A Geophysical Outlook—Part 8

Interactive interpretation comes of age

H. Roice Nelson, Jr., General Manager, Allied Geophysical Laboratories, University of Houston, Houston.

20-second summary

A widespread movement in the oil industry is underway to develop computer systems and methods that will assist explorationists in handling the volumes of data being worked with today. Independent consultants and some contractors are using new microcomputers to increase the amount of data that can be evaluated over a given time. Simultaneously, the major oil companies and larger geophysical contractors are putting together very large, complex and expensive systems that promise to open many new doors for geophysical interpreters. This article, the eighth in a series on new exploration technologies, reviews the major recent developments in interactive interpretation techniques, of which the author is aware.

COMPUTER AIDED ANALYSIS of geophysical data is the logical direction being taken to efficiently handle the volumes of data being worked with today. When tied to new developments in computerized display devices,[1,2] this application of computer technology is particularly relevant to interactive interpretation methods. Geophysical interpretation has not evolved, however, at the same rate or to the same degree as instrumentation, processing or field acquisition over the last few decades.[3] Therefore , it is reasonable to predict that interactive interpretation techniques will see substantial change and development in the near future.

WHY COMPUTERIZE?

As more and more explorationists are beginning to demand 3D seismic surveys for evaluating complex geologic sequences, it is apparent that a large problem with such survey data is paper mass. The paper handling problem is enormous and requires new methods of storage, manipulation and display. Attending the Norwegian Petroleum Society's 3D seismic techniques conference in March of this year, the author was astounded at the number of geophysicists insisting on 3D surveys for their interpretation work. And again, the paper handling problem was apparent.

The use of interactive computer graphics appears to be the best available solution to this problem. And, of course, as seismic display techniques are developed for such interpretation purposes, it follows that parallel applications will also arise for displaying seismic data on a CRT (cathode ray tube) in the field or in processing centers for quality control.

Another reason interactive interpretation is becoming an obvious solution for geophysicists is that they spend too much of their time doing things like timing sections, posting maps, contouring maps, calculating isochrons, converting time maps to depth maps (isochron maps to isopach maps), migrating contour maps, calculating potential reservoir volumes, doing economic analyses, and in general, "number crunching." With the time shortage explorationists face, it is key that new computer technologies be applied to interpretation techniques to improve the quality and quantity of work accomplished per unit time.

COMPUTER APPLICATIONS

Microcomputer. The microcomputer is one device that can help seismic interpreters use their time more effectively. Fig. 1 shows three hardcopy examples of one company's use of a microcomputer for such timesaving purposes. The system hardware consists of a Z80-based microcomputer with two 1-Megabite floppy disks, a black and white graphics CRT, a digitizing data tablet and a printer with graphics output capabilities. This system is being designed to handle the data on a "by prospect" basis and will allow entry of seismic lines, seismic horizons, faults, well logs, gravity or magnetic surveys, model parameters, and the like for a specific prospect.[5]

There are several geophysicists, including some independent consultants whom the author knows, who have bought small microcomputers themselves and have developed personal software packages to aid in different exploration number crunching operations. Given recent advancements in small computers, the ease of linking them to other computers (minicomputers or mainframes) and their lowered costs, a great increase in the number and sophistication of such systems is certain. Explorationists surely will be using these systems in remote locations away from the office.

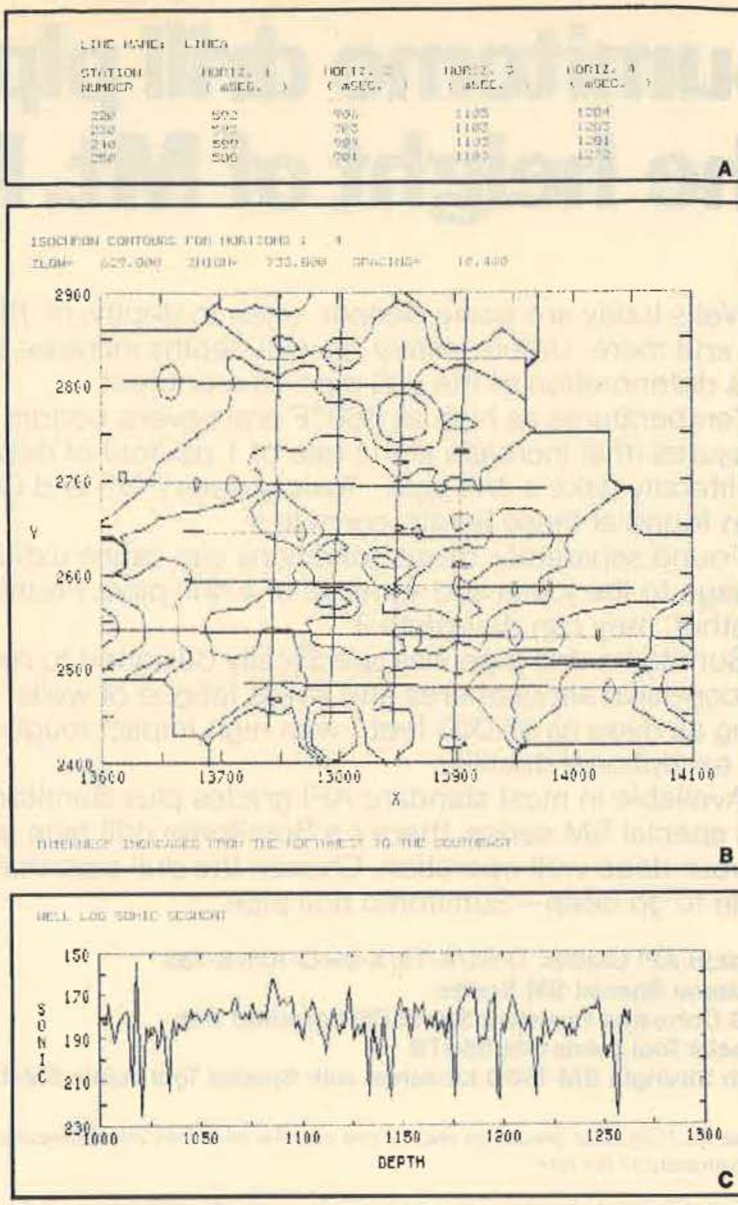
Having such inexpensive number crunching aids will be of particular benefit to consulting interpreters. The microcomputer will provide an economic and logistic tool with the potential of greatly increasing productivity and accuracy. An example of the type of tools, or package, that will become more available is theoretical modeling.[6] The ability to take an interpretation and generate critical synthetic traces or sections will provide consulting interpreters with a check on their work as well as support for client presentations. As areas are worked, the interpreter can build a digital information file about each specific prospect. This provides compact storage of key information like horizon picks, contour maps, well log information, etc. The computer forces an organized storage system if the files are to fulfill their planned and potential use.

Minicomputer. As the complexity of interpretation problems increases, microcomputers must then be linked to larger minicomputers. The microcomputers can be used as an intelligent terminal that "talks" to the larger computers; however, these small home computers do not

have computation power sufficient to perform complex operations like calculating a 2D forward model seismic section. Basic parameters defining the model can be entered over a phone line from the microcomputer, and then the results picked from a supporting computer facility after the run is completed.

Computers in general. The use of any type of computer in resource evaluation is new and requires new skills and innovative applications to take advantage of the capabilities. Examples of the ways new computer power is being used in exploration were presented at the Tenth Geochautauqua on Computer Applications in the Earth Sciences in Ottawa, Canada (Oct. 23-24, 1981).[7] One paper presented a statistical evaluation of oil and gas prospects in the Outer Continental Shelf of the Gulf Coast. For structurally controlled traps mapped by seismic techniques before drilling, John Davis (Kansas Geological Survey) and John Harbaugh (Stanford University) developed simple statistical relationships between the size, shape and other attributes of the traps and the presence and size of their petroleum and natural gas reservoirs. Predictions based on regressions between seismic structural properties and reservoir volumes had significant correlation. These statistical techniques have obvious application as part of an interactive interpretation system.

