CURRENT TRENDS IN GEOPHYSICS

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الخلاصة

ان الاهداف المتوخاه من الاستكشافات الجيوفيزيائية تتجه بشكل وطيد نحو تقديرات كمية وجيولوجية متقدمة بشكل أكبر .

ومنذ عقد مضى من الزمن كان يكتفى بمسح البنية الاجمالية لمنطقة معينة ، أما الآن فانه ينظر الى التقديرات الموثوقة لبارامترات الصخور ، مثل مقاييس السرعة والكثافة وأخيراً عنصر الهيدروكربون .

وفي سبيل استخلاص مثل هذه المعلومات الهندسية الدقيقة والمعلومات الخاصة بعلم الصخور وضعت الطرائق الجيوفيزيائية احتياجات ملحة على عمليتي التكنولوجيا وتسجيل المعلومات معاً ، ومع استمرار هذه الاتجاهات بالنسبة المرتفعة لانحلال الصخور الا أن ثقة الاستكشافات في الاداة الجيوفيزيائية كمؤشر كمي للهيدروكربون تنمو بشكل مستمر .

ABSTRACT

The projected goals of geophysical exploration have been shifting steadily toward more quantitative and sophisticated geologic estimates. Where a decade ago we might have been satisfied to map the gross structure in the zone of interest, we now hope to determine reliable estimates of such rock parameters as velocity, density, and, ultimately, hydrocarbon content.

To extract such precise geometric and lithologic information from surface geophysical methods places heavy demands on both the recording and processing technology. As these high resolution trends continue, the explorationist's confidence in the geophysical tool as a quantitative hydrocarbon predictor grows accordingly.

CURRENT TRENDS IN GEOPHYSICS

INTRODUCTION

Geophysics is advancing more rapidly today than at any time in the history of the industry. The gains have been made on a broad front ranging from innovative recording techniques to the imaginative use of color displays in interpretation.

The goal of modern geophysics may be expressed as *resolution*, both structurally and lithologically. Today's explorationist must be prepared to predict fluid content as well as the entrapment structure. The days of the "geophysical success" - the structure was there, but the oil wasn't-are gone for good.

The resolution required to distinguish an igneous "bright spot" from its gaseous counterpart places heavy demands on all phases of geophysical exploration, from field to final display.

While there is much overlap and interdependency in today's trends, we will identify four areas of especially rapid growth to illustrate the current advances: (1) field methods; (2) geoseismic modeling; (3) wave equation processing; (4) interpretation.

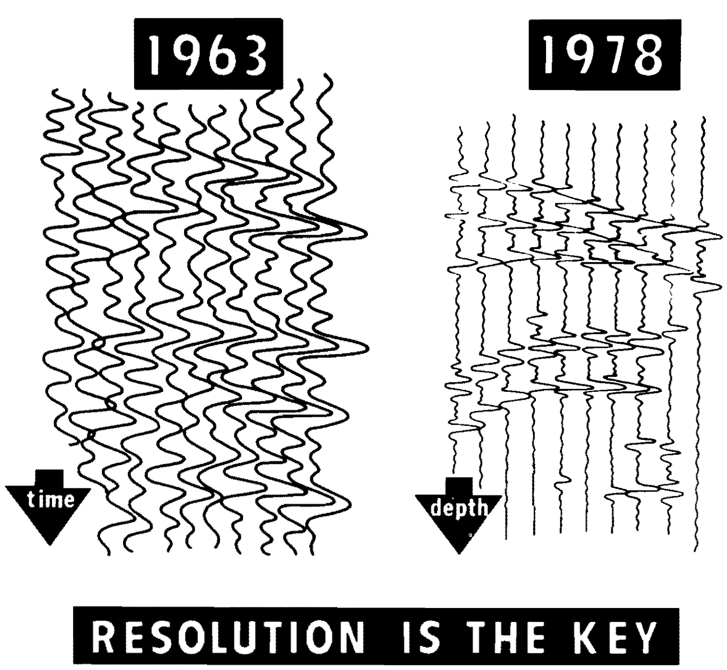

Figure 1

1. FIELD METHODS

Essential to the goal of resolution is a saturation of *dense sampling* in three dimensions (two spatial, and time). The accuracy and resolving power of the subsequent processing steps depend on adequate sampling. Four millisecond (msc) digital time sampling has given way to a 2 msec rate with $1, \frac{1}{2}$, or even $\frac{1}{2}$ msec sampling in the offing. Spatially, the trend is toward

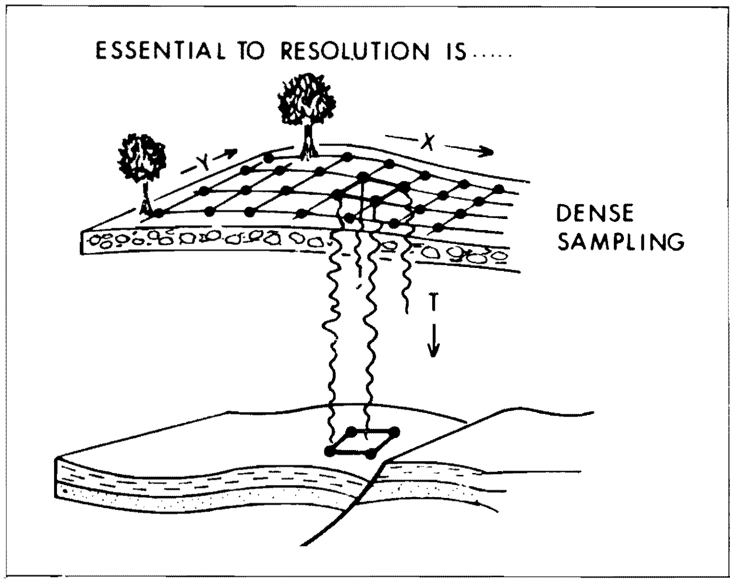

Figure 2

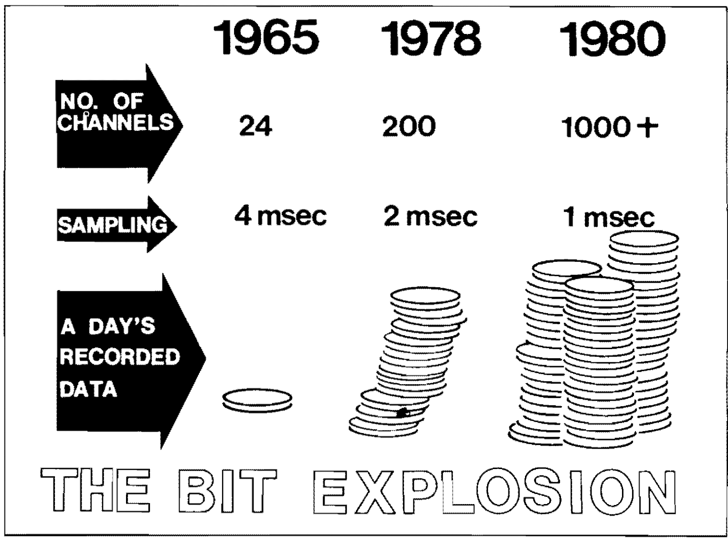

Figure 3

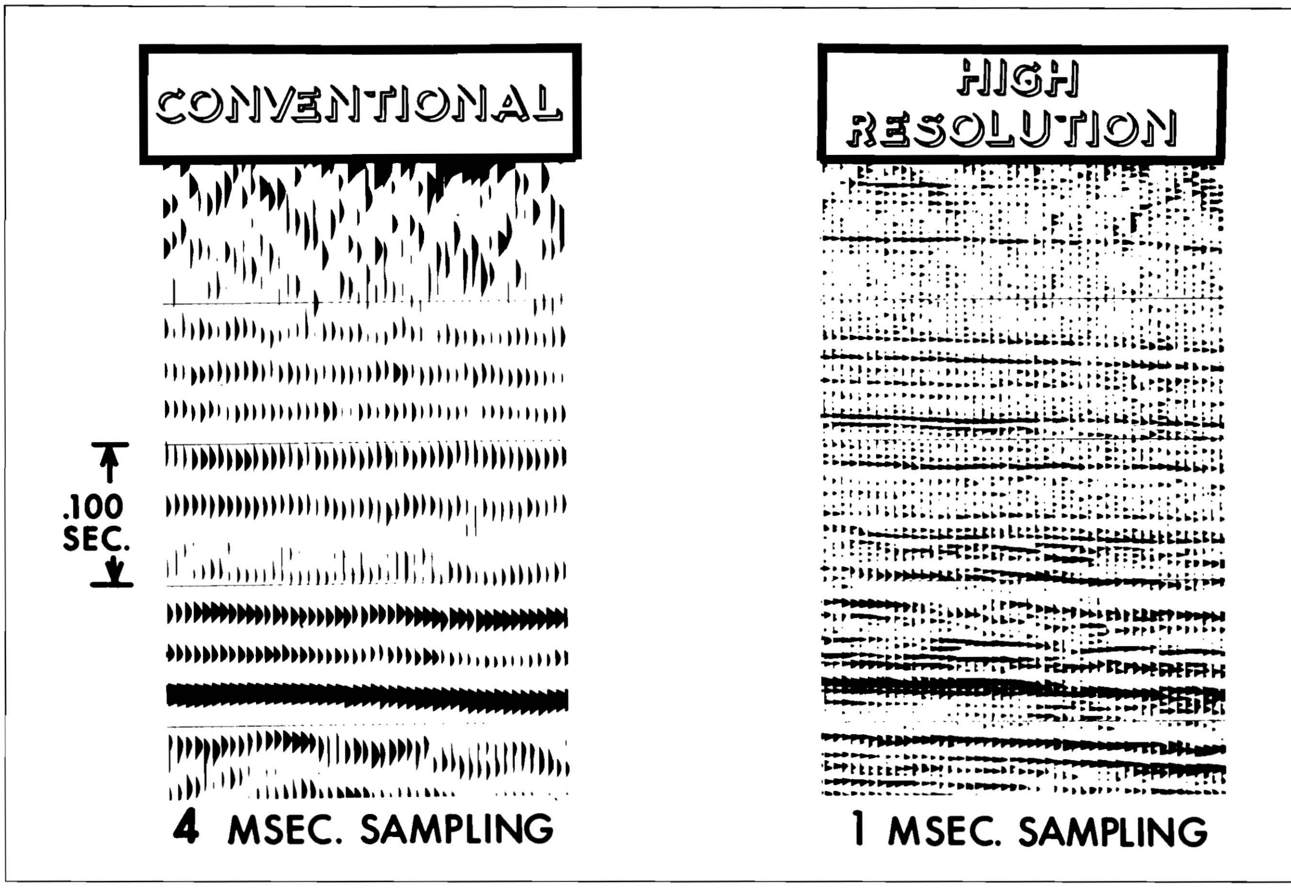

Figure 4

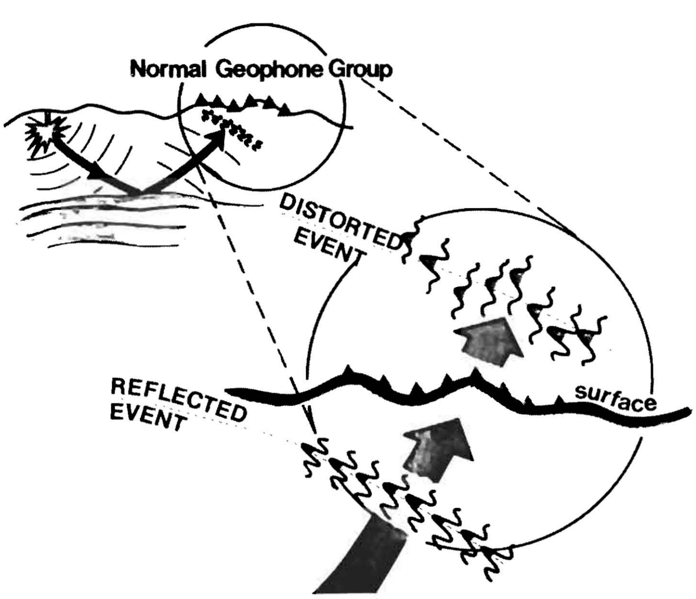

Figure 5

finer group intervals with individual recording channels for each of the receivers within a group.

This *"super" multi-channel recording* strains the capacity of much of our modern instrumentation. Both land and marine recordings require scores of digital tapes, or other media such as video discs, to store the massive amount of data generated.

The increased costs are appreciable, but commensurate with the enhanced information of the seismic display. Consider Figure 4 in which we compare a conventional recording (4 msec sampling) with its high resolution counterpart sampled at 1 msec. We note the sharp delineation of events so characteristic of the higher and broader frequency content of the high resolution section. In both displays the ground position and type of receivers were identical.

The increase in resolution wrought by finer temporal sampling is obvious from the diagram. Less apparent is the need for *separate recording channels* for geophones *within a group*, since eventually they are to

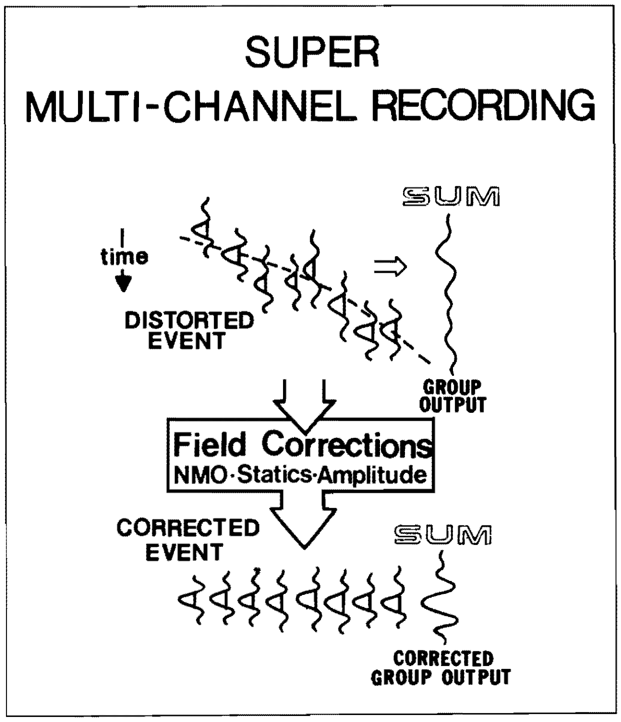

Figure 6

be combined (summed) into a single seismic trace. Given that an array of geophones is desirable for the purpose of attenuating ground roll and other surface noise, what benefit derives from individual recording? Figures 5 and 6 provide the answer.

