Introduction to interactive 3D interpretation

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Geophysical interpretation has not evolved at the same rate or to the same degree as instrumentation, processing, and field acquisition techniques in the last few decades. With the acceptance and widespread use of three-dimensional (3D) seismic techniques, there is an increased need for improved methods of manipulating, viewing, and interpreting a volume of data.

To this end, interactive computer graphics is gaining in usage because it allows both geophysical and geological data to be viewed simultaneously in such a manner that the actual subsurface geology is perceived by the interpreter.

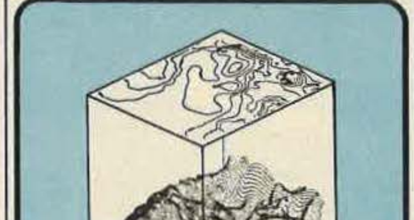
Many interpreters have a hard time visualizing structures in 3D from 2D time sections until they contour time maps. If the structure can not be mentally visualized in 3D, the interpreter may try perspective drawings (Fig. 1), fault plane maps, isometric displays, fence diagrams (Fig. 2), or 3D physical models.

The extension from profile lines to areal coverage brings seismic data into conformance with geological, geochemical, and potential data. Eventually, explorationists will be able to interactively interpret all of this data on the same display (Fig. 3). Townsend[10] has described one example of industry preparations to do this by making computer data bases.

Eventually, interactive interpretation can be done on true 3D display devices (Sher[9], Johnson [4]). However, line drawing vector refresh graphics (calligraphic displays) are available devices that can be used to interactively manipulate a volume of data. Using these systems, motion parallax or a stereohood simulate data in 3D space.

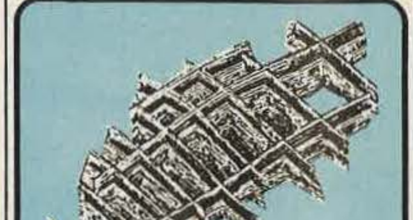
This paper presented at 1980 SEG convention in Houston. Courtesy SEG.

Fig. 1
Perspective drawing*



*Of a contour surface

Fig. 2
Isometric fence diagrams



This is a different concept than the other major form of computer graphics display, i.e., a raster, or "tv like" system.

This is an idea paper, meant to show previous work (Brown[1], Gardner[2], Hilterman[3], etc.).

Definitions. In refresh graphics, a *3D view* is an isometric or perspective drawing of an actual 3D structure. An *interactive machine* is one whose capabilities allow the interpreter to modify the data set or the view of a display between CRT screen updates. This update needs to occur 30 times per second to appear interactive to the human eye. An *interactive system* permits rapid evaluation of trial choices of parameters for an interpretation.

Hardware capabilities. To appreciate the interpretational potential of vector refresh graphics, some state-of-the-art capabilities and terminology are outlined below.

This hardware can be visualized as part of an interactive interpretation console (Fig. 4).

Perspective—Visual representation of objects as seen by the human eye in 3D space that gives an illusion of 3D without the need for motion.

Line Fading or Depth Queing—The data's brightness varies inversely with depth which prevents optical inversion, improves depth perception and image understanding.

Dynamic Motion—Creates the illusion of 3D because of motion parallax.

Rotation—Allows the data volume to be viewed from any angle.

