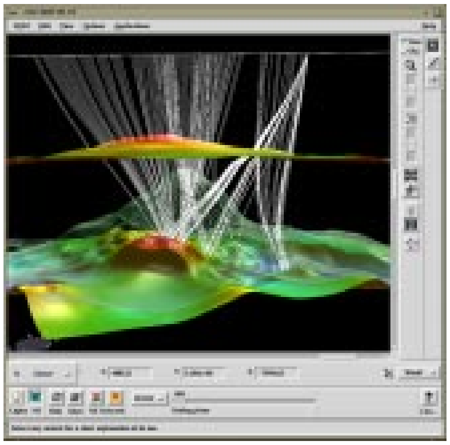

Figure 1 - Raypaths near a salt diapir illustrate the 3D out of the plane effect and ray bending in complex regimes.

3D prestack depth migration is capable of imaging signal in very complex data. It is widely accepted as a more accurate technique than time domain techniques for solving imaging problems in complex structure where lateral velocity variation wreaks havoc on the propagation of seismic energy. Prestack depth migration corrects for this ray bending. The result of depth imaging is focused reflected energy, events positioned properly both laterally and in depth, and a detailed depth velocity model optimized to best image the seismic data. All of this adds to knowledge of the earth model, reducing drilling risk in exploration or development (Figures 2 and 3).

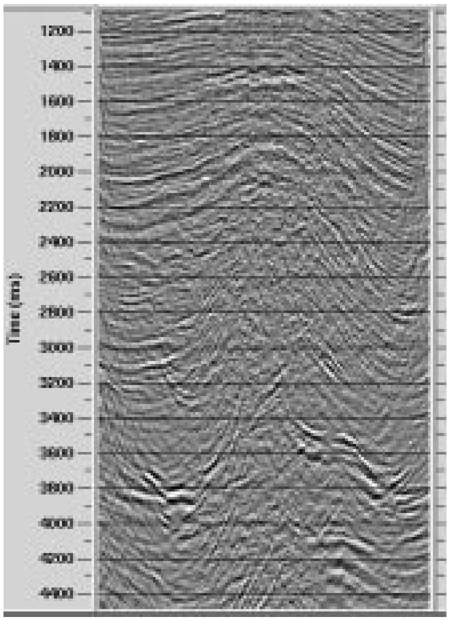

Figure 2 - Conventional time domain processing fails to properly image base of salt and subsalt reflectors.

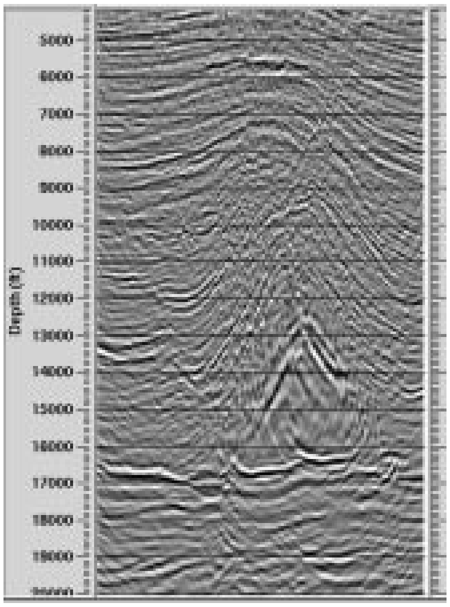

Figure 3 - 3D prestack depth migration from Landmark Graphics focuses reflected energy and more accurately positions events in depth. Note the fault delineation in the shallow section and strong reflectors below the salt.

The subsalt play in the Gulf Coast is one example of a complex setting with great potential. This play has generated significant interest since discoveries in the early 1990's. The

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biggest hurdle in this play is resolving the complex shape of the salt body and imaging reliable interpretable events beneath the salt. The potential of this and other complex plays is driving the development of 3D prestack depth imaging technology. Successful companies are leveraging their investment in 3D data by employing prestack depth imaging techniques to get more information from their 3D data in these complex regions.

