LANDMARK

GRAPHICS CORPORATION

H. Roice Nelson, Jr.
Senior Vice President

January 25, 1985

Dr. John T. Kuo
Aldridge Laboratory of Applied Geophysics
842 S. W. Mudd
Columbia University
New York, N.Y. 10027

Dear Dr. Kuo:

Enclosed are 5 preprints of our paper, as you requested in your letter of Janurary 15th. If there are any questions or problems please call or write.

Regards,

Roice Nelson

H. Roice Nelson, Jr.

1011 Highway 6 South • Suite 120 • Houston, Texas 77077 • 713/531-4080 • Telex 750203 LNDMARK HOU UD

APPLICATIONS OF LANDMARK WORKSTATIONS IN INTERACTIVE PROCESSING AND INTERPRETATION

H. Roice Nelson, Jr. and Dr. H. A. Hildebrand
Landmark Graphics Corporation
1011 South Highway 6
Houston, Texas 77077

ABSTRACT

Computer graphics systems are just beginning to be used in a production mode to more accurately and efficiently solve substantial geoscience problems. One of the most exciting technical advances is the use of powerful standalone or networked microcomputer based workstations to evaluate three-dimensional arrays of data. Applications presently available on the Landmark Graphics system include the interactive interpretation of two-dimensional (2D) and three-dimensional (3D) seismic surveys. The hardware and software tools used to build a solution to these needs are summarized. In addition, the software development philosophy will be reviewed, along with a description of how present capabilities have been adapted turn-key by seismic processing shops to do interactive processing parameter selection and data evaluation.

INTRODUCTION

Turnkey microcomputer applications are available that can help solve oil and gas exploration problems. Over the last decade microcomputer hardware has evolved to rival the power of mini and even mainframe computers of years past. In addition, users are becoming more computer literate and applications are being developed that solve problems in the user's language. The results are cost effective, powerful tools for simple, user-friendly solutions using complex data structures.

Interactive 2D (two-dimensional) and 3D (three-dimensional) seismic interpretation are examples of these new tools. A system developed for computer aided interpretation by Landmark Graphics Corporation will be the basis for paper. First is a summary of the hardware capabilities. Following this is a review of a software philosophy designed to build solutions. Then is a brief description of the 3D interpretation software and how it can be used turnkey in a seismic processing environment.

HARDWARE

The LANDMARK interpretation station is designed to look like a desk. It is for standalone use in an office or a computer room environment. Also, the system can be networked to standalone workstations in other offices or to a host computer. A large desk top workspace provides room for paper seismic sections, maps, well logs, etc. One and two monitor configurations are available. The two monitor system is the most popular, because the base map and seismic data are concurrently available. The CPU is in a small tower on the left of the desk and varying numbers of larger expansion cabinents go on the right for disk storage and tape input.

The CPU (central processing unit) is the Intel 80286 microcomputer. This is the same chip used in the new IBM AT (Advanced Technologies) microcomputer. The Intel 80287 floating point accelerator is standard, along with 1 MB (megabyte) of main memory. As operating system improvements develop, the full 16 MB main memory supported by the 80286 will be available. In addition, an optional 1 Megaflop array processor can be installed. The CPU boards are installed in a 21-slot multibus. The system uses the MS-DOS operating system, and the applications described were developed using standard ANSII-77 FORTRAN. Other languages, such as C and Pascal, are also available.

Key peripherals include the graphics processor, the console subsystem, the tape subsystem, and the disk subsystem. The graphics processor supports one or two high resolution monitors (1280 x 1024 pixels). These monitors can be either 30 hertz interlaced or 60 hertz noninterlaced. The console subsystem consists of an alphanumeric console for text listings and system work, a printer, an embedded digitizing tablet and puck, and a 5 MB removable Winchester disk for downloading program updates, horizon files, and other data transfer. Modems are also available for remote transfer of small files. Large files are shared between interpretation stations and also hosts computers using the Ethernet local area network (LAN) at rates up to 1 Mbit per second. This allows sharing of disk and tape resources for sites with multiple system installations.

The tape and disk subsystem can be part of a standalone station, or located at one node of the LAN as shared resources. Tape subsystems can be 1600 only or 6250/1600 b.p.i., and handle standard 9-track SEG-Y seismic tapes, UKOOA navigation tapes, etc. Typical disk configurations are 440 or 880 MB. However, up to 16 separate 440 MB disks, or 7.0 GB (gigabytes or 10**9 bytes) can be put on a single interpretation station. Data files can span multiple logical and physical drives and be up to 4.0 GB each. This is comparable to the capabilities of computers in the megamini class.

Although a microcomputer system, as shown by the hardware options described above, it is not necessarily limited in computer power. In fact, the expansion and networking options available allow development of extremely powerful systems, with large digitizing tables, camera systems, and plotters. This is especially true if the capabilities of the microcomputer are packaged with appropriate peripherials to provide resources needed for specific applications, such as seismic interpretation.[1]

SOFTWARE PHILOSOPHY

With the availablity of these relatively inexpensive, yet powerful hardware systems, it becomes feasible to build applications and place microcomputer driven solutions in an explorationist's office. However, since many explorationists are computer illiterate, it is important to develop easy-to-use software for specific applications. Systems need to provide user-based tools to solve tasks at hand, in a manner similar to the way the job would be accomplished manually. In addition, this must be done cost effectively.

A best development approach is to define a substantial geoscience application and attack it by developing major software tools that can be used to build solutions to other geoscience applications. The tools underlying the 2D and 3D interpretation examples presented here are based on generic and independent software subsystems that are used as building blocks for major applications. Examples include software subsystems for graphics. menu managers, the array processor, viewport managers, seismic data access, large file I/O (input/output), seismic display, horizon data access, message control, and tape handling. In addition, the methods of accessing Landmark files are available; files like data files, horizon files and picture files.

