The Evolution of Log Analysis Methods

by
E.R. (Ross) Crain & C.I. (Christl) Caldwell

E.R. (Ross) Crain, P. Eng., is a consulting well log analyst, with nearly 25 years experience in the oil and gas industry. He is president of Log/Mate Limited, the firm which developed the first commercially available microcomputer system for log analysis.

He is also president of E.R. Crain Management Limited, which is contracted to D & S Petrophysical, a division of D & S Petroleum Consulting Group Limited, to develop a new generation of log analysis software.

Mr. Crain is assisted by C.I. (Christl) Caldwell, a graduate of the University of Toronto, Ms. Caldwell has been managing the Calgary office of the Association of Professional Engineers, Geologists and Geophysicists of Alberta (APEGGA) for two years. Her activities include active participation with seven technical societies including the Canadian Well Logging Society.

The authors are also preparing a three volume log interpretation handbook for publication in 1984 and 1985. The material in this article was taken from one of the introductory chapters.

This article covers the early years (1929-1949). Subsequent articles will cover the middle years (1949-1968) and the recent years (1969-1979).

Introduction

The evolution of log analysis methods over the past fifty years is a fascinating and illuminating subject. There have been many methods developed independently in response to the then current set of logging tools, many of which are still in use today. It is illuminating because obsolete but traditional definitions, abbreviations, symbols and methods still pervade the industry.

Newcomers often wonder why these old fashioned ideas persist. In other cases, methods were developed which required better logging tools or more powerful computational methods than were available at the time. Such methods fell into disuse to be resurrected years later when the appropriate tools were developed. Simultaneous equations solutions fall into this category.

Well logging is a relatively young science, but initial work in the field dates back over 100 years. As early as 1869, about the same time as Drake made the first discovery of oil in the USA, Lord Kelvin in Britain was making interpretations of heat flow in shallow well bores by measuring temperature versus depth. Later, surface measurements of electrical resistance of rocks by Conrad Schlumberger in 1912 led he and his brother Marcel, to consider similar measurements in boreholes. In 1927, they convinced the Pechlebronn Oil Company, drilling in Alsace, France, to try such electrical measurements as an aid to understanding the rock layers. The first such log in the USA was run on 17 August 1929 for Shell Oil Company in Kern County, California. The first well logs in Canada were run in 1937 for a gold exploration project in Ontario, and in 1939 for oil in Alberta.

During the depression years, Schlumberger continued to run logs in Venezuela and Russia. By 1933, with the Great Depression nearly over, well logging was a common event in the USA, as well as the rest of the world.

Other milestones in the history of logging were quick to follow. The first radioactive log (gamma ray) was run in 1934, by Well Surveys Inc., the
The state of the art of well log analysis involves the intelligent use of a multiplicity of log curves in complex programs which evaluate many unknowns at once. Sophisticated analysis of this type requires highly trained technical staff for programming, data entry and evaluation. To reduce dependence on the expertise of the programmer and user, a number of companies are using the use of artificial intelligence (expert systems) to guide less experienced analysis through the analysis procedures.

The Early Years (1929-1949)

The development of log analysis methods closely paralleled the invention of individual logging tools. The first recognizable technical paper on log interpretation was by the Schlumberger brothers and E.G. Leonard, describing the electrical resistivity log and the spontaneous potential log, published by the American Institute of Mechanical Engineering (AIME) in 1932.

Log analysis using these new tools involved curve-shape recognition, which is still a valid and commonly used qualitative approach to interpretation. Log curve shapes are determined visually from the appearance of the recorded data when plotted versus depth.

These curve shapes were related to rock sample and core description data to determine general rules-of-thumb for separating permeable, porous, oil bearing beds from non-productive zones.

The early success of curve shape interpretation was quite accidental and depended on the fact that the formation water in the first wells logged were quite conductive due to dissolved salt. Had these logs been run in shallower, fresh and brackish water wells, such as those drilled in west Texas at the beginning of the twenties, the fresh water sands may have given such confused interpretations that well logging might never have become popular.