3D depth imaging is a relatively young technology, but it is impacting exploration in very complex regions. Steve Natali of Barrett Resources in Denver says " I see the potential of depth imaging emerging much the way we saw the potential of 3D data 15 years ago. Depth imaging has already been crucial to our success in complex regimes, but I predict within five years prestack depth migration will become an everyday procedure." Massell adds "This technology provides another round of risk reduction, and it is the amount of risk reduction that will determine how quickly the technology will be accepted. The incremental risk reduction has to be worth the cost. I would guess that within five years 3D prestack depth migration may be required before drilling a well in complex areas."

Cost Effective Computing Power

The mathematical solution to depth migrating prestack data has been known for quite some time. However, the widespread use of this technology has been constrained by the compute intensive nature of the process and until recently, the absence of practical depth migration software. Considering the staggering amount of prestack data in a 3D survey and the intense computational nature of prestack depth migration algorithms, we are faced with a formidable data management and computing task. In the not too distant past, main frames and massively-parallel supercomputers were the only possibility for depth migrating 3D prestack volumes of data. These computers were not an economically viable solution for most companies. Nor could most companies afford the turnaround time associated with a depth imaging project. Fortunately, the price to performance ratio of today's high-end UNIX workstations has improved greatly.

The falling cost of computing power cannot take all of the credit for making prestack depth migration achievable today. While 3D prestack depth imaging technology is still in an early stage of development, efficient applications are available. Effective depth imaging software takes advantage of the SMP computing architecture of today's high-end workstations and provides a practical approach to prestack depth migration. Effective software manages the compute load on a multiple-node SMP machine to balance data preparation time, interactive analysis requirements, and pure number crunching requirements during a depth imaging project. During the day more nodes can be devoted to data preparation, velocity model analysis, and interpretation. After working hours the compute intensive workload can be distributed to more available nodes.

Practical 3D Prestack Depth Migration

Effective depth imaging software is not only optimized to manage computing efficiency on the latest SMP machines, but also provides an array of options for "target" oriented 3D prestack depth migration. Target oriented 3D prestack depth migration provides the flexibility to output the target image of interest. This might be a gather, line, arbitrary traverse, depth slice, or a volume of the 3D survey (Figure 4). The target oriented approach is a practical way to balance turnaround time constraints with the computing requirements of 3D prestack depth migration while fulfilling the goal of estimating the earth model. This practical approach reduces turnaround time, from what once took months for a large volume, to days or hours depending on the target image of interest. Today's cost effective SMP architecture provides the computing power to support target oriented 3D prestack depth imaging.

Migrating target oriented subsets of data supports various cost effective velocity analysis and model building techniques. This practical approach can be used to quickly migrate 3D data to selected prestack depth gathers for velocity analysis or velocity model quality control. Data can also be 3D prestack depth migrated on to key lines intersecting a prospect. Target depth images show the potential of 3D prestack depth imaging in a complex setting before committing computing or manpower resources to a volume prestack depth migration. Falling prices in compute power plus practical implementation of 3D prestack depth migration is allowing smaller companies to compete with tools that were once considered the technology of the major oil companies. There are fewer and fewer compelling reasons to rely on 2-D methods to solve 3D problems. 3D prestack depth imaging is achievable today.

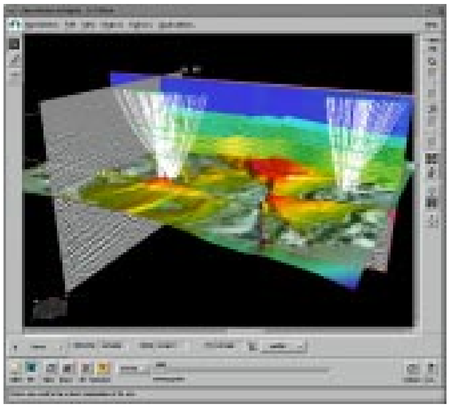

Figure 4 - Target oriented 3D prestack depth migrated images with an interpreted horizon, velocity backdrop, and rays from shot gathers, all viewed with Landmark Graphics OpenVision graphics tools.