Once the tools were developed for interactive 3D interpretation. the basic interactive 2D interpretation package was developed in merely three months. Of course. this basic package will be enhanced, improved and expanded upon for years. The development of many other geoscience applications holds a similar relationship once the basic tools are developed. Handling well logs and synthetic traces can be compared to handling wiggle seismic traces. Signal processing algorithms to post-stack process 3D seismic traces can be used to process 2D sections, well logs, or numerically derived model synthetics. Velocity information can be treated like 2D or 3D seismic data for lithology interpretation. Reservoir models are based on 3D boundaries similar to seismic horizon files. Of course, the same software development tools can be used for development of proprietary supplements to existing application packages.

It is also important to note that microcomputer systems have an economy-of-scale not possible with host computers.[2] End user access to microcomputers is much more widely available today than access to the host computers was in the past. Instead of users inputting batch jobs to a few large computers, users can now try different ideas on many computers. Although microcomputer applications have typically been less sophisticated, more applications are being developed, and those that are worthwhile can be integrated as third party software packages on an integrated system. This implies development of a system with the largest possible number of solutions available in the shortest possible time frame.

The main benefits of this new instrumental product are the turn-key software applications for working with large multi-dimensional volumes of seismic data. Presently available software includes packages for interactive 3D interpretation, interactive 2D interpretation, creating surfaces and isometric displays of interpretations, and programming libraries to allow user development of new applications.

2D AND 3D SEISMIC INTERPRETATION

Complete interpretation of large seimsic surveys, particularly 3D seismic surveys, is not viable using traditional colored pencil techniques[3]. The two biggest reasons being: (1) too much data to manually keep track of; and (2) the excessive time requirements. In softcopy display the computer keeps track of where the data is stored and the interpreter accesses the data as required in order to create a picture of subsurface geology. Sections can be retrieved from the x, y, z axes or from arbitrary locations within the data volume. This allows easy tieing of well information to seismic data.

Seismic surveys are often collected over complicated geology with stratigraphic traps[4]. Time management improvements in interpreting this complex geology allows an interpreter, with minimal training, to do a more detailed interpretation of more sections per unit time. Examples of computer graphics interpretation advantages illustrated include: coloring data to enhance the geology in the mind of the interpreter; animation of related data (parallel time-slice or time-series sections;

sections pivoted around a proposed well location. etc.); seismic attribute display and studies (Figures 1-3), digitizingmultiple horizons (Figure 4) paleogeologic studies (flattening horizons. as shown by Figures 5 and 6, or by extracting amplitude at or parallel to different horizons), and studying geologic changes over time; horizon computations (isochron creation, net producible sand studies, smoothing, etc.); mixing map display information of the same or different horizons; and making composite pictures of different interpretation steps for presentation and as an interpretation aid.

Processed 3D surveys form a regular three-dimensional lattice of points. This lattice can be used by a computer, which is sufficient resources, to relatively easily keep track of all of the traces, samples and horizons. The computer can sort traces out of the data volume that are in-line, cross-line, or along some arbitrary user specified direction, such as when connecting wells or defining the dip direction within a fault block. The computer can also create and keep track of time-slice or paleo-sections (sections showing amplitude distributions across or parallel to a 3D horizon), and combination time-slice and time-series sections. The data in Figure 4 came from picking a loop of data for display on an offshore Texas 2D survey. (Data in all figures was courtesy of Grant/Norpac.)

The ability to store animation files on disc for retrieval in a fraction of a second is a key example of the power of interactive 3D interpretation. The Landmark workstation is unique in its ability to animate large files directly from the disk to the screen (a single file can be up to 4,000 MB). In doing a 3D interpretation, the quick response time associated with working with animation files can save hours in interpretation time[5,6]. In addition, since the data is in softcopy it can be displayed in color, scaled, or have special processing applied. The animation files replace the need for tacking sections all around a conference room to overview the survey's structural and stratigraphic style.

Looking at data movies it is easy to find critical dip, and quickly move through the sections digitizing horizons. In softcopy it is easy to try different interpretation options, edit picks, and use capabilities like automatic horizon picking. In addition, looking at several sections in movie format provides visual pattern recognition of geology not seen on a single section. Three-dimensional data relationships can be studied. including structural changes and spatial changes of seismic attributes. An important animation characteristic is to study depositional changes, like the spatial changes in concordent extracted amplitudes sections. An example of geological significance of animation is to make a movie of sections pivoting around a well location. This allows evaluation of critical dip, the relationship of faulting and the well, etc.

Another important capability is to be able to make a composite of several pieces of data on a single display for simultaneous visual evaluation. It is easy to fold paper sections and get several related items all together for evaluation (even if it is hard to find the paper and put it back in place so it can be found next time). This interactive system provides the same capabilities with comparable ease, by using composite displays.

One interesting point is the emphasis users have on displaying wiggle trace displays. This is until they start working an interactive interpretation project. It has been shown that in many cases it is easier to recognize reflections on variable density displays than it is on wiggle variable area sections.[7] It is also a fact that interpreters tend to first start on an interactive system with wiggle or black and white sections, but shortly migrate to using colored variable density displays.

The regular 3D lattice of 3D surveys provides a nice framework for softcopy horizon picking and map display. Given picks on one section, these can be carried to a parallel section and converged to the appropriate peak, trough or zero-crossing using the automatic picking mode. This makes picking horizons with reasonable continuity very fast and accurate. Picks are automatically posted to an horizon file. At any point of a 3D interpretation the horizon can be evaluated in map view. Two-dimensional survey maps are fit with a surface and displayed in map view (Figure 7) or perspective view (Figure 8). Horizon files can be manipulated and displayed in several ways. Horizon surfaces can be subtracted to form isochrons, multiplied for depth conversion, have amplitudes extracted along or parallel to them, smoothed, and many other operations.