In 1941, G.E. Archie developed the empirical data behind the concept of "formation factor" - term used to relate the porosity of a zone, the resistivity log reading from the electrical log and the water saturation in the zone. This revolutionized log analysis, as the subject was now quantitative rather than only qualitative. In practice, however, the errors due to borehole effects on the measurements and uncertainty about other factors relating formation factor to porosity, prevented really accurate results.

W.O. Winsaver, with others, modified the Archie equation slightly in 1952, and is the formula used today, although most people still call the modified equation the Archie equation.

M.P. Tixier of Schlumberger published details of the so-called "Rocky Mountain" method in 1949. It was based on Archie's water saturation equation, but avoided the need to know porosity by using the ratio of deep and shallow resistivity readings. Hence, the term resistivity ratio method is used for this technique. It still required knowledge of water resistivity and also the resistivity of water in the zone investigated by the shallow-reading resistivity log.

This zone is usually called the "invaded zone", since fluid from the drilling operation invades the rocks near the borehole.

Studies of invasion profiles and water chemistry reactions were thus common during this period.

From its earliest beginnings in 1929, the spontaneous potential log was interpreted by its curve shapes. Since an SP voltage was developed across sandstones, and not in front of shale beds, it was relatively easy to identify sandstone from shale by the shape of the SP curve. Between 1943 and 1949, much work was done on the theory behind the spontaneous potential. The interpretation of this curve is still popular because it gives approximate values for formation water resistivity in clean (non-shaly) sandstone formations or the shaliness of the formation in shaly sandstones.

Shale content calculations were enhanced by the introduction in 1934 of the gamma ray log. Shale emitted natural gamma rays and clean sandstone and limestone did not. The log was calibrated to present a curve similar in shape to the spontaneous potential log. Although the gamma ray log has existed for 50 years, its appearance has not changed much. However, its resolution and accuracy have improved greatly due to more efficient and smaller gamma ray detectors.

The electrical, SP, and gamma rays all measured the average value of rock properties over 18 inches to five feet of rock thickness, so beds thinner than this could not be detected or evaluated. The microlog was introduced in 1948 and allowed measurement of resistivity in beds as thin as two or three inches.

The curve shape approach to analysis was commonly used for micrologs data, although laboratory derived charts allowed quantitative interpretation of formation factor (and hence porosity). The curve shape analysis for micrologs provided rapid

Continued on page 28
visual identification of zones which were invaded by drilling fluid and were thus permeable to at least some small degree. The log is still used today for this purpose.

The structural dip of rock formations is important to geologists. The first dipmeter log, using three simultaneous spontaneous potential measurements spaced equally around the perimeter of the borehole, was run in 1942. It was superseded in 1947 by three simultaneous resistivity measurements. The theory of interpretation was simple. Slight offsets in the depth of the bed boundaries recorded by each of the three curves, plus the tool geometry, hole diameter and tool orientation in space, could be reduced to give the dip of the bed boundary. Initially this was done by hand comparison, later in manually operated optical comparators and now by computer cross-correlation. The work was tedious and fraught with difficult decisions when the curves wiggled too much or not enough.

The modern dipmeter tool, first used in 1969, records four simultaneous resistivity curves, which provides considerable redundancy, and hence improved quality in the results. Data is often so good as to allow interpretation of stratigraphic features, such as crossbedding in sandstone deposits, as well as the much larger structural features of the rock layers detected by earlier tools.

The section gauge (or caliper log) also appeared in 1942 and made possible the application of borehole size corrections to all kinds of resistivity logs. The use of laboratory derived departure curves for this purpose, between 1949 and 1955, was a common event in a log analyst's life. The corrections were seldom satisfying and may have been "gilding the lily" somewhat. Modern resistivity logs need well borehole correction if run in well designed mud system in reasonably good holes.

Three other logging tools have existed for a long time, and are used as aids to interpretation of other logs. One is the formation tester, which measures the formation pressure and obtains a fluid sample, usually of the invaded zone. It was first run in 1957.

Refinements with digital recording techniques proved very helpful in sorting out reservoir fluid content and reservoir continuity. The log made by the formation tester is of pressure versus time instead of a depth dependent log. Many such tests taken at different depths can provide a formation pressure versus depth log for analysis of pressure gradient.

