detailed aerial and oceanic surveying scarcely before possible.

Remote sensing imagery including thermal techniques adds new dimension to geological mapping and resource exploration generally. In association with extended surface geochemical and other inputs, wide new horizons continue to open.

As a geologist might I conclude by expressing the exploration industry's greatest remaining need — namely, a technique or techniques that more directly characterise, localise and/or pin-point buried hydrocarbon deposits. The seismic "bright spot" technique is obviously a successful step in this direction. Obviously, electrical and electromagnetic sounding techniques need more research and development with the hope of making still better use of oil's relatively high resistivity and other unique characteristics.

LAND SEISMIC WORK IN AUSTRALIA

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In the evermore urgent search for oil and gas reserves, one scientific aid stands out. The reflection seismograph is the industry's most important tool for resolving complex subsurface geological problems. In Australia the search for oil has been in progress for the past one hundred years. Prior to the 1950's the exploration effort was, at best, spasmodic. It is significant that continuous exploration for oil reserves commenced with the introduction of the seismic tool in Western Australia during the 1950's. In the ensueing thirty years of application, in excess of 215 crew years or some 250,000 line kilometres of seismic coverage have been recorded onshore in Australia. As we move into the 1980's, it is instructive to review our past experiences and consider how we may apply the lessons of the past to the improved tools of the present and the challenge of the future. There have been several reviews of the seismic method since its introduction in the 1930's. During this period predictions were made regarding the future progress of the science. Historically, most of these predictions have come true, at an accelerated rate and with the development of a technology, not known, at that time.

The goal of seismic exploration for the 1980's is quantitative measurement of subsurface lithologic parameters. Given this goal, we need to examine the tools and processes available to achieve it. From the 1950's to the end of the 1960's, almost all land seismic work in Australia was recoded on analog tape (if, in fact, tape was used at all!), with extremely simple field techniques such as split spread continuous or jump profiling. In the 1960's, horizontal stacking field techniques became widely used. Energy sources were predominately dynamite in shot holes, with substantial use of weight dropping and vibratory energy sources. The most profound change in the 1970's was the near universal use of digital recording instrumentation. The key to achievement of the goal suggested above is, of course, resolution. The key to resolution is sample density in three dimensions — two spatial and one time. Hence, actual field configuration of source and receiver arrays will undergo major changes from the styles that we in Australia have been accustomed to. 3-D methods are already in use in other countries. Energy sources will become more efficient. Dynamite will remain, in the foreseeable future, as the prime energy source, rich in high frequency content but with a less than savoury reputation in certain quarters. Methods and techniques, both mechanical and chemical to generate usable envelopes of shear waves will become apparent. Vibratory sources will evolve so that substantially higher input frequencies will be generated and recorded. It seems that although the field recording equipment will become more and more complex and sophisticated, the supplementary (albeit vital) field equipment such as geophones, cables etc. will evolve, just as they have over the past forty years. Geophone sensitivity (in its broadest sense) is governed by physical limitations, and refinements are the likely route of improvement. Digital telementery transmission of geophone signal will be improved, probably to the extent of eliminating cables completely. However, replacement of the jug hustler seems highly improbable.

The developments of the last decade in the recording instrument technology field suggest that in the 1980's, we will be using equipment capable of recording many thousands of data channels, with the attendant finer sampling rates in time and space. Even now, land seismic crews using in excess of 1000 data channels are operating in various parts of the world. Inherent in the use of these types of hardware are advances such as simultaneous recording and real time processing of data. The complexities of such a venture will lead to almost total onsite computer control of the recording process. The field combination will lead to variable recording parameter control (such as filtering etc.) from point to point.

The major changes expected tin the industry over the next decade will emerge in the data processing field. Processing advances will occur in two basic channels — geoseismic modelling and wave equation processing. Modelling advances foreseen are in the forward and inverse forms. The familiar synthetic seismogram is an example of forward modelling. Refinements in the application of these techniques are expected. Of great importance in our goal of understanding the subsurface of the earth are the inverse modelling systems. We start with the observed field seismic data, and attempt to work our way backwards along a path strewn with pitfalls, ambiguities, over-simplifications and unknowns to the geologic column. It is in this field that major advances are to be expected. The essential element of the modelling methods is the determination or estimation of the seismic "wavelet" which is embedded in the date. The "wavelet", which is a combination of effects ranging from source to recording instruments, is revealed by both statistical and deterministic methods. The source wavelet may even be measured directly as in the Vibroseis method. With an appropriate wavelet established, it is possible to generate synthetic or simulated sonic logs from the seismic data. Given adequate geological control, such methods appear to be of great promise in our hunt, particularly, for the elusive stratigraphic trap.

