A Geophysical Outlook — Part 6

Interactive graphics enhance seismic data display

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20-second summary

New advances in computer graphics technology are cautiously being accepted in today's world of exploration geophysics. There have been tremendous advances in CAD/CAM (computer aided design/computer aided manufacturing), aerospace, medical and other industries that are now being evaluated for their potential use in displaying and keeping track of the large quantities of seismic data being collected,[1] processed[2] and interpreted today. This article, the sixth in a series on new exploration technologies, describes advances in display equipment and summarizes the expected impact on exploration geophysics.

DATA VOLUMES from a 3D seismic survey[3] require new methods of storage, manipulation and display. With the increased use of high-density tapes, large capacity disc drives and solid-state memory chips, the problem of enough data storage for interactive geophysical analysis has been effectively solved. However, few, if any, companies have established a workable system for either seismic data base management or interactive seismic display.

Part of the reason for the current limited use of interactive displays is that the end product of data collection and processing is still paper sections. As the amount of data to be evaluated increases, the amount of paper used increases even faster. When management makes a strong commitment to utilizing available computer display technology, it will be required that efficient procedures for retrieving data from the seismic storage medium for display on a graphics terminal be developed.

TRADITIONAL DISPLAY TERMINALS

In the past, when an exploration geophysicist has talked of computer graphics, he usually refers to a Tektronix* storage tube display terminal. This terminal typically has a 19-in. diagonal screen with both refresh and storage display capabilities. The resolution can range from 1,024 x 780 to 4,096 x 3,120 displayable raster points. A typical system will have on the order of 2,048 x 1,536 displayable points.[4] This means that the screen is displaying 153 dots per inch along the x-axis and 115 dots per inch along the y-axis. The resolution on a standard 8 1/2-inch-wide Gould plotter is 80 dots per inch. Even though storage tube resolution is greater than this, the screen limits the amount of data that can be displayed along both the x and y axes. A plotter allows long strips of data to be printed out and spliced if desired, so that a large scale display of an entire seismic line can be viewed as a whole by a geophysical interpreter. Also, electrostatic plotters are up to 22 in. wide and have resolution of up to 200 dots per inch.

Because of the small screen size, the amount of data that can be viewed is reduced; as a result, the major applications of this technology have been in modeling rather than production work. There are examples of complex ray-tracing algorithms in the libraries of most of the major exploration companies. Other common programs have included gravity and magnetics modeling, synthetic trace generation (especially to evaluate potential bright spots, or direct hydrocarbon indicators) and contouring packages. These terminals can be connected to a hardcopy unit, so that a paper record of the progress of each session can be kept.

In addition, many of these systems are augmented with local intelligence and peripherals to reduce mainframe processing requirements needed to support remote terminals. Plug-in firmware, a local software/hardware combination, provides capabilities like keyboard programmability, local symbol design, scaling, clipping and rotation. There are many peripherals besides the hardcopy units. For data storage there are cartridge tape recorders, disc cartridges and mass storage units. Peripherals for recording data on paper include digital pen plotters and dot matrix printers. One commonly attached device is a graphics tablet for digitizing maps, time-velocity pick pairs and other two-dimensional data sets. These can range from 11 in. square units to a 40 in. x 30 in. tablet with 0.01 in. resolution. There are also screen cross-hair controlling dials and joysticks for moving graphics interactively.

Digicon drives the 4014 Tektronix screen with the rasterizer on their VAX-based processing systems. They can display 5 seconds of data on 192 traces on the screen in 8 seconds. At a 4 ms sample rate this is 240,000 data points. The cost for this type of terminal is in the range of $15,000 with a 22-week delivery.

*Throughout this article the author makes reference to company product names simply as examples of the equipment under discussion. There are thousands of graphics hardware vendors, therefore the author makes mention of those with which he is familiar. No product endorsement is intended.

However, the system is not used in practice for production work. Research labs tend to use the systems much more than processing centers.[5] These terminals could be used for quality control and picking velocity times, but they are "too complicated" for the people who do the work. In general, the oil industry is very slow to implement new ideas. Geophysical contractors present new ideas, but tend to not push them until their customers want the product. Presently there are very few processing programs that are directly tied to graphics display systems.