Two basic problems associated with geophone arrays are depicted in Figure 5. The reflected wave from a subsurface horizon of interest is usually a smooth surface as it returns to the recording station. If the offset distance between the source and receiver is appreciable, as it often is with modern techniques, then there will be a significant time differential between the arrival of the event at the near and far phone of the group. This time shift amounts to "normal moveout" across the array. If the separate signals were summed before this underisable differential is removed, the even would be badly smeared, thus destroying its resolution in time and amplitude. Each group having a different offset will cause this distorting effect to vary. Furthermore, the smearing action will vary with recording time, just as normal moveout does.

A second deteriorating feature is shown as the static pattern across the array caused by elevation and velocity differences in the near surface. A summation without correction of this problem would lead to an attenuated group output trace as shown in the top part of Figure 6.

Super multi-channel recording allows field correction of these and other difficulties (e.g., amplitude variations) *prior to summation.* As shown in the lower pare of Figure 6, the group output is significantly enhanced by the process. We anticipate an increasing use of this procedure in both land and marine recording.

Other areas showing rapid development are: shear wave recording; land and marine sources, and telemetry.

A group of some 13 oil companies, led by Conoco, has recently completed a broad geographical and geological sampling of *shear wave* data in the United States. Vibrating shear wave sources and horizontally oriented receivers have produced shear information of surprisingly high signal-to-noise ratio.

Controlled and monitored *sources*, both land and marine, are being developed and finely tuned on an acceletated schedule. Air gun technology, for example, is at the point where a stable, broad band, high resolution wavelet is consistently generated. The significance of this in subsequent wavelet processing cannot be over-emphasized.

Digital *telemetry* of seismic signals has benefitted from the space age technology. Digitization at the receiver coupled with multiplexed transmission, has reduced, in a major way, the "cable noise" problems of yesteryear.

The emergence of 3-dimensional migration, as an important processing tool, has made *areal recording coverage* a virtual necessity for detailed subsurface delineation. A simple method of producing areal coverage is shown in the diagram below (Figure 7). In the perpendicular arrangement of shots and receivers, reflection points are shown as the mid-point between each shot and the line of geophones (solid dots). Each successive shot produces a line of reflection points as seen by the geophone array. The grid of open circles shows the total areal coverage of the 3-D recording.

A number of imaginative schemes for recording areal data with efficiency and no loss of conventional multi-fold, common depth point (CDP) coverage have been developed by the various geophysical contractors. In Figures 8a - 8e, we see first the area to be 3-dimensionally covered, with CDP data required along the indicated lines.

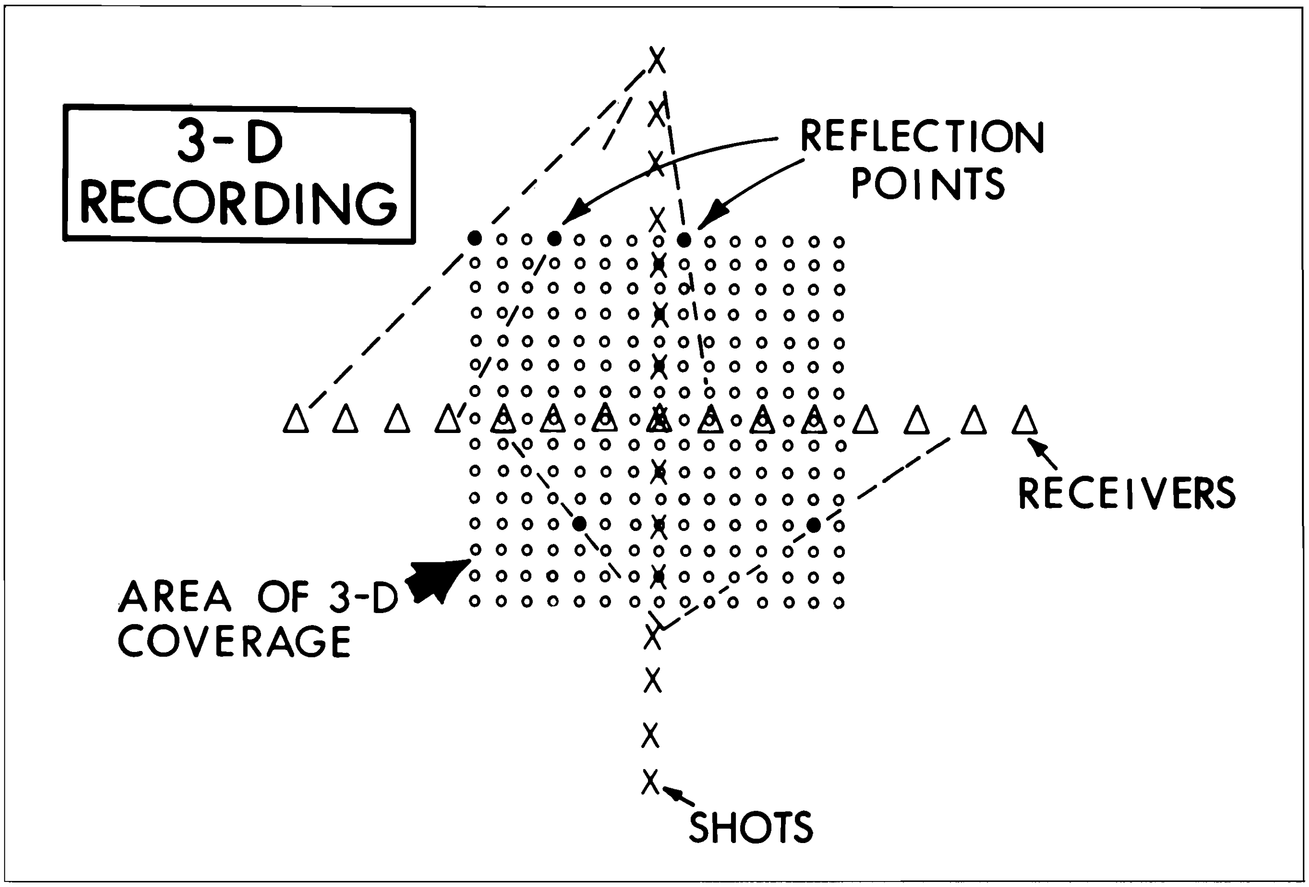

Figure 7

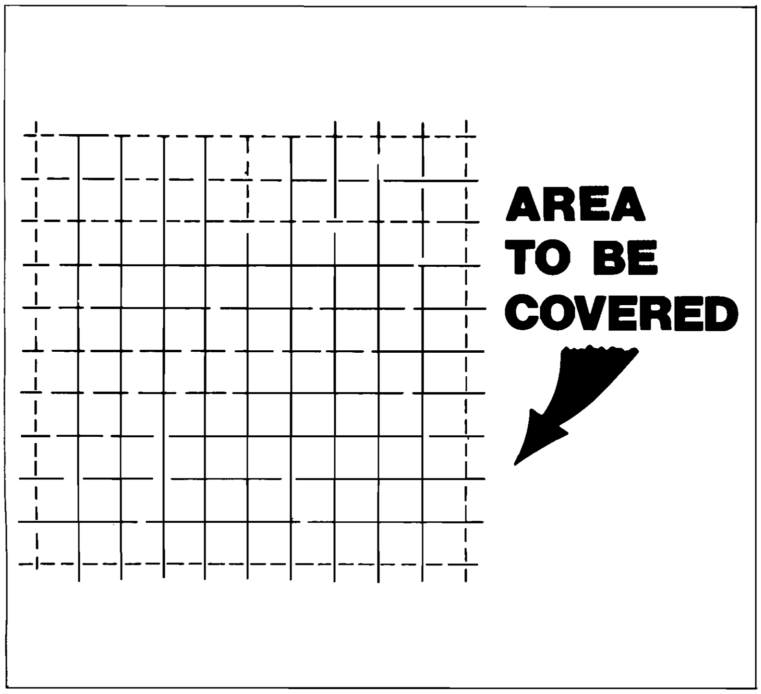

Figure 8 a

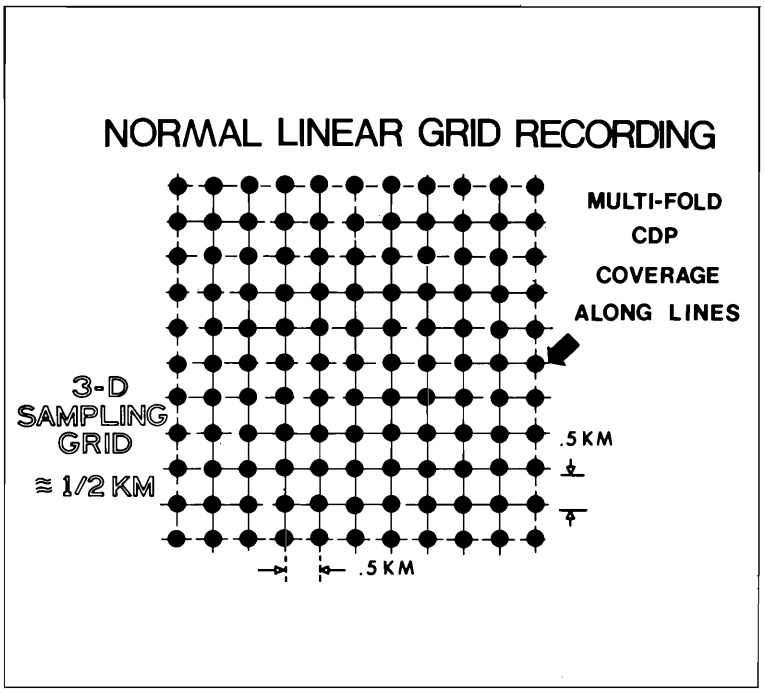

Figure 8 b

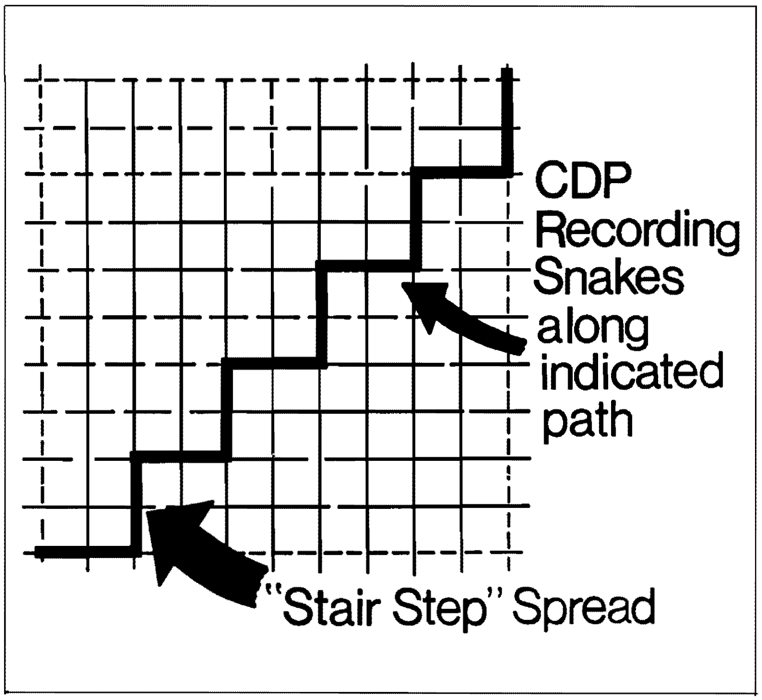

Figure 8*c*

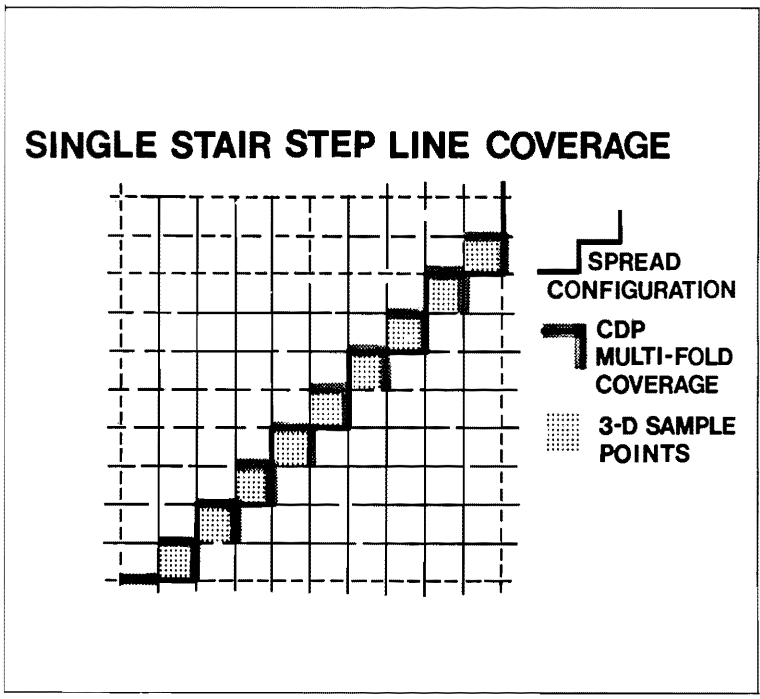

Figure 8*d*

Normal roll-along recording along the given lines (Figure 8b) produces the required CDP coverage, but the 3-D sampling grid at 0.5 km is far too coarse for 3-D processing.

Recently, in a jungle environment, a technique was used which yields the desired multi-fold CDP cover while at the same time, and at no appreciable increase in cost, records a much *finer grid of areal data.* Figure 8c depicts the basic method in which the roll-along recording is done along a "stair-stepped" configuration cutting more or less diagonally across the area. The resulting coverage for one such stair-step line is shown in Figure 8d. The shaded lines show a set of disjointed CDP coverage, while the square dotted zones symbolise single-fold 3-D sampling.

When a series of such lines are recorded, the disjointed CDP segments fit together and we find that the areal coverage is complete (Figure 8e). The resulting 20m grid size is more than adequate for a wide range of 3-D processing, including migration.