The 3D package has also been used turn-key to aid in seismic processing. It is most efficient to have the workstation networked to the processing host computer. However, early work has been accomplished by loading SEG-Y format tapes of different processing steps directly on the workstation. Two sections can be juxapositioned in an animation file showing the data before and after a processing step. Fliping back and forth between the pictures allows detailed analysis of the differences. Animation files of different filters, or different stacking velocities on the same section are a new method of picking the best filter or stacking velocity for a specific time. Field records can be loaded on the system as a 3D survey, where common offset sections are in the in-line direction and common midpoint gathers are in the cross-line direction. This allows studies of amplitude variations with offset. Picked horizons on the common midpoint gathers could represent mute patterns, normal moveout velocity hyperbolas, etc. for different common-midpoint gathers.

SUMMARY

Turnkey applications are avaiable on microcomputers that can help solve significant oil and gas exploration problems like interactive 2D and 3D interpretation. Proper packaging of presently available microcomputer controlled hardware can provide tools that can be taken to individual users cost effectively. There will be a proliferation of this type of technology as geoscience computer users become more computer literate and applications mature and are developed in the users language.

REFERENCES

[1]Nelson, H. R., Jr., Hildebrand, H. A., and Mouton, J. O., "Color Softcopy, Animation and Interactive User Interface in Interpretation Station Design," Presentation at 53rd Annual International SEG Convention, Explanded Abstracts of the Technical Program with Authors' Biographices, pp. 571-572, Las Vegas, Nevada, September, 1983.

[2]Nelson, H. R., Jr., "Seismic Interpretation and Microcomputer Economies-of-Scale," Presentation at the 46th Meeting of the European Association of Exploration Geophysics, Technical Programme and Abstracts of Papers, pp. 78-79, London, UK, June 19-22, 1984.

[3]Cole, R. A., and Nelson, H. R., Jr., "Interactive Computer Graphics and the Interpretation of Three-Dimensional Seismic Surveys," Presentation at 54th Annual International SEG, Expanded Abstracts of the Technical Program with Authors' Biographies, pp. 412-413, Atlanta, Georgia, December, 3-6, 1985.

[4]Simson, S. F. and Nelson, H. R., Jr., "Seismic Stratigraphy Moves Towards Interactive Analysis," World Oil, three part series, December 1984, March and April 1985.

[5]Ottolini, R., Sword, C., and Claerbout, J. F., "On-line Movies of Reflection Seismic Data with Description of a Movie Machine."

Geophysics, Vol. 49, No. 2, pp. 195-202, February, 1984.

[6]Nelson, H. R., Jr., "Animation, a Tool for Evaluating Multi-Dimensional Data Sets," Presentation at SEG/USN Joint Technical Symposium, U.S. Navy Research Facility, March 13-14, 1984.

[7]Fegin, F. J., "Seismic Data Display and Reflection Preceptibility," Geophysics, Vol. 46, No. 2, pp. 106-120, February, 1981.

FIGURE CAPTIONS

Figure 1. This is a useful method to study geologic changes between wells, evaluate true dip sections, etc. This set of five arbitrarily selected lines generally runs toward the northeast (left to right) through the data volume.

Figure 2. A pixel zoomed display of an instantaneous phase section from a North Sea 3D survey. The user can instantly change this display using the linear color adjust option to give the illusion of phase shifting the data. All 8 figures are from the interpretation of this same survey.

Figure 3. An instantaneous phase section has been flattened on a seismic horizon, and an isochron between a flattened and another seismic horizon picked.

Figure 4. This chair display has a time-slice section at 2800 ms and is connected to cross-line sections 150 and 350. The black-to-white color table has had a visual AGC applied using the exponential color adjust.

Figure 5. Once an area of interest is identified, composite pictures of scaled vertical sections allow several sections to be evaluated simultaneously.

Figure 6. Simultaneous display of several time-slice sections is illustrated here. Also, time-slice or time-series displays can be preformatted as animation files and evaluated as movies.

Figure 7. The colored map view of a seismic horizon surface has been modified with six 100 ms white-to-black bands. with a red marker hightlighting the 2848 contour.

Figure 8. The contour map shown in Figure 7 has been colored white-to-black, pixel zoomed, and overlain with contours every 40 ms from the same horizon. This concept can be expanded to mix information from different type maps, like isochron, amplitude, residual, etc.