ERGONOMICS, or the physiological interaction between man and machines, has provided major changes in graphics systems over the past few years. These changes can make a significant impact on the willingness of geophysical processors or interpreters to use CRT (cathode ray tube display screen) technology. Advertisements today often stress that a system is human engineered to minimize discomfort. Screens can be adjusted 18 in. in height and swiveled from side-to-side 15° on one system. Screens are shaded to minimize glare. Also, storage tube displays are furnished with blue glass light filters for enhanced contrast and safety.[6]

Detachable keyboards that enable users to position them to conform to individual space requirements are becoming more common. There are optimum sizes specified for key size, pressure and spacing. Concave keys with a matte finish minimize reflections and improve operator efficiency. Screens should have variable-brightness control, as well as being unobtrusive and attractive, like a telephone or a typewriter.[7]

This same source reports that as terminals become more common in the marketplace, there have been more health complaints registered by users than non users. These mostly include short-term effects like blurring, itching and burning eyes, as well as backaches, neck aches and other muscular problems.

The definition of and solution to these problems is improving the work environment for those who spend many hours in front of a CRT.

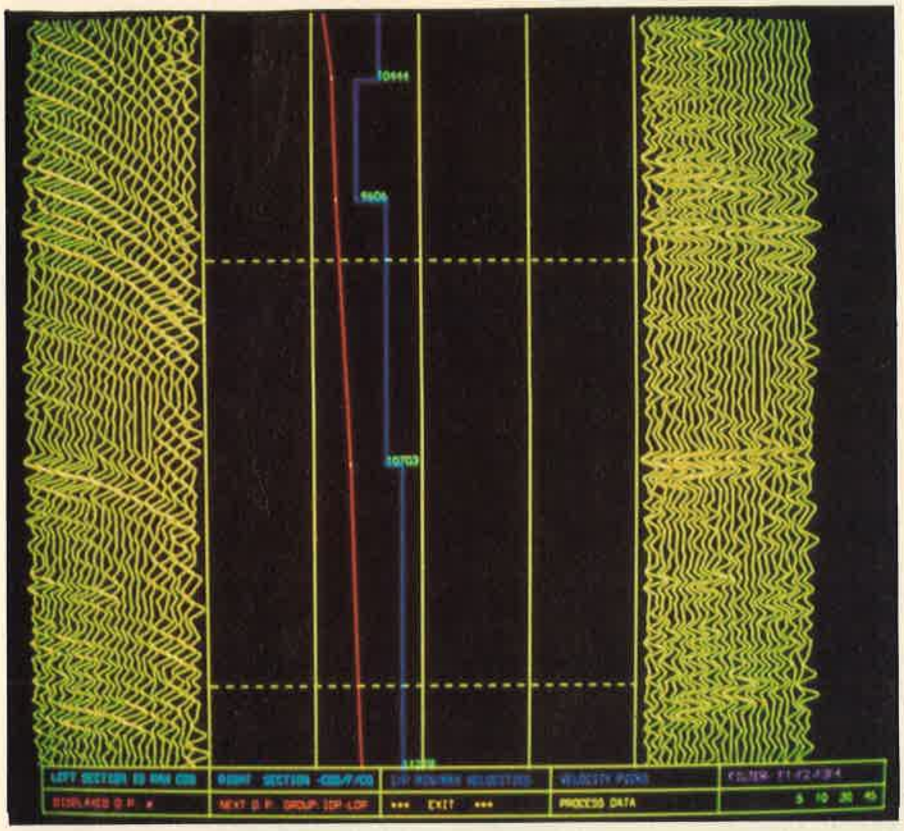
Fig. 1 — Horizontal time-slice seismic section displayed on a Ford Aerospace image processing system. A 3D survey was collected over a physical model of an amorphous sand body, 3D migrated, and displayed as a function of the instantaneous phase.[12]

It does take time to set processing parameters and evaluate the results on a CRT, or to do interactive interpretation and map making. If the tool itself is distracting, then the cost benefits of interactive analysis are never evaluated. Possibly the introduction of radical changes in display technology for seismic data will bring a change in traditional methods of seismic analysis.

COLOR RASTER GRAPHICS

The state of the art in color raster graphics is rapidly changing. A typical graphics system today usually has more than one RAM (random access memory) plane that stores data with a 1:1 tie to the screen pixels (individual picture elements). The normal system has a resolution of 512 x 512 pixels. Screen sizes range from 13 to 25 in. diagonal, which corresponds to between 55 and 30 dots per inch. State of the art resolution for a raster CRT is 1,024 x 1,024 pixels or between 115 and 60 dots per inch for the same range of screen sizes.