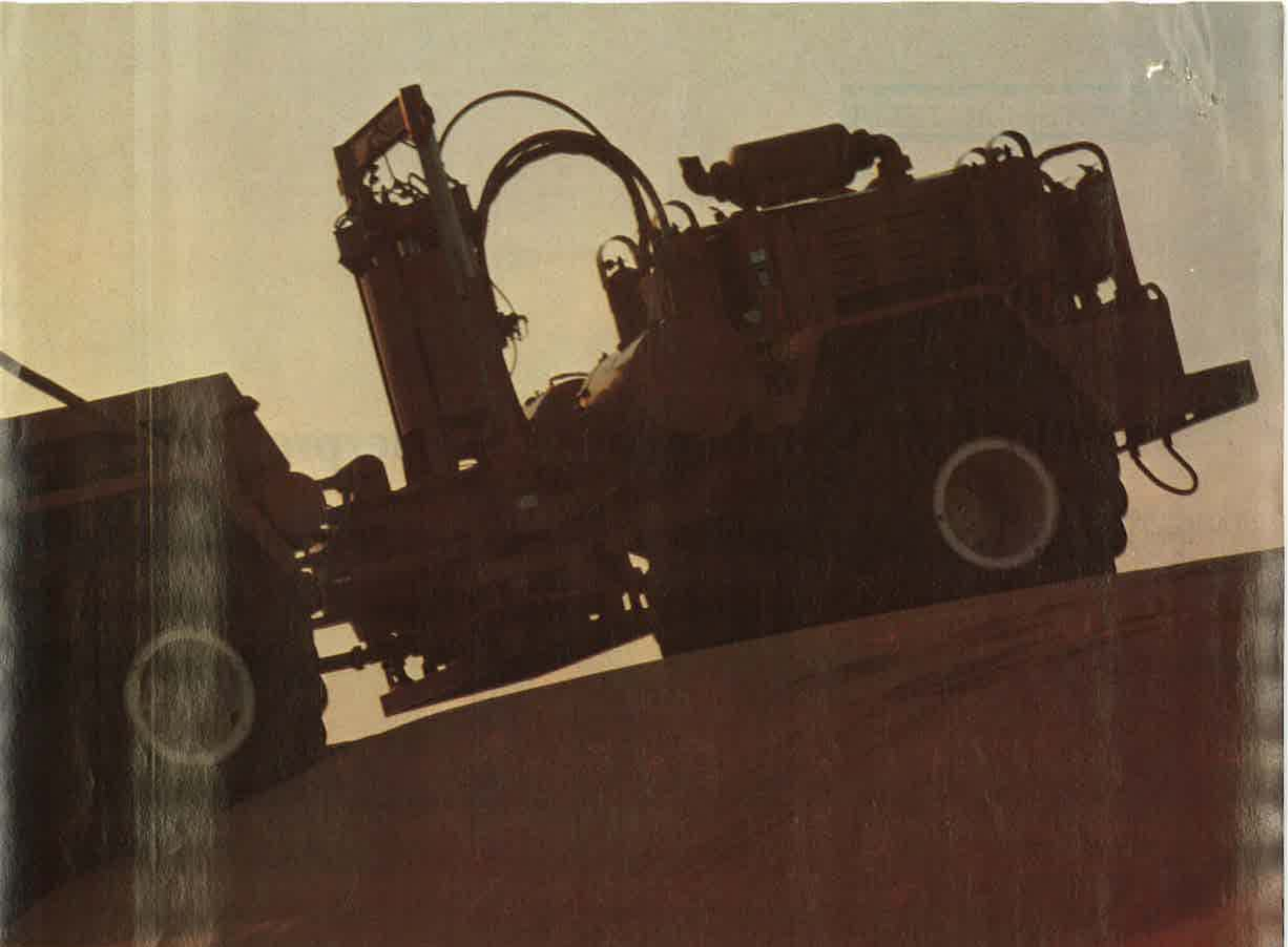
Zoom—Magnifies on the display screen the entire data base or details of a smaller subset.

Translation—Shifts the display along a specified axis.

Compound Linear Transforms—Allows multiple interactive data manipulations and modifications by the interpreter with minimal tax on the host computer.

Homogeneous Coordinate System—A matrix arithmetic procedure of automatically scaling a data base. Allows perspective displays and also displays of a large data volume where the values defining data samples are outside the range of integer computer definition.

