A geophysical outlook

New technologies will meet exploration needs

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20-second summary

Following is a generalized overview of the new technologies that are being used today in exploration geophysics. New data collection methods, processing developments, interactive interpretation techniques and the hands-on training of tomorrow's explorationists are summarized. Trends and developments that point to new tools and new exploration methods are included in this overview article, which is the first of a series. Subsequent articles will expand on particular technologies in respect to their expected effects on geophysical exploration methods in the 1980s.

THE INCREASED RATE of technological breakthroughs during the last decade points to the 1980s as the time for solving many of the problems traditionally faced by explorationists. Today's geophysicist is looking for smaller and more complex fields. The most modern techniques and tools are required to find small plays that are structurally or stratigraphically separated from previous discoveries already in production. The recent well-publicized wildcatting successes in the Utah and Wyoming overthrust belt, as well as in other complex areas, underline the value of employing the most modern exploration methods available. Since 1973 oil and gas economics have pointed to an ever increasing use of the new and expensive exploration tools at the forefront of technology.

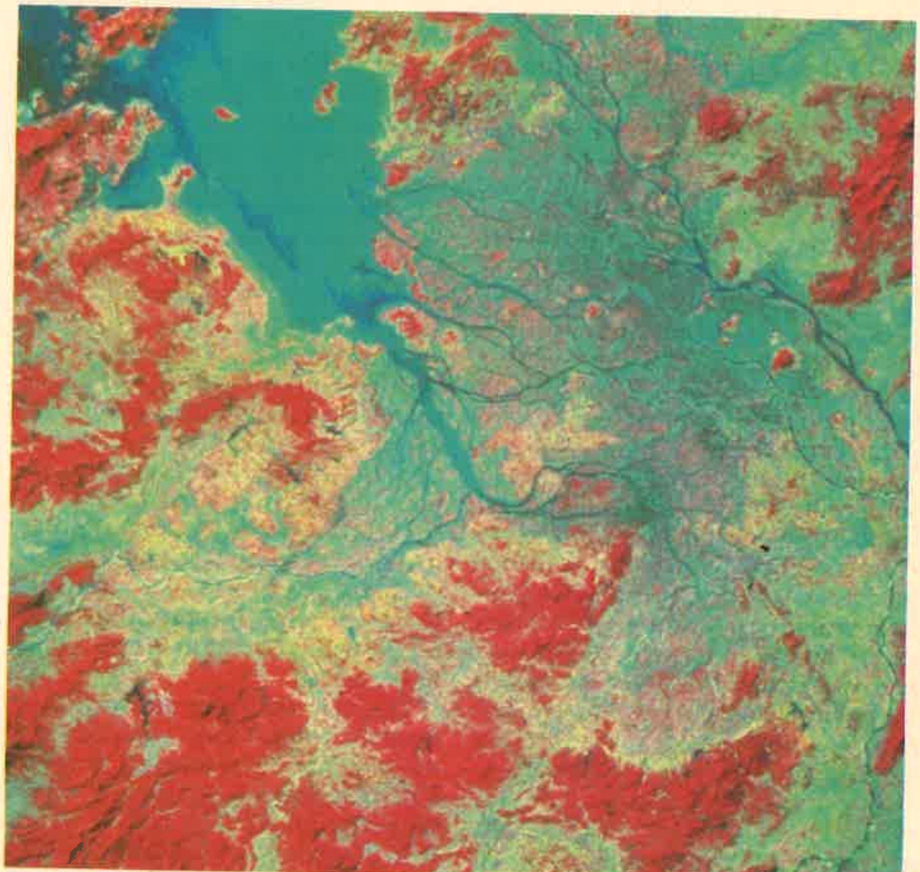

Fig. 1—Example of an enchanced Landsat, satellite imagery, photograph that is currently used as a primary exploration tool. Efforts are underway to increase the resolution of display equipment so that it approaches the resolution attained by such Landsat images.

DATA COLLECTION TECHNIQUES

Micro-computers. Imagine a scenario where an observer on a seismic crew gets an Apple computer for a Christmas present. After all, he works with computers and would enjoy playing with such a toy. Alternatively it might just as well have been a Radio Shack TRS-80 or one of a dozen other brands of micro-computers. In following the consequence of this fictional situation, the bottom line is that this "toy" soon becomes a very useful tool for several members of the crew. An impact printer is obtained and the observer is soon using the computer to keep track of maintenance schedules, crew breaks and vacations, and the daily log of data collection.