However, an important difference in comparing CRT resolution to an electrostatic plotter is the fact that raster graphics can vary the intensity of each pixel, while the dots from an



Courtesy Geosource Petty-Ray Research

Fig. 2 — Interactive velocity analysis. A field record is displayed from a tape (left yellow), a stacking velocity is picked (red), the Dix interval velocity is instantly calculated and displayed (blue), and NMO applied to check the velocity picks (right yellow).[15]

electrostatic plotter are either *on* or *off*. Normal intensity variation on a raster display device is 8 bits, or 256 gray levels (2 to the 8th power equals 256), for each pixel. To obtain the same intensity variation on a 200 dot per inch electrostatic plotter requires that sets of 16 dots (four on the x-axis by four on the y-axis) be set up to represent each pixel element. This does reduce the resolution on the plotter output by a factor of four, from 200 dots per inch to 50 dots per inch. It might be said that a CRT with 50 dots per inch resolution and 8 levels of intensity is equivalent to having a hardcopy resolution of 200 dots per inch.

The use of color to display seismic sections is becoming more common, despite the fact that most of the present procedures for generating a color section are complex, time consuming and expensive. However, the potential exists for color graphics to infuse the same type of new vitality to seismic data display as color film did for photography many years ago. Psychological studies have found that color-coded graphs can be perceived 80% more efficiently than black and white graphs.[8] With the proper choice of colors, seismic sections are not only more pleasing to the eye in color, but also are more easily understood. Explorationists are exposed, at least at conventions, to sections displayed in color that enhance certain seismic attributes, like velocity, amplitude, frequency or phase.

There are three general categories of color raster display devices. The lowest priced group is based on four memory planes. One memory plane consists of a 512 x 512 set of one-bit data. Each pixel is either on or off. A two-memory plane system has two bits of information for each pixel. Therefore a four-memory plane system has 2^{4th} or 16 possible variations for each pixel. This is normally broken down into 16 separate colors or else eight separate colors plus blink (the ability of the pixel to flash on or off). These systems normally cost about $15,000 for a display terminal, and have a resolution of 512 x 512.[9] However, they can be set up for a 1,024 x 1,024 screen. In fact, there is a complete spectrum of possible variations between each of these artificial categories.

The second category is typified by the Ramtek 9300, and ranges in price from $25,000 to $40,000. This type of system is based on 12 memory planes, or 4,096 (2^{12th}) possible variations in each pixel. Normally in this price range there would be a 4-bit DAC (digital to analog converter) for the red, green and blue electron guns. This results in 16 separate intensities of each of the three primary colors or a total of 4,096 possible colors. With look-up tables (stored reference codes) and wider DACs, this 4,096-color palatte can be selected from a wider range of colors. Most systems at this level have a microprocessor attached. The microprocessor is used to zoom or scale the data and to pan a display window through a larger data set.[9] This processing is not accomplished in anything close to real time. At least one new system, Spectragraphics, uses the microprocessor for polygon fill.[10] This is more common in the much more expensive systems used for flight simulation.

The third category upgrades the display and processing capabilities for finer resolution and more specific types of data processing and manipulation. The price is proportional and can be over $150,000 per unit. This type of system will have up to 24 memory planes. Each color is assigned eight memory planes or 256 pixel variations. An 8-bit DAC is also assigned to each primary color, producing 256 shades per primary color. This results in over 16 million different color combinations that can be assigned to each pixel.[11] This allows very subtle shading, as is seen in displays like the NASA Saturn pictures.

For geophysicists, one of the greatest problems with new color graphics developments is that there are so many options it is difficult to determine what is going to solve the display problem most effectively. Further, if a fairly acceptable solution is arrived at, new developments in graphics technology may soon make it obsolete. For example, many graphics systems are just replacing 16-bit memory chips with 64-bit memory chips as standard products. However, possibly the main reason why more advantage has not been taken of the new color raster graphics technologies is that there is not an off-the-shelf software application package meeting seismic display needs. Also, geophysicists want to use the display to do more than just display the data. There is a need to be able to filter, evaluate seismic attributes, and perform other real time enhancement operations on the display. This is image processing instead of just display technology.