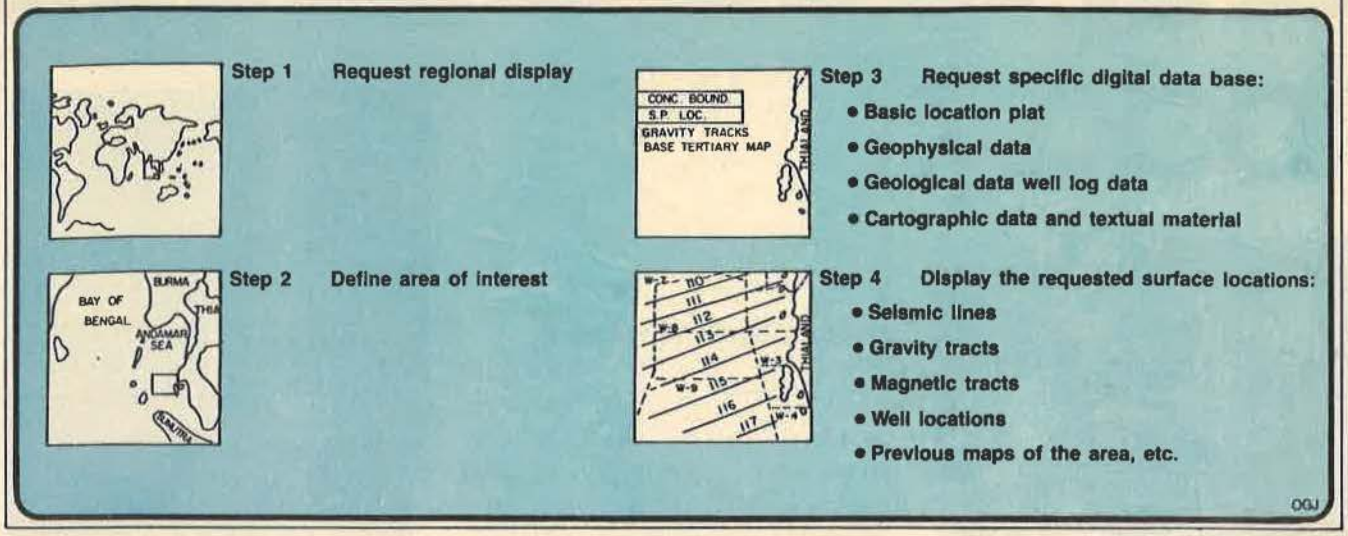
Clipping Planes—Provides a viewing box of any thickness and thus a movable look at a thin or thick set of data without data wrap around.



zons During The '80's

Interactive data retrieval

Fig. 3



Split Screen—Presents multiple displays on the screen simultaneously. With this ability, the interpreter can view the same data from different positions simultaneously. Also, one can display a menu of functions to apply to the data. Stereoscopic pairs can be displayed on a split screen.

Character Generator—Provides full ASCII symbol generation and the ability to define additional symbols: such as, oilwells, triangles, elipses, etc., all of which can have various sizes and orientation.

Line Generator—Allows for variations of dashed, dotted, or solid lines which can be used to represent different seismic horizons.

Raster Segment Generator—Converts the vector display from a maximum 23,000 specified lines to a maximum of 228,000 gridded cell locations. Thus, 240 traces with 1,000 samples each can be displayed with one byte resolution (Fig. 5).

Color—Two types of color display are available. Beam penetration color allows red, yellow, orange, and green to be displayed. Shadow mask full color allows the addition of blue and a spectrum of 64 hues and 8 saturations of each hue. Color creates an additional dimension which is especially useful in 3D interpretation of multiple horizons or multiple faults. In studying molecular interaction, the value of color has turned out to be greater than the most optimistic estimates (Langridge[5]).