Interpretive Depth Imaging

At first glance depth imaging may appear to fall into the traditional processing camp as opposed to the interpretation camp. This may be due to the use of prestack seismic data and geophysical algorithms. However, our goal of estimating the earth model in terms of reflector position and layer velocity in depth is an interpretive process. Inherent velocity-depth ambiguity requires close interpretive analysis of velocity estimates and the spatial position of reflectors in depth. Natali says "The interpreter must be involved in building the depth-velocity model. He who builds the velocity model is also building the structure map". Processing and interpretation are taking place at the same time and therefore

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an interpretive approach throughout the depth imaging process, guided by knowledge of the area's geology, will insure a reasonable range of feasible models and greater confidence in drilling decisions.

Massell added the following, while reflecting on a recent successful depth imaging project. "The interpretive process begins even before the depth imaging stage. The processing preparation we do to clean up the prestack data allows us to move ahead and do the velocity analysis. To get the velocity detail that we needed meant that we had to know a little bit about the signal that was expected. The right signal has to be passed on to velocity analysis and if you don't know what signal you are looking for you are only shooting in the dark. The prestack conditioning brings a lot to the table, but it requires interpretive input and feedback. It is this interpretive approach that allowed us to bootstrap our way to a better velocity model."

Multidiscipline Teams

Geoscientists having the most success are approaching depth imaging with multidiscipline teams. EPIC Geophysical and one of their oil company clients fully subscribe to the value of multidiscipline teams and have taken this approach to heart. They went to school together to learn about a new software application for depth imaging and when they got back to the office they sat down and worked through a depth imaging project together. They are absolutely convinced that without a collective effort they could not have arrived at the optimum solution.

Getting more information from 3D data means that interpreters can no longer focus on stacked volumes of data alone. Using the interactive tools available today interpreters are taking a much closer look at the prestack data to give them better input to the earth model. Prestack depth gathers can reveal a lot of information about velocity that we cannot afford to throw away (Figure 5). There is also an iterative nature to this interpretive process which incrementally adds value to the earth model and narrows the range of feasible solutions. Between each iteration, experts from different disciplines can determine parameters and verify results. Interpreters are testing geologic concepts and quickly seeing if the data supports the concept. The processing expert can help verify that the seismic data supports the interpreted result. Information from one iteration is then fed back into the model for another iteration. Multidisciplinary teams are guiding the range of possible earth models based on the collective expertise of the team, integration and analysis of all of the data, and knowledge about the geology of the area. Drilling risk is reduced because decisions are based on better information.

The Right Tools For The Job

Depth imaging can provide superior depth images and add accuracy to the earth model in a wide variety of complex geologic settings. Depth imaging software needs to support a range of interpretive methods for estimating the depth-velocity model in different geologic regimes. With this flexibility an appropriate method can be chosen to balance computing requirements and necessary accuracy with the degree of geologic complexity. Even within a given depth imaging project, complexity can vary dramatically from the shallow overburden portion to the deeper section where lateral velocity variation may be severe.

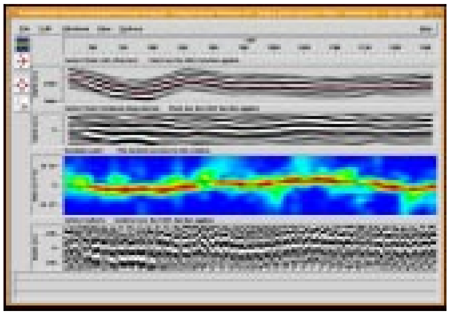

Figure 5 - Prestack depth migrated data provides valuable information about the velocity model. ProMAX MVA from Landmark Graphics provides interactive horizon oriented analysis of depth gathers for quality control and velocity model updating. "Flat" gathers (bottom window) indicate an accurate velocity model. "Residual" moveout on the gathers indicate that the model is too fast or too slow.