The sidewall core gun (sample taker) was first used in 1942. It uses a large hollow bullet, tied to the tool by wires, to retrieve a small plug of rock from the well bore. Anywhere from a few up to 48 bullets can be shot sequentially in one trip into the well. Other than an SP or GR correlation log taken for depth control, no useful log is recorded by the sample taker.

The temperature log, used to detect entry of gas into the well bore, was made available about 1936.

Much evolution was going on behind the scenes that the log analyst never really appreciated, but the logging engineer did. The rag-line logging scale gave way in 1947 to steel armoured multiconductor cable which was far stronger and more reliable. The tools evolved from purely electrical devices with ammeters and voltmeters, to vacuum tubes in the late forties, to transistors in the early sixties and finally integrated circuits and computers in the seventies and eighties.

Trucks changed radically from short wheel base, open cab flat decks with equipment bolted to the floor and shaded from the elements by an umbrella, to canvas covered vans in the early forties. Bread wagon style panel vans appeared in the late forties, to be superseded by the six and ten wheel "corn binders" of the fifties and sixties. The air conditioned behemoths of today, that look ever so much like space age garbage trucks, are the result of the computer revolution.

Service availability, both in the number of trucks and the number of locations where they are available increased dramatically. The far flung network was held together by the professionalism and integrity of the early pioneers. Today it's big business.

Trucks were moved offshore by barge and boat in the forties, and finally in 1947 when you could not see land from the rig anymore, genuine offshore skid units were built and placed on the rigs. Wave compensation devices and corrosion engineering solved many initial problems by the late fifties.

In all, the early years were a period of invention and ingenuity — solving problems as they arose, and surviving the Great Depression and World War II by sheer determination.
The evolution of well log analysis

By E.R. (Ross) Crain & C.J. (Christl) Caldwell

Ross Crain, P. Eng., is a consulting well log analyst with nearly 25 years experience. He is president of LogMate Limited, which developed the first commercially available micro-computer for log analysis, and of E.R. Crain Management Limited, which is contracted to D & S Petrophysical to develop a new generation of log analysis software. Mr. Crain is assisted by Christl Caldwell who has been managing the Calgary offices of the Association of Professional Engineers, Geologists and Geophysicists of Alberta for two years and is active with seven technical societies including the Canadian Well Logging Society.

The authors are preparing a three volume log interpretation handbook for publication in 1984 and 1985. Material from this has been abstracted for a three-part serial in this magazine. In the last issue, the early years (1929-49) were covered. Here, the focus is on the middle years (1949-68) and in the next issue, the recent years (1969-79) will be featured.

All the logs mentioned so far, except the caliper, needed a conductive fluid in the borehole in order to operate. The induction log was introduced in 1949 to overcome this requirement in holes drilled with air or oil based drilling mud. The log was calibrated to read rock conductivity by inducing currents with electromagnetic coils - instead of impressing currents into the formation by means of direct application of voltages from the logging tool electrodes, as was the case with the earlier electrical log. In addition, over the next ten years, the induction log became popular in wells drilled with fresh mud.

Interpretation of water saturation became more reliable because of reduced borehole effects on the resistivity measurements, compared to conventional electrical resistivity logs. To some degree, bed boundary effects were more predictable and compensated for electronically. The induction log has evolved considerably over its 35 year life and is the most common log run today.

The laterolog was also introduced in 1948 - 1949. It was a multi-electrode electrical log designed to minimize borehole effects in salty drilling mud. Again, improved resistivity values led to better water saturation and porosity determinations, still using the Archie methods.

The microlaterolog, to replace the microlog in salt mud, was first seen in 1952. Curve-shape analysis was not easy, but standard Archie methods worked well with this data. Other similar tools, such as the proximity log, and the micro-spherically focussed log, are variations of the microlaterolog designed to improve shallow resistivity measurements in a variety of borehole conditions.