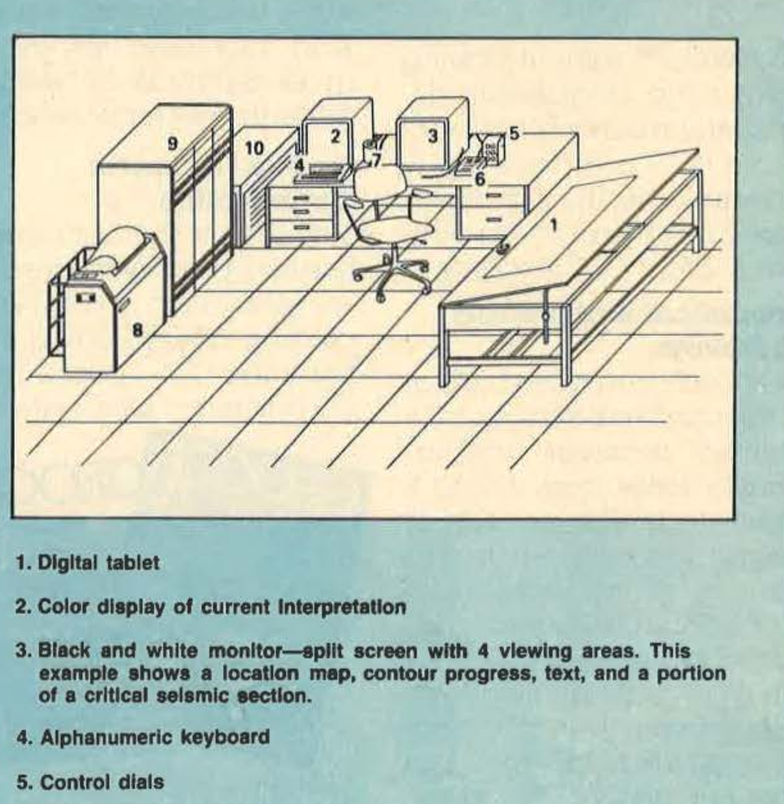
Fortran—Standard computer language.

Alphanumeric Keyboard—System can be used as a programming terminal.

Control Dials—Hand-operated dials which perform rotation and translation in x, y, and z, clipping

Console arrangement*

Fig. 4



1. Digital tablet

2. Color display of current interpretation

3. Black and white monitor—split screen with 4 viewing areas. This example shows a location map, contour progress, text, and a portion of a critical seismic section.

4. Alphanumeric keyboard

5. Control dials

6. Function switches

7. Joy stick

8. 22-in. electrostatic plotter

9. Supporting mini computer (optionally tied to main computer)

10. Graphics processor

*For interactive 3D interpretation

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only 1000-channel today.

An operator controls the system by responding to parameter requests displayed on the CRT terminal.

VARISWEEP™ without slowing down data acquisition. Finally, the resolving power of GEOCOR IV is dramatically increased by the signal-to-noise improvement resulting from 512 fold CDP stacking.

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Fig. 5

Rastorized vector display*

*Of seismic data. Figure on left is a view of two 24 trace field records. On the right is a rotated closeup of ten traces. (Courtesy Adage Inc.)

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plane movement, and zooming.

Interactive pointing and positioning devices (light pen, joy stick, 3D cursor, etc.).

Light Function Switches—Similar to the control dials, but for multifunction presentation (selection of perspective or orthographic view of the display; selection of data to display; etc.).

Limitations. Present refresh CRT technology is limited by the amount of data that can be presented flicker free. The beam deflection rate required for vector rewrite is the major boundary. Approximately 18,000 disjoint vectors or 21,500 connected vectors can be displayed before flicker is observed on the screen. For seismic data, this means 370 traces with 75 samples each can be displayed in vector mode.

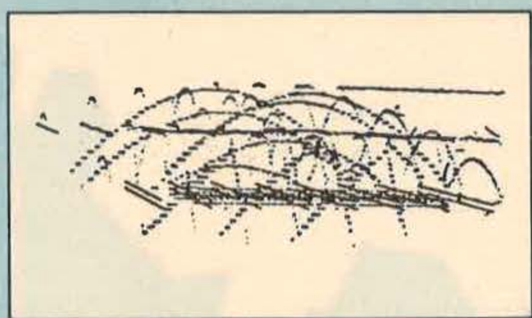
Another major limitation is the lack of seismic application programs. However, much of the available seismic software such as synthetic seismogram generation and computer contouring could be modified for a line drawing system.