The velocity model for a relatively simple overburden can be solved with ray tracing and map migration techniques. Layer by layer, in an iterative fashion, velocity is updated and horizon positions determined from a poststack depth migrated section. As complexity increases prestack depth migration will be required and a Constant Velocity Half Space approach can be employed. In this method, data below the overburden model is prestack depth migrated over a range of geologically feasible test velocities. The resulting common image depth gathers are inspected to determine which trial velocity produced a "flat" common image gather. In the situation where noise is a problem, stacks of common image depth gathers will improve the signal to noise ratio and can therefore be analyzed with greater confidence (Figure 6). Horizon position is interpreted from prestack depth migrated stacked sections using the new velocity field. The depth-velocity model and interpreted horizons are updated in a layer by layer fashion. Geostatistical integration techniques provide a powerful method for constraining the depth-velocity model with well control. The target oriented prestack depth migration approach lends itself nicely to this technique, minimizing the amount of data that must be migrated for each analysis location, making the procedure cost effective and time efficient. Employing a combination of practical and effective tools matched to the complexity of each situation reduces turnaround time, improves accuracy of the velocity model and ultimately reduces project costs.

Integrated Software Supports Multidisciplinary Teams

Software applications have evolved to support the collective effort of multidisciplinary teams. Applications must allow quick integrated access to geophysical and geological data. The benefits of integrated tools begin with reducing data loading or transfer time. Integrated systems allow a depth imaging team to have access to the same data that the processing team is working with. Extracting the earth model from 3D data requires an iterative flow of data and information between conventional processing steps for preparing data, attenuating noise or multiples and the 3D depth imaging techniques. Integrated processing and depth imaging tools facilitate this work flow.

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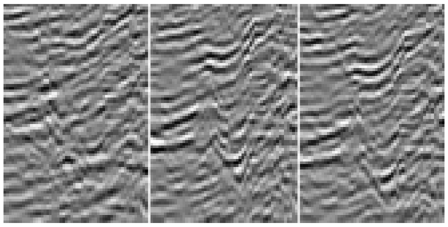

Figure 6 - Target oriented 3D prestack depth migrations support a Constant Velocity Half Space approach to velocity analysis in complex areas. Target data is prestack depth migrated over a range of constant velocities. The velocity field for the middle set of traces yields the best image of the fault at XLIN 130.

The same level of integration between depth imaging tools and interpretation tools facilitates the flow of data and interpreted horizon position information. At the end of the day it is more efficient for the interpreter to pick horizons and faults, and incorporate well data from the same interpretation system that will produce the final interpreted result. Interpreting directly in the depth domain is becoming a routine part of the workflow in complex plays. In an integrated workflow the depth domain is the common domain for communicating with geologists and engineers.

A more accurate earth model in less time is a huge competitive advantage in today's business environment. Applications that facilitate integrating data and expertise from several disciplines leverages depth imaging technology. This leveraging of depth imaging technology leads to better exploration and development decisions.

A Practical Depth Imaging Workflow

A practical depth imaging workflow, achievable with integrated software from Landmark Graphics, begins with an assessment of the complexity of the imaging problem. Are sharp velocity variations distorting the time domain seismic results? Are there 3D effects complicating the imaging process? In the case of subsalt objectives the answer is most likely yes. Time domain processing will not yield an accurate structural image. 3D data will be required to accurately resolve the geometry of the salt body and delineate complex fault blocks surrounding or beneath the salt. Depth imaging is required to accurately determine the depth velocity field and image horizons in their correct positions in depth. Solving this complex problem effectively requires a practical integrated workflow.