Several basic design considerations for building an effective interactive interpretation system have been described by Robert Hodgson, President of Geoquest, et al.[8] First, it is reasonable to plan system development on an evolving basis with expansion capability. This development includes hardware, data bases, applications and user training. Second, it is important that the systems be "user friendly." As graphics systems for interactive interpretation become more widespread, most of the users will not be computer experts, nor will they use a system unless it is simple, reliable and solves specific number crunching problems. Third, the system must address interface design. This means that existing capabilities, like data bases and application programs or procedures, need to be integrated into the new system. Fourth, these systems need to accommodate different levels of user expertise. This



Courtesy C.E. Burton and S. Stockton, Professional Geophysics, Inc.

Fig. 1—Microcomputers can help seismic interpreters more effectively use their time. Shown here are hardcopies from Professional Geophysics, Inc.'s microcomputer system called the "Explorationist's Workbench." **Fig. 1A** lists the time in ms of four horizons at specific station numbers along a seismic line. These values can be picked from paper sections using a standard 15 sq. in. digitizing tablet. **Fig. 1B** shows how the map line locations can be merged with the horizon times for a specific prospect to generate an initial isochron contour map. The key to good interpretation is to use this information to build the maps needed for client or management observation. **Fig. 1C** shows how the system also can be used to show the segment of a sonic log. This information can be converted to a synthetic seismic trace, scaled and output in hardcopy form to tie to the paper seismic sections.

allows a technician to generate accurate exploration base maps, or an experienced geophysicist to do theoretical modeling, on the same system. The system that allows all of these options will have more capacity than the standard available microcomputer, and would be more closely related to a small minicomputer.

Computer mapping systems have already developed to the point where they are becoming the basis for another type of interactive interpretation system. A key problem in using any system for this purpose is to accurately register and merge the different base maps that will be used. There are several mapping systems available that have effectively solved this. For example, a base map can be placed on up to a 44 in. by 60 in. (111 cm by 152 cm) digitizing tablet, and then each point on the map can be digitized with an accuracy of 0.01 in. (0.25 mm).[9] The key to any of these systems is building a file of information that can be recalled to aid in interpretation. The same input procedures can be used for well locations, directional drilling data, leases, formation tops, seismic sections (at least a line drawing representation of key horizon picks), well

A

B

Courtesy SEG[3]

Fig. 2—Eight generalized steps for doing interactive interpretaton.

Courtesy University of Houston Research Computation Lab

Fig. 3—Typical example of type of "intelligent" terminals, available in most oil companies, that can be modified to be an interactive interpretation console. This system consists of a Tektroniz 4081, tied to a large digitizing tablet, a hardcopy unit and a VAX minicomputer. The CRT on the right is a standard VT-100 Digital Equipment Corp. user terminal that has been modified for color and vector display (resolution 512 by 480 pixels).

logs, production data, and legal property information such as lease description, land owner, lease holder, lease expiration date and other pertinent information.

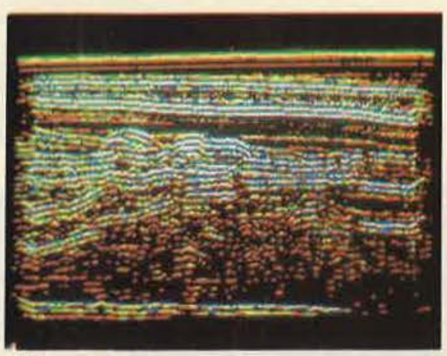
One system, the Integraph system, allows access to the exploration data base in graphical form, tabular form, or both.[10] The data processing hardware of some of these mapping systems is based around Digital Equipment Corp. processors, like a PDP-1134 or a VAX. Several major contractors have geophysical processing packages built around this same type of equipment. As these system capabilities are merged, they become capable of interactive geophysical analysis.

INTERACTIVE INTERPRETATION

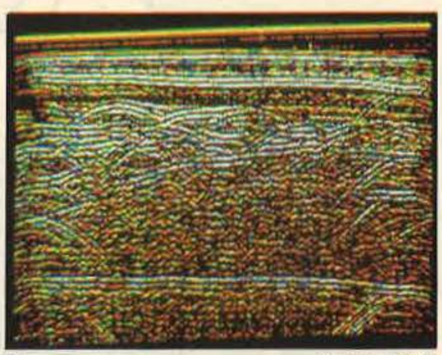
In order for seismic interpreters to effectively take advantage of computer number crunching capabilities, the data that will be interpreted needs to be digitally stored and displayed.[1] Once this is accomplished, it is possible to follow the eight generalized steps of doing interactive interpretation as described in Fig. 2.[3]

The basic hardware to accomplish these operations presently exists in most oil companies. Fig. 3 shows this kind of basic system. With a useable software package, this system can be used to save an interpreter hours of needless number crunching.

With one more relatively inexpensive hardware modification, one of these standard systems (for example a VT-100 programming terminal) can be converted to include color and vector display capabilities. The smaller CRT unit shown in Fig. 3 (costing about $2,000) has been modified with a graphics package and for color display of eight colors (another $4,000). Fig. 4 shows examples of vertical seismic sections being displayed with the eight colors being a function of reflection amplitude. These sections are from a complex physical model, called SALNOR, built by the University of Houston's Seismic Acoustics Laboratory (SAL) for Statoil of Norway. The sections represent a typical North Sea geologic sequence. An unprocessed section and a 3D migrated section are shown for comparison. One problem with this particular display is that it is not interactive. In this case the VT-100 is connected to a VAX system via a 9,600 baud line. It takes 15 minutes to build a single picture on this system.



A



B

Courtesy Statoil

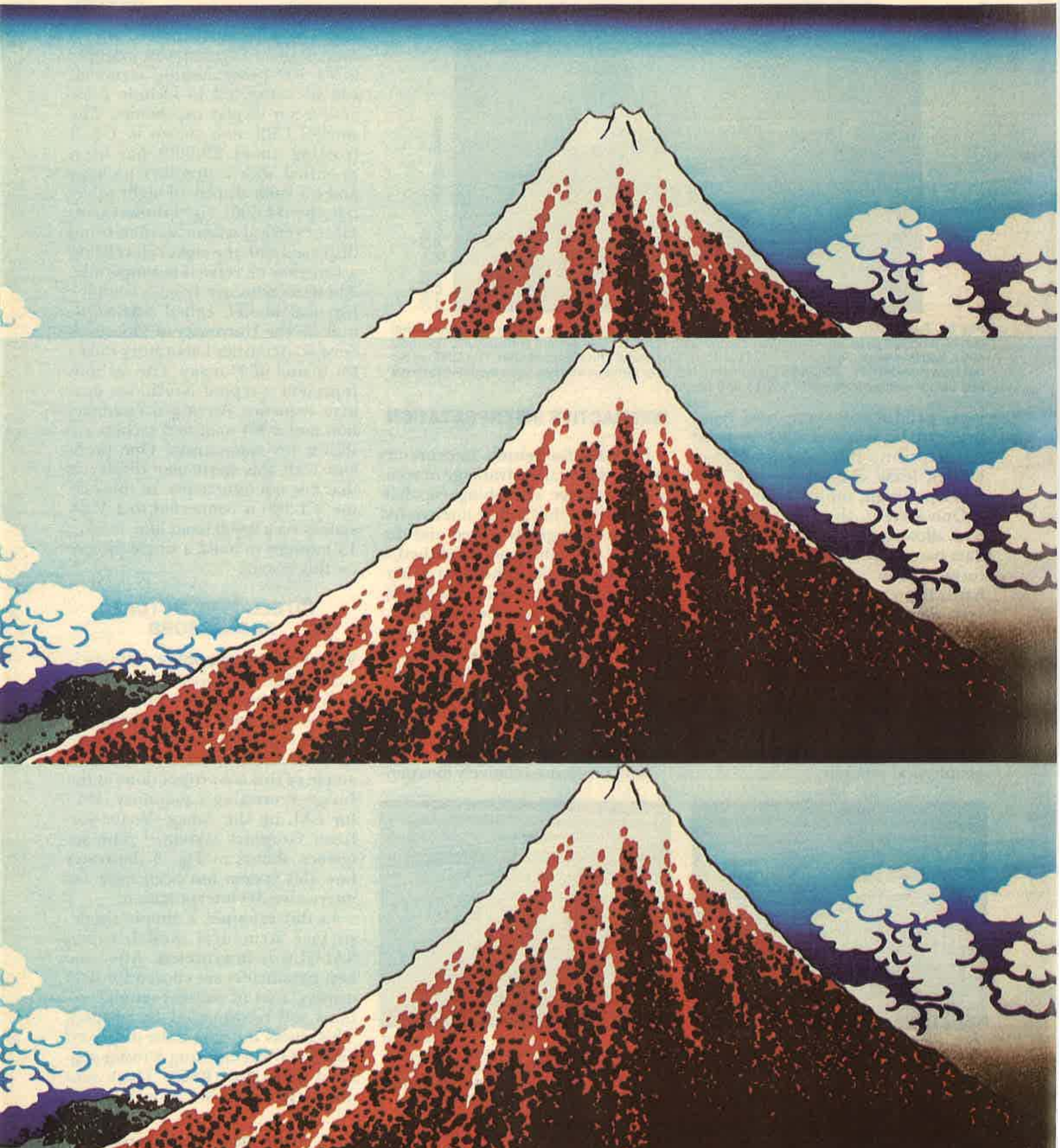
Fig. 4—The seismic sections shown are displayed on a modified VT-100 terminal. The first illustration is of an unprocessed section and the second is a 3D migrated version of the same data. The eight colors are assigned to each pixel as a function of the amplitude of the seismic trace. The data is from a model built to represent a typical North Sea geologic sequence.