Cost has also been a restraint. Computer scientists have made efforts to quantify the increased efficiency of an interactive over a batch system (Sackman[7]). However, once a specific area of application for VRG is defined, geophysicists will need to quantify expected increases in accuracy and efficiency for cost justification.

Data reduction. Data reduction involves the removal of sample points that do not contribute to the information content defining the subsurface. Determining what contributes to information content is a major problem. A window of data can be displayed at recorded resolution and then panned through a much larger data base. A

Fig. 6

Theoretical sections*



*Across two domes and a fault (Bill French's model)

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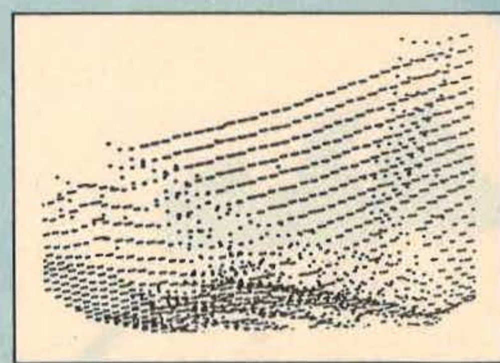
Fig. 7

Twenty-four sections*



*Across a theoretical faulted area (Fred Hilterman's model)

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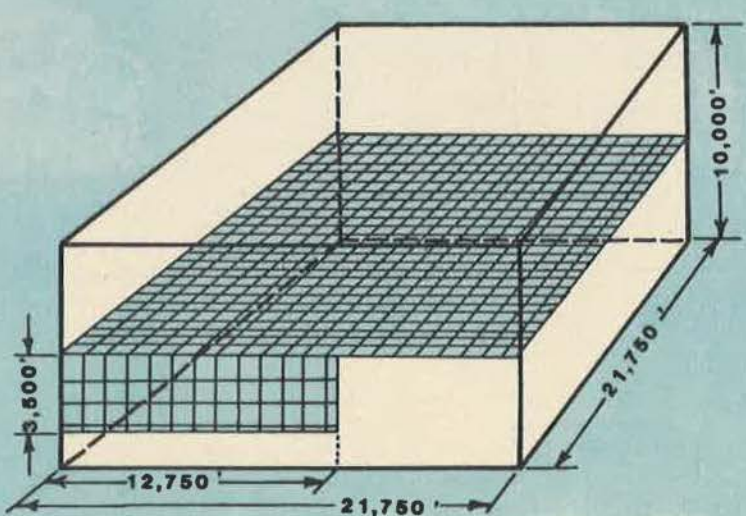
Fig. 8

Subsurface area*



*Displayed for horizontal vs. vertical seismic sections. Each area has the same number of vectors.

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more common method would be to reduce the number of input samples to increase the data volume.

If the frequency band is predominently below 62 Hz, band bass filtering then decimation from 4 ms to 8 ms will not appreciably destroy the information content. Centroid sampling will also serve the same purpose. By observing the spatial frequencies, a similar decimation could be performed by displaying every other trace. In other words, for less complex areas, more seismic traces can be left out of the data volume for the initial overview. Dropped traces are added as the specific anomalies are interactively defined. Figs. 6 and 7 show sets of physical model data displayed with a single vector of length proportional to the maximum amplitude drawn for each positive peak above a specified threshold. A similar data reduction scheme is to use dots of various intensities and colors to represent specific samples. This has been shown effective in studying molecular interactions (Langridge[5]).

In most geological areas, the same number of graphic vectors will display a larger area in a horizontal section than in a vertical section. The increased coverage is best portrayed by taking 21,500 vectors, referenced earlier, and showing the relative surface area coverage of vertical and horizontal sections. A vertical section will hold 86 traces of 25 samples each. With a velocity of 7,000 fps and 150 ft trace spacing, the vertical display would be 45×10^6 sq ft. However, a horizontal section is equivalent to 473 $\times 10^6$ sq ft. Fig. 8 illustrates this concept.

McDonald[6] has shown the value of color plots of horizontal data. Full color shaded video images can be constructed on a raster scope to give the illusion of a photograph of the subsurfaces. However, the same information can be displayed much simpler as sets of contours. Line drawings are a major data reduction down from photographs and are often more easily understood visually.