In an example situation we might have 3D seismic, some key horizons interpreted from time domain stacks and some well control from an old field. We are confident, due to the complexity of the area, that depth imaging will improve delineation of faults in the vicinity of a producing reservoir. While we are at it we might as well see if reflectors under the salt can be imaged to help evaluate the deeper subsalt potential.

The shallow velocity field above salt is fairly simple compared to that around or below the salt so the velocity analysis method should provide a quick but accurate shallow velocity solution. In this case a coherency inversion approach utilizing full 3D ray tracing algorithms insures a quick 3D solution where an iterative prestack depth migration velocity analysis is not necessary. A typical workflow might look something like the following:

- Preprocess 3D seismic data, attenuate multiples and noise
- Output sparse gathers for coherency inversion velocity analysis
- Coherency inversion analysis of gathers over a sparse but regular grid
- Establish the velocity field for a layer
- Map migrate the time horizons to depth
- Depth migrate seismic and refine map migrated horizon picks
- Repeat the process, layer by layer, using migration algorithms with restart capability to minimize run times
- Calibrate the velocity field with geostatistical information from well control if available

At this point the overburden velocity field down of the top of salt reflector will have been estimated, quickly and cost effectively, using tools capable of solving this degree of complexity. The velocity of salt is known and can be added to the velocity model. Typically the velocity model is flooded with salt velocity below the interpreted top of salt horizon.

3D Prestack depth migration will be required to image base of salt , subsalt reflectors, and estimate the velocity field below the salt. Target oriented prestack depth migration efficiently supports the remainder of the work flow, minimizing computing time and minimizing the amount of data that is migrated. Interpreting horizons may best be accomplished on a 3D interpretation workstation and tools familiar to the interpreter. The next steps in the workflow follow:

- Determine velocity of the next depth step below the salt using a Constant Velocity Half Space (CVHS) technique where data is prestack depth migrated over a range of velocities
- Velocity picks can be made from depth gathers or stacks of depth gathers if signal to noise ratio is poor
- Interpret the structure of reflectors after prestack depth migration
- Employ CVHS to determine velocity of next depth step
- Restart the migration from the previous depth step to save computing time
- Complete the velocity model and structural interpretations, layer by layer, in the depth domain

The use of flexible velocity analysis tools matched to the degree of complexity provided an estimate of the earth model in the least possible time. Accuracy of the earth model is ensured by leveraging integrated tools and implementing an interpretive approach throughout the depth imaging project.

Most of the simple structural exploration and development has occurred. Given the potential to replace reserves from complex regimes, successful E&P companies of all sizes are employing 3D prestack depth imaging technology to get more information from their 3D data. Integrated software available today leverages the technology even further, supporting an interpretive approach where the collective expertise of multidiscipline teams can use all available data to estimate the earth model. The result promises to be better business decisions.

NORTH HARRIS COLLEGE

GEOSCIENCE TECHNOLOGY TRAINING CENTER

SPRING 1997 COURSE SCHEDULE

For information concerning REGISTRATION, FEES, COURSE DATES/ TIMES, LOCATION and GENERAL COURSE INFORMATION contact: (713) 443-5600 - Voice; (713) 443-5633 -Fax

ACADEMIC COURSE - The Spring Semester begins in January - Sign up early as this class fills fast.

COMPUTER APPLICATIONS IN GEOLOGY

4 Standard College Credit Hours

A semester-long workstation interpretation course featuring four weeks of UNIX, six weeks of GeoQuest IESX, and six weeks of Landmark SeisWorks geophysical interpretation. Students learn basic UNIX commands and syntax. Students will also interpret two 3D seismic prospects while learning the basic interpretation components of Landmark Graphic and GeoQuest interpretation software. Evaluation is in the form of a written UNIX exam and interpretation skills tests.