Neutron logs first appeared in 1938, but were not common until 1946, when better sources of neutron radiation became more readily available. Neutrons emitted by the source, were absorbed by hydrogen atoms, which are

The sonic log revolutionized porosity interpretation (left) and the long spaced sonic (right) is useful in rough or large holes. Many logs can be run in combinations, such as the sonic-induction log. Illustration courtesy of Dresser Atlas.
common in water and petroleum. Qualitative interpretation of porosity (which contains water or oil) was possible by detecting the number of neutrons which were not absorbed but were scattered back to the detector. In some tools, the capture gamma rays created by the neutron bombardment were counted instead of the neutrons. This was the first independent source of porosity information that did not rely on Archie's formation factor concept and the resistivity log data. The tool had and has its faults, but modern neutron logs are careful quantitative interpretation aids. Again, better detectors have increased the resolution and accuracy of the measurements. The modern version of the neutron log compensates for borehole size and a number of environment factors automatically.

The two-receiver acoustic travel time (sonic) log showed up in 1957. Laboratory work had demonstrated that the travel time of sound in a rock, after adjustments for fluid and matrix rock travel time values, was capable of estimating porosity. Thus, another independent source of porosity data was born.

Interpretation of sonic logs for apparent porosity using the time average equation was published by M.J. Wyllie in 1956. It is probably the most common analysis method in use today. The laboratory work and relationships between porosity and sound velocity (or travel time) was exhaustively studied between 1940 and 1965. Much of the work was aimed at solving problems with seismic survey interpretations. Strangely enough, the Wyllie formula, for all its success over 30 years of use in log interpretations. Strangely enough, the Wyllie formula, for all its success over 30 years of use in logo interpretations, can be shown to be physically incorrect in the laboratory and in theory for many situations, especially those involving compressible fluids such as gas.

The sonic-resistivity crossplot was invented shortly after the sonic log. It allowed visual as well as quantitative presentation of porosity and water saturation, plotting one piece of paper without the use of additional charts, nomographs or slide rules (hand calculators had not yet been invented). It was tedious work, but thousands of crossplots were made during the sixties and a few less progressive analysts still use them today.

Quick look methods to differentiate hydrocarbons zones from water zones also followed the introduction of the sonic log. One such technique, the "Kva Method", is still very popular.

The principle used was to quickly calculate from the Archie water saturation equation and the sonic log porosity value, the apparent water resistivity which would make the zone 100 per cent water saturated. If a particular value of water resistivity was considerably higher than the trend of many other values from above and below it in the borehole, then hydrocarbons could be suspected in the anomalous zone. No scale corrections were made, so shaly sands often showed poorly in this analysis.

Another quick look method is called the overlay method. The simplest approach was to overlay the resistivity log and the sonic log in such a way as to have the two curves fall on top of each other in the obvious water zones. Zones in which the resistivity log fell to the right of the sonic log were either potential pay zones or tight (non porous).

The overlay method was improved by generating compatible scale logs so that scaling differences did not cause false shows. The compatibility could be created by transforming the resistivity and sonic curves to apparent porosity or to apparent formation factor. This was done at thewell site by appropriate function formers in the surface electronics, or back in the office by the use of computer processing.

The invention of the logarithmic presentation for resistivity data, when the dual induction log was introduced in 1962, made quick look overlay methods even more popular and practical at the well site.

This gradiometer, or fluid density log, indicates unwanted fluid entry into a gas well from the upper set of perforations and from the adjacent casing collar. — Illustration courtesy of Schlumberger.

Many modern logs are designed to give good visual impressions of lithology, porosity or hydrocarbon by means of compatible scale overlays. The density-neutron combination log is the most common example. The latest versions of computerized logging tools, even the separation between compatible scaled logs to emphasize the apparent prospective zones.

The density log was introduced in 1959 and allowed another independent source of porosity data. With three sources of apparent porosity (sonic, neutron and density), in addition to the resistivity methods, it was now possible to account for more variables. This led to crossplot or chartbook methods which compared the apparent porosity values from two sources, to help identify lithology (shale content or limestone - dolomite ratio, for example). The sonic-density crossplot was common in the early sixties, with the density-neutron crossplot becoming more common in the late sixties, as the neutron logs became better calibrated and scaled in porosity units.