The permit agent finds the "toy" to be a tremendous aid as a portable word processor. He uses the compu-

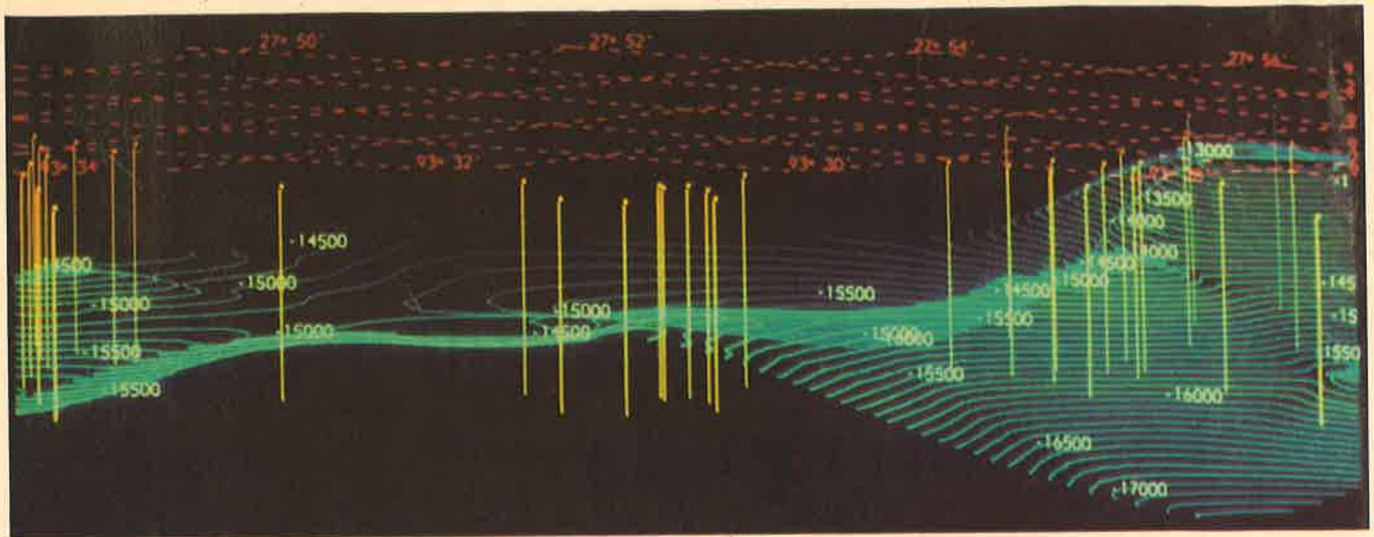

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FIG. 2—Example of a full-color, 3D display that is rotatable around an axis. Such capability enhances seismic data interpretation in our 3D world.

ter to type out multiple agreements where the only change is the name of a landowner. The surveyor discovers the ease of using the machine to check, type out and store survey notes. The observer develops an accounting package for the party manager to ease the handling of $150,000 expenses per month.

A quality control geophysicist visits the crew for a week and becomes enamored with the "toy." The first day he creates noise response curves. This is followed by his outlining a method for designing optimal field programs within the limitations of topography, permits and culture. The computer is introduced to other company seismic crews, and within two years there is a micro-computer users group sharing ideas and successes. Fictional? Observe what is happening with seismic crews and this will not seem far out for very much longer, if in fact it is now.

Surveying improvements. One of the most critical problems in seismic data collection is accurate spatial location. Surveying and navigation errors are still the major problem in accurately tying different seismic surveys together. Accurate interpretation and proper processing are possible only if the data location is accurately recorded. There have been many advances in the last few years, and there is research in several other areas that herald new technologies to meet the needs of accurate surveying.

Satellite location is becoming commonplace on marine crews. With more satellite passes it is becoming easier to get a quicker and much more accurate location. The portable Magnavox satellite positioning station will determine position accurately within 3 meters latitude and longitude and 10 meters elevation from 40 satellite passes at Wyoming latitudes. This many passes will normally happen in less than 4 days. By translocation from a known position within 200 miles, the horizontal accuracy is ±1 meter and the vertical accuracy is ±3 meters (Arnason, 1981). However, there are new problems created by this extraordinary accuracy. For example, it may be found that county lines, property boundaries and even well locations are not actually located where the legal description indicates.

The new electronic measuring devices are providing significantly more accurate surveying records. These devices are accurate to within 1 cm over 1.6 km. The slope is off less than 30 cm per 1.6 km and a careful surveyor will only be off 60 cm over 40 km. This can be improved by taking accurate temperature and pressure measurements since they affect light transmission. The controls are as easy to use as a hand held calculator. The LED (light emitting diode) displays are easy to read and not subject to variations between surveyors, as can occur with a transit.

There are, of course, limitations. The equipment can not be used on extremely hot days when there are strong heat waves or when there is much dust in the air. It is hard to use a laser diode device in heavy brush, where part of the light to and from the reflector is scattered. However, it is a tremendous advantage to be able to record the survey notes once, in the field, on a digital memory device. This minimizes the mistakes that come from poorly written notes, copying notes, keypunch errors, etc. Digitized shotpoint location numbers can be automatically dumped onto a cassette or put into the data tape header by using the dog house computer. In the evening the surveyor not only saves the time he used to spend working up his notes, but he can use available software/hardware to automatically dump the notes out onto a shotpoint location map.