Interactive 3D interpretation. Seismic interpretation is relying more and more each day on the computer. By the end of the century interpreters and analysts will possibly become computer programers (Savit[8]), just like the job of the field seismic 'computer' has been replaced in the last two decades. However, today's interpretation is still an art, and 3D display devices will aid 3D visualization and routine calculations. By using available technology, managers can coordinate a more efficient and accurate exploration effort.

Eight generalized steps for doing

Fig. 9

Eight generalized steps*

STEP 1. Digital definition of data surface locations.

STEP 2. Digital definition of data in depth.

STEP 3. Process data file as required.

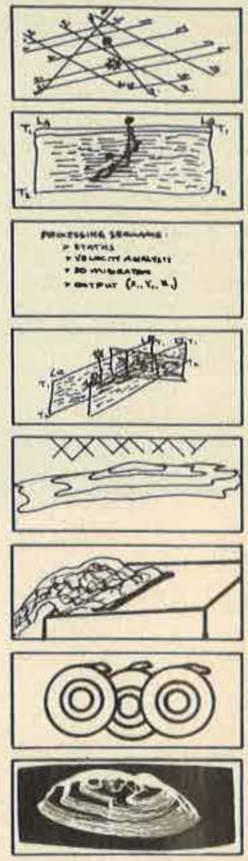
STEP 4. Display data file.

STEP 5. Interactively interpret data file.

STEP 6. Document interpretation progress on paper.

STEP 7. Store interpretation on tape or disc.

STEP 8. Retrieve interpretation for presentation.



Then add to and revise previous work.

*For doing interactive 3D interpretation

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interactive 3D interpretation are summarized in Fig. 9. This same procedure can interactively be used to interpret fault planes (Fig. 10), do a bright spot analysis, build a Seiscrop™ type interpretation, correlate well logs in 3D, contour in 3D (Fig. 11), pick and compare multiple velocity profiles, determine statics corrections, make a filter selection, do an F-K analysis, analyze the complex trace (Fig. 12), study particle movement of P and S waves as a hodograms, show geologic processes in 3D, do reservoir size evaluation, design and evaluate theoretical models (Hilterman[3]), compare synthetic and real seismic data, etc. Applications of 3D display devices are limited only by the imagination of the interpreter, processor, researcher, or educator.

The ideal way to interactively interpret data is to display it on the screen.

Fig. 10

Fault picks*

*Used for building an isometric fault plane display

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However, the complete integrity of the data can be kept by using the vector refresh graphics to display a line drawing interpretation while mapping the seismic or well log picks