2. GEO-SEISMIC MODELING

Interpretation is essentially a process that might best be described as model fitting. The explorationist conceives a geologic model which he calculates would reasonably give rise to the observed geophysical data. In the seismic case, such a model, given the governing physical laws would generate a set of simulated seismic traces which would match or *fit the actual recording.*

In the past, this procedure has been an implicit or 'mental' modeling. Of late the process has become well defined and highly computerized. Interpretation is fast becoming an explicit, iterative modeling of structure and lithology. While the computer makes it all possible, it should be noted that man is by no means out of the picture. His direct control at every stage is vital and indispensable.

Geophysical modeling takes on two forms: forward, as illustrated in Figure 9, and inverse, shown Figure 10. The geophysicist often makes use of both schemes in exploration.

The *forward modeling* (Figure 9) shows the evolution of a theoretical seismic trace. Starting with well data, we extract velocity and density estimates whose products from an "impedance" log. The contrast in impedance values yield a set of reflection coefficients (the stickogram). Using an estimate of a seismic *wavelet* (perhaps from an air gun monitored signature, or like source) the theoretical seismogram is constructed by the process of convolution - essentially a replacement of the sticks with the assumed wavelet. The seismic model trace may then be compared to actual data to uncover significant variations which are suggestive of stratigraphic change.

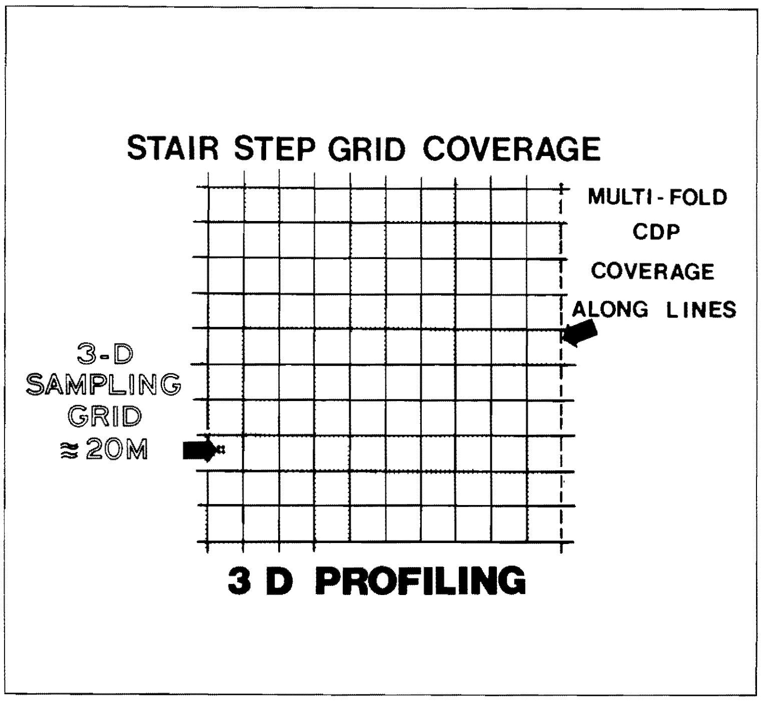

Figure 8*e*

Inverse modeling is, of course, a direct expression of the interpretive process. In Figure 10 we start with the recorded data (the seismic trace) and work our way backwards to the geologic column. Not a trivial task since the path is strewn with pitfalls, ambiguities, and over-simplifications. Getting from the wiggle trace to something resembling a stickogram is a major and often unsuccessful undertaking. There is, however, much progress being made in this area. Reports of verified successes are growing numerous and widespread. Virtually every geophysical contractor offers a program which leads to some estimate of geologic parameters.

Figure 11 through 13 illustrates a general approach to inverse modeling. They are not intended to duplicate any particular scheme, but to demonstrate some of the basic elements common to most of the techniques for *geo-seismic modeling*.

Essential to all modeling methods is some way to estimate the seismic "wavelet" which is embedded in the