INTELLIGENT PICTURE PROCESSORS

Vector refresh graphics. If there is a direct memory access (DMA) link between a picture processor and a supporting computer, the display of data sets can occur rapidly enough to be considered interactive. One example of this is a project done at the Image Processing Laboratory (IPL) for SAL on the Adage Vector Refresh Graphics system.[11] The sequence shown in Fig. 5 illustrates how this system has been used for interactive 3D interpretation.

In this example, a simple single-surface structural model, called SALGLF, is interpreted. After the best parameters are chosen for data display, a set of parallel seismic sections are reformatted for display. This allows the data to be displayed on a CRT screen using a raster segment generator (RSG). These seismic sections can be shown on the

go deep—to nearly three times



"Thunder Shower at the Foot of Mt. Fuji" by Katsushika Hokusai (1760 – 1849), one of Japan's most famous woodblock print artists

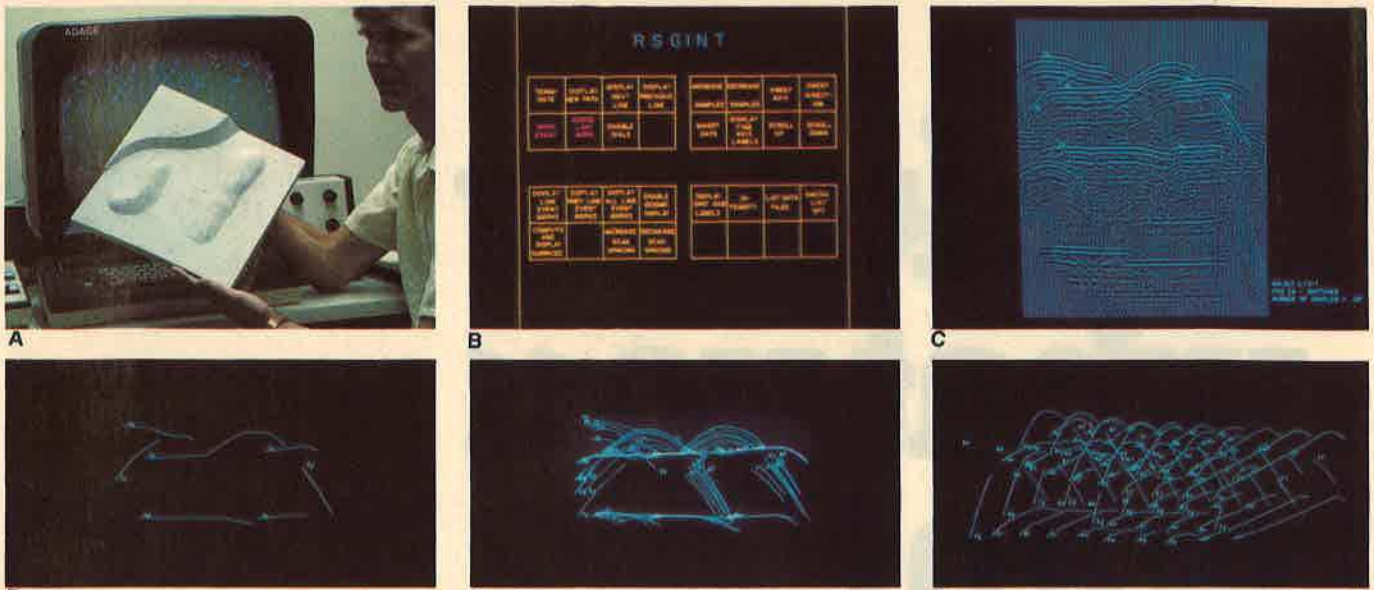


Fig. 5—This sequence of photos illustrates the steps taken in interpreting seismic data using an Adage Raster Segment Generator. The 12 sq.in. (12,000 ft) physical model the seismic data was taken from is shown by Richard Verm in **Step A.** The function buttons shown in **Step B** illustrate the procedures that can be chosen for interactive interpretation of the data displayed. **Step C** shows one vertical seismic slice taken across the model, while **Step D** illustrates the interpreter's picks from that data. **Step E** is the compilation of picks from 10 different vertical seismic sections across the model and **Step G** is the rotation of the same data.

screen one after another in the time it takes to push a function button (if the multiprocessing central processing unit is not being taxed). This allows the interpreter to move rapidly through a data set and obtain a general feel for structural attitudes.

Utilizing the graphics screen is quite simple. The roles of the 16 function buttons are available on the screen at the push of a switch. When the user is ready, the proper function button is chosen and enabled (activated), and the events are thereby displayed on the screen. The user can then choose, "pick" or mark the areas of interest from each display by using a standard digitizing tablet and linked screen cursor. This is the interpretation stage.

After one display is interpreted, the next parallel section is displayed and interpreted, with the previous interpretation also being displayed for reference, if needed. At any time, the user can disable the seismic section being displayed and look only at the interpretation of a single line, or at all of the interpretations from previously displayed sections.

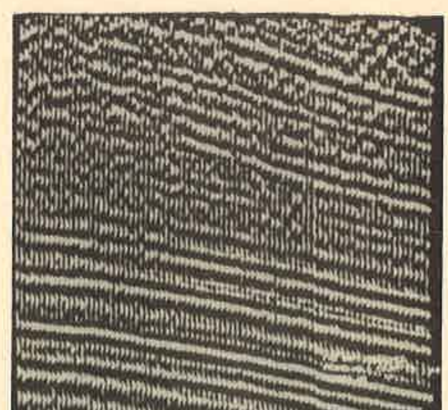
During this entire process, the user/interpreter has the option to rotate the interpretation being displayed. The motion parallax that accompanies the rotational movement of the interpretation makes it appear 3D to viewers.[2] The result is that a 3D interpretation is accomplished interactively in a relatively short time.

Illustrating the time-saving ability of such interactive processes is simple. Consider that a more complex single-surface model than the one used in the foregoing illustration has been used for several years by Fred Hilterman in an SEG workshop titled "3D Seismic Techniques."[12] In attempting to interpret the seismic sections taken over this model, which includes complex faulting, teams of experienced interpreters have needed up to six hours for completion. Using the Adage interactive interpretation program, a visually understandable interpretation of this same data set has been built in about 30 minutes.

Field data also can be readily interpreted using this same display equipment. The sequence of seismic sections shown in Fig. 6 illustrates the zooming in on a chosen portion of a larger seismic section. This example is from the Wind River basin overthrust area. The resolution is certainly good enough for an interpretation to be done using the same procedures described for interpreting the physical model data in the preceding paragraphs.