GEOL 2404 Sec. 12001
T/TH Spring and Fall Semesters
6:30 PM - 9:30 PM
The Winship Building Room 261

January 1997:

WORKSTATION INTERPRETATION - SEISWORKS

24 Classroom hours

Students will utilize a UNIX workstation, LANDMARK SeisWorks and 3D seismic data to interpret faults and horizons, create time slices, and contour maps using a variety of workstation viewing options and utility functions.

CGTTC 2E051 NNH01
T/W/Th. — 1/28 - 1/30
8:00 AM - 5:00 PM. WN 261

AN INTRODUCTION TO ORACLE

24 Classroom hours

This class is designed to introduce students to the ORACLE database administrator, and is the first in a series of three ORACLE courses. Topics will include client/server computing, networking and related issues, SQL, and PL/SQL.

CGTTC 2F011 NNH01
M & W — 1/13 - 2/5
7:00 PM - 10:00 PM WN 265

WORKSTATION INTERPRETATION - GEOQUEST

24 Classroom hours

Students will utilize a UNIX workstation, GEOQUEST IEX-IESX and 3D seismic data to interpret faults and horizons, create time slices, and contour maps using a variety of workstation viewing options and utility functions.

GTTC 2E031 NNH01
T/W/Th. — 1/21 - 1/23
8:00 AM - 5:00 PM. WN 261

AN INTRODUCTION TO UNIX-BASED SYSTEMS ADMINISTRATION

24 Classroom hours.

This introductory course will discuss UNIX-based workstation systems administration from the viewpoint of the systems administrator. System maintenance, data base administration and storage, backup and restoration procedures, networking, space allocation, and security are some of the topics to be addressed by this course.

CGTTC 2D012 NNHO1
Wed. — 1/22 - 2/26
6:00 PM - 10:00 PM WN 261

WORKSTATION-BASED GEOGRAPHICAL INFORMATION SYSTEMS

24 Classroom hours

This course discusses cartographic techniques and explores the use of GIS on a personal computer. It will cover the basics of what GIS is and what it can accomplish. GIS has technological applications in the petroleum industry, environmental sciences, city and utility planning, and for sales and marketing analysis.

CGTTC 2C011 NNH01
Sat. — 1/18 - 2/1
8:00 PM - 5:00 PM CE 201

WORKSTATION INTERPRETATION - CPS - 3

24 Classroom hours

This course will utilize GeoQuest's CPS - 3 mapping software to explore the mapping of geophysical and geological data on a computer workstation. It will cover mapping coordinate systems, projection types, importing of data files, gridding, Base map generation, contouring, editing and display techniques.

CGTTC 2E011 NNH01
Sat. — 1/11 - 1/25
8:00 AM - 5:00 PM WN 261

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WORKSTATION INTERPRETATION: SEISMIC MICRO TECHNOLOGY

24 Classroom hours

Students will utilize 2d/3dPAK seismic interpretation software to interpret a seismic data set on PC's. Students will interpret faults, horizons, create time slices, polygons, create various vertical seismic displays, and manipulate colors using a variety of workstation viewing options and utility functions.

CGTTC 2E071 NNH01
T/W/TH — 1/7 - 1/9
8:00 AM - 5:00 PM CE201
CGTTC2E071 NNH02
Sat. — 1/11 - 1/25
8:00 AM - 5:00 PM CE201

February 1997:

WORKSTATION INTERPRETATION - SEISWORKS

24 Classroom hours

Students will utilize a UNIX workstation, LANDMARK SeisWorks and 3D seismic data to interpret faults and horizons, create time slices, and contour maps using a variety of workstation viewing options and utility functions.

CGTTC 2E051 NNH02
Sat. — 2/1 - 2/15
8:00 AM - 5:00 PM WN 261

WORKSTATION-BASED GEOGRAPHICAL INFORMATION SYSTEMS II

24 Classroom hours

This course teaches students the basic ARC/INFO commands which create, edit, and produce geographic data. Topics include using logical queries to create new data, changing existing data, producing maps, linking geographic data to external spreadsheets. Prerequisite: knowledge of basic mapping techniques or instructor approval.