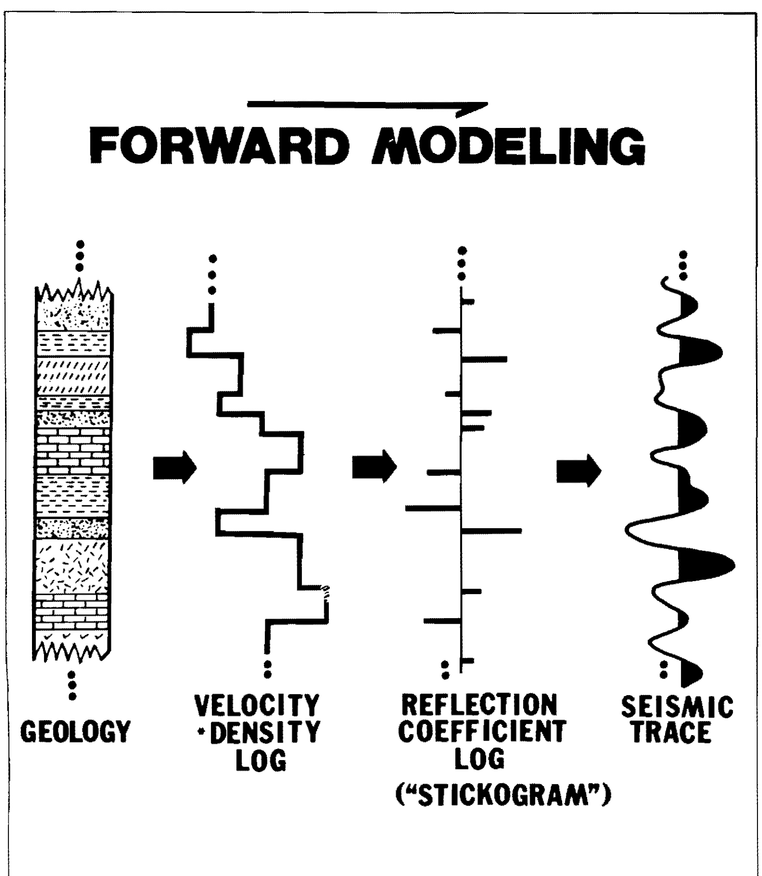

Figure 9

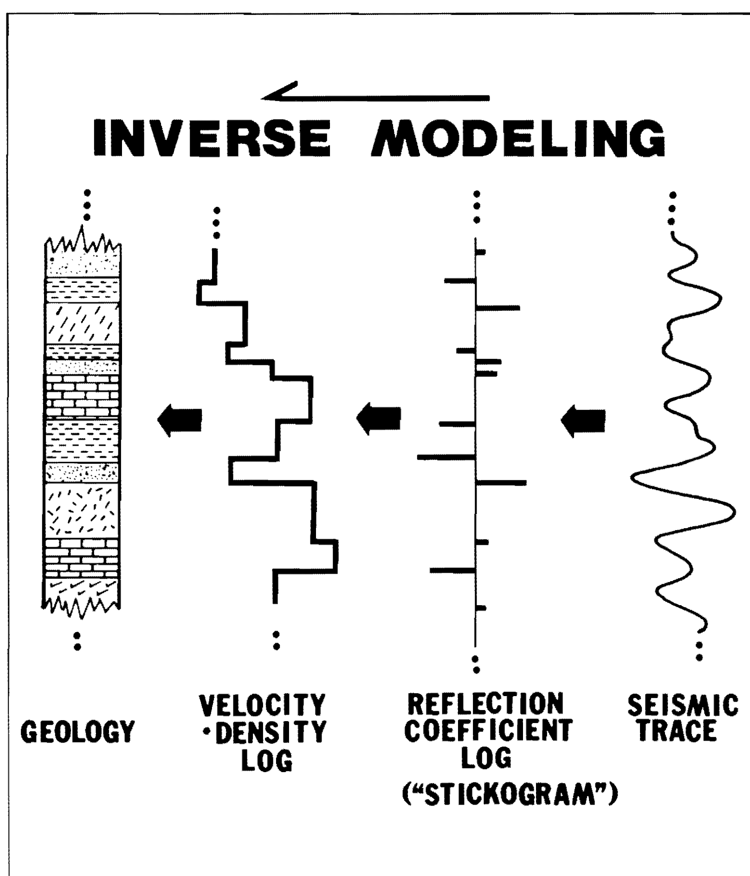

Figure 10

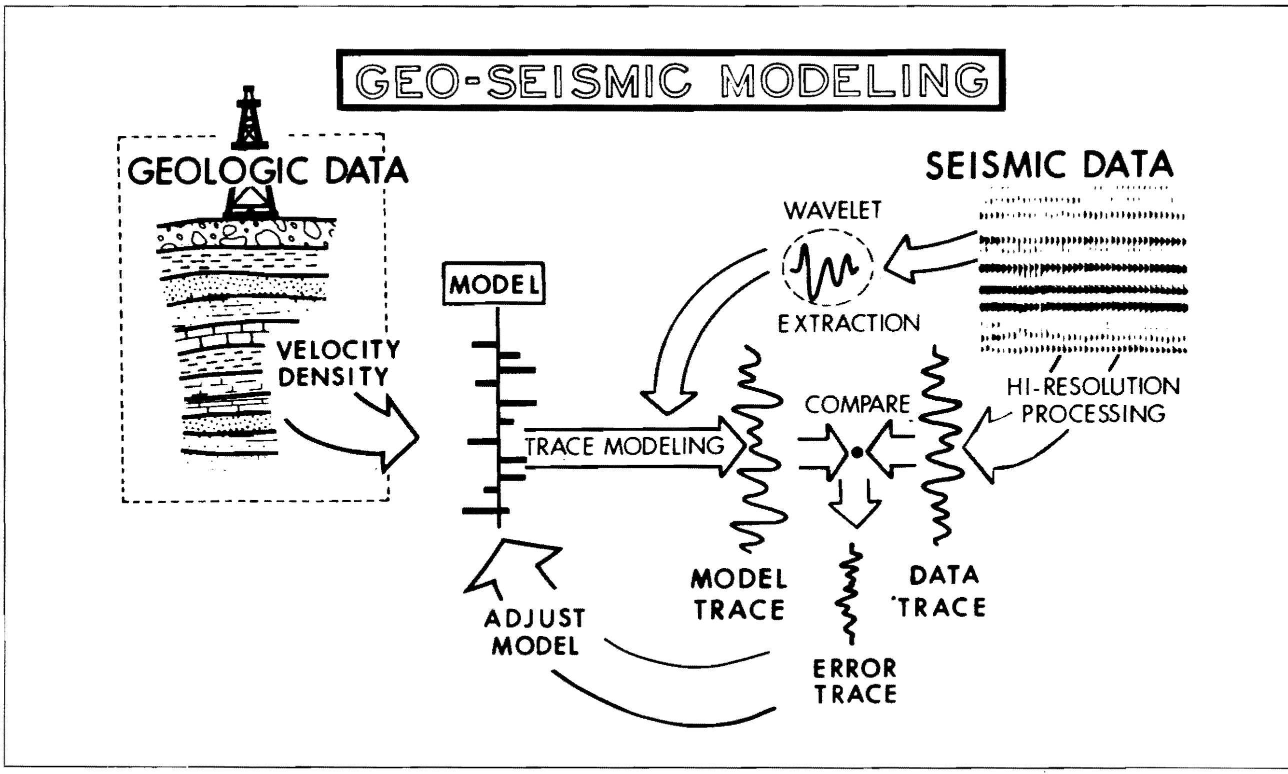

Figure 11

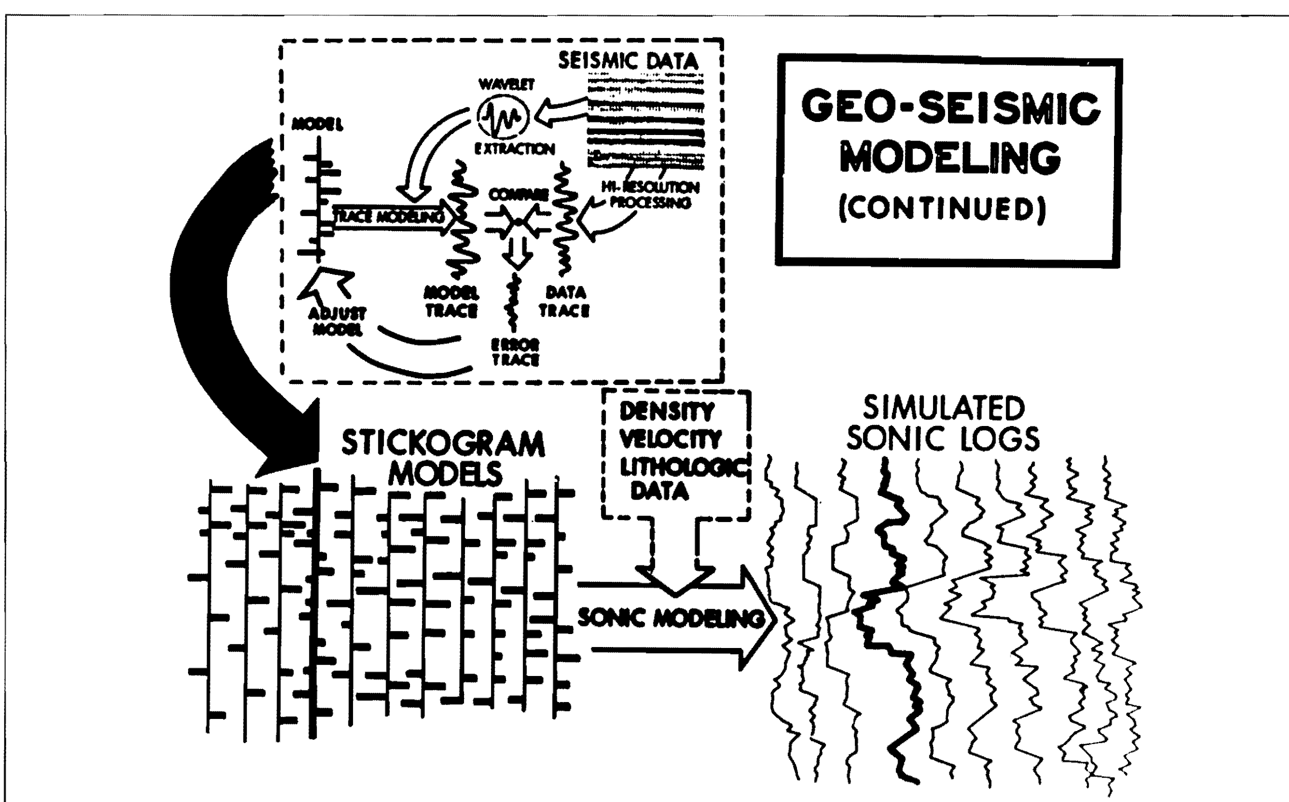

Figure 12

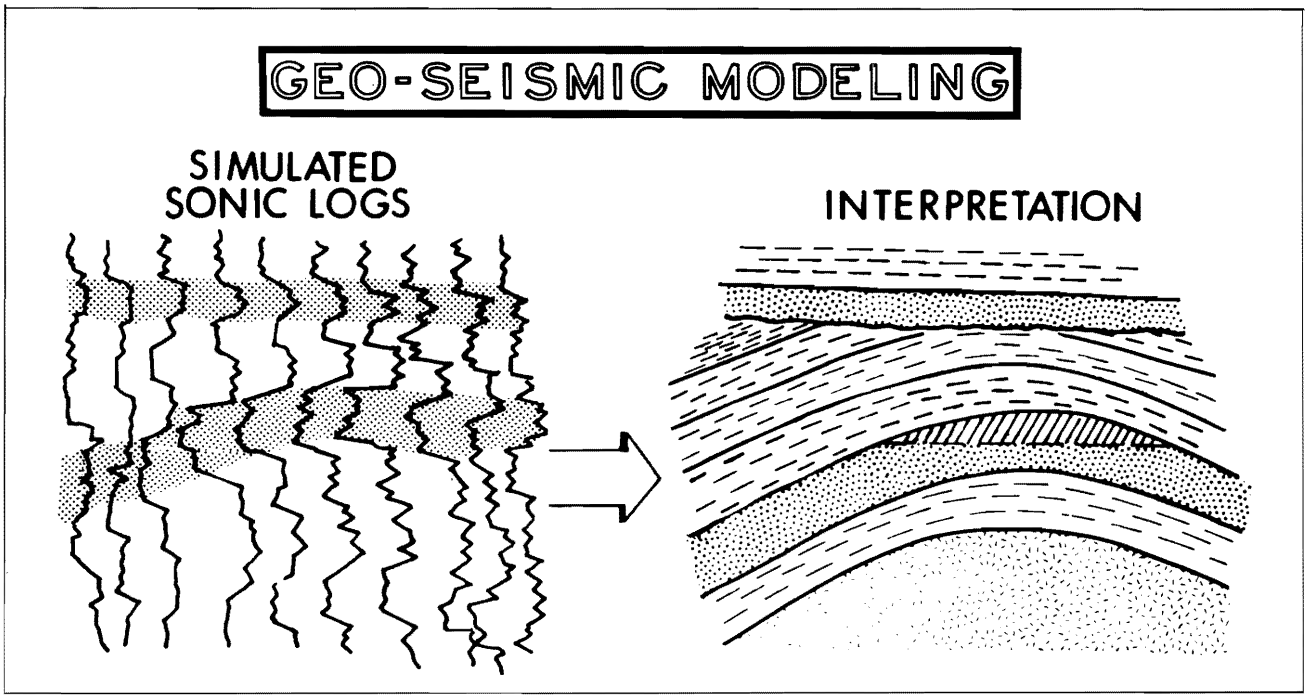

Figure 13

data. The wavelet, which is a combination of effects ranging from the source to the recording instruments, is uncovered by both statistical and deterministic methods. The source wavelet is often amenable to direct measurement as is done, for example, in the case of Vibroseis or air gun signature. Near surface effects are usually approached statistically as with deconvolution. In any case, the best estimate of the wavelet is extracted for use in creating the *model trace* from the stickogram (reflection coefficient series) model, and for high resolution processing of the actual data.

The starting model for the stickogram might come from nearby well data or any other source of geologic information. Once initialized, the basic idea is to compare the synthesized trace with a representative sample of the "cleaned up" actual data. This comparison step may take the form of a simple subtraction leaving a difference or *error trace.* The total power of this error trace becomes the measure of the goodness of fit (or lack of it). A high amplitude error function would require an *adjustment* of the model in such a way so as to reduce the error.

The iterative procedure continues until the error falls below some acceptable threshold. At that point, we *extract the model* for use in a linear or areal array of similarly derived stickograms (Figure 12). This suite is pushed further toward the ultimate goal by simulating *sonic* (*velocity*) *logs* using, if available, external information on density, velocity or other pertinent lithologic parameters.

From this point we continue the inverse modeling by forming a geologic picture structurally and lithologically compatible with the simulated sonic logs. This stage is illustrated in Figure 13. Often this final step in the interpretive process is enhanced through the use of enriched display techniques (see under 'interpretation, Section 4).

3. WAVE EQUATION PROCESSING

Spearheaded by Jon Claerbout's Stanford Exploration Project (SEP), the field of wave equation work is probably the most obvious area of rapid and beneficial advance in recent geophysical history. The equation, which gives a physical description of the propagation of seismic waves in terms of earth parameters, has led to a dazzling array of varied applications. While migration is usually the first thing we think of in this connection, wave equation processing is by no means limited to this important concept. Improved velocity estimates, stacking procedures, coherency, near surface resolution, modeling, attenuation measurements, and so forth, are but a few of the myriad of applications pouring forth from the project.

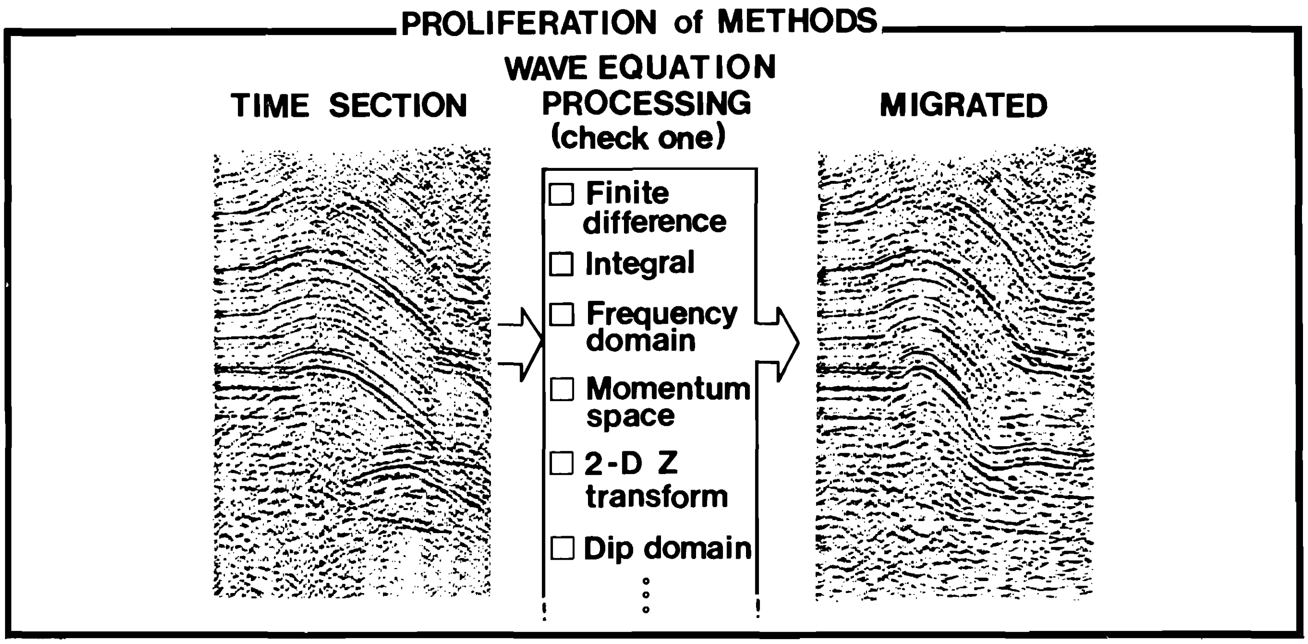

Figure 14

While the work at Stanford led directly to the early breakthroughs in unravelling the mysteries of the wave equation, geophysicists in other laboratories have been busy refining of redefining the basic SEP techniques. Figure 14 suggests the unrestrained growth of pathways from seismic time section to migrated section.

Seemingly quite different in their mathematical algorithms, the various methods lead, nevertheless, to the same basic product. Diffractions are collapsed, buried foci are unravelled, synclines are expanded, anticlines are shrunk, and dipping beds are put in their place, all while maintaining proper amplitude and frequency perspective.

There are differences, however, and these are usually cited as advantages for the particular method at hand. Some of the various advantages attributed to one or more of the wave equation approaches are listed in Table 1. For the most part, these claims are valid, and the proliferation of methods, therefore, has proven to be of real interpretational value to the explorationist even at the expense of added technological confusion.

One specific area which has received much study is *migration before stack*. It has long been known that application of the wave equation to a stacked time section is not a strictly valid concept. One way of expressing the difficulty is to say that events of different dips require different stacking velocities (for normal moveout removal). In the upper part of Figure 15, we see this idea illustrated.

The same data has been stacked using five different velocity functions, generally increasing from right to left. For the area in question, the velocity function actually used yields the stack, we see in the central portion of the figure. A feature of note is the presence of a very steep and coherent event best shown in the high velocity stack (far left). This is thought to be the fault plane reflection. This critical and diagnostic event has all but disappeared from the central stack. Were this time section to be migrated, the event would not be available for placement in its proper geometric position. Simply stated: it was stacked with the wrong velocity.

The lower part of Figure 15 demonstrates the potential benefits of migration before stack. In this procedure, common offset data are first separately migrated and then followed by a conventional stack. The effect is elimination of dip dependent velocity prior to stacking. The chosen velocity function is then suitable for proper normal moveout removal. Observe that the fault plane reflection is now clearly visible on the central stack.

Migration before stack is not without disadvantages, however. First, the present cost of such a program would be prohibitive except in special cases. Fuether, the procedure leads directly to a migrated section and leaves the interpreter without his familiar CDPS time section, Digicon recently reported on a method which attacks these two objections while enjoying the basic benefits of migration before stack.

Table 1. Advantages Claimed for Various Wave Equation Approaches

Handling of Steep Dip
Less Migration 'Noise'
Lateral Velocity Variation
Near Surface Problems
Velocity Estimates
Coherence of Stack
Economy

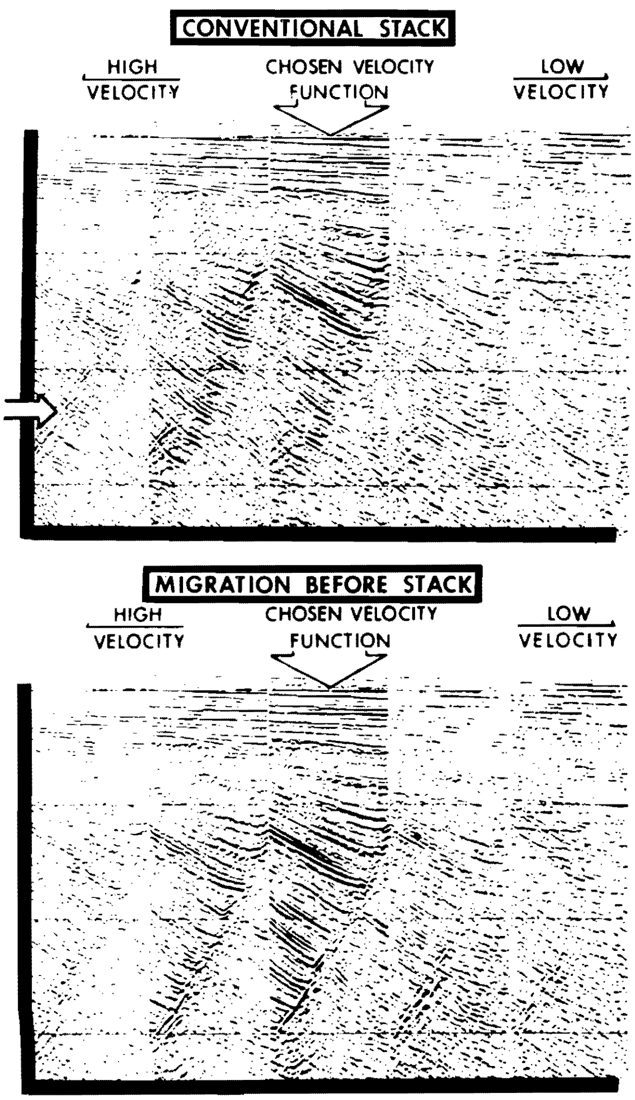

Figure 15

Called DEVILISH (Dipping Event Velocity Inequalities Licked), the program essentially does what might best be described as a partial migration before stack. A "partial migration" applied to a diffraction curve, for instance, would squeeze the curve inward, but not totally collapse it. The effect of this step is to remove the stacking velocity differences at different dips, just as full migration before stack attempts to do.

Figure 16 compares a conventional stack ("CDPSUM") followed by migration, with Digicon's DEVILISH before stack. While the flatish events are essentially the same for both procedures, we note a very definite improvement in the DEVILISH section with regard to the steeply dipping events, particularly the fault plane reflection. The interpretational benefits are obvious.

In Digicon's report, the DEVILISH-stack-migrate product has been shown essentially equivalent to a full migration before stack.

While it may seem to some that the geophysicist is blissfully oblivious to the 3-dimensionality of the world, as he continues to produce flat pictures of volumetric traps, it should be said in his defense that until recently there really wasn't much he could do about it.

Aware that what appears on a seismic time section is not restricted to geologic reflectors from a narrow slice immediately below the recording line, the geophysical processor was nevertheless powerless to separate the "out-of-the-plane-of-section" energy from the valid events directly beneath. The problem was that the old time linear recording gave no usable information about the third dimension. More recently, the recording techniques have been aimed at acquiring areal coverage for attacking the 3-dimensional problem (see under field methods, Section 1). The processing of these data has kept pace through *3-D migration.*

An immediate and obvious benefit of such migration is the placement of reflectors in their proper spatial position. After the movement of the events within the volume of seismic data, the result may be displayed as a vertical slice through the migrated information. Only then does the section truly represent a cross-sectional view of the earth. Simple 3-D modeling experiments have forcefully demonstrated the deceptive nature of 2-D processed displays of 3-dimensional data. Phantom events, displaced structures, interference are just a few of the disturbing features which are largely eliminated by 3-D recording and processing.