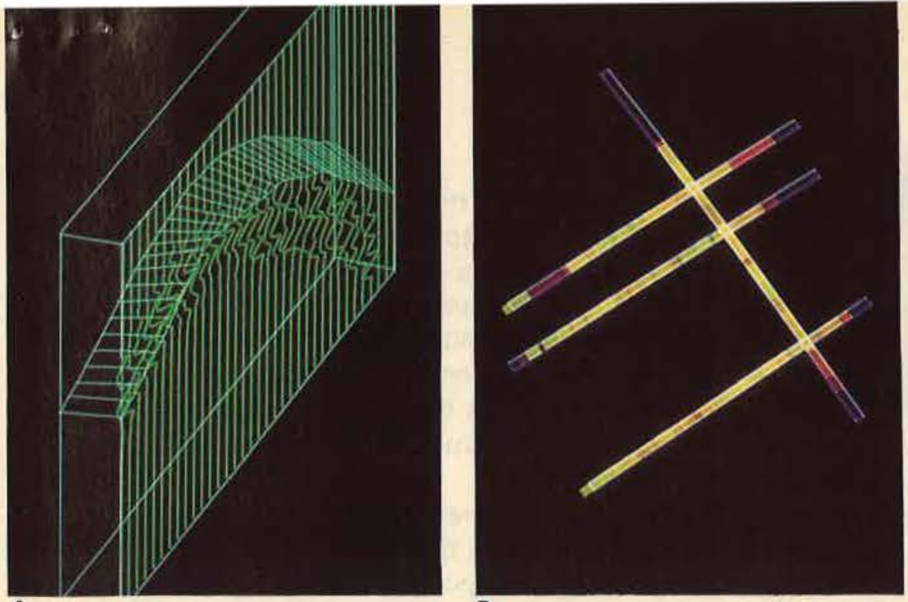
Note that the Fig. 6 displays are black and white only; yet, there is as

A

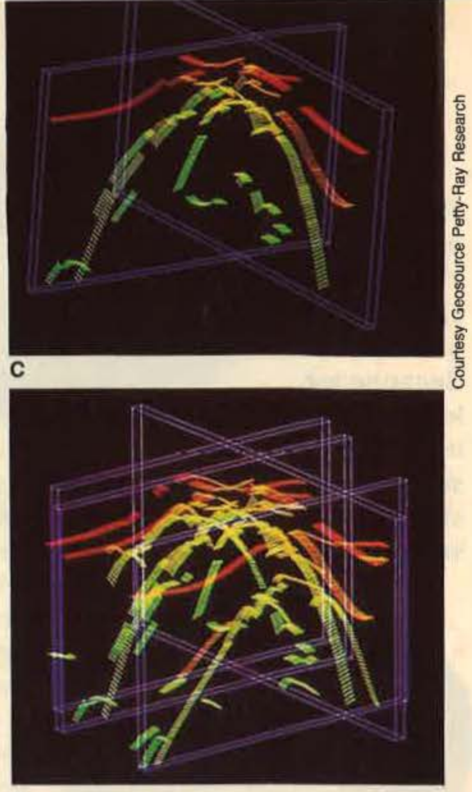


B

Fig. 6—This sequence illustrates zooming in on a set of stacked field data from the Wyoming Wind River basin. Using an Adage Raster Segment Generator (RSG), the first section is displayed at 1-bit resolution (each sample is either off for negative polarity or on for positive). This allows 1,000 samples to be displayed on 240 traces without flicker. The last section, an enlarged portion from the first, is displayed at 2-bit resolution (each sample can be off, on with 1 unit length or on with 2 units length). This allows 1,000 samples to be displayed on 120 traces without flicker for a single scan.



A B



C D

Fig. 7—This sequence illustrates the use of high-resolution color graphics for simultaneous display and interpretation of a marine cross-dip survey. **Step A** shows the relative location of a pair of lines collected about 1,000 m apart. A portion of the wiggle trace for the critical time window of one of the sections is displayed along with the cross-dip ladder connecting the interpretations. **Step B** is simply four of the cross-dip survey pairs rotated and viewed from the top down. The color coding is for the cross-dip component from different horizons. In **Step C,** two of the perpendicular cross-dip sections are rotated back to be viewed from the side, and **Step D** shows four of the cross-dip pairs in relationship to one another. When this data is rotated on the CRT screen, the 3D relationships are easily recognized.

much information as is normally required for an interpretation. Using color, however, will provide an entirely new dimension. If it is added properly, color will allow a visual interpretation of the spectral analysis of the data. That is, data can be displayed as a function of varying seismic attributes such as amplitude, instantaneous phase or frequency, apparent polarity, velocity, etc.[13,14,15]

The successful use of color for interactive display has been undertaken by Geosource. This company is using an Evans & Sutherland color vector graphics system to display similar interpretations from data collected from offshore through the use of a marine cross-dip survey.[15] The sequence of data shown in Fig. 7 is the displayed result of this survey.

As Fig. 7 illustrates, the data consists of sets of parallel lines that are collected from two sources, offset from either side of a ship by paravanes. These sources alternate shooting into a single cable.[16] The two lines that are collected have a subsurface separation of about 1,000 m. After the data is processed, each pair of lines is interpreted on the CRT screen in order to obtain the cross-dip component, as illustrated in Fig. 7A.

The same cross-dip data is displayed in Fig. 7B, only in map view (from the top down). Each of the four seismic lines shown is really a pair. In this case, where 48 miles of Gulf of Mexico cross-dip data is seen, the map geometry is maintained, but the separation of the parallel lines is exaggerated. The cross-dip component from different horizons is color coded to match from line to line.

In Fig. 7C, again a portion of the same data set is shown, only the two perpendicular line pairs chosen have been rotated in order to evaluate the structure. And in Fig. 7D, the picked cross-dip components on all four line pairs are displayed. Although it is confusing in the still picture, when the data is rotated the 3D relationships are easily recognized.

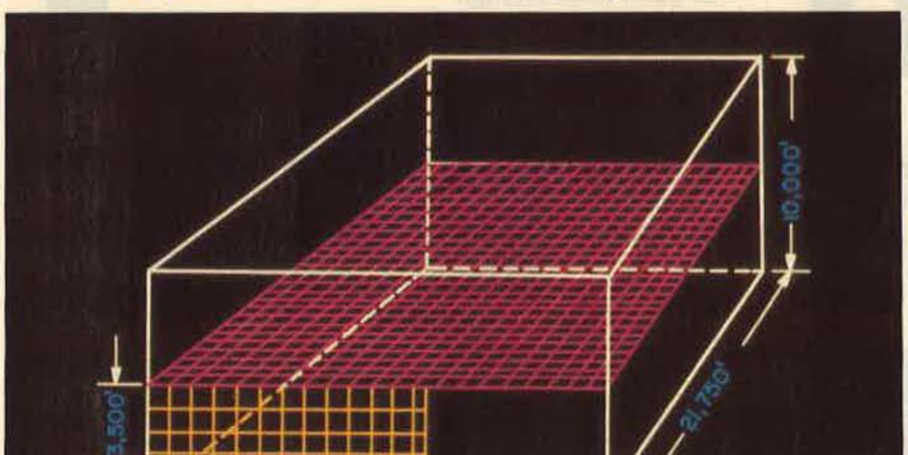


Fig. 8—This graph illustrates the relative subsurface area that can be displayed using the same number of pixels for a horizontal versus a vertical seismic section. The difference is due to the difference in temporal and spatial sampling.

Color raster graphics. While vector refresh graphics is workable for interactive interpretation, there presently appears to be more widespread use of color raster graphics in the oil industry. Fig. 4 shows there is enough resolution on even a 512 by 480 raster scope to view sufficient data for an interactive evaluation. And this viewing capacity is further enhanced when working with data volumes from 3D seismic surveys.[4] As Fig. 8 illustrates, an increased area can be viewed by displaying horizontal rather than vertical sections on a CRT. The reason is that the spatial sampling is much larger

That's not bragging, either. Just a simple statement of fact. Because we know you won't put

up with second rate, we manufacture and stock some of the world's finest cementing equipment, storage tanks, crank balanced pumping units and sucker rod pumps. And because we know you can't afford to wait, we have more than 100 field locations, in every major drilling and production region of the country, with qualified service technicians on call every hour of every day.