Since a crossplot is merely the solution to three simultaneous equations in three unknowns, the use of computers to solve these equations was a

Continued on page 20
popular subject in the early sixties. Extensions of this concept to four, five or six simultaneous equations demanded a computer since graphical methods could not cope with the multi-dimensional aspect of the job. The desired results from such methods are porosity and the percent of each matrix rock type present. Usually one extra component can be found for each additional independent tool measurement used in simultaneous equations. The method suffered if the list of unknowns in the equations did not match the real rock sequence. This can be mitigated, at least in part, by allowing the computer program to search for the best lithologic model.

Linear programming (simultaneous equations with constraints) was tried. It was not very successful, because knowledge of rock properties, the so-called known data, was not very well known. As well, tool response to rock mixtures was not well defined.

The late fifties and early sixties also saw a great deal of work in atomic physics and both the pulsed neutron (or atomic activation) log and natural gamma ray spectroscopy log were described. However, suitable tools did not become available until 1968, and were not common until 1972.

The pulsed neutron log provides another apparent porosity evaluation, as well as an independent assessment of water saturation. The logs are also called thermal decay time logs, chlorine logs, carbon/oxygen logs or spectral gamma ray logs (note the lack of the word "natural" in this case) depending on the details of the source-detector systems and the rock properties derived from the data. They are usually run in cased holes.

The natural gamma ray spectrometer allows interpretation of uranium, thorium and potassium content in a formation. This is used to help segregate shale from other naturally radioactive rocks, such as uranium bearing dolomites. In conjunction with other log data, it can help define the types of clay minerals present in the shales.

The nuclear-magnetic resonance log was described in 1956. The theory suggested that effective porosity and permeability could be determined from the measurements. Good examples of this are still rare even after nearly 20 years of refinement.

Other methods for interpreting permeability, based on empirical relationships between porosity and water saturation had been presented prior to 1960 and are still used today. Some examples are the Timur, Wylie-Rose and Coates-Dumanoir methods.

Prediction of abnormal pressured zones, and potential drilling or blowout problems, were developed from the various porosity estimating logs, beginning in 1956. This was based on depth-trend line analysis of the sonic log primarily, although most logs, including density, neutron, and resistivity logs can be used.

The log types and interpretation methods discussed so far are all used in open-hole conditions. That is, after the well is drilled but before it is cased with pipe and cement, and finally completed to flow oil or gas (or heaven forbid, water). All the radioactive logs (gamma ray, spectral gamma ray, neutron, pulsed neutron) except density logs can be run in cased holes, and interpreted with approximate corrections for casing size and thickness. Resistivity and sonic logs cannot be run in casing to obtain information about the rocks, although the sonic log is used to evaluate the cement behind the casing.
The evolution of well log analysis

By E.R. (Ross) Crain & C.I. (Christ) Caldwell

Ross Crain, P. Eng., is a consulting well log analyst with nearly 25 years experience. He is president of Log/Mate Limited, which developed the first commercially available micro-computer for log analysis, and of E.R. Crain Management Limited, which is contracted to D & S Petrophysical to develop a new generation of log analysis software. Mr. Crain is assisted by Christi Caldwell, who has been managing the Calgary offices of the Association of Professional Engineers, Geologists and Geophysicists of Alberta for two years and is active with seven technical societies including the Canadian Well Logging Society.

The authors are preparing a three volume log interpretation handbook for publication in 1984 and 1985. Material from this has been abstracted for a three-part serial in this magazine. In the first issue, the early years (1929-49) were covered, and in the second part the focus was on the middle years (1949-68). Here, the recent years (1969-78) and future trends are featured.

The Recent Years (1969-1979)

A major effort was made in the mid sixties to perfect water saturation interpretation in shaly sands. Archie's equation was not designed for this situation. Many competing methods were proposed, but the fallout left the Simandoux equation (about 1965) with the Waxman-Smits method (1968) holding sway for a decade. Most of the methods, including Simandoux, suffer from lack of rigour or have a physically unsatisfying model. The Waxman-Smits method is theoretically acceptable, but some of the data needed for the equations (such as cation exchange capacity of the rock) cannot be obtained from logs reliability. It is difficult and expensive to get from measurements on cores of real rocks, especially if there are no wells to be found from the zone in question.