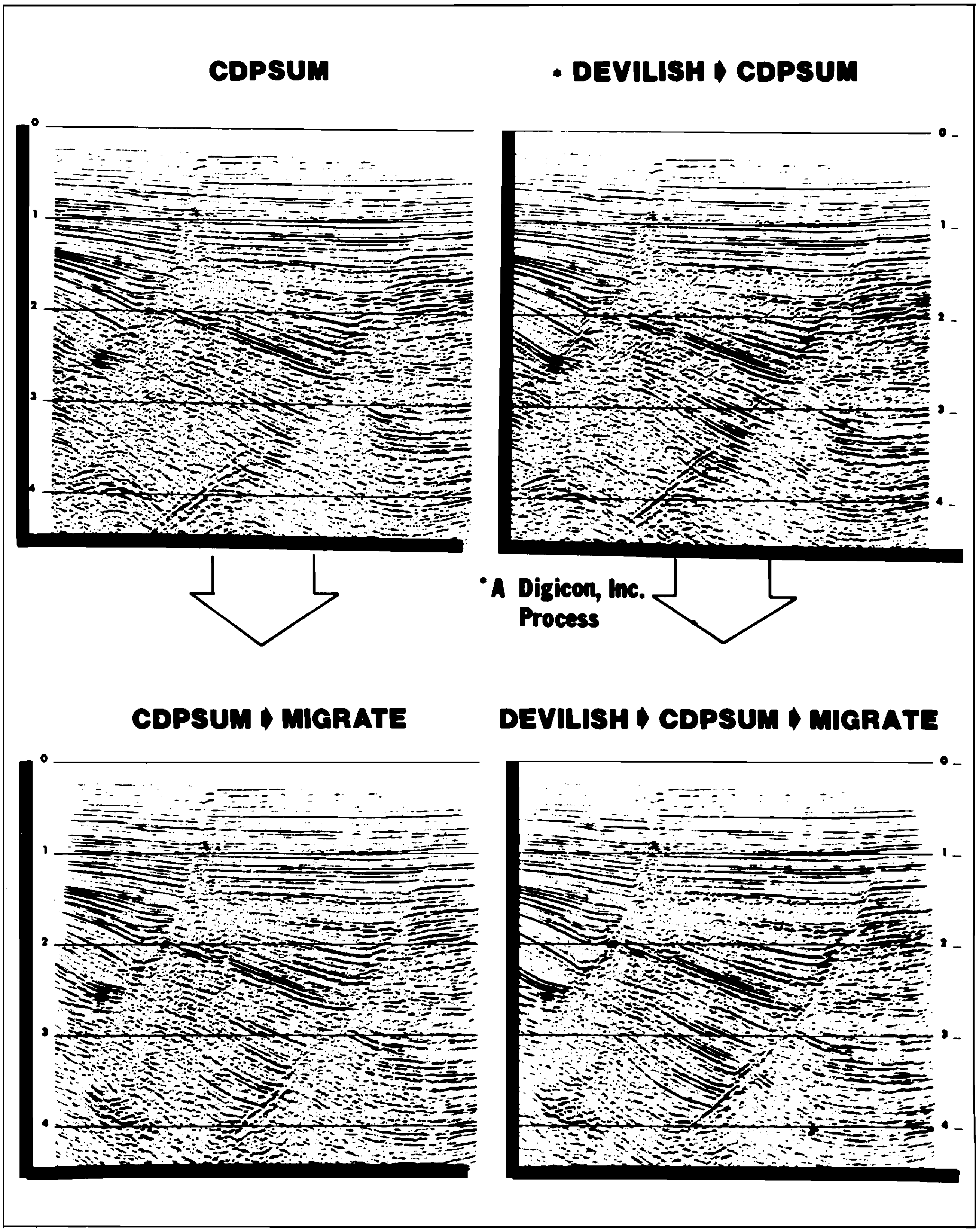
CDPSUM
* DEVILISH ▶ CDPSUM
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Figure 16

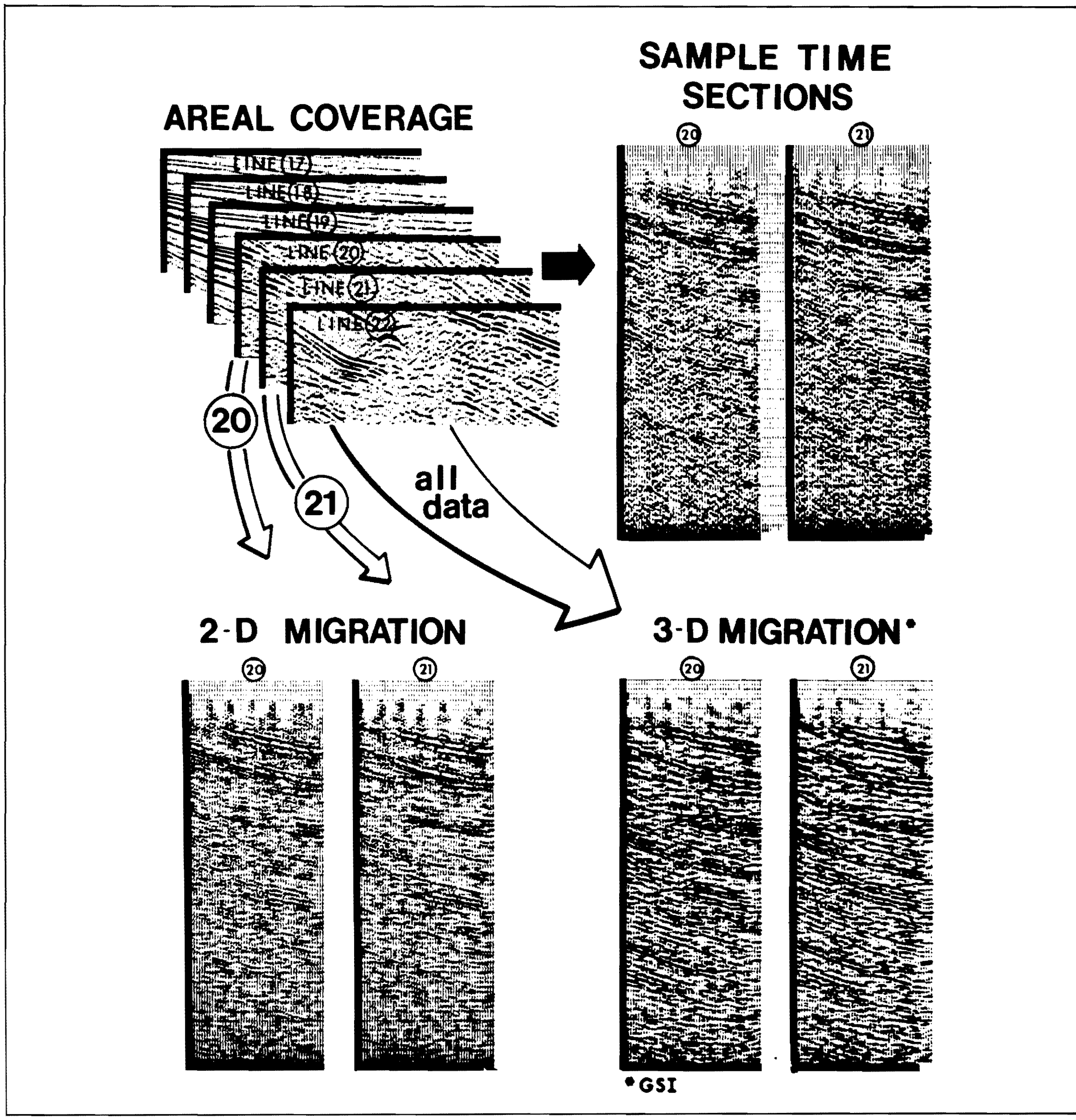

Figure 17

A somewhat unexpected benefit of 3-D migration is the significant improvement in *coherency* of events once the out-of-of-plane interference has been removed. Figure 17 shows a comparison of two and three dimensional migrãtion. GSI recorded and processed this grid of seismic data. In the upper left we diagrammatically depict a set of closely spaced parallel lines. Another set of perpendicular lines, not shown, forms the areal grid for the prospect. At the upper right are given two representative samples of the seismic lines, here displayed as stacked *time sections*.

In the lower left we show *2-D migrations* of the sample lines. In each case, the only data used in the migration was that which was available from the corresponding time section, that is, 2-D migrated section 21 contains information from time section 21 only.

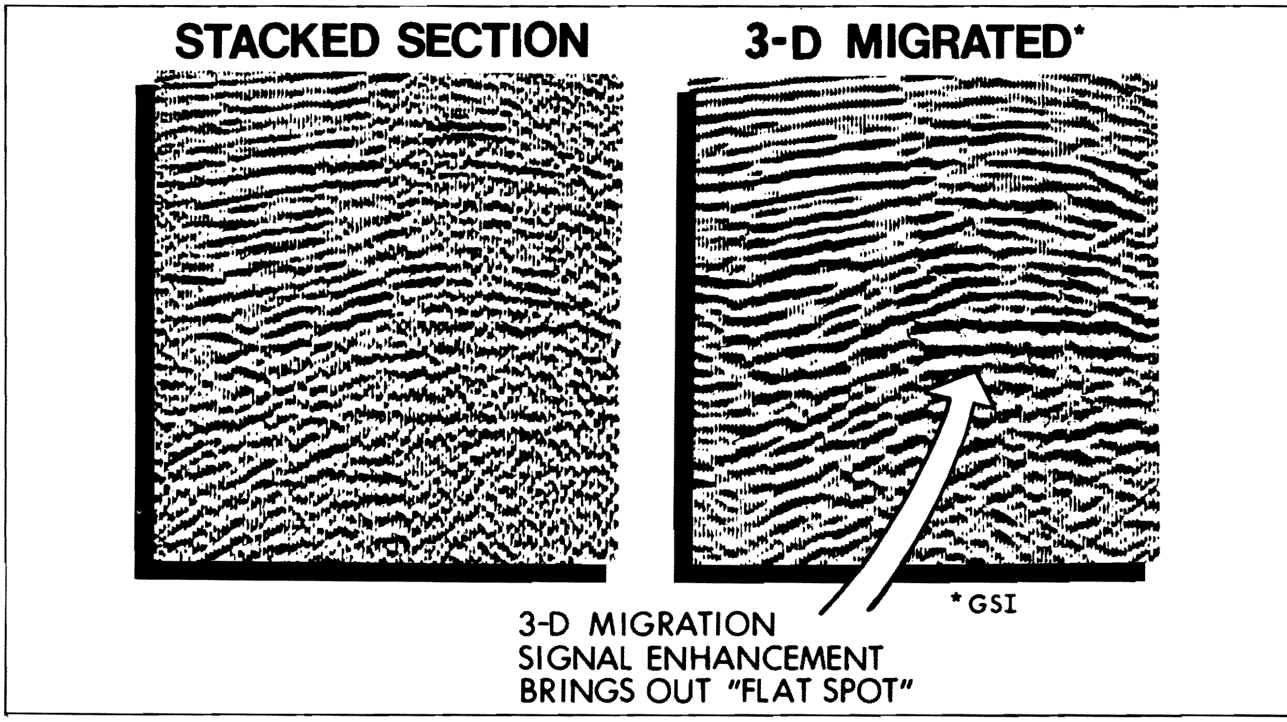

Figure 18

The 3-*D migrated sections* shown at the lower right, utilize data from the entire set of areal recordings. In effect, cross conponents of various events are determined and the reflector is migrated to its proper spatial position. The data are displayed as vertical sections through the migrated space. Labeled 20 and 21, these sections share a common surface trace with the other displays in the figure. What the 2-D migration purports to be, the 3-D migration is.

Note the surprising improvement in event coherency in the 3-D migrated sections resulting from the removal of the broad-side energy.

Another example of the power of 3-D migration is given in Figure 18. The flat spot which pops out of the migrated section later proved to be the gas-brine interface. Again, the processing shown here was done in the GSI laboratories. Examples such as this lend much to the argument justifying the increased cost of recording and processing areal data. Many geophysicists feel that 3-D migration is the hottest trend in the industry today.

4. INTERPRETATION

In addition to the obvious boost that interpretation is given by the foregoing developments

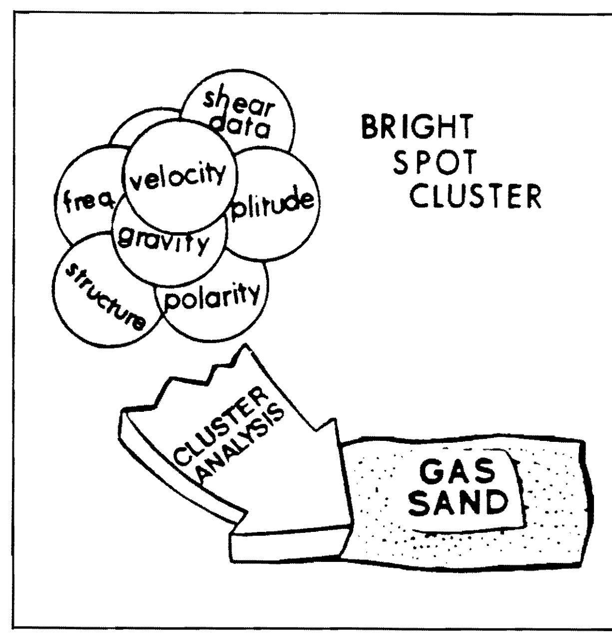

Figure 19

(migration, modeling, etc.), we note the growing interest in and use of the following methods: interactive computer modeling; cluster analysis; use of shear data; remodeled velocity; dephasing; and display. While hardly comprehensive, this list does suggest a number of the current trends.