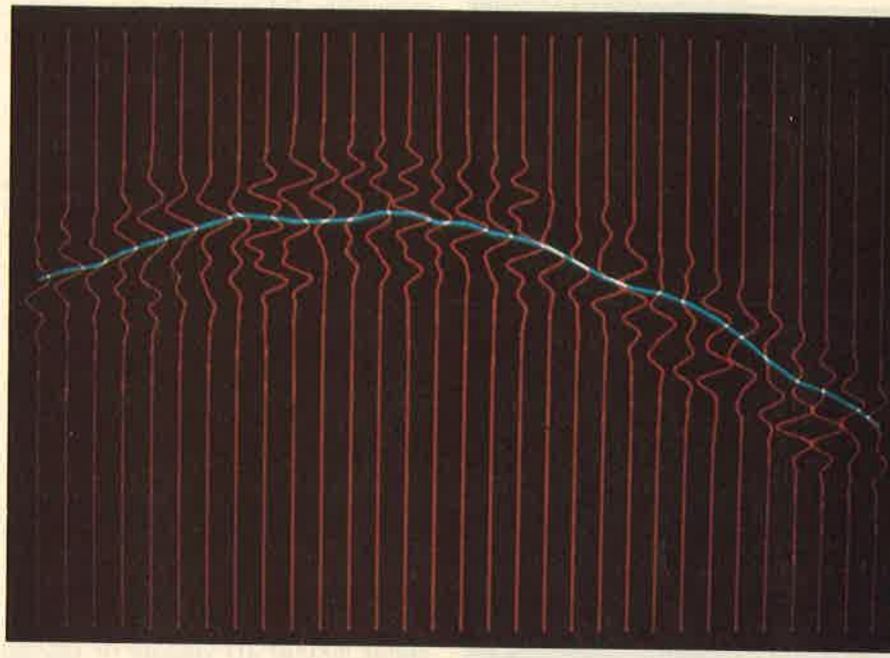


Fig. 3A — Interpreting wiggle traces on a color vector refresh graphics scope.[15]

Courtesy Geosource Petty-Ray Research

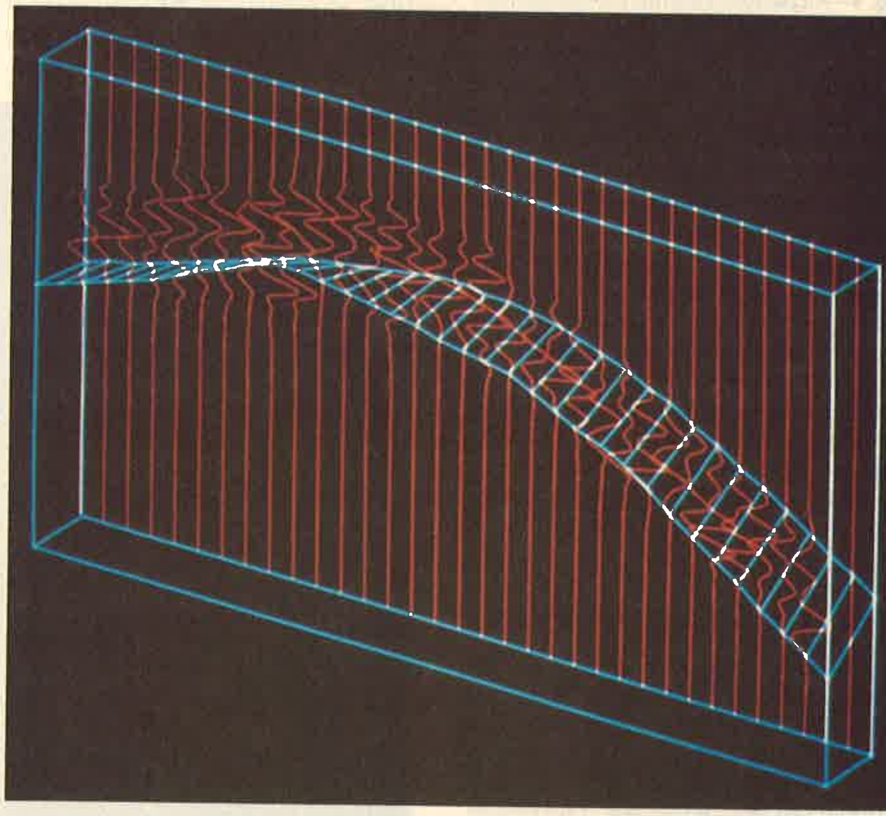


Fig. 3B — Rotation in 3D of the cross-dip interpretation of two parallel lines 1,000 meters apart.[15]