A dream of geophysicists concerned with the problem of accurate location is to have a self-locating geophone. There are "chains" available that are filled with fluid. When used to chain between shotpoint locations along a line, the elevation differential between different shotpoints is recorded. Devices that triangulate on individual geophones in a two-dimensional receiver pattern also are being developed.

Source/receiver improvements. Compressional-wave vibrators have become a standard method of data collection. A vibrator crew can, under most conditions, get more production than a crew tied to shot hole drillers. The environmental improvement is evident in the field. Vibrators have been made larger, modified to be more versatile and improved for more reliability. An example is varying the frequency on different move-ups on the same shot point to increase the signal-to-noise ratio.

Shear wave vibrators, introduced a few years ago, have four "pyramids" on the base of the vibrator pad that are worked down into the ground to get a coupling. The plate, vibrated from side to side instead of up and down, creates shear wave energy rather than standard P-waves or compressional energy. Although this technology has not yet proved as fruitful as was hoped, it illustrates the innovative attempts being made by geophysicists to find what is in the subsurface.

There are new sources that are being tested, ranging from a marine steam gun that does not produce a bubble to a portable land source that fires a small shotgun shell for shallow work. In areas only accessible by foot, crews use backpack or helicopter portable drills for planting shallow dynamite seismic sources. Surface and staked explosives also are being used more widely. The need to better understand the source waveform, and to increase the accessability of remote areas while not damaging the environment motivates the development of newer energy sources.

There are also new developments with the phones that receive the seismic energy. The development of shear wave eqiupment has resulted in the need for a string of geophones that record energy along one axis. The next step beyond shear wave phones will be the development and use of three-component geophones for reflection seismology. Three-component geophones are presently being used for down hole recording, or vertical seismic profiling. Another improvement for land receivers will be self locating geophones. Marine hydrophone cables are closer to accomplishing this, with "birds" that are used to control the depth of the cable.

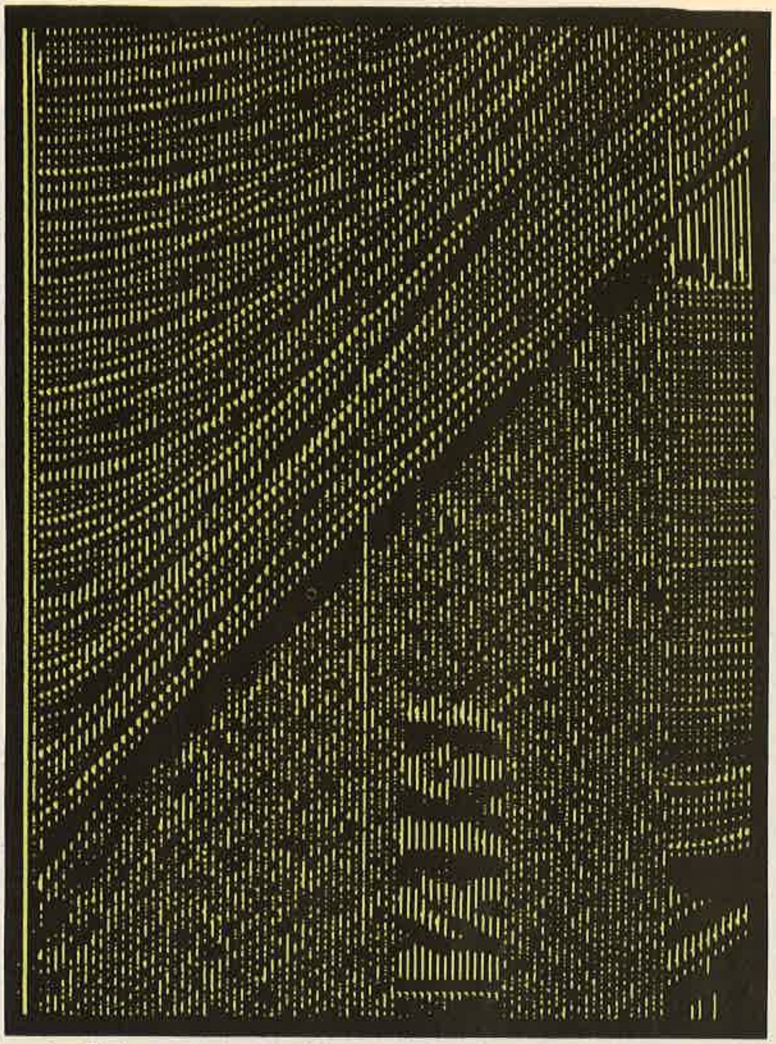

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Fig. 3—The image displayed is taken off a vector refresh graphics terminal. Seismic data displays require large amounts of trace data to be viewed simultaneously so that correlation between traces can be analyzed.