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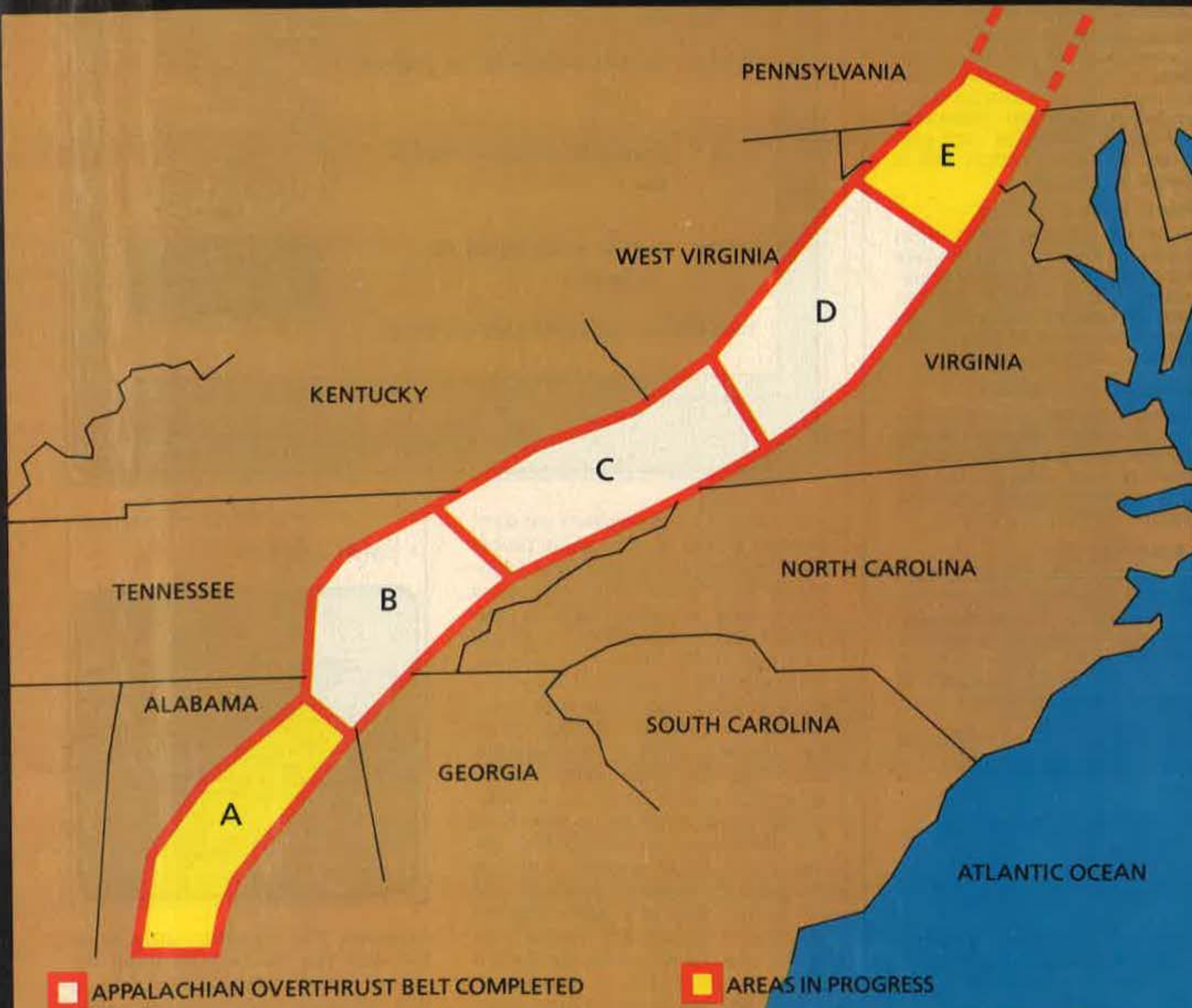


Fig. 11

Two views*

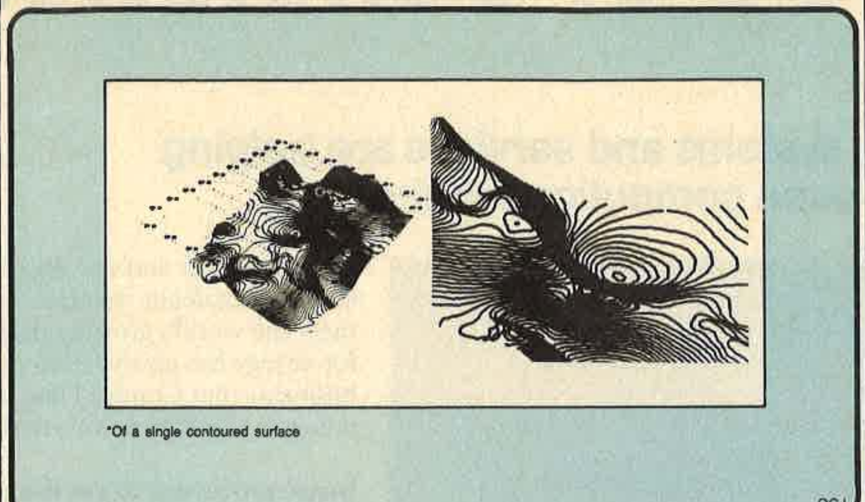
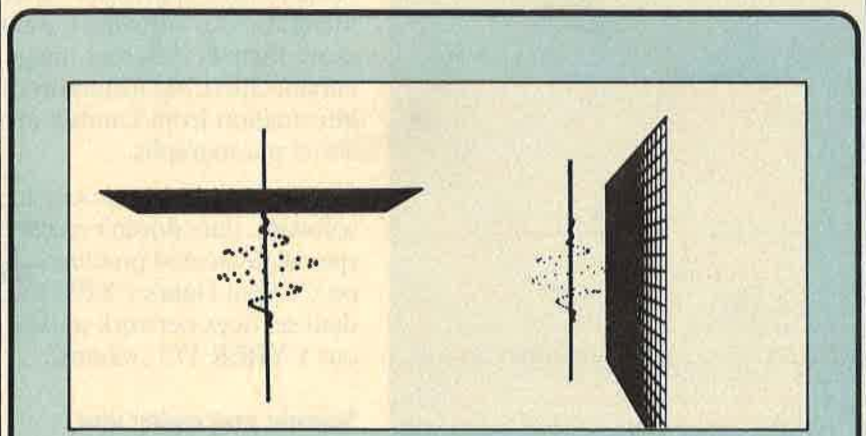