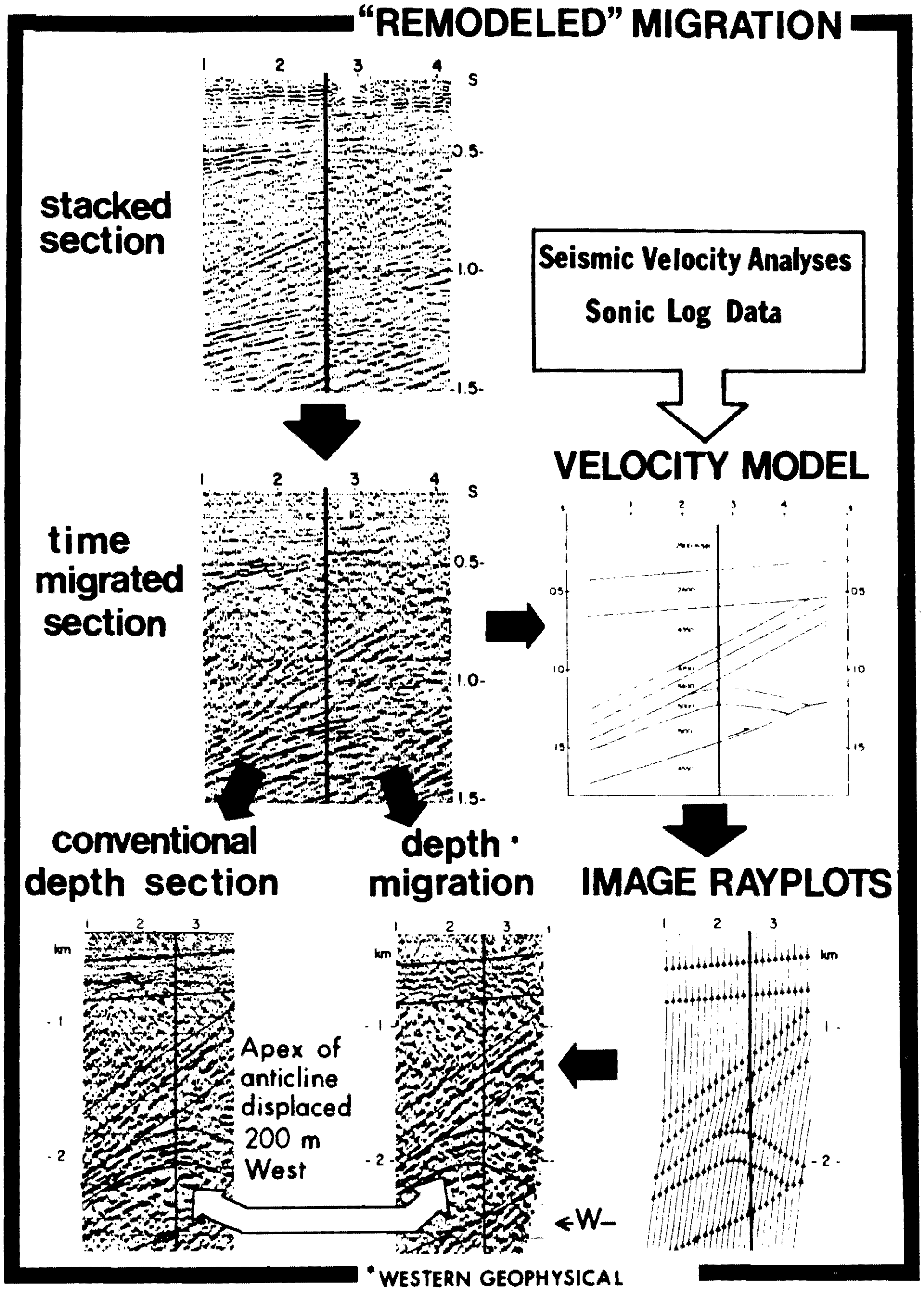

Figure 20

Cluster Analysis A fallout of the LANDSAT data processing procedure has been the concept of cluster analysis. Given a large volume of assorted data, it was observed that certain groupings of measured parameters were diagnostic of remote properties. For example, a certain combination of LANDSAT spectral band ratios was found to be uniquely related to specific types of agriculture.

In the seismic case, we could, for instance, use data parameter clusters for diagnosis of gas-induced bright spots: high amplitude, negative polarity, relatively low velocity, flat spots, low density, and so on. The computer is of obvious benefit in doing the tedious clustering work for us.

Shear Data The successful recording of shear data adds a new dimension of valuable information available to the interpreter. Comparisons of shear and P-wave velocities and amplitudes may well yield quantitative estimates of certain elastic constants enabling the explorationist to identify directly the rock type and fluid content.

Interactive Computer Modeling From velocity analysis to contouring maps, the man-machine combination has proven to be a vital and synergistic relationship. While many clever algorithms exist for adjusting models in a mathematically optimum way, there is no substitute for the trained human brain in reasoned judgment.

' *Remodeled Migration* All migration schemes require a description of the velocity distribution within the earth. Even with an incorrect velocity model, the migration generally heads in the right direction, that is, diffraction are compressed, synclines expanded, and so forth. Typically a very simple velocity model is used, one which allows only gradual lateral very simple velocity model is used, one which allows only gradual lateral variation. This usually proves adequate for most geologic conditions. Occasionally a complex velocity configuration may lead to critical displacements in the time structural positions on the migrated display.

Western Geophysical Company (WGC) recently developed a process they call DEPTH MIGRATION which aims at solving this particular problem. Figure 20 illustrates the principles of WGC's program.

The *stacked section* (shown at the top of the figure) is first migrated using a simple velocity model. This is a "*time migration*" in as much as the vertical scale is still in time, with the event movement taking place in the lateral direction. Normally, at this stage, each trace would be converted to depth by a simple "stretching" of the trace according to the velocity function. This *conventional depth section* is shown at the lower left of the illustration. Western's scheme calls for the use of the time-migrated section, together with external velocity data (sonic logs, velocity analyses, etc.), to form a structural *velocity model* (middle right in the figure).

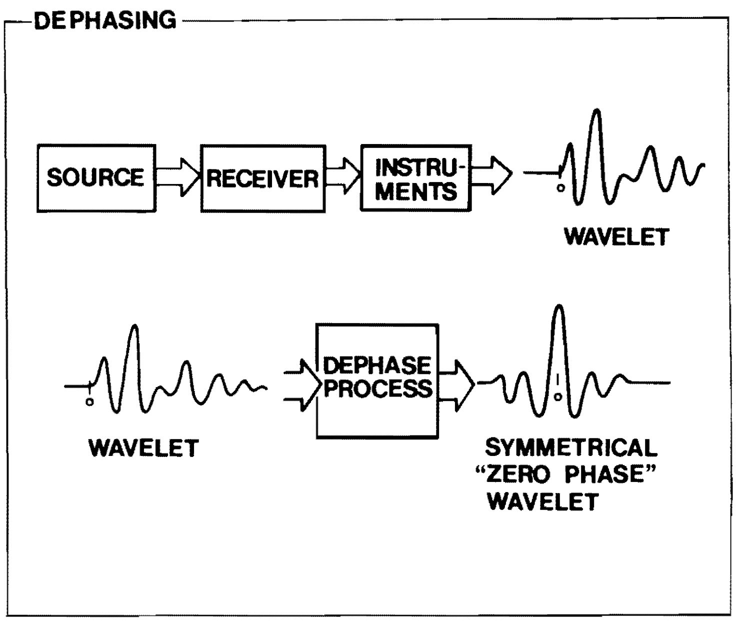

Figure 21

A series of rays are then traced through the model. These rays show how the time migrated traces are to be bent (refracted) in converting to depth. The individual traces of the initial migration are then stretched along these ray paths resulting in the *Depth Migration* section shown in the middle portion at the bottom of the diagram.

Of significance in the example given is the movement of the crest of the deep structure some 200m to the west. The results here have been verified by the drill.

De-Phasing Part of the overall operation of wavelet processing in the removal of known phase effects of the various components involved in seismic recording (Figure 21). This procedure has been termed "de-phasing", and has led to enlightened interpretation when successfully done.

Normally one wishes to compress (shorten) the seismic wavelet so as to improve resolution of individual events by elimination of ,overlap. Equally important to the goal of resolution, however, is the concept of *symmetry*. The phase associated with the recording components (source, receiver, instruments, etc.) manifests itself as elongated asymmetry of the wavelet. De-phasing the wavelet leaves it with the same length, but generates resolving power nevertheless: more *standout* of the event (higher peak value-to-

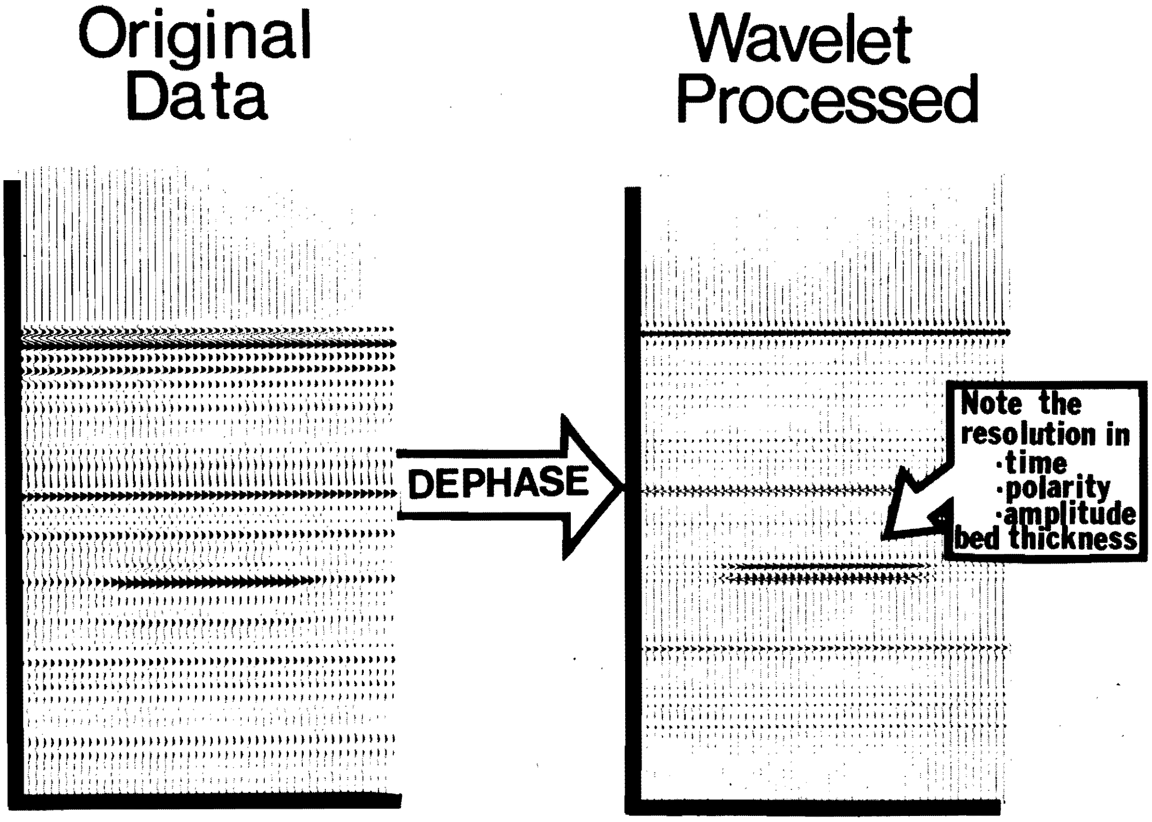

Figure 22

average level); and correct *timing* (peak occurs at the event time). These features mean resolution in time and amplitude.

Figure 22 demonstrates the efficacy of symmetry in analyzing a bright spot. On the left is shown the original data in which occurs an obvious bright spot of unknown cause. Note the effects of de-phasing: the bright spot event is separated into two distinct events representing the top and bottom of the layer. Since the peak amplitude occurs at the event time, we can measure accurately the depth and thickness of the layer. Moreover, we can determine, at least on a relative basis, the amplitude of the reflection. This later feature allows estimation of relative reflection coefficients and, in turn, velocity-density estimates. By comparison of the event polarity to a known reflector's polarity (here we use the positive ocean bottom reflector), we may determine the sign of the reflection coefficient, thus revealing whether the top of the bright spot is of higher or lower velocity than the layer above it. In this particular case, the bright spot is of positive reflection coefficient, which suggests it is not caused by a gas sand. (Better to find out now.)

Display Often relegated to last place in the chain of interpretational aids is the display of data. Thus cast in the trivial role of a simple cosmetic step, it is easy to overlook the enormous potential of display. Some 20 years ago, seismic sections were wiggle-trace paper records taped together. The section plotter, coupled with *variable area* display, provided the geophysical interpreter with what many consider to be the greatest single improvement in data processing of its decade.

True, no new information was added, but the enriched display significantly enhanced the visual interpretability of the data. And so it is with many of our modern display techniques. Much of the current trend in display centers around the use of *color* to emphasize and/or to augment the data with externally derived parameters.