Recording technology changes. Rapid developments in the electronics and communications industries have been mirrored by developments in geophysical recording equipment. New recording devices have more channels and record more samples per second. Multi-channel crews curently in the field record up to 1,024 channels at one time. It is anticipated that this will expand to 4,096 channels within the next few years. The crews with this many channels record only a sign-bit, i.e., 0 or 1, for each sample and build a standard seismic trace from this by correlation. Recording 16-bits of data per sample is the present standard.

There are multi-channel crews that record 16-bit data in 4-channel remote memory boxes. One portable recording device stores this data on cassette tapes. Another system uses wire line telemetry to send the data to the recording truck. Still a different recording system returns the data to the dog house by means of radio telemetry. With the improvements in satellite communication it does not take much imagination to see the day coming when data will be radioed directly to a central processing center.

The development of faster, smaller and less expensive memory not only affects the number of channels recorded, but also the sampling rate. It is not uncommon to do high resolution surveys with a 1 millisecond sampling rate or less. Data is traditionally recorded at 4 milliseconds per sample.

The development of computer bubble memory devices is an example of new technology that will change seismic recording boxes. These changes will be expanded with parallel developments in other areas. For example, the research being done in fiber optics data transmission will affect seismic recording instruments. Developing ways to record with variable precision from 1 bit to 16 bits will affect the amount of data to be recorded on new high density recording medium, like 6,250 bpi (bits per inch) tapes and eventually video discs.

The potential use of these recording technology changes is being hinted at by the use of mini-computers in the field for doing processing to prepare for migration. There are several marine data collection systems that have full processing capability aboard the seismic ship. One company accomplishes field premigration pro-

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cessing with mini-computers installed in semi trucks.

3D seismic techniques. Seismic reflection studies are undertaken for the purpose of solving geological problems that are invariably 3D (three-dimensional). The earth is 3D, and yet traditional seismic reflection techniques are tied to collection of 2D seismic sections. Three-dimensional seismic techniques include the collection of seismic traces over an area, processing these traces, and intrepreting the subsurface geology from the data. The simplest component method of collecting seismic over an area is to place the receivers along one line and shoot into these receivers along a perpendicular line. The resulting midpoints cover a two-dimensional area, and the seismic traces represent a 3D volume of the earth. The extension from profile lines to areal coverage brings seismic data into conformance with the geological, geochemical and potential data available over the same area (Gardner, 1979).

TABLE 1 —Areal vs. Linear Survey data

	AREAL	LINEAR
Type	Crossed Arrays	CDP
Channels	96	96
Length	∞	22 miles
Area	2 miles x 4 miles	0
Grid	50 feet	50 feet
Redundancy	4	8
Number of Traces	80,000	40,000
Volume	16 sq. mi.	0
Time	9 days	29 days
Source	Dynamite	Dynamite

By properly planning a 3D survey, seismic crews can collect enough data to accurately evaluate a geological problem cost-effectively. Table 1 (from McDonald, 1981) shows a comparison of the data collection statistics for two experimental surveys using the same crew and the same system. Note that twice as many traces are collected in one-third of the time with the same crew when using areal survey techniques and that this data more readily lends itself to the understanding of a 3D geologic setting as it exists in nature. Further, the volume of information produced in collecting areal survey is a basic key to the merging of reflection seismology with reservoir evaluation and with other production techniques.

PROCESSING TECHNOLOGY

Over the last decade processing techniques have developed even faster than the changes in field techniques previously described. A majority of the topics described in the literature fall into the four main topics of wave-equation migration, seismic inversion, wavelet processing and deconvolution, and statics and velocity estimation (Rice, *et al*, 1981). Transition from conventional 2D to 3D processing techniques is becoming more common.

Processing technology improvements will for the most part be an extension of present capabilities. There will be more near surface, high resolution analysis to correct for weathering effects. Methods for doing statics corrections for 3D data are being developed. Procedures for doing 3D velocity analysis where lines cross and dealing with 3D volumes of data are being polished and put into production. Migration is being expanded to 3D with the standard Kirchoff, F-K and finite difference methods. New methods of seismic stripping, depth migrating and direct inversion are being worked on. Forward modeling or the inverse procedure of migration is developing in a

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parallel manner. It is even possible that an exact solution of the wave equation will be developed.

Distributed processing. Geophysical processing in the 1980s appears to be headed towards heavy use of small mini-computers. The VAX 11/780 is being enhanced and marketed by several of the seismic contracting companies. Having multi-processing capabilities, these computers manage the scheduling of processing jobs automatically, and multi-programming capabilities allow many users to be working with the system at what appears to be the same time. Other mini-computers are made by Data General, Perkin-Elmer, Raytheon, SEL, etc. These computers have seismic processing software packages and can be configured with array processors, mass storage devices, rasterizers, 22-inch 200 dot-per-inch electrostatic plotters, 1,000 dot-per-inch laser film plotters, high resolution display devices, programming terminals, etc. It is also possible to front end these computers to a large main frame that will handle extensive number crunching.