Fig. 12

Two views*



Picture on left shows 85 samples in 3D space. Picture on right shows a projection of the real portion.
*Of a complex trace.

or real data on a digitizing tablet. Rotating and zooming on the line drawing allows even a "one eyed" interpreter to visualize complex structures in 3D. Surface fitting on interpreted picks or contours and volume calculation algorithms have been developed that can be applied to this data (Uselton [11]). This increases the visual 3D effect.

Conclusions. There is a need for improved methods of interpretation and display in order to catch up with advances in other geophysical and geological exploration activities. Digital techniques are placing vast quantities of information from many sources in the hands of the interpreter. The massive volume of data to be manipulated and viewed from a single 3D seismic survey is a good example of why interpretational improvements are required.

Interactive 3D vector refresh graphics is a device on the market that allows data and interpretations to be displayed, manipulated, and modeled in a view that appears to mirror the actual subsurface position of the data. The interpreter using this equipment can find ways to work within the hardware limitations. Methods of doing this include data reduction by decimation, filtering, interactive interpretation, and using horizontal rather than vertical seismic sections.

Specific examples of how these machines can be used include horizon picking, fault plane mapping, Seiscrop-type interpretations, bright spot analysis, contour mapping, velocity analysis, 3D well-log correlation, and complex trace analysis.

Other uses of 3D display devices are limited only by the imagination of the interpreter, processor, researcher, or educator.[1,2,3,4,5,6,7,8,9,10,11]

Acknowledgment

The Polaroid photos used in this report were provided by Evans and Sutherland, Salt Lake City, Utah.

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BOOKS

Proceedings of the 2nd International Symposium on Computer Aided Seismic Analysis and Discrimination, *published by IEEE Computer Society, P.O. Box 80452, Worldway Postal Center, Los Angeles, Calif., 90080. 163 pp., $12 to members of IEEE, $16 for nonmembers.*

The symposium was held in North Dartmouth, Mass., Aug. 19-21, 1981. Contained in the proceedings of this symposium is an outstanding collection of papers on various topics, including migration and geophysical inverse techniques, pattern recognition, power spectrum analysis, multiple sensor data analysis, and digital filtering.

Improved Pressure Coring System, *published by DOE Bartlesville Energy Technology Center, P.O. Box 1398, Bartlesville, Okla., 74005. 16 pp.*

Sandia Laboratories and Pressure Coring Inc. have developed two coring improvements described in the report. First, researchers used coring bits with synthetic diamond cutters. These bits allowed coring rates up to 1 ft/min, while improving core recovery.

Second, a special low invasion fluid placed in the core retriever resulted in reduced core invasion or flushing by the drilling mud. This coring fluid also helps decrease the complexity of preparing cores for analysis.