For a number of years Seiscom-Delta has been a leading proponent of the display of certain geophysical attributes as a color overlay on the normal section (in either time or depth). The purpose of the color display of, say, reflection strength is to expand the available

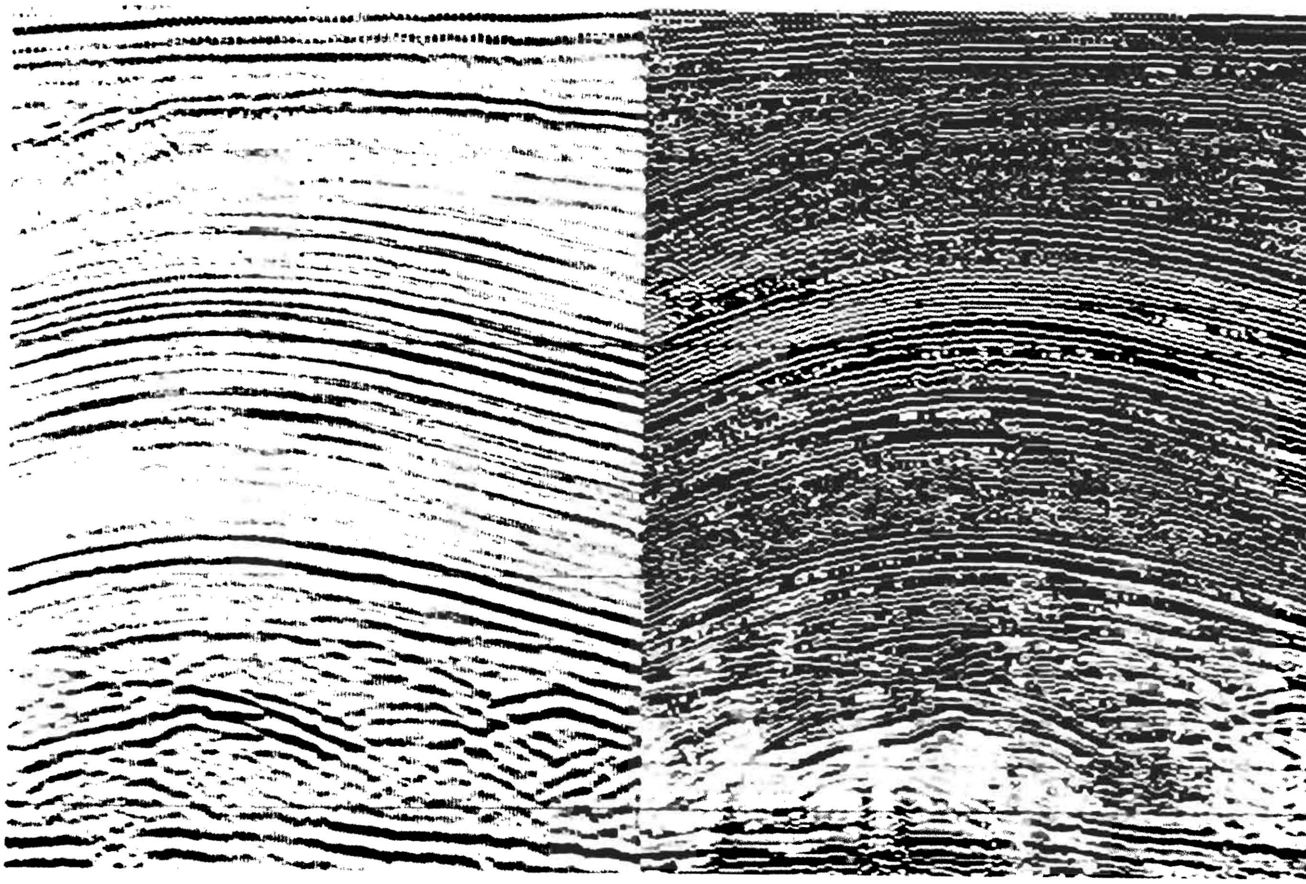

Figure 23 BRIGHT SPOT COLOR - VELOCITY ANOMALY

TIME SECTION

(BLACK & WHITE)

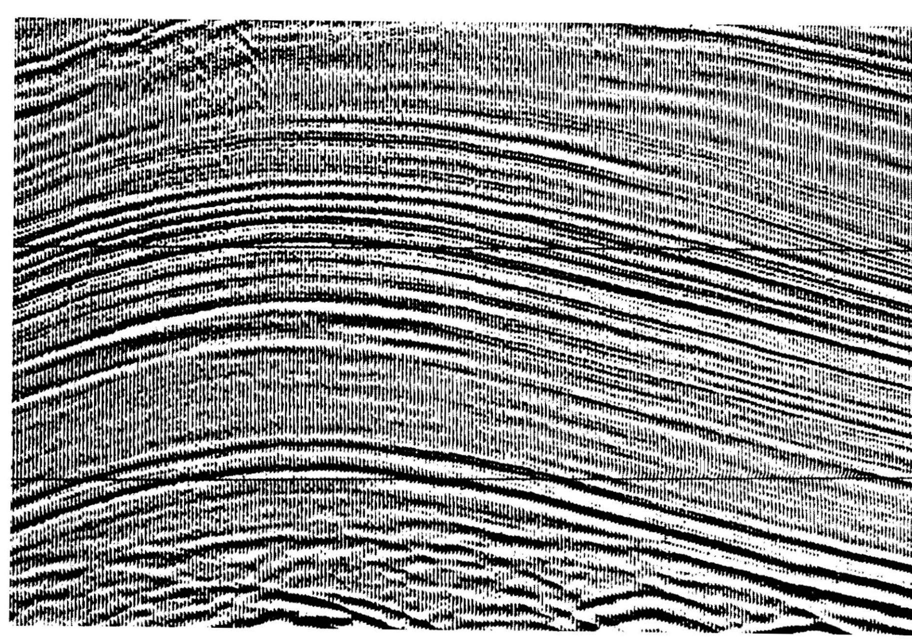

Figure 24 (a)

Figure 24 (b) VELOCITY COLORED

visual dynamic range thus giving the interpreter quantitative estimates of amplitude. The purpose in color displaying other attributes, such as polarity, frequency, phase, velocity, and the like, is to enhance the interpretability through added data.

Figure 23 shows a North Sea anticlinal feature exhibiting a bright spot. The left side (in back and white) is repeated on the right with a color overlay of *velocity*. The anomalously low velocity verifies the gas-related nature of the bright spot.

Figure 24 depicts a blow-up of the same structure in two modes: *time section* (black and white), and *velocity* (colored). Again the combination of high amplitude and low velocity "clusters" to indicate gas.

A similar situation is illustrated in Figure 25 from the Gulf of Mexico. Here Seiscom has displayed three seismic attributes in support of a bright spot analysis. The first section (color-coded *reflection strength*) clearly shows a bright spot. The *velocity section* shows a favorable velocity reversal, while the third section

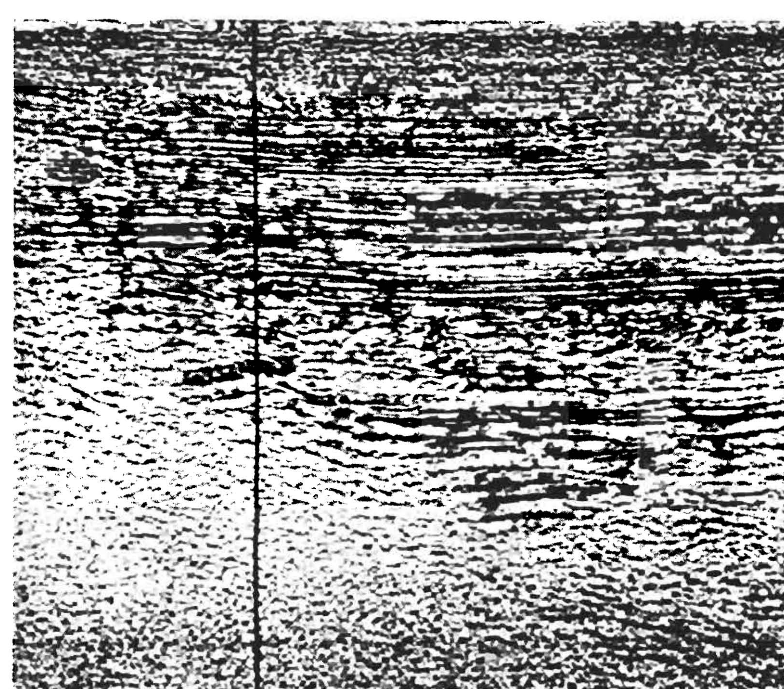

Figure 25 REFLECTION STRENGTH

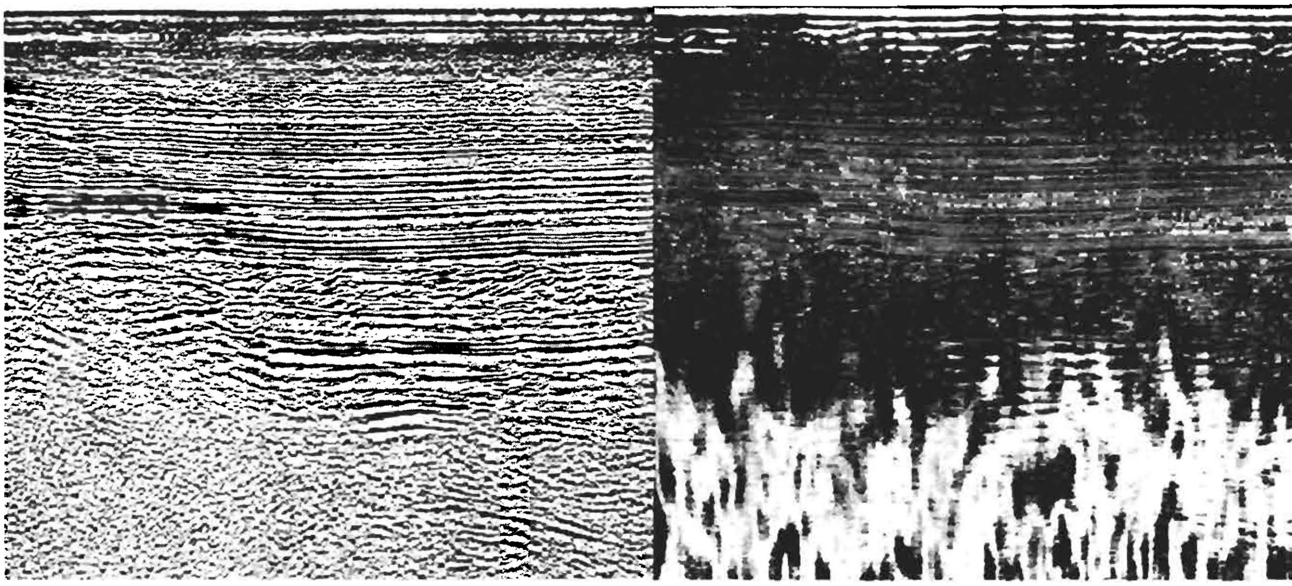

Figure 25 POLARITY VELOCITY

(*polarity*) indicates a negative reflection coefficient. The combination is supportive of a gas sand interpretation. Conventional methods of display would be strained to yield the information contained here in a quick glance.

Areal displays are similarly suited to color augmentation. In Figure 26 we see a *contour map* overlain with *reflection strength* (left) and *polarity*

Figure 26 (a) Display of Relative Reflection Strength over an Interpreted Horizon

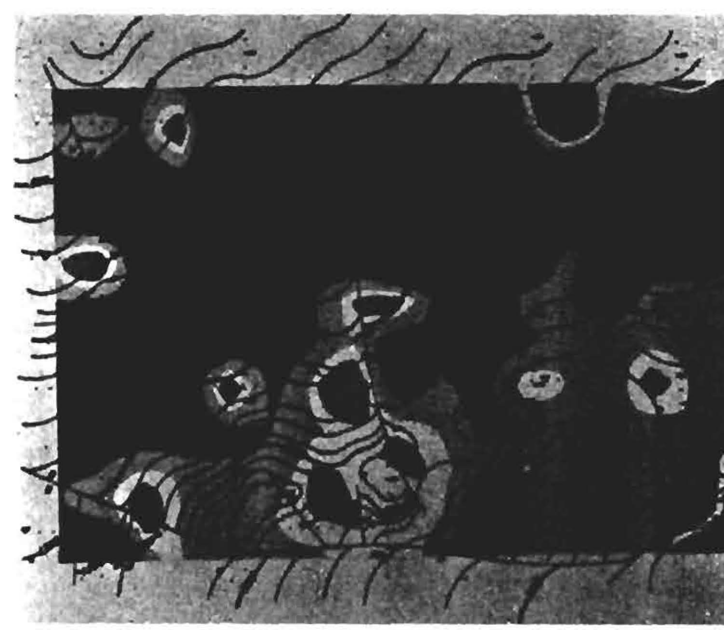

Figure 26 (b) Display of Apparent Polarity over an Interpreted Horizon

(right). This usage allows the interpreter to add bright spot attribute data to his structural picture.

The isometric displays of Figure 27 are interpretationally useful in a qualitative way. They may be used to identify gross structures and/or zones for more detailed investigation. The spatial perspective gives the interpreter a prospect overview often lacking when surrounded by sectional details.