Super computers. The new vector computers can run up to 1,000 times faster than the largest scalar computer available, if the software is properly vectorized for parallel processing. The major vector computer systems are the Cray-1 and the CDC-203 or 205. A simplified description of how these phenomenal computation speeds are achieved can be shown by a couple of comparisons.

First, instead of processing repetitive mathematical or logical operations by going through each program step 'n' times, a vector computer will process the repetitive steps in parallel. Second, the data is run through processing pipes that change it on the fly (as quickly as it can be run through the pipe), similar to an array processor. Assuming some basic input/output problems can be solved, it is estimated that a 2D fourier synthetic modeling program that takes 10 hours to run on a VAX will take 5 minutes on a CDC-205 (Kosloff, 1981). The movement of the data is very critical on improved speeds, and this is why these vector computers will have several of the largest scalar processors feeding them data.

With the tremendous amount of data involved in a 3D survey there is a real need for geophysicists to take advantage of these new computer capabilities. There is considerable development needed on moving the data to where it can be used so the computer is not input/output bound. As inversion and forward modeling techniques are improved, it is feasible to see iterative seismic section matching. This is similar in scope and complexity to work being done in the area of reservoir analysis.

INTERACTIVE INTERPRETATION

Improved methods of manipulating and viewing the large volumes of data available to today's explorationist are desperately needed. Determining subsurface geology in order to find hydrocarbon traps is the name of the game. Industry preparations for developing computer data bases have been described in the literature (Dillahunty *et al*, 1980).

Dovetailing nicely with computer improvements and data storage/retrieval systems are the improvements in display technologies. There are some procedures that are being done interactively. The ability to interactive-

ly display and interpret 3D volumes of data is getting closer to reality. In the mean time many geophysicists, especially independent consultants, are developing interpretation aids on their home micro-computers. This work includes synthetic trace programs, map migration routines, etc.

New display equipment. There have been tremendous advances in developing inexpensive, new raster and storage tube terminals. The resolution is increasing from the home television 512 by 512 pixels (single picture elements) to multiple memory planes of 1,024 by 1,024 pixel resolution. CRT (cathode ray tube) display of satellite imagery data is the most common example of this picture resolution. The resolution allows enough data to be displayed to aid interpretation (Fig. 1). In order to get an overview of a geologic objective, the rapid display of a sequence of 2D digital images can be used. For normal seismic section interpretation, this can aid the continuity of following a fault or other anomaly. The effectiveness of moving through a series of horizontal seismic sections has been shown by G.S.I.'s Seiscrop© presentations (Bone *et al*, 1976).

When the geophysical interpreter steps into the world of 3D data volumes, there needs to be a way to display the data in 3D space. One tool that creates an apparent 3D display is high resolution vector refresh graphics (Nelson *et al*, 1980). These display devices have been used for some time in the computer-aided design of 3D objects. One such display creates a full-color, 3D set of vectors that can be rotated (Fig. 2). Another has a raster segment generator that displays up to 240 traces with 1,000 samples on each trace simultaneously (Fig. 3). Vectors with 3D coordinates are drawn as an interpretation over these sections. As the sections are moved through the data volume the interpretation becomes a series of rotatable 3D vectors.

There are several true 3D display devices that have the potential of helping in the evaluation of 3D data volumes. One uses a high resolution electrostatic scope to create a series of virtual images in 3D space behind a vibrating mirror (Sher, 1979; Johnson and Baxter, 1979). Another device, developed at M.I.T., uses computer controlled LEDs on a rotating plane to create a 3D image (Jansson *et al*, 1981). A third method uses multiple CRT's and beam splitters to place the images in 3D space (Ricks, 1981). The simplest 3D illusion is made by facing two parabolic mirrors together, so that an object placed inside on the base mirror is optically projected above a hole in the base of the top mirror (Simpson, 1981). However, there will be several years of research work before any of these devices will meet the needs of geophysical interpreters.

Interactive interpretation consoles. There are several companies that have developed mapping consoles. These normally use a storage tube display and are tied to a data base manager. They are the first step towards developing an interactive interpretation console. As more explorationists gain access to the new mini-computers, there will be a demand for software that allows for an easy exchange of information between users as well as between multi-level data base systems. With the new mini-computers there should be a decentralized company computer network established. Local interpretation groups will need to buy computer time from a large main frame to handle large number