CGTTC 2C012 NNH01
Mon. — 2/10 - 3/17
6:00 PM - 10:00 PM WN 261

DATABASE ADMINISTRATION IN ORACLE

24 Classroom hours

This course is intended as a continuation of Introduction to ORACLE. Topics include understanding ORACLE database administrative utilities, configuring and securing the database, monitoring and tuning database server performance, and using complete SQL queries.

CGTTC 2F012 NNH01
Sat. — 2/15 - 3/1
8:00 AM - 5:00 PM WN 265

GEOGRAPHICAL INFORMATION SYSTEMS - ENVIRONMENTAL

24 Classroom hours

This ***PC based*** course will study the applications of GIS and ARC/INFO software to study such environmentally important issues as ground water flow and contamination, waste management, air pollution, and how to identify and track such problems through map generation and data-base management.

CGTTC 2C021 NNH01
Sat. — 2/22 - 3/8
8:00 AM - 5:00 PM CE 201

WORKSTATION INTERPRETATION - Z-MAP PLUS

24 Classroom hours

This course will utilize ZYCOR software to explore the mapping of geophysical and geological data on a computer workstation. It will cover mapping coordinate systems, projection types, importing of data files, gridding, Base map generation, contouring, editing and display techniques.

CGTTC 2E061 NNH01
Sat. — 2/22 - 3/8
8:00 AM - 5:00 PM WN 261

COMPUTER WORKSTATION MODELING - AVO

24 Classroom hours

This course deals with the analysis of Amplitude Variations with Offset (AVO) and post-stack amplitude inversion. Topics will include seismic data processing and displays, forward modeling using well log data, synthetic models, and model-based inversion methods utilizing well logs and NMO velocities, and seismic trace attribute extraction.

CGTTC 2B011 NNH01
T/W/Th. — 2/25 - 2/27
8:00 AM - 5:00 PM WN 261

GEOLOGICAL INTERPRETATION - StratWorks

24 Classroom hours

This course deals with the interpretation of geological data using a Unix workstation. Topics will include the use of well logs and log correlation, construction of cross-sections, mapping of geological data including contours, horizon interpretation, and map editing.

CGTTC 2E021 NNH01
T/W/Th.— 2/18 - 2/20
8:00PM - 5:00 PM. WN261

WORKSTATION INTERPRETATION: SEISMIC MICRO TECHNOLOGY

24 Classroom hours

Students will utilize 2d/3dPAK seismic interpretation software to interpret a seismic data set on PC's. Students will interpret faults, horizons, create time slices, polygons, create various vertical seismic displays, and manipulate colors using a variety of workstation viewing options and utility functions.

CGTTC2E071 NNH03
Sat. — 2/1 - 2/15
8:00 AM - 5:00 PM CE201

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March1997:

EXPLORATION ECONOMICS, AN OVERVIEW

24 Classroom hours

This lecture-based course will provide students with a basic understanding of economics and how economics relates to exploration and development project planning. Topics will include the value of money through time, risk assessment, return rates on investments, profit margins, and basic economic definitions and concepts.

CGTTC 2G011 NNH01
T & Th. — 3/18 - 4/3
6:00 PM - 10:00 PM WN 262

GIS: REMOTE SENSING I

24 Classroom hours

This course will introduce students to the basic fundamentals of remote sensing and the growing role of this technology in industry through lecture, lab activities, demonstrations, and team exercises. Emphasis will be on practical, real world applications including petroleum exploration, environmental monitoring, oceanography, land use mapping, and new uses for remote sensing. This introductory class is not computer-based.

CGTTC 2C031 NNH01
Sat. — 4/5 - 4/19
8:00 AM - 5:00 PM. WN 259

WORKSTATION INTERPRETATION - GEOQUEST

24 Classroom hours

Students will utilize a UNIX workstation, GEOQUEST IEX-IESX and 3D seismic data to interpret faults and horizons, create time slices, and contour maps using a variety of workstation viewing options and utility functions.