We don't do everything in the oilfield. But what we do, we do right.

We make cementing simple.

For instance, our B&W Division has everything you need to get a perfect cement job. Every time. Our patented Kon-Kave Centralizers have a rounded profile to reduce the plow effect and increase strength; our Multi-Flex and Nu-Coil Scratchers condition the hole without destroying it. And that's just for starters. Let's just say that B&W has everything — from Liner Hangers to Float Shoes and Collars — to do any cement job you're likely to encounter.

Because every drop counts.

Our Columbian Division has been making bolted steel liquid storage tanks since 1918. So we've got a lot of experience under

our bolts. We make them in a wide range of sizes and configurations from 4,000 to over 1.2 million gallons. If you like, we can give you Trico-Bond 478, a factory applied coating that shrugs off the effects of corrosion in everything from sour crude to liquid fertilizer, yet is safe enough to be approved by the EPA and the FDA for the storage of potable water. And since they're from Trico, they'll go up right and stay on the job.

Think of us when the drilling stops.

Trico has the largest field inventory of sucker rod pumps and parts, polished rods, rod liners and clamps, Page on and off tools, couplings, stuffing boxes, sucker rods and oilwell servicing tools in the U.S. So if you need something, you'll have it. Fast. But more than that, our philosophy of excellence through engineering innovation, metallurgical advances, and new manufacturing techniques means that Trico pumps, parts and tools are some of the best you can buy. Which makes not waiting for them that much better.

The pumping unit with the two-year guarantee.

There are a lot of people in the crank balanced pumping unit business nowadays. But darn few of them have enough confidence in their product to offer a two-year guarantee. We do. Because Trico Pumping Units incorporate significant improvements on the same basic design that's been pumping oil for generations of oilmen. It's available in 114, 160, 228 and 320 sizes, and we can deliver one a lot quicker than you'd think. And we guarantee it. Because we believe in it.

Trico: We've got it.

We're growing. Because we've got a commitment to excellence and a simple philosophy.

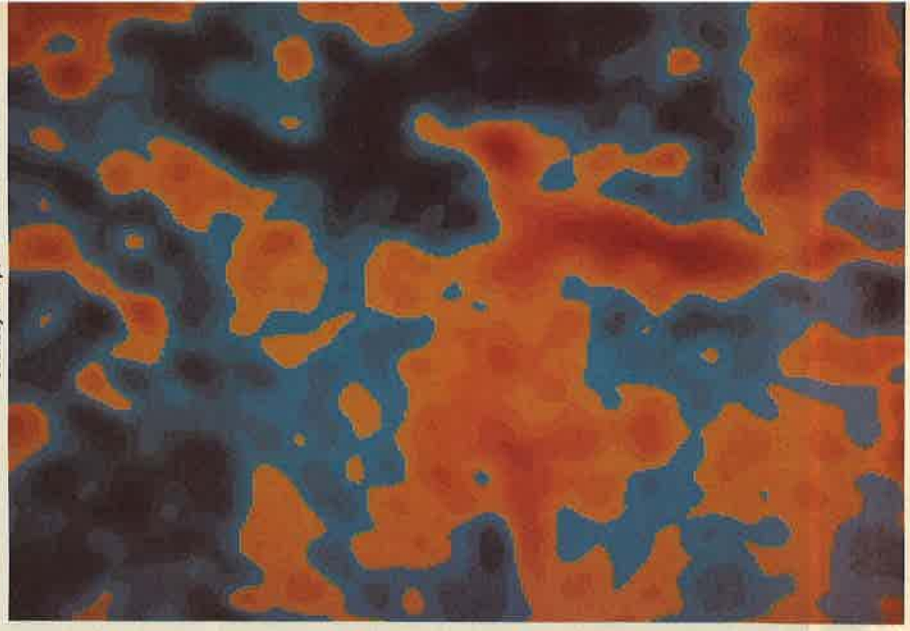
We know what you want. And we've got it.

Trico

Circle 197 on Reader Service Card

than the temporal sampling.

Phillips Petroleum recently provided a 3D seismic volume to several raster graphics vendors for use as a benchmark. Some of these horizontal section displays have been released for public showing by the vendors. Fig. 9 illustrates the resolution that can be obtained in displaying a horizontal time section on a high resolution raster CRT. It seems reasonable that an interpretation could be accomplished from this data in the same way that it is using G.S.I.'s Seiscrop Interpretation Table.[17] In fact, if these horizontal time slices can be animated fast enough on a raster graphics system, they should replace the currently commonplace "movie presentations" of horizontal sections. This type of animation has been accomplished on the Adage system with each new seismic section being displayed in less than a second.[11] If raster CRTs are configured correctly they can exceed this refresh rate.

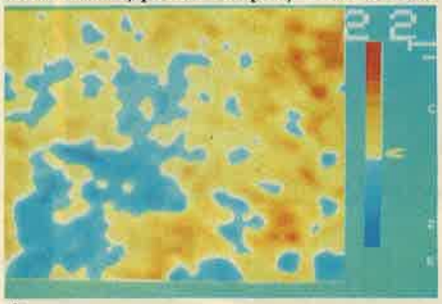


Courtesy Phillips Petroleum and Ramtek

Fig. 9—Note that the resolution possible on this display of a horizontal seismic section on a high resolution raster scope is quite adequate for interpretation.

Fig. 10 is a series of slides of the same Phillip's data set, displayed on an Ikonas graphics system. From this series of examples it is apparent how this type of display device can allow interactive interpretation. Phillips provided 39 times slices that were sequenced through forward and backwards at variable speeds. Note that four time slices are shown, labeled 22, 23, 24 and 25. Fig. 10C shows pseudocontouring, whereby one (or more) amplitude levels are blacked out. With specific amplitude(s) blacked, the data set can still be sequenced through. Figs. 10D, E, and F show how the relationship of the color in reference to the amplitude values can be changed through color map animation. Fig. 10G illustrates annotated contouring that was saved from the time slice as shown in Fig. 10A. Again, this series of examples shows how this type of display device could allow interactive interpretation, if new data can be displayed rapidly enough.

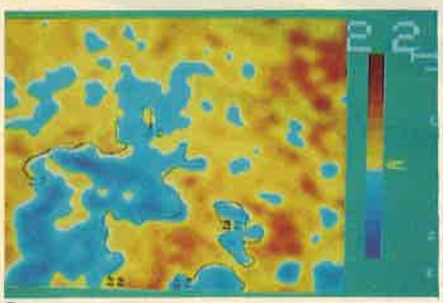
True image processing systems. These add yet another dimension to an interactive processing system. With a digital image and a pipe line processor, there are numerous ways a data set can be manipulated and certain characteristics enhanced in real time, which is impossible to accomplish when the data being



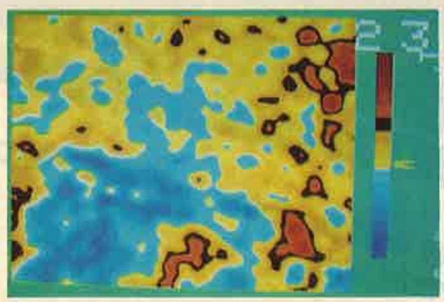
A

Fig. 10—In this sequence of horizontal seismic sections, as displayed on a high-resolution raster scope, four time slices are shown, labeled 22, 23, 24 and 25. **Fig. 10C** shows psuedocontouring, whereby one amplitude is blacked out. **Fig. 10D-10F** show how interpretation of a single time slice may vary based on color assignments. As seen here, the color is used to enhance changes in geologic characteristics. This type of change in the display is user interactive. Contouring is also user interactive. The contouring shown in **Fig. 10B** can be recalled and displayed on another time slice, as in **Fig. 10G**, to aid interpretation.