Wave equation processing is an obvious area in which rapid and beneficial advances in our industry have been made. While migration is usually the first application associated with wave equation methods, it is by no means the only use. Improved velocity estimates, coherency studies, near surface resolution, modelling, attenuation measurements etc. are but a few of the myriad applications. Use of wave equation processes is an important contributor to the success of the 3-D methods mentioned above. Migration of events on a conventional seismic section deals with the events on that section as coming from the plane of that section. This is, of course, patently absurd, but generally, as true optimists, we have acknowledged the problem, and then promptly done nothing about it. Alas, no longer may we plead such a defence.

Given all the improvements in instrumentation, field techniques and processing, there remains the proof of the pudding – Interpretation. It is a trite but mostly true expression that nearly all the big structures have been drilled onshore Australia – and found wanting.

The nature of the traps that we are exploring requires more than a gross structural interpretation. We are therefore required to use a host of methods even now that were impossible a few years ago. The most obvious interpretative aid for the geophysicist will be the interactive computer terminal. Granted the complexities of programming, it would seem that in the next decade, the masses of data to be handled for interpretation will demand a computer data base even for the housekeeping. The joys of reiterative modelling of an interpretation will become commonplace as we seek finer and more subtle information. The man-machine combination will form a vital synergistic relationship in applications from velocity analysis to contouring. The most elegant algorithms for mathematical optimisation are only an aid to the trained, experienced, human brain in reasoned judgement.

More statistical analysis methods will be used in the future as an inerpretation tool An example is the use of cluster analysis for indentification of genuine gas induced bright spots. The combinations of high amplitude, negative polarities, lower-relative velocities, flat spots, edge diffractions etc. can be studied to separate the real from the maybe.

The relationship of shear and P-wave velocities and amplitudes will yield quantitative estimates of certain elastic constants related to rock type and fluid content.

An extremely important aspect of the interpretative process is the display. The development from the pasted together mōnitor records through to the variable area section display has often been cited as the greatest single improvement in data processing in the 1950's and early 1960's. A similar improvement is likely in the use of colour displays overlaid on the conventional monochromatic structural section. These colour displays of seismic attributes such as reflection strength, polarity, frequency, phase, velocity and the like increase the visual dynamic range of the interpreter and allow him to more precisely define anomalous zones. In the display of 3-D data, the movie-like succession of horizontal sections known as Seiscrop are valuable tools to the interpreter.

It is apparent that the improvements of the past in our industry and the predicted trends for the future rely heavily on the skills of the people involved. In the ultimate judgement, the interpreter, well trained in geology and geophysics, will provide the resources of the future. This is the key to success in the 1980's.

QUANTIFIED STRATIGRAPHY – AN EXPLORATION APPROACH FOR THE EIGHTIES

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Quantified stratigraphic parameters from seismic and well data provide the paleogeographic and facies information necessary for the development of an accurate geologic framework for hydrocarbon exploration. The key parameters are (1) geologic age, (2) sea-level changes, (3) paleobathymetry and paleotopography, (4) subsidence and uplift, and (5) sedimentation rate. This paper discusses how these parameters are quantified from and applied to seismic and well data using seismic stratigraphy and geohistory analysis.

Seismic stratigraphic analysis permits interpretation of the geologic age, paleobathymetry, paleotopography, and gross facies directly from seismic data. Well control provides verification or modification of these interpretations by carefully tying the well control to the seismic data using synthetic seismograms. The well information in turn provides the data for geohistory analysis. This approach quantitatively illustrates the interrelation of the stratigraphic parameters and allows the interpreter to evaluate the effects of each.

This procedure is applied to offshore Western Africa. It demonstrates how quantified stratigraphic parameters affect the interpretation of basin evolution and sedimentary filling and how a quantified stratigraphic framework is developed for hydrocarbon exploration.

THE DEFINITION AND DEVELOPMENT OF THE MACKEREL FIELD

GIPPSLAND BASIN

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The Mackerel Oil Field located offshore in the Gippsland Basin was discovered in April 1969, with the Mackerel-1 well. The field contains oil in Eocene/Paleocene reservoir sands which lie beneath an unconformity at the top of Latrobe Group. Calcareous shales and mudstones of the Oligocene Lake's Entrance Formation seal the field which is a topographic-erosional feature. By the end of 1973, 235 kms of seismic had been shot in an irregular grid involving