Courtesy Geosource Petty-Ray Research

IMAGE PROCESSING

An image processing system is as much a computer as a display terminal. As an example, DeAnza can store an image that is 2,048 x 2,048 and pan through it with either a 512 x 512 or a 1,024 x 1,024 window with 16-bit memory chips. When these are replaced with 64-bit memory chips there should be four times the storage. This system has a pipe line processor with a feed back loop, for real time image processing. Once a data set is displayed, the display is interactively enhanced by the operator without going back to the original numerical definition.

If an image processing system has 12 memory planes, these might be split so that six would store the infrared and six the visual picture for a Landsat type of analysis. Then using local function buttons or a trackball, the image processing system can be used to overlay the two pictures. For example, the visual picture could be drawn when the infrared intensities are between a specific range, and replaced with the infrared picture otherwise. Interaction between two pictures like this has proven very useful. Another example is subtracting the heat sources recorded on an old picture from a new infrared picture to show new heat sites.[11] Overlaying seismic attributes like velocity, amplitude, frequency and phase promises to provide similar insights for seismologists.

Fig. 1 is an example of some work done on physical model data using a Ford Aerospace image-processing system. In this example, a 3D survey was shot across a physical model of an amorphous sand body. It was 3D

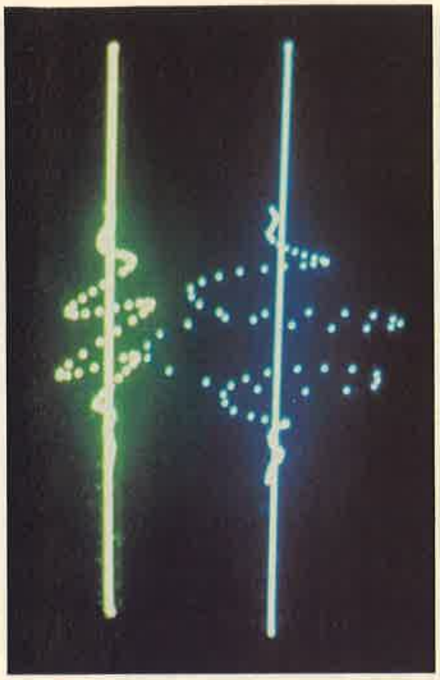


Fig. 4—Projection of the real component from 280 samples of a complex trace.[16]

migrated, a horizontal cross-section was extracted, and the resulting data was evaluated on the graphics system. The colors represent changes in the instantaneous phase.[12] The final result of these interactive operations is twofold. The subjective result is the visual image on the screen, which graphically illustrates information not readily apparent on the original unenhanced image. It is very useful to have a procedure for making hardcopy pictures of results of interest as image processing proceeds. Objectively, the results can be stored for later recall and manipulation.

VECTOR REFRESH GRAPHICS

Another type of graphics device being evaluated as a tool for exploration geophysics is the vector refresh graphics terminal. These systems have the advantage of creating what appears to be a 3D image. The image is really an isometric or perspective drawing that can be rotated, or it can have depth queues (indicators) such as line fading or perspective added to make the drawing appear 3D. The motion parallax accompanying rotation causes the 3D relationships to come alive.[13] Like the raster systems, calligraphic or vector refresh graphics can be used in the CAD/CAM marketplace for some time.

Instead of drawing each horizontal line on the scope face like a raster system does, a line drawing system draws a vector between specified coordinates. The speed at which the stroke generator moves to draw these lines limits the number of vectors that can be drawn before the display begins to flicker. The number of vectors that can be drawn with one of these systems has changed considerably just within the last year. Most of these systems can draw 21,500 3D black-and-white vectors. Vector Automation's Graphicus-80 draws up to 66,000 1/2-word vectors or up to 44,000 1-word vectors.[14] Evans & Sutherlands PS-300 draws about 90,000 2D vectors or 60,000 3D vectors on a screen with 4,096 x 4,096 resolution. The Evans & Sutherland MPS 64-color system is limited to about 12,000 3D vectors.