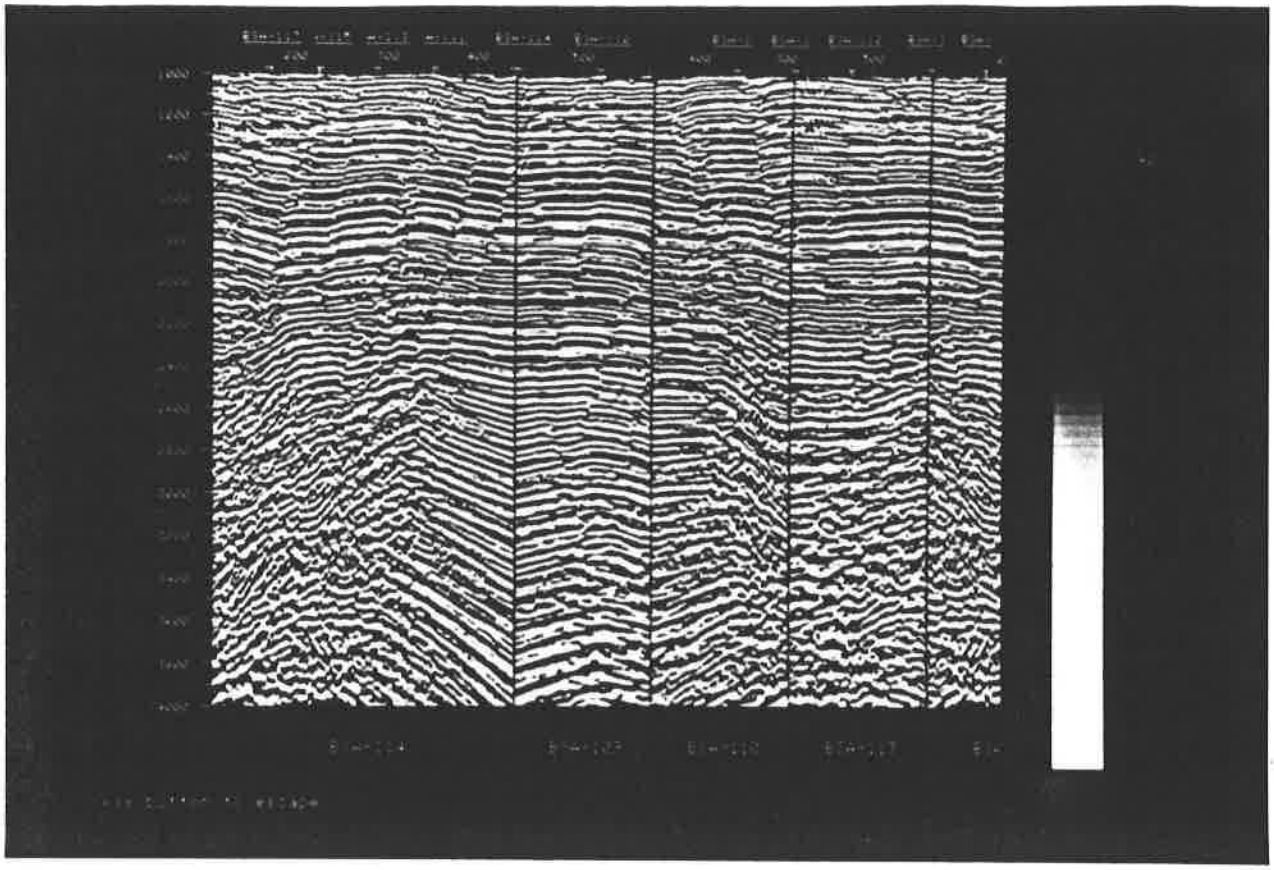

FIGURE 1

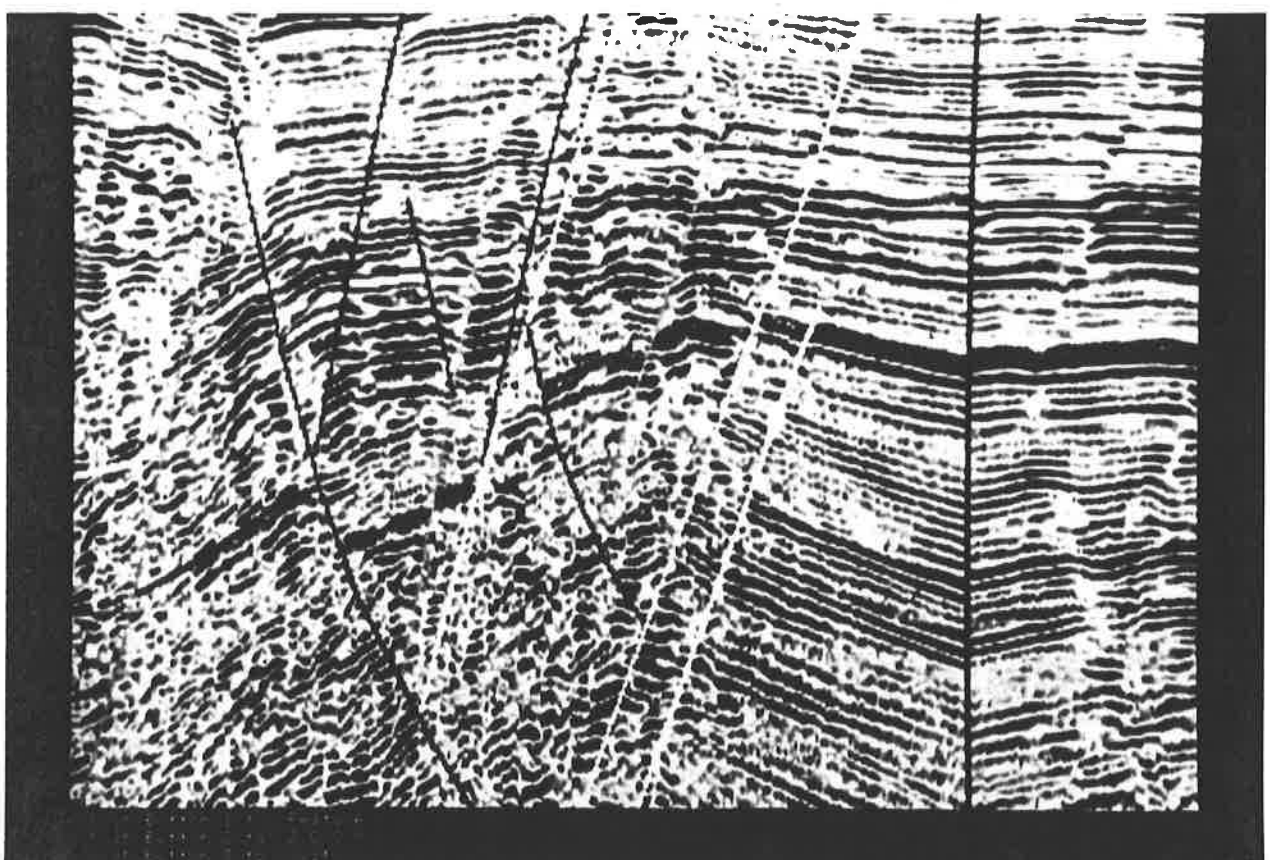