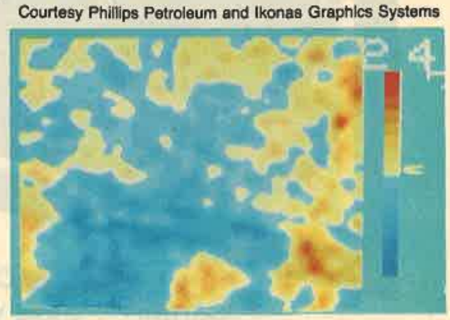
Courtesy Phillips Petroleum and Ikonas Graphics Systems



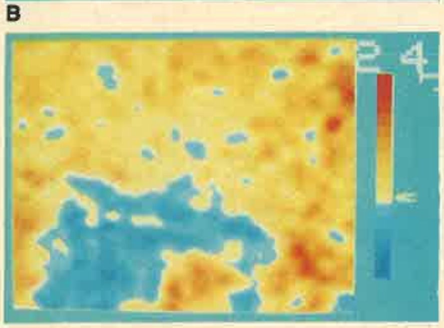
B



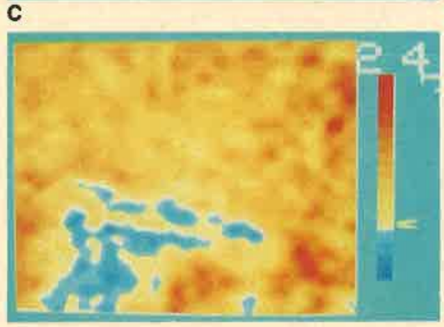
C



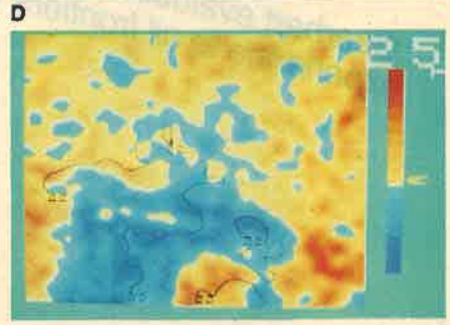
D



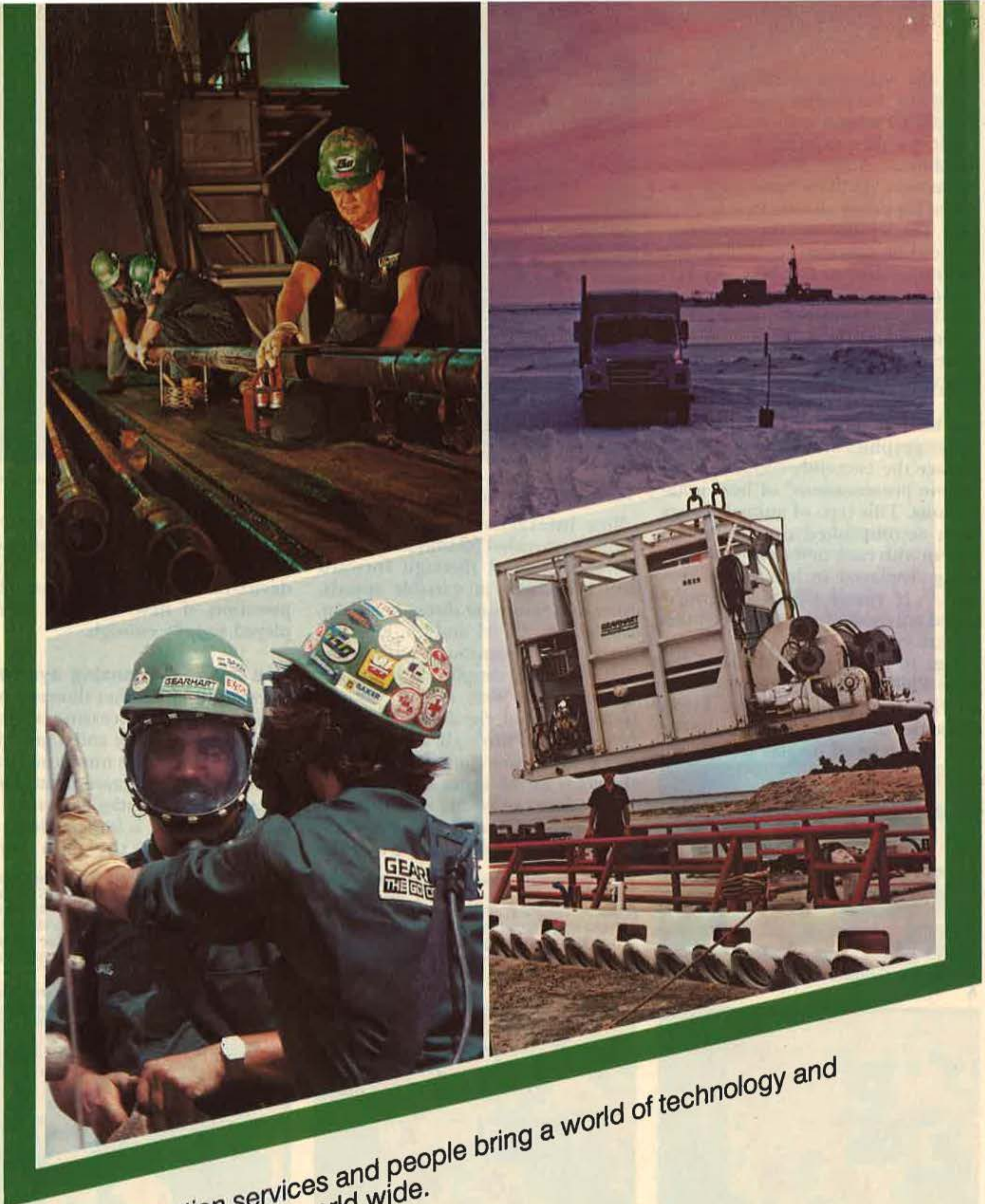
E



F



G


GEARHART

worked with is stored on a film medium. Some of the basic manipulations include image addition, subtraction, multiplication, scaling and look-up type corrections. These operations can be accomplished in a one-frame time period on many image processing systems.[18] More advanced operations include digital filtering, matrix multiplication, statistics, vector dot products, image merging (weighted sums) and edge operations.[19] The interactive interpretation systems that will find general use within a few years will allow overlaying of different types of sections (raw, filtered, migrated, synthetic, etc.), gravity, magnetics, landsat, well log information, among others. Imagine the assistance to an interpreter of interactively picking a section, calculating a synthetic section from the interpretation, and overlaying or subtracting the synthetic from the original data to see where there are problems with the interpretation.

Of course, while manipulation of softcopy is desirable, it is important that a hardcopy also can be made of critical steps in the CRT softcopy interpretation. Prakla Seismos produced some interesting soft- and hardcopy seismic displays using a system called Uniras. The seismic section is first previewed on a Lexidata color CRT and then plotted on an Applicon Ink Jet Plotter.[20] A simpler hardcopy procedure seems to be to take a picture. There are Polaroid 8 in. by 10 in. systems available, and if the time necessary for slide processing is not critical, then any good 35 mm camera will do. One of the best hardcopy procedures is to dump the display images through the CRT video bus to a video recorder. This provides storage of animation sequences, as well as what happened during an image processing session like filtering, matrix multiplication or image overlaying.

INDUSTRY PRESENTATIONS

Largely due to competition within the seismic industry, presentations that display how computer graphics can be used as an aid to interactive interpretation have been generalized and vague. However, one of the best presentations the author has seen was made by Conoco Oil Co. personnel at the 1981 SEG convention in Los Angeles, Calif.[21] In this presentation it was illustrated that each lithological unit boundary can be distinguished by a unique color pattern, where color is used to illustrate simultaneous changes in all seismic variables. Instant, on-the-spot enhancements are possible for the interpreter. The system is described as an interactive color video display, and is based on hardware from International Imaging Systems. This technology is especially useful in working with 3D data volumes. A movie was presented showing how an interpreter would move through typical vertical sections or horizontal time-slice displays from a cube of 3D data. The examples included showed how these techniques apply to both bright spot and 3D data sets.

The display of 3D data volumes using interactive graphics has also been done by Chevron.[22] Their system is based on a Grinnel graphics system tied to a dedicated VAX. They can put a new frame on the screen every 12 seconds. When the speed is increased a hundred times for a movie presentation, an effective display for 3D seismic data evaluation results.