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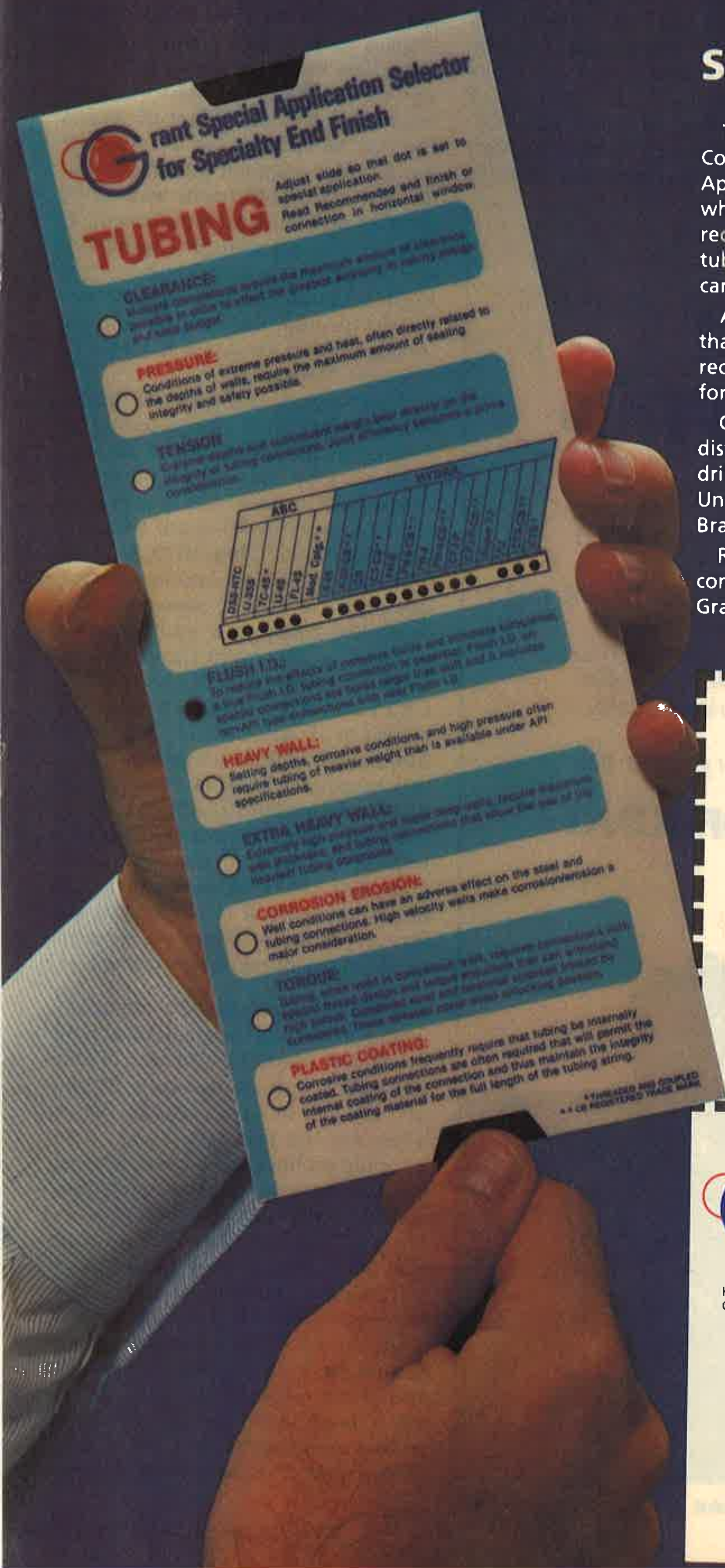

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It has yet to be shown conclusively that an interactive interpretation console would be accepted by interpreters, or that it is cost effective. A specific comparison of the efficiency and accuracy improvements of an interactive over a batch interpretation system needs to be made. Activities that are repetitive enough to be useful in this type of a test include velocity analysis, bright spot analysis, tying synthetic modeling to a seismic stratigraphy interpretation, ray trace modeling, etc.

Distributed data base management systems. Many exploration companies have regional or division offices that handle all of the data for a specific area. Most of the data bases have no master plan, and it is usually very hard to retrieve data unless the interpreter has worked with the specific filing system for some time. A true explorationist needs to have fingertip information from geophysics, geology, and well logging. This information is all interrelated and requires a quick and accurate method of extraction.

This is why one of the major technologies requiring emphasis in the 1980s is data base management. System level computer software interpreters that will be able to extract information from present data storage systems will make that data available interactively to explorationists. This will be the major improvement in data handling techniques and interactive interpretation in the 1980s. Coordination of these technologies allows the integration of seismic data with location maps, landsat, surface geology, potential data, well logs, geochemical information and with other large sets of exploration data.