FIGURE 2

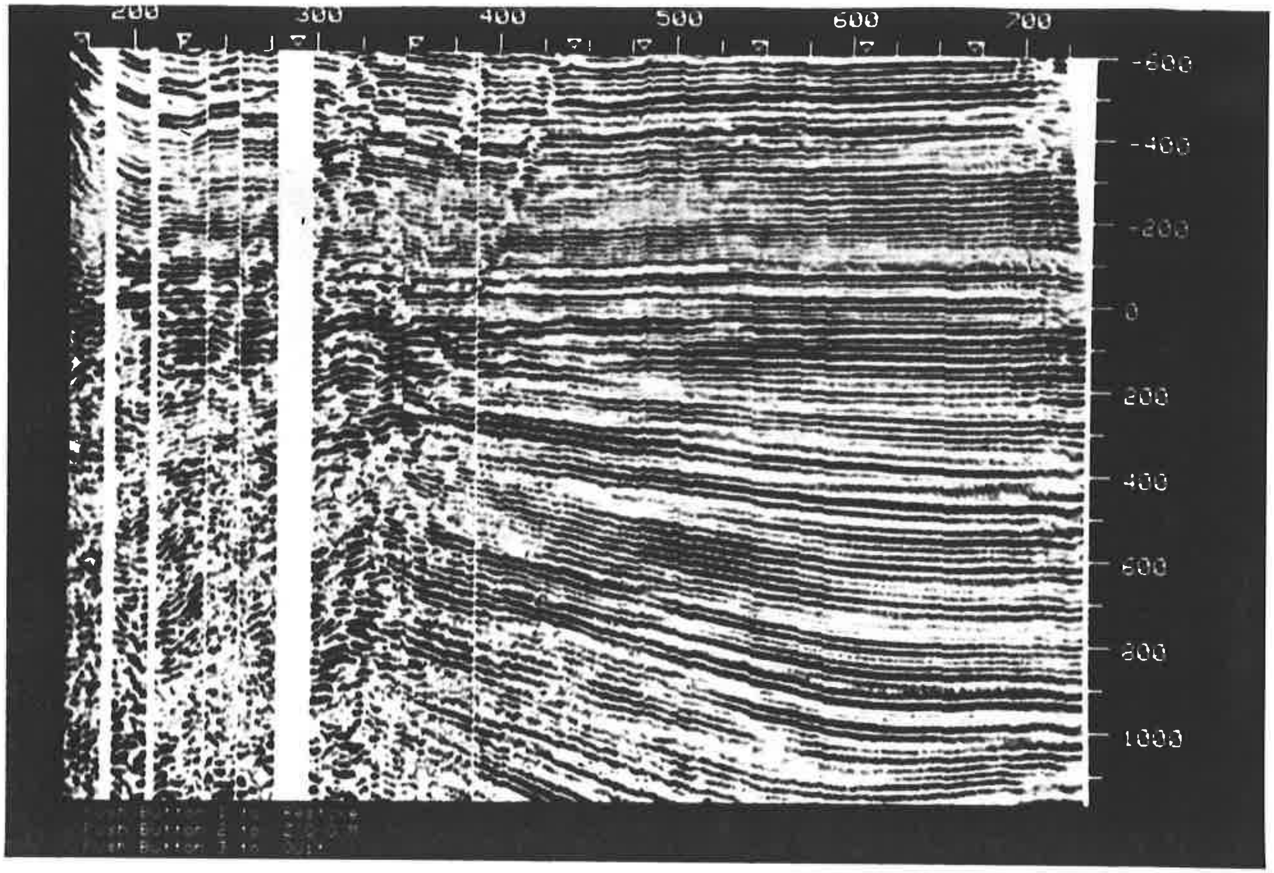

FIGURE 3