Two examples of Chevron's work were shown in Norway. The first involved data from the symmetric SALGLF model. Beginning the presentation, a sequence of vertical sections was marched through along both the x and y axes. Then the movement was repeated for a sequence of horizontal sections moved up and down the z axis. Next, a cube was outlined on the screen, and the visible faces filled with the appropriate seismic sections. The horizontal and vertical sections were again stepped through, only this time they appeared to be within the cube outline that remained displayed. The last sequence was to display a rotation of vertical sections around one edge of the cube. This started with a section along the y axis, for example, and ended with an x axis section. This same procedure was repeated with a 3D field survey over the East Painter field in the Wyoming Overthrust belt.

APPROACHING DEVELOPMENTS

As software development proceeds in time, interactive interpretation capabilities will be enhanced correspondingly. One problem still remaining with 3D seismic data volume is correlating vertical sections to the appropriate horizontal time slice, or two perpendicular vertical sections to one another. Currently, the only way this can be done effectively is through the bending, folding and manipulation of hardcopies of the sections in question. However, with time, it will become possible to do this type of display splicing on the CRT itself. This will be of great benefit to the interpreter in the evaluation of complex 3D relationships.

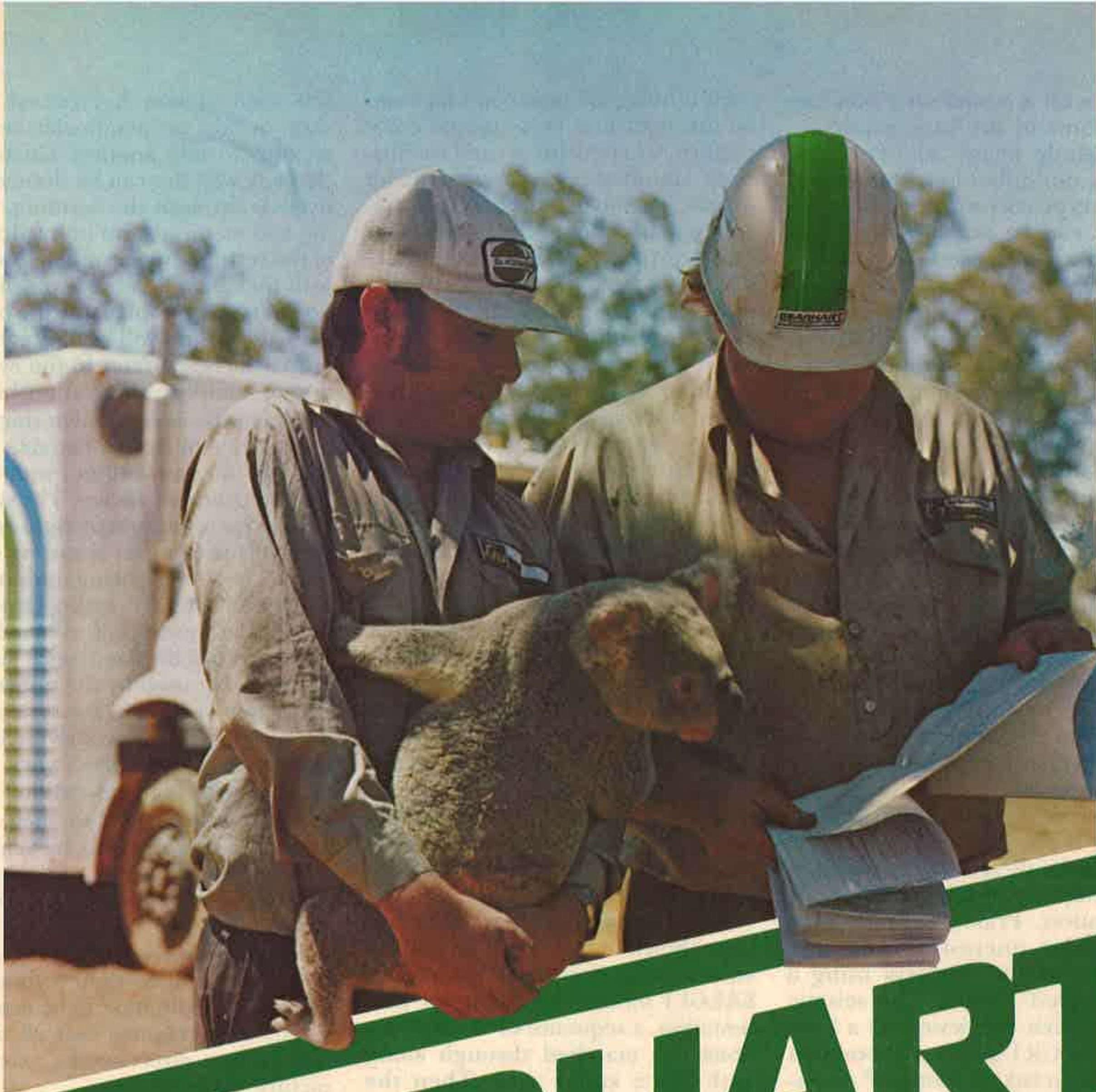
Also in the development stage is a display system that will enable large displays (40 in. by 40 in.) with 3 mil line width and no flicker. The system will have a minimum of eight colors, with vector or raster scanning capability. The project, being undertaken by The Denver Processing Center, is still labeled research. It is based on a liquid crystal display device similar to one being used by the military. A projection version of the system will be based on a laser driven liquid crystal, which will allow very large displays with high resolution.

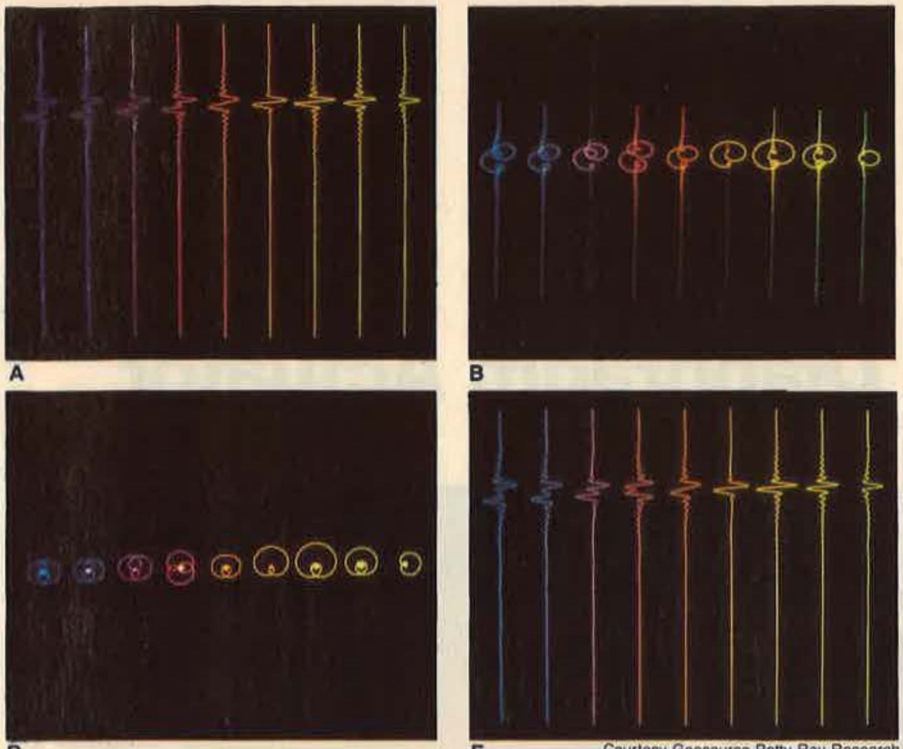
An approximation to such large screen display can also be achieved with present commercial devices by designing the software to move the display window through the data volume. If an overview of a larger data set is needed then a zoom-out capability would have to be incorporated. This requires that all of the data be in a direct access, extended picture memory.