CHANGE

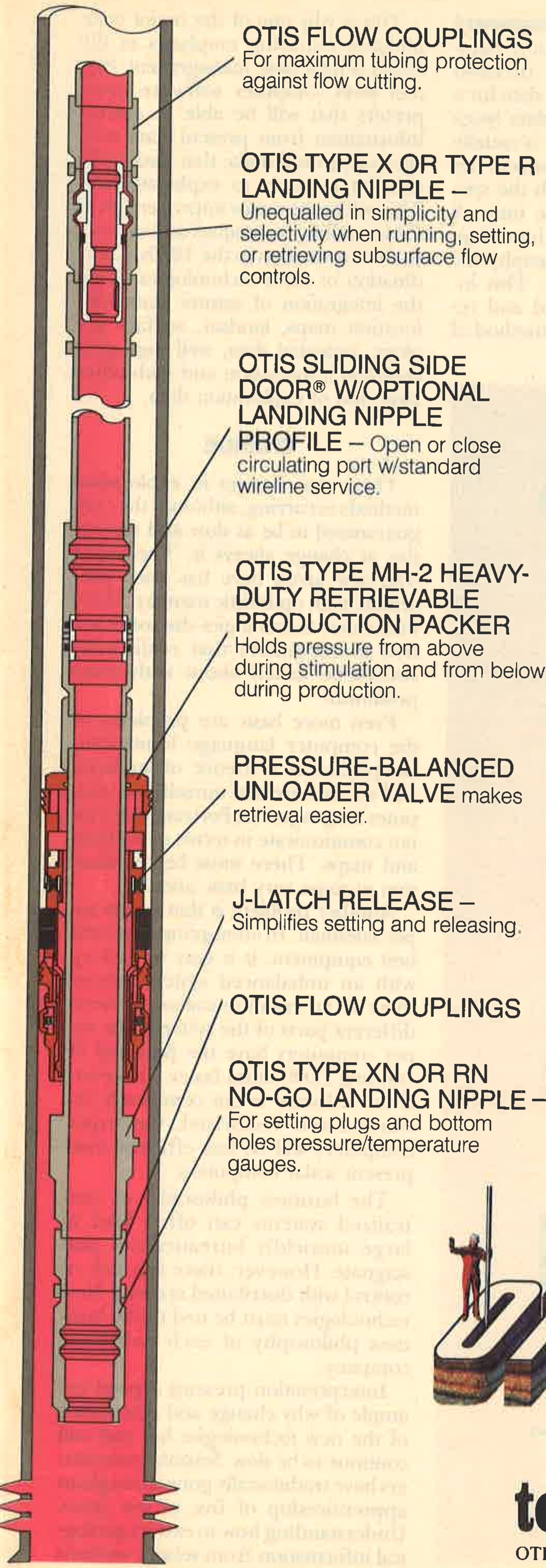
There are changes in exploration methods occurring, although they are guaranteed to be as slow and disruptive as change always is. The broad overview given here has been presented in an optimistic manner. Many of the new technologies discussed are tied to computers that realistically should be talked about with some pessimism.

Even more basic are problems of the computer language limitations. Geophysics is a science of surfaces, and yet we have tied ourself to a computer language, i.e., Fortran, that cannot communicate in terms of surfaces and maps. There must be reevaluation in some very basic areas.

Another problem is that of the super salesman. In attempting to get the best equipment, it is easy to end up with an unbalanced system, where there is no communication between different parts of the system. The super computers have the potential of running 1,000 times faster. However, if the software is not completely reworked and vectorized, the super computers will be less efficient than present scalar computers.

The business philosophy of centralized systems can often lead to large unwieldly bureaucracies that stagnate. However, there is a lack of control with distributed systems. New technologies must be tied to the business philosophy of each individual company.

Interpretation presents a good example of why change and acceptance of the new technologies has and will continue to be slow. Seismic interpreters have traditionally gone through an apprenticeship of five to ten years. Understanding how to extract geological information from seismic sections



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takes experience. The people that are good interpreters went through this apprenticeship. It is often hard to see how a machine can help substitute for experience. Confusion has diminished from the time computers first entered the market place. As procedures are shown to be truly effective, they will be incorporated.

TRAINING EXPLORATIONISTS

The biggest problem for oil and gas exploration in the 1980s is the shortage of well-trained explorationists. There are many scientists being attracted from related fields like physics, mathematics and geochemistry. However, it takes several years to educate them in geology, processing techniques, data collection procedures, etc. There is tremendous competition for those who do have the training and any experience. Small companies are buying the best brains and experience available. The Houston division of one major oil company has had such a large personnel turnover that over half of the present work force has not been with the company long enough to have earned vacation time.

Steps are being taken to train more explorationists in universities throughout the world. With government funds drying up, one of the biggest boons to applied geophysical education and research has been the development of industry-sponsored research consortia. The impact of these groups is starting to be seen in the literature and in the job market. One mid-sized oil company is sponsoring at least 13 separate university research consortia.

The University of Houston is an example of one school that is attempting to meet this need for educating applied geophysicists. In 1977 Dr. Fred Hilterman in the Department of Geology and Dr. Keith Wang in the Department of Electrical Engineering organized one of these research groups to specifically study physical modeling and in general 3D seismic techniqes (Hilterman *et al*, 1981). They have since left the University of Houston but the Seismic Acoustics Laboratory (SAL) continues under the direction of Dr. G.H.F. Gardner and Dr. John A. McDonald with the sponsorship of 42 major oil exploration companies. The SAL has been so successful that there has been a whole new organization formed to develop applied geophysical research and help train explorationists. This new organization is called the Allied Geophysical Laboratories (AGL) and presently consists of six separate research groups, with the SAL as the largest. AGL is an interdisciplinary enterprise being jointly endorsed and recognized by the departments of geology and electrical engineering.