Geosource Petty-Ray Research is developing some very interesting applications for this last system.[15] Fig. 2 illustrates an interactive velocity analysis program. The processor first loads a standard demultiplexed field tape. Then from the display console a record is requested. This is displayed on the left hand side of the screen in about the time it takes to read the tape. Stacking velocities are picked, the Dix interval velocity immediately calculated and displayed, and NMO (normal moveout) correction applied to see if the velocity picks are correct. The velocities can be interactively repicked and NMO reapplied immediately.

Because of the limited number of vectors that can be drawn, some data reduction is needed to efficiently use this type of graphics system. One technique is only to display a small temporal window of interest, where the window follows an event of interest across the seismic section. This is illustrated in Fig. 3A. In this exam-

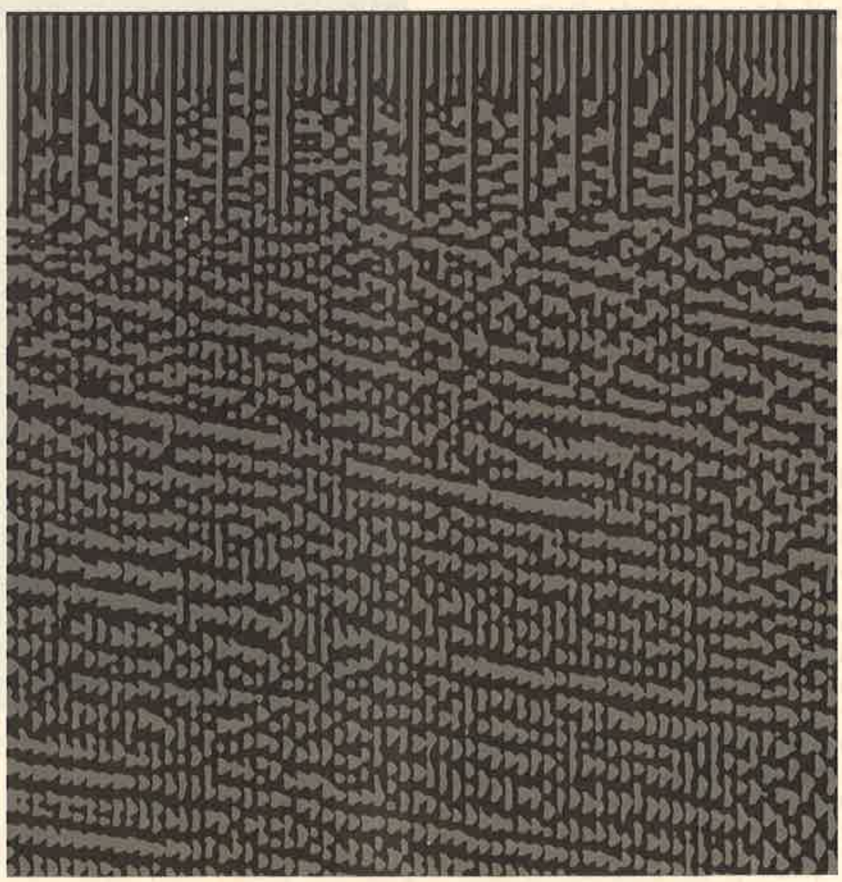


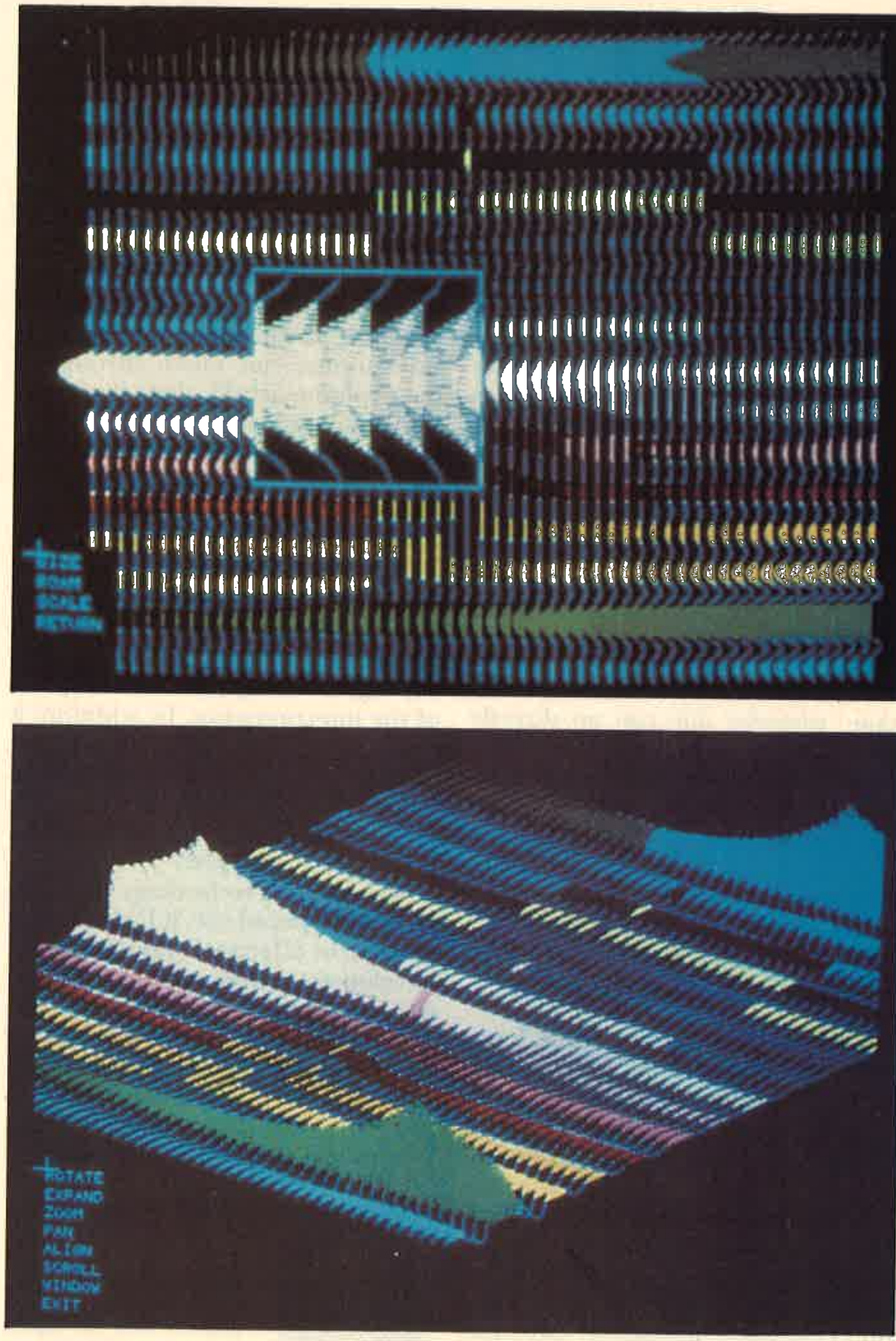
Fig. 5 — Display of 1,000 samples on 240 traces from a Wyoming Wind River basin overthrust seismic section using the raster segment generator.[17]

ple, an event was picked using a digitizing tablet. The interpretation of the same event on a parallel line 100 meters away was connected and the results rotated to show the cross-dip of the structure (Fig. 3B).[15] Because the display device draws 3D pictures, it is possible to display and rotate a "3D corkscrew" complex trace. Fig. 4 is a 1980 example of a display of a few samples of a complex trace. The complex trace appears to be a corkscrew in x, y and z. By projecting the real portion of the trace onto an x, y plane, the standard wiggle trace appears.[16] Eventually, interactive graphics will make complex trace analysis much easier and more useful.

RASTER VECTOR COMBINATIONS

Several ways have been developed to merge the capabilities of raster and vector scopes. The most extravagant and expensive are the flight simulator systems. The author is aware of two systems that provide interesting capabilities for geophysical data display. The first is the Adage 4145 with a Raster Segment Generator. In this system, a firmware package packs up to 16 data values into each word, and the picture is displayed in raster format. This increases the number of vectors that can be displayed before flicker by a factor of better than 10. There is one vector displayed for each sample. Therefore, 1,000 samples on 240 traces can be displayed before flicker. Fig. 5 is an example of a partial seismic section from the overthrust zone in Wyoming's Wind River basin. Because this is a vector refresh graphics system, the response time is very quick. Therefore, when another section is requested, it appears on the screen as fast as the function switch is acknowledged. This allows a stack of horizontal sections to be animated in movie form on the computer graphics terminal.[17]

The other hybrid system is the Megatek Whizzard 7200. This is also a vector picture processor, but the display tube is raster. The data from the digital vector generator is dumped into double-buffered raster memory planes. The raster display is updated from one of the memory buffers. This means there is no flicker or display delay during picture processing.