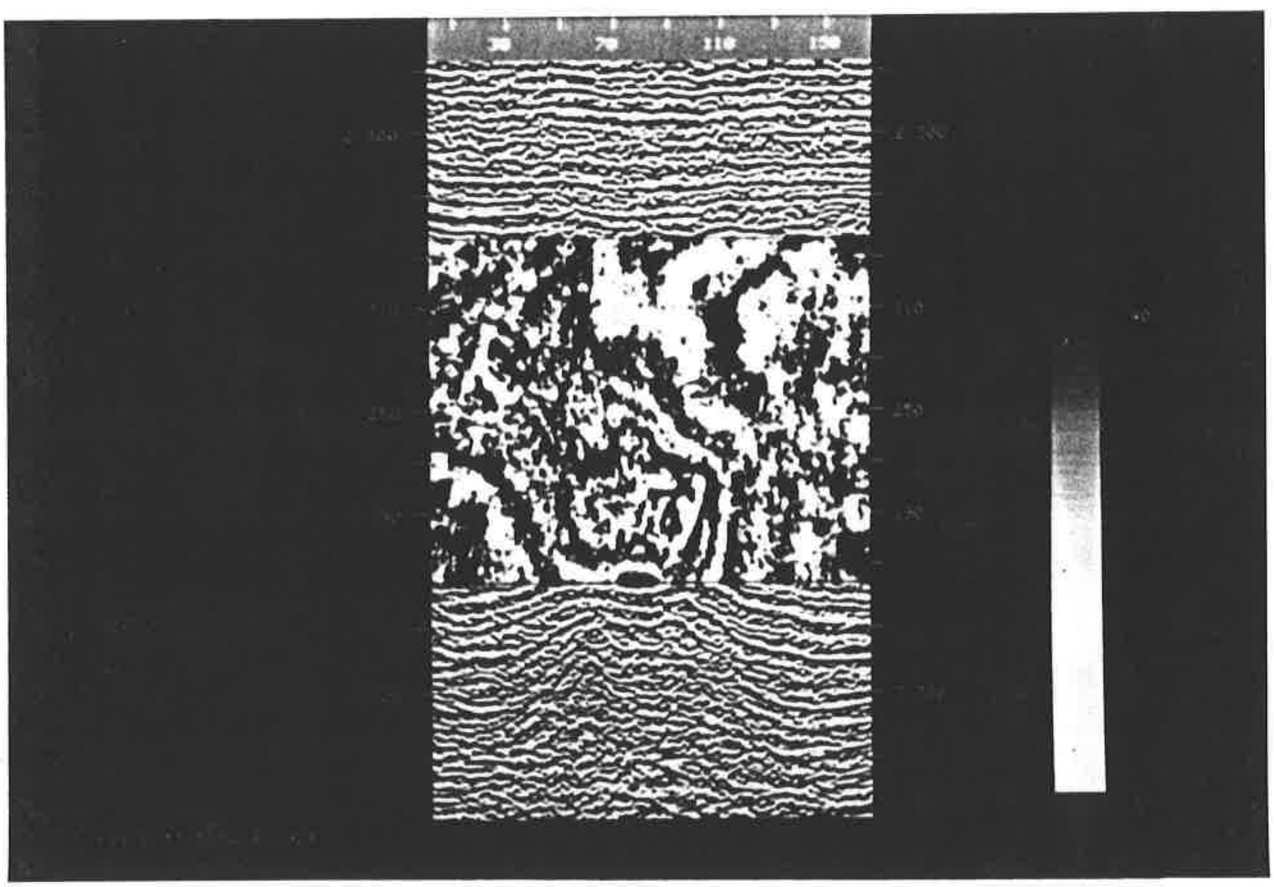

FIGURE 4

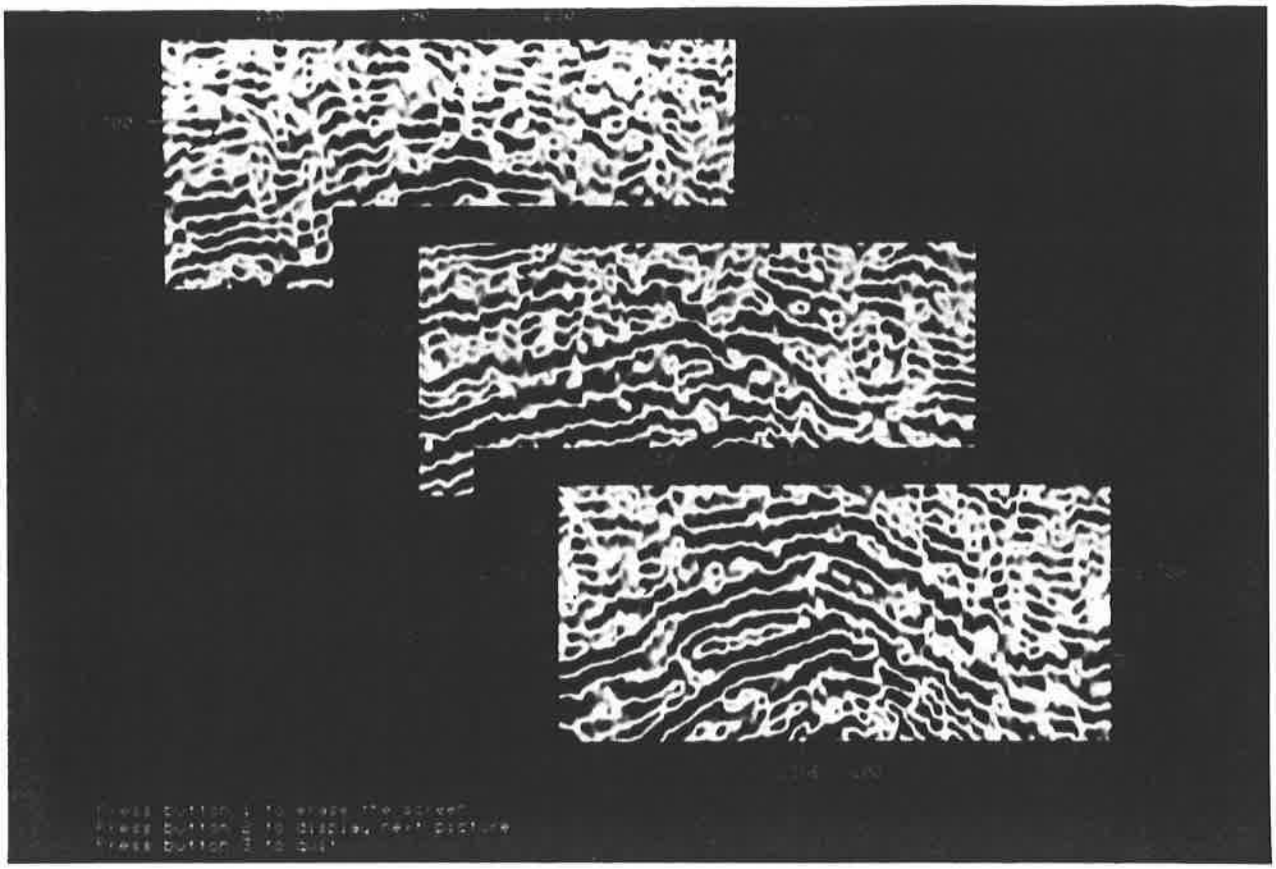