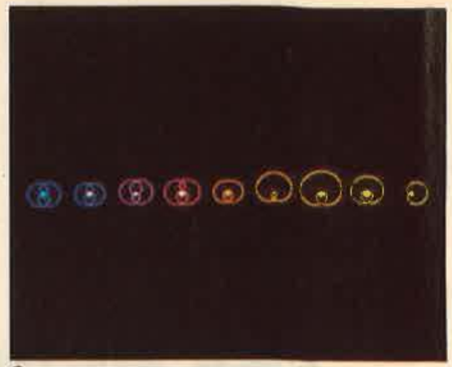
As devices with this capability are developed, there will be other applications found. For example, if there is enough memory to store a complete raw 3D data volume, it is reasonable to think of doing a 3D migration of that data without having to page data from different migration aperture locations in and out of memory. Other applications of such memory capability include subjects like pattern recognition, artificial intelligence and automatic computer interpretation.

The final benefit from these enhancements in speed, size and flexibility of display will be improvements in the quality of interpretation. Interactive access to other geologic/geophysical data sets will allow seismic interpreters to build a better geologic interpretation of the subsurface. Data that will be incorporated includes gravity, magnetics, geochemical, well log, and others.

Interpreters also will come to understand subtle characteristics of







A B C D E Courtesy Geosource Petty-Ray Research

Fig. 11—This sequence of photos displays a 90 degree phase shift of one synthetic trace across a formation pinchout. From **Fig. 11A** to **11B** the traces are rotated, until a top down view is reached in **Fig. 11C**. At this point, all of the traces are in phase. In **Fig. 11D**, the fourth trace from the left is rotated to an out-of-phase position. It remains in this out-of-phase position when the entire group of traces is then rotated back to their original vertical position (**Fig. 11E**). It now appears that the fourth trace no longer fits into the pinchout. Such discrepancies are commonly found when trying to tie seismic sections together from different surveys. This is only one example of the subtle characteristics of and problems with seismic data interpretation.

and problems with the seismic data when they have tools that allow a detailed and rapid analysis with many options. For illustration, consider the sequence of pictures in Fig. 11 provided by Wulf Massell, director of research at Geosource Petty-Ray Research.[15] In this example, complex synthetic traces across a pinchout are displayed. Note the tuning effect in Fig. 11A (the colors are only used to keep track of different traces). When these traces are rotated (Fig. 11B) and looked directly down upon (Fig. 11C), they are all in phase. However, notice that the fourth trace from the left (red) is rotated 90 degrees out of phase (Fig. 11D) before the entire sequence is rotated back to its original position, as illustrated in Fig. 11E. The fourth trace in Fig. 11F no longer seems to fit into the pinchout. Such a phase shift is commonly found when tying sections together from different seismic surveys. Of course, there are numerous similar data problems that are not obvious on standard sections, or else not compatible with the same time frame available for detailed analysis by interpreters using present techniques. Interactive techniques will allow such subtle characteristics of seismic data to be evaluated.

SUMMARY

Interactive interpretation techniques have come of age for the explorationist. They are desperately needed to handle the volumes of data being worked with today, particularly data from 3D seismic surveys. Many different kinds of systems are either in use or under development to meet this need. This trend towards increased research in the field of interactive interpretation has been underway among major oil companies and contractors for several years now, and it is reasonable to project that development of this technology during this decade will be more rapid than that of most other new technologies in exploration geophysics. Just as children have left their television for video arcades, explorationists will soon replace their colored pencils with a computer graphics terminal.

ACKNOWLEDGMENTS

Thanks to Anne Simpson, director of the University of Houston's Image Processing Laboratory for editorial assistance on this article, and to those who provided illustrations and background information. My wife Marti and the kids provided tremendous help and support, as always.

LITERATURE CITED

[1]Nelson, H.R., Jr., "Interactive Graphics Enhance Seismic Data Display," *WORLD OIL*, pp. 76–82, Mar. 1982.

[2]Nelson, H.R., Jr., "Will True 3D Display Devices Aid Geologic Interpretation?," *WORLD OIL*, Apr. 1982.

[3]Nelson, H.R., Jr., Hilterman, F.J., and Gardner, G.H.F., "Introduction to Interactive 3D Interpretation," *Oil and Gas Journal*, pp. 106–125, Oct. 1981.

[4]Nelson, H.R., Jr., "3D Seismic Techniques Aid Exploration, Development," *WORLD OIL*, pp. 115–120, Dec. 1981.

[5]Burton, C. E., Professional Geophysics Inc., personal communication, 1982.

[6]Nelson, H. R., Jr., "Modeling Resolves Complex Seismic Events," *WORLD OIL*, pp. 61–70, Feb. 1, 1982.

[7]McCammon, R.B., Agterberg, F.P., "Computers Seeking Minerals," *Geotimes*, pp. 14–16, Jan. 1982.

[8]Hodgson, R.N., et al, "Online Graphic Systems Speed Exploratory Analysis," *WORLD OIL*, pp. 37–48, Feb. 15, 1982.

[9]Here's the Simplest Way to Analyze Your Petroleum Data, Computer Research Corp. brochure, 1981.

[10]Product Summary, Intergraph brochure, 11081.

[11]Nelson, H.R., Jr., Gardner, T.N., and Hilterman, F.J., "Interpretation of Physical Model Tank Data with the Raster Segment Generator," SEG Technical Papers, V. 6, pp. 3619–3634, Los Angeles, 1981.

[12]Hilterman, F.J., and Morgan, T., "Interpretation Workshop Problem," SEG 3D Seismic Techniques School Notes, Section 4, Houston, 1981.

[13]Taner, M.T., Koehler, F., Sheriff, R.E., "Complex Seismic Trace Analysis," *Geophysics*, V. 44, No. 6, pp. 1041–1060, 1979.

[14]McDonald, J.A., Gardner, G.H.F., and Kotcher, J.S., "Areal Seismic Methods for Determining the Extent of Acoustic Discontinuities," *Geophysics*, V. 46, No. 1, pp. 2–16, 1981.

[15]Massell, W.F., Winningham, D.J., and Nelson, H.R., Jr., "Interactive Geophysical Analysis with 3D Color Graphics," SEG Convention, Los Angeles, paper S3.1, 1981.

[16]Whittlesey, J.R.B., and Neidell, N.S., "Marine Cross-Dip Seismic Surveys—Three-Dimensional Recording and Mapping," OTC preprint, paper No. 3847, 1980.

[17]Brown, A.R., "3D Seismic Interpretation Methods," preprint of presentation given at the 48th annual international SEG meeting, San Francisco, 1978 (see also abstract, *Geophysics*, V. 44, No. 3, p. 383, 1979).

[18]RDS-3000 Image Memory and Video Control, Ikonas Graphics Systems brochure, 1980.

[19]Outline of Digital Video Processor Specifications, De Anza Systems brochure, 1981.

[20]Seispak, A Uniras Product, European Software Contractors ApS brochure, 1981.

[21]Rice, G.W., Stebens, B.B., and Hall, P.M., "Interactive Color Display and Analysis—An Added Dimension To Seismic Interpretation," SEG Convention, Los Angeles, paper S7.5, 1981.

[22]Peters, D.C., "Graphic Display of 3D Seismic Data," presentation at Norwegian Petroleum Society's Conference on 3D Seismic Techniques, Kristiansand S., Norway, March 8–10, 1982.

[23]Tegland, E.R., "3D Seismic Methods, Turnaround Time and What the Future Holds," presentation at Norwegian Petroleum Society's Conference on 3D Seismic Techniques, Kristiansand S., Norway, March 8–10, 1982.

About the author

H. ROICE NELSON, *Jr., received a B.S. degree in geophysics from the University of Utah in 1974 and an M.B.A. degree from Southern Methodist University in 1981. He was employed by Amoco Production Co. in the summers of 1970 and 1973. From 1974 to 1980 he held various geophysical positions with Mobil Exploration and Production Services, Inc., in Dallas, Texas. He became a senior researcher with the Seismic Acoustics Laboratory at the University of Houston in January 1980 and held that position until recently being appointed general manager of the Allied Geophysical Laboratories, associated with the same university. He is currently serving as a member of the SEG Research Committee.*