Another approach is called the dual-water model (or bulk volume water method), published by various authors between 1968 and 1971. It segregates the total amount of water into formation into two parts - that bound to the shale (bound water) and that in the pore space (pore water). The method is currently popularized in most service company programs, both in the office and on the computerized logging trucks at the wellsite.

Controversy still rages over the best water saturation method and the ultimate water saturation equation has yet to be presented.

Water saturation interpretation in shaly sands and porosity determination were both being studied in the late sixties. With several independent sources of data, and with more unknowns than measurements, a new style of interpretation was proposed. Instead of solving a fixed set of simultaneous equations, various iterative solutions were used to minimize the change in one or several computed results. This occurred when high powered computers, digital data recording (first achieved in 1965) and great patience, since results did not appear quickly. Weeks or months might be needed to get results for even a small group of related wells. This situation has improved markedly in the last three or four years.

More advanced computer programs for carbonate rocks appeared in 1971 to provide a similar service as was available for the shaly sand situation. The goal in this program was automatic hydrocarbon correlation and mineral identification.

The best known examples of these programs are Schlumberger's SARABAND (now superseded by VOLAN), CORIAND and Dresser Atlas' EPILOG products. All these methods are iterative refinements of the crossplot or simultaneous equation solutions.

Today, the method can be programmed on low cost sophisticated hand calculators, and if large volumes of data are required, desktop computers with digitizers, plotters and printers can be obtained.

Continued on page 110

[Image: Diagram showing various log analysis methods and interpretations]
Well log analysis

Continued from page 109

from several sources. The first truly portable stand-alone desktop system that did not require connection to a large mainframe computer was LOG/MATE, developed by the author and D.W. Curwen in 1977.

It has since been mimicked and improved upon by many others, so that a wide range of such systems are available today.

Timeshare systems using computer terminals to larger mainframes or mini-

computers were first seen in 1965, and are still used. Both batch processing systems and interactive time share systems can be found in many oil companies, service companies and consulting firms.

Log analysis methods vary from crude to complex and the quality of results varies with the knowledge and experience of the analyst. The quality of input data is always a problem to consider. Simpler systems, with a good analyst at the controls, often provide better results, because of the personal input and knowledge of the analyst. More complex programs tend to do unexpected things and are not easy to control, even by expert log analysts.

Moving the analysis from the office to the field, to speed up decision making, has always been a driving force in interpretation techniques. Of course, all the manual methods described above could be performed at the wellsite, using charts and slide rules, and later with electronic calculators. In 1963 attempts were made to interpret porosity and water saturation automatically by recording the so-called moveable oil plot. This involved analog processing of log curves to obtain the appropriate data.

While digital recording of well logs began in 1965, early trials of digital computation at the wellsite did not begin until 1972. After this data, the major service companies have almost completely replaced all their older analog logging units. This provided both log interpretation and calibration control by computer. The best known interpretation examples are Schlumberger’s CYBERLOOK and Dresser’s PROLOG products.

The recent years in well logging can be termed the era of digital data, giving tool designers and analysis the power of the computer to bring to the surface more data of higher quality than ever before.

The State of the Art (1979-1984)

A number of new tools, with revised uses of older tools, and significant advances in computer processing of log data have been introduced in the last few years, and are gaining rapid acceptance by well operators.

The litho-density log is an improved density log with reduced statistical variations on the density measurement, and a new curve - the photo electric capture cross-section curve, better known as the Pe curve. Its value depends on the rock lithology and is relatively unaffected by porosity and pore fluid type. Therefore, it can be used to assist in lithology identification in simultaneous equation solutions.

The natural gamma ray spectrolong mentioned earlier, is now also widely used to resolve lithology problems, such as radioactive dolomite or granite wash formations, or to help define clay types in shale. It provides three primary curves - the potassium, thorium and uranium curves, which when summed, give the total gamma ray curve. These three curves, plus the three porosity curves (density, sonic and neutron), and the Pe curve provide seven independent measurements of formation properties, which should allow a total of eight lithologic properties to be calculated from the data.