FIGURE 5

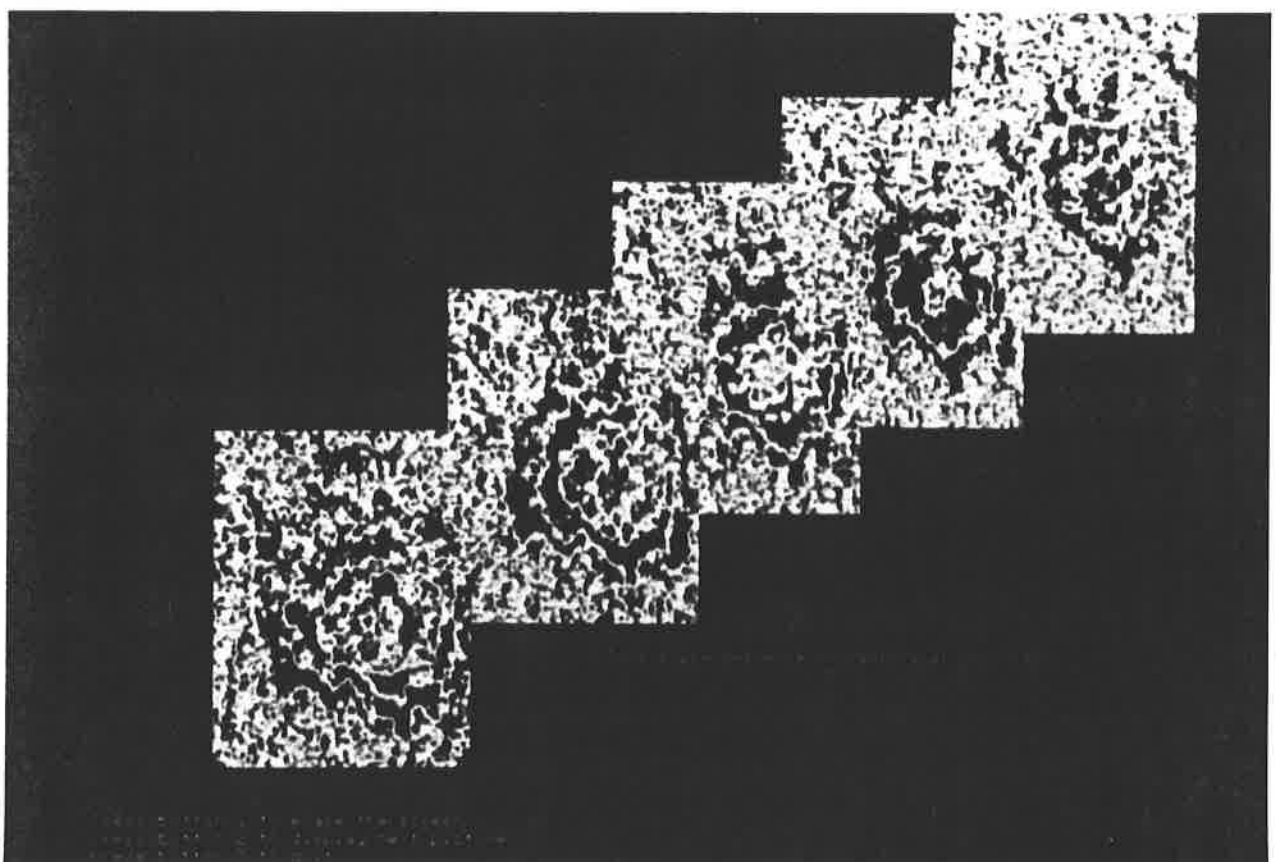

FIGURE 6