Two grants of $500,000 each to the newly-named Department of Geosciences started two of the other groups. One grant, from the Cullen Foundation, has been used to help establish the Cullen Image Processing Laboratory. This lab is working on new ways to access the volumes of information in 3D surveys and ways to display and interact with this data. A vector refresh graphics system with a raster segment generator has been obtained, and a true 3D display device is expected the first of 1982.

The other grant, from the W.M. Keck Foundation (named for the late William Keck, Sr., founder of Superior Oil Co.), was used to purchase a VAX-based Digicon geophysical processing system. This computer system forms the basis for the Keck Research

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Computation Laboratory. Thanks to a grant from CDC this lab is also doing work on a CDC super computer in Minneapolis via Cybernet. The other labs are the Field Research Laboratory, the Paleomagnetics Laboratory, and the Well Logging Laboratory. This last lab is in its third year under the Department of Electrical Engineering and has 16 sponsors.

The AGL is providing a synergistic forum for developing and expanding 3D seismic techniques. More importantly it, like other university research consortia, is providing hands-on training in modern exploration geophysics techniques for students from both electrical engineering and geology fields.

Summary. The new technological breakthroughs of the 1970s and 1980s are changing the methods of exploring for petroleum energy. Many of these changes are a result of computer technology, ranging from microcomputer developments to special configurations of mini-computers to the new super computers. These developments are greatly affecting data collection, all the way from surveying to recording technology. New methods for displaying and working with seismic data point to the possibility of interactive 3D interpretation. However, technology is not an answer to all exploration problems. In order for an impact to be made, these new developments need to be coupled with properly trained personnel to bring about smoother transitions. University applied research consortia are one of the best ways to develop the needed manpower to help solve the energy problem.

ACKNOWLEDGMENTS

Many of the ideas presented in this article are from conversations with my colleagues and industry contacts at the Allied Geophysical Laboratories. Special thanks go to Gerry Gardner, John McDonald, Anne Simpson and my family.

REFERENCES

Arnason, Byron, Mobil Exploration and Producing Services, Inc., field operations, personal communication, 1981.

Bone, M. R., B. Giles, E. Pegland, "Seismic Data Analysis with Time Seiscrop Techniques," annual SEG meeting, Denver, Oct. 1975, (see also abstract, *Geophysics*, V. 41, No. 2, p. 342, 1976).

Dillahunty, R. C., J. L. Fash, L. R. Parsley and D. W. Townsend, "Geophysical Data Bases: System Considerations," *Geophysical Prospecting*, V. 28, No. 4, pp. 495-512, 1980.

Gardner, G. H. F., "3D Seismic Techniques Introduction," SEG 3D Seismic Techniques School notes, Segment 1, 1979.

Hilterman, F. J., H. R. Nelson, Jr., G. H. F. Gardner, Offshore Technology Conference, "Physical Modeling: An Aid for Production Geophysicists," paper No. 4022, pp. 139-147, 1981.

Jansson, D. G., E. P. Berlin, Jr., Isidor Straus, J. T. Goodhue, "A Three-Dimensional Computer Display," SAL *Semi-Annual Progress Review*, pp. F8-25, 1981.

Johnson, Steven and Brent Baxter, "Utah 3D Volume Viewer a True 3D Display for Graphics Geophysical and Other Applications," SAL *Semi-Annual Progress Review*, V. 5, pp. 225-232, 1980.

Kosloff, D. D., visiting professor of geophysics at University of Houston, personal communication, 1981.

McDonald, J. A., "Design of Areal Collection Systems," SEG 3D Seismic Techniques School notes, Segment 7, 1979.

Nelson, H. R., Jr., F. J. Hilterman, G. H. F. Gardner, "Introduction to Interactive 3D Interpretation," *SEG Proceedings*, V. 1, pp. 415-458, 1980, (see also abstract, *Geophysics*, V. 46, No. 4, p. 409).

Rice, R. B., *et al*, "Developments on Exploration Geophysics, 1975-1989," *Geophysics*, V. 16, No. 8, pp. 1088-1099, 1981.

Ricks, D. E., "A New Interactive 3D Display Provides High Resolution Color Images," SAL *Semi-Annual Progress Review*, V. 7, pp. F41-48, 1981.

Sher, L. D., "The Space Graph Display: Principles of Operation and Application," SAL *Semi-Annual Progress Review*, V. 5, pp. 212-214, 1980.

Simpson, A. L., "The Image Processing Lab: Status and Plans," handout presented to SAL Semi-Annual Meeting, 1981. ■

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