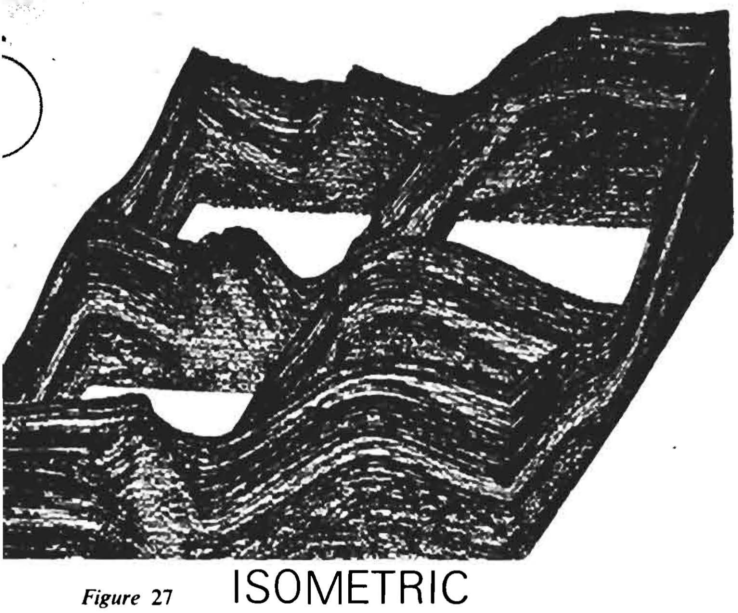

Figure 27

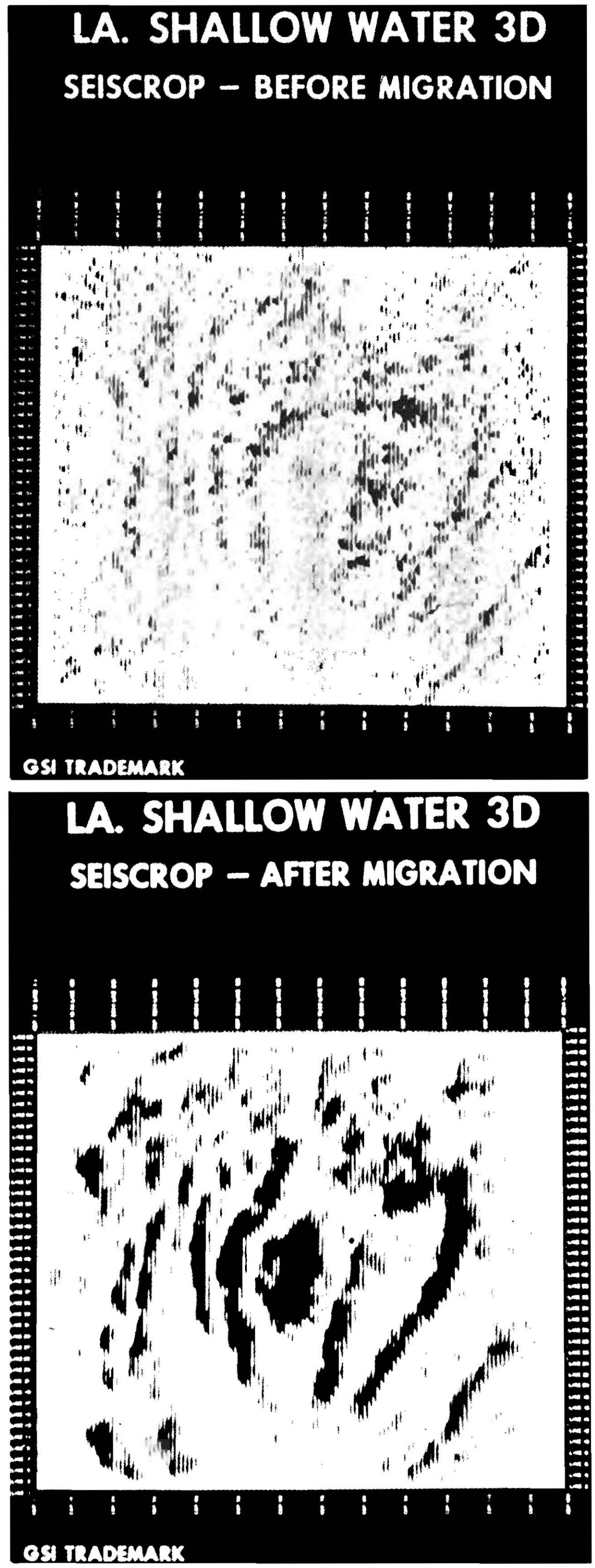

Figure 28

In Figure 28 we compare *horizontal* slices through a volume of offshore Louisiana data. The section on the left is a slice through the original time data before migration. This display is a GSI product known as SEISCROP. On the right we see the area sliced after 3-D migration. Note the improvement in signal-to-noise ratio analogous to that we observed in section displays of 3-D migration.

Typically, these SEISCROP displays are available as a series of horizontal slices. When viewed sequentially, they simulate a vertical trip through the structure while peeling off layers of strata.

Finally, we see in Figures 29 and 30 an application of color to the interpretation of geo-seismically modeled velocities. The original time section (Figure 29) gives no clear evidence of the discontinuous nature of the gas sand indicated by the arrow. An inverse modeling procedure produces the suite of simulated sonic logs shown at the upper part of Figure 30. While all the necessary information is contained in these log plots, the detailed correlation is not as obvious as it might at first seem. When color-coded contours of the velocity are displayed (lower part of the figure), the lateral separation of the low velocity layer segments becomes quite clear. In this particular case, the interpretation was influenced significantly by the display.

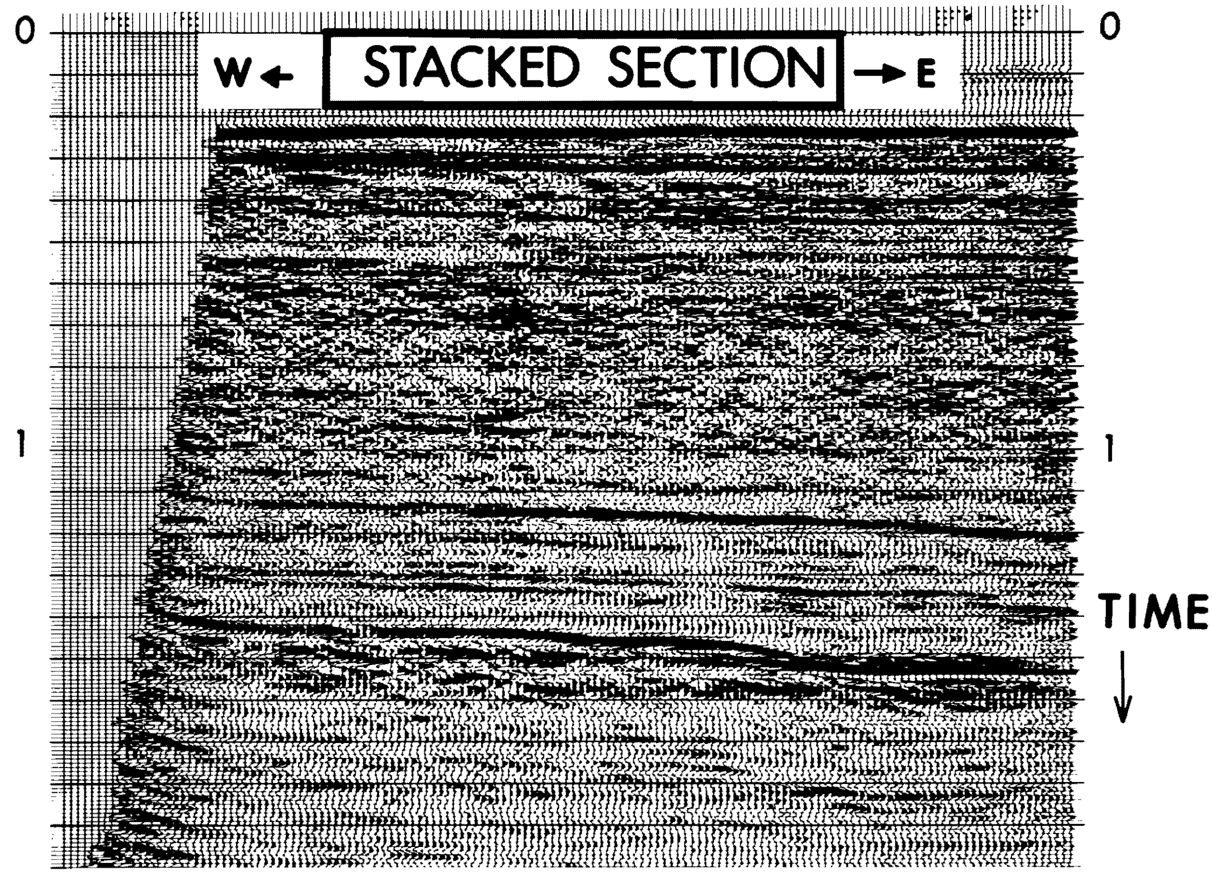

Figure 29

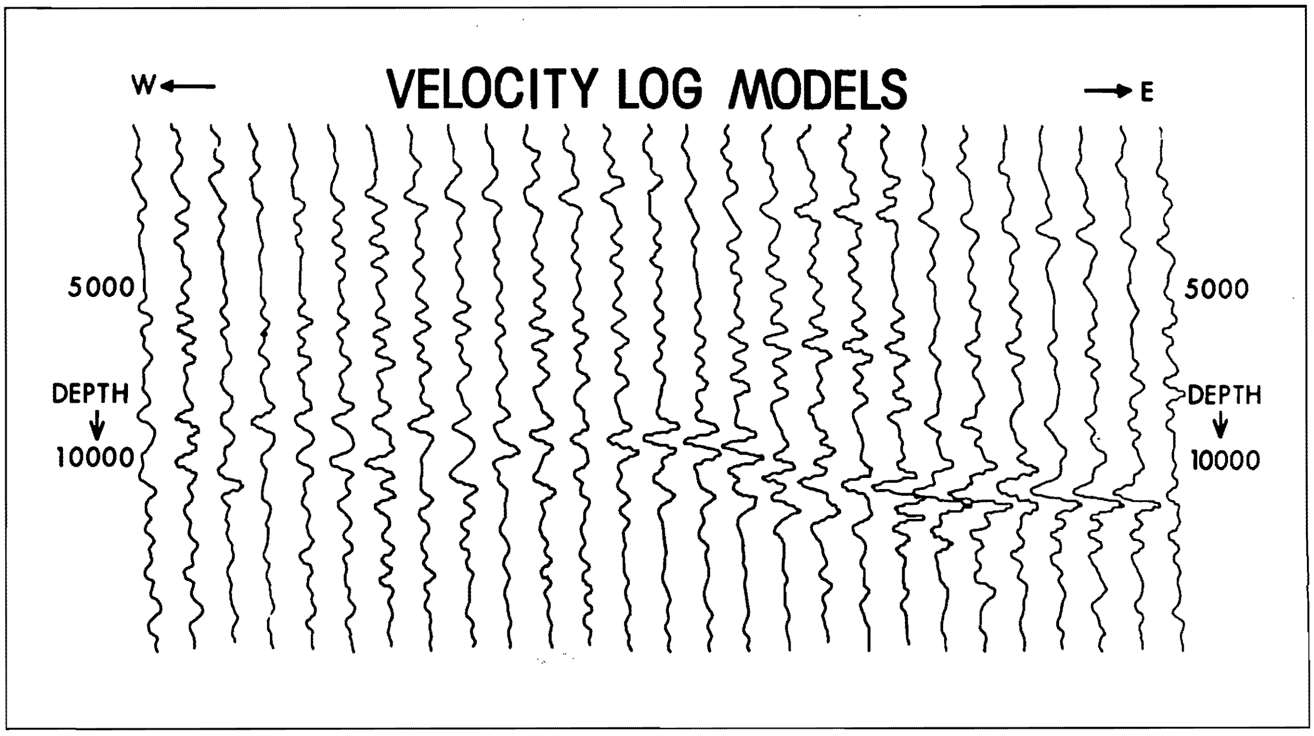

Figure 30

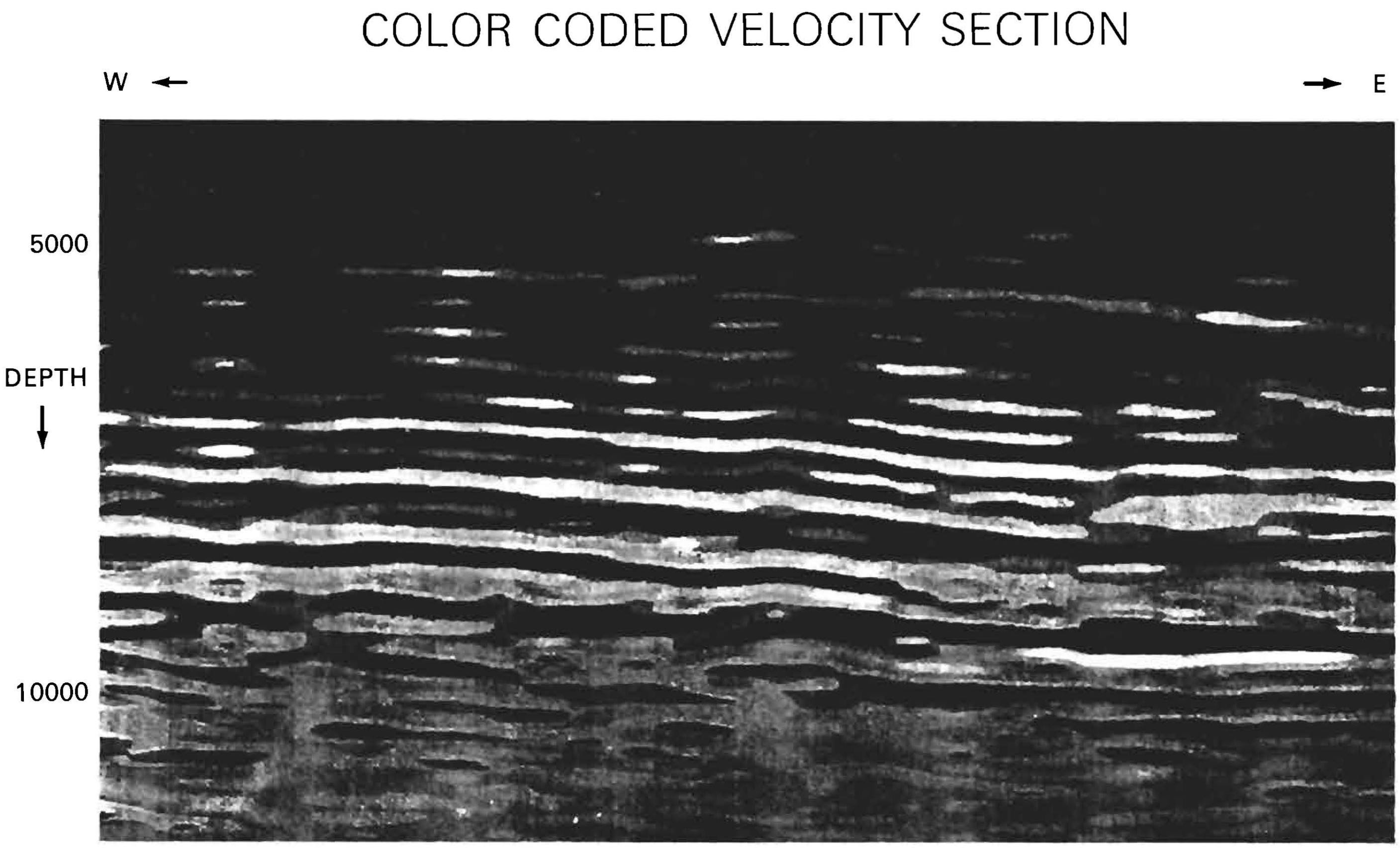

Figure 30

FUTURE TRENDS

The areas of most probable development is the next few years are best predicted by a study of those subjects now under active investigation in joint university-industry projects. In each of the fields listed in Table 2, there is much activity. In some cases, the project is quite mature and has already yielded much in the way of trend setting (as is the case with *wave equation processing*, investigated and developed by the Stanford group). On the other hand, projects such as *3-D modeling* and *attenuation* are only now getting underway. Undoubtedly, the explorationists of 1980 will be guided by results of these studies.

Table 2. Active Academic-Industry Projects
Wave Equation Processing
Shear Wave Studies
Three-dimensional Modeling
Attenuation

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