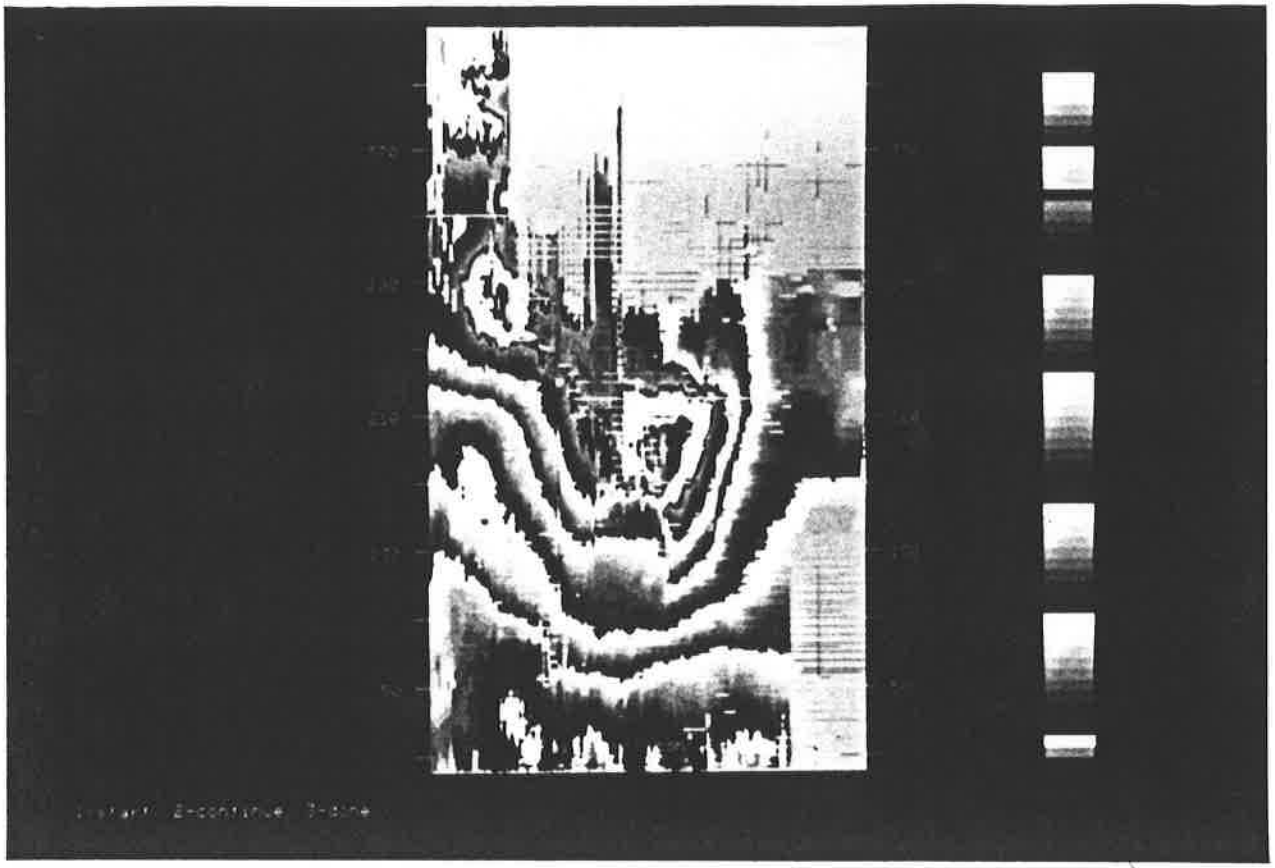

FIGURE 7

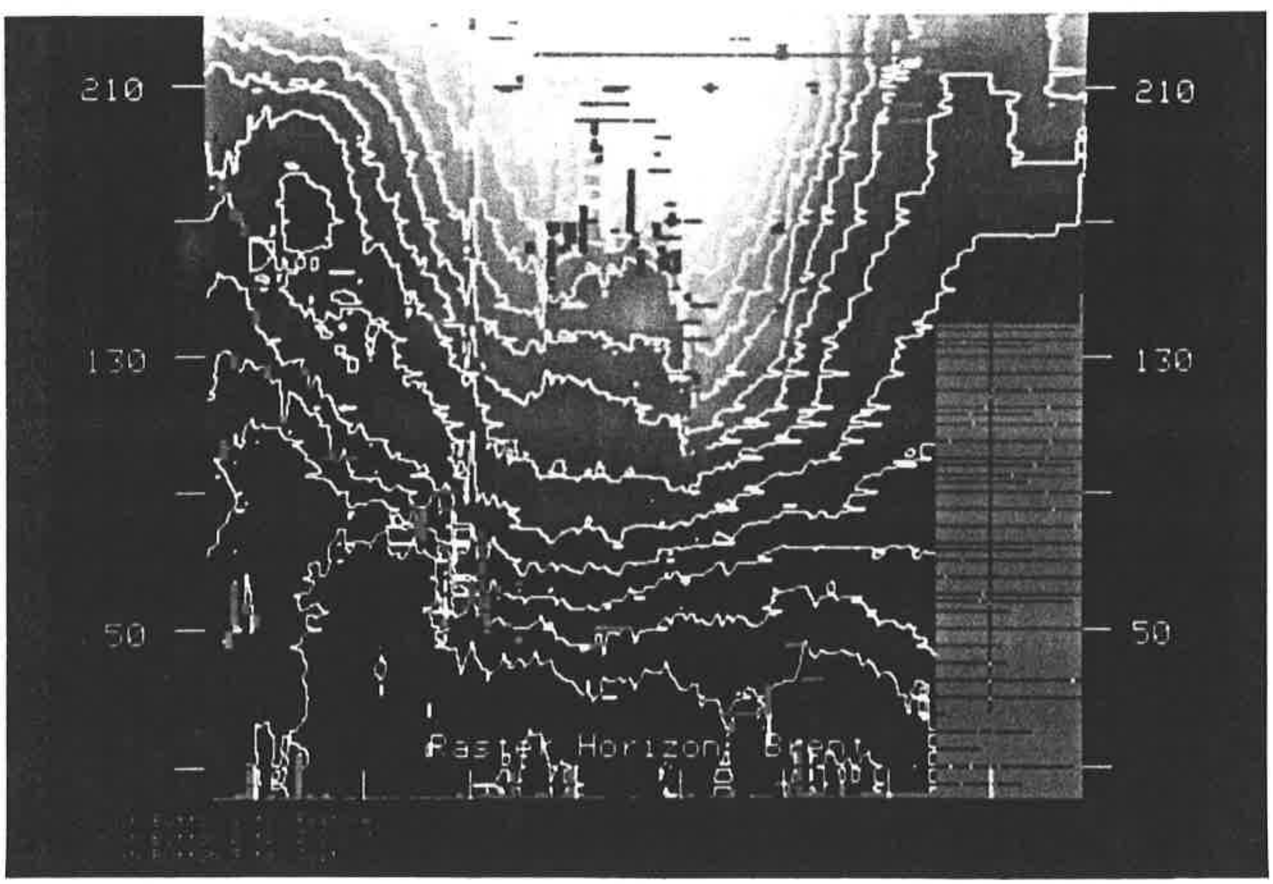

FIGURE 8