Courtesy Megatek Corp.

Fig. 6 — Examples of a 2D and 3D color rasterized vector synthetic seismic displays.[18]

The system can be configured with a calligraphic vector generator, which removes the raster capability and makes it a line drawing device.[18] Rapid dynamics is not usually required for most geophysical applications. Fig. 6 shows a color raster seismic benchmark that can be rapidly rotated in 3D space.

HARDCOPY

A basic requirement for an interactive graphics system for geophysical analysis is that there be an easy and efficient way to make hardcopies of the screen display. This is one reason that the Tektronix tubes are so widely used. They have a fast, accurate, easily used, screen-to-hardcopy unit. Devices like the Adage and the Megatek can be directly interfaced to an electrostatic plotter. With the rasterizer this is a fast process. However, without the rasterizer, a long time is needed to plot out the vector files.

The best way to obtain a hardcopy of a color seismic display off of any monitor is with a Polaroid camera. Dunn, Ramtek and others make camera units that will do this. Slides and movies can even be made with proper camera equipment. Other methods to obtain hardcopies include the use of color pen plotters that can be interfaced to a terminal, or full color digital dot matrix printers, which currently are being developed.

One of the best storage mediums for horizontal section movies is video tape, whereby one can go directly from the computer to the tape. There are also black and white electron beam recording systems available that operate from digital form directly to microfilm or slides. Unfortunately, making hardcopies is an area that does not have a nice, clean answer as to what is the best method.

GRAPHICS JUSTIFICATION

New display technologies have many potential applications in exploration seismology. The need to have a more efficient and accurate method of handling the data volumes being utilized today will eventually justify developing this technology. There are several factors that, when tied together, point to graphics as having a major effect on exploration seismology over the next few years. First are all of the new developments occurring with graphics technology. The new raster, vector and image processing systems are at a stage where only proper software application packages are needed to justify their use.

It has been known for many years that there is a tremendous increase in efficiency using an interactive over a batch system. Computer scientists have tried to quantify this.[19] However, there needs to be a detailed evaluation of how interactive techniques affect a processing and an interpretation environment. Is there an increase in the accuracy of workers? Does interactive seismic display make it easier to visualize data relationships in building an interpretation? Is it easier to visualize a complex 3D geological feature if it is viewed in 3D? How much improvement is there in measurable quantities such as interpretation time? If interpreters can move through a data volume at will, does it aid the understanding of data interrelationships? How can apprenticeship time be shortened in the training of "good" interpreters?

Interactive graphic systems that include a graphics device with an interpretation package and the raw data in storage have the advantage of allowing an interpreter to walk a manager through the critical parts of the interpretation. In addition, it is easier to store data digitally for recall, updating, or even for moving from one place to another. Digital data transfer can be by satellite, phone, tape, disc, etc.

Because this technology does not have widespread use, it has not been *proven* cost effective. Many still ask if development costs can be offset by the decrease in the manhours required for geophysical analysis using an interactive system. It is obviously effective to have interpretations keep up with data acquisition and processing, and interactive interpretation techniques do help in this area, especially in regards to keeping up with 3D surveys. If there is any increase in the number of successful wells, as a result of better interpretations, then the development of interactive geophysical analysis techniques *is* cost justified.

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.*

SUMMARY

Computer graphics technology has made tremendous advances because of the CAD/CAM market. These advances have placed this technology on the doorstep of geophysical exploration techniques. Although there are many reasons why color raster and vector graphics are not used more widely in our industry today, data handling needs and the necessity to stay abreast of seismic data collection and processing advancements point to this as being an area of major progress over the next few years. As these developments are cost justified, they will have an accelerated acceptance.

ACKNOWLEDGMENTS

I would like to thank Anne Simpson, director of the University of Houston's Image Processing Laboratory, and Sam Uselton, assistant professor in the UH computer science department, for proofing this article. Special thanks go to the many people I called for information, and to my family.

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