CGTTC 2E031 NNH02
Sat. — 4/26 - 5/10
8:00 AM - 5:00 PM WN 261

RESERVOIR ENGINEERING I ... New!

The Geoscientist will be introduced to basic reservoir engineering concepts including: capillary properties of rocks, relative permeability, PVT behavior, fluid sampling, multiphase flow, and mobility ratio. In addition, classic reservoir engineering equations will be presented, including the instantaneous GOR (Gas Oil Ratio) equation, fractional flow equation and material balance. Behavior of oil and gas reservoirs will be discussed, including: dry gas, wet gas, retrograde gas, volatile oil, and black oil.

CGTTC 2H011 NNH01
M & W — 4/14 - 4/30
6:00 PM- 9:00 PM WN ?

X-WINDOWS, INTRODUCTION

24 Classroom hours

Introduction to the usage of the UNIX-based X-Windows System and its structure.. Starting and exiting X, basic procedures and problems, differences and similarities of such window management systems as Motif and OpenLook. effective use of the X-term window, and other related topics will be discussed, including Tcl and Tk programming. Some basic knowledge of UNIX is required.

CGTTC 2D022 NNH01
M & W — 4/21 - 5/7
7:30 PM. - 10:00 PM WN 261

April 1997:

ORACLE ADMINISTRATION II

24 Classroom hours

This course is designed to further the techniques acquired in “Oracle, Introduction” and “Oracle Database Administration” on a more advanced level.

CGTTC 2F023 NNH01
Sat. — 4/5 - 4/19
8:00 AM - 5:00 PM WN 265

UNIX FOR THE WORKSTATION SCIENTIST

24 Classroom hours

Introduction to the use of UNIX as a tool for workstation manipulation and improved project management. Topics include basic Unix architecture and concepts of shells, file systems, directory paths, and client/server relationships in addition to basic UNIX commands. Experience with keyboard and “mouse” manipulation recommended. This is NOT UNIX for dummies.

CGTTC 2D011 NNH01
Sat. — 4/5 - 4/19
8:00 AM - 5:00 PM WN 261

WORKSTATION INTERPRETATION - PHOTON

24 Classroom hours

Students will utilize a UNIX workstation, PHOTON Software and 3D seismic data to interpret faults and horizons, create time horizons, and contour maps using a variety of workstation viewing options and utility functions.

CGTTC 2E041 NNH01
T/W/Th. — 4/22 - 4/24
8:00 AM- 5:00 PM WN21

May 1997 - Watch for further announcements

For information concerning course content or instructional software please contact:

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Submittals and suggestions should be sent to the GSH Editor at 7457 Harwin, Suite 301, Houston, TX 77036, or call Cliff Kelley, Editor, at 368-8103, or Fax to 368-8182. Deadline for submission is the 1st of the month preceding publication: e.g., September 1 for the October issue. Digital or electronic submittals required.

JANUARY 1997

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
			1	**2**	**3**	**4**
5	**6**	**7**	**8**	**9**	**10**	**11**
12	**13** **GSH Reservoir Geophysics SIG** Texaco EPTD	**14** **GSH Technical Breakfast** Mobil Exploration & Producing's Greenspoint Area Headquarters	**15** **Data Processing SIG** Texaco Auditorium	**16** **Interactive Workstation SIG** British Petroleum **Potential Fields SIG** HESS	**17**	**18**
19	**20**	**21**	**22**	**23** **Environmental Applications SIG** BP Plaza	**24**	**25**
26	**27**	**28** **Subsalt Technology Conference** George R. Brown Convention Center	**29** **Subsalt Technology Conference** George R. Brown Convention Center	**30** **Subsalt Technology Conference** George R. Brown Convention Center	**31**	

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