Add to this, the three usual resistivity curves, the caliper curve(s), and data from the electromagnetic propagation log which is currently being used to determine flushed zone water saturation.

A division of NEI Canada Limited is part of a major British group of companies with worldwide engineering experience. Manufacturers and suppliers of:

• Diesel engines for baseload power generation, semi-submersibles power generation and propulsion and for anchor handling/supply ships.

• Compressors for air systems, instrument air, air tools, and fuel gas compression.

• Epicyclic and parallel shaft gears for gas turbine driven generators and compressors.

• Steam turbines; on-platform general purpose thrusters; winch motors; pedestal cranes; pressure controllers; communications and protection equipment; friction welding machine; draw works; mud pumps; rotary tables.

IN CANADA: APE CANADA LTD.,
Head Office
121 Industry St.,
Toronto, Ontario,
M6M 4H3
Tel: (416) 769-5522

Well log analysis

Continued from page 110

It is clear that the solution mechanism is beyond chartbook and calculator capabilities. Most popular computer programs have been modified in the last few years to provide specific hard-coded solutions for specific combinations of these tools and individual lithologic models. For example, Dresser lists eight different open hole and five cased hole programs to adapt to the changing times.

When one considers adding multiple passes of the thermal decay time log (pulsed neutron log) for each year of well life, the data explosion becomes increasingly difficult to cope with.

One new product, called FACIOLOG, by Schlumberger, is an attempt to reduce this data overload to a minimum. It provides a detailed electro-facies log which, when calibrated to rock samples and core data, can be very useful in understanding depositional environments and well to well correlations. It can also be presented on a seismic time scale to assist in correlating normal seismic data, or vertical seismic profiles taken in the same well or in a nearby well. The type of shading used by geologists while doing visual curve shape analysis, comparable to what was done earlier.

A second approach by Schlumberger has been to create a universal log interpretation program, in which the log data, the lithologic model and the log-rock response equations are provided by the user, instead of being hard coded. This product is called GLOBAL and can be classified as a linear programming solution. It has additional features which make it unique, such as a complete set of detailed corrections, and a statistical evaluation section which attempts to minimize the inconsistency between input data sources and assumptions, and the interpretation model being used. The uncertainty in each input data value is also considered by the program. This approach is independent of the log interpretation model used and which could be VOLAN or CORIBAND or any other model supplied by the user.

Another area of advance is in dipmeter interpretation, as more sophisticated computer programs provide more coherent data for evaluation of detailed stratigraphy and permeability direction. This is especially practical when combined with a product like FACIOLOG.

The nuclear magnetic log is also being pursued again for its ability to predict

MINIMET™

HIBERNIA SURVIVOR

By Design

Enduring 50 foot waves and gale force winds of the Hibernia oil fields, MINIMET™ telemetered reliable wind/wave data for the duration of a Canadian Government test. MINIMET™ performance has set new standards and will send you the data that proves it.

At one-tenth the size of any other wind/wave buoy, MINIMET™ delivers quality data in the roughest of seas and never experiences more than 10⁹ lll. Its unique compliant mooring system works with the sea, not against it.

MINIMET™ calculates wave spectral coefficients and vector averaged wind speed and direction. It provides air and water temperature, barometric pressure, solar radiation, relative humidity, current metering, buoy position and a variety of other data. The incredible versatility of on-board microprocessor based electronics permit rapid data format changes as well as sensor additions or deletions. In fact, if you add a sensor to your MINIMET™ at a later date, we'll make the software change free. That's simple.

All data collected by MINIMET™ are stored on board and telemetered ashore via RF, GOES, METEOSAT or ARGOS Satellite. It was a MINIMET™ that telemetered the last data using METEOREBURST technology.

So, for the affordable, simple and reliable answer to the ocean's trickiest data acquisition problems, count on full-performance MINIMET™ at a price that won't leave you beached.

Coastal Climate Company Ltd.
316 Second Avenue South
Seattle, Washington 98104
USA (206) 622-8534 Telex: 4949490

permeability, fluid viscosity and irreducible water saturation.

These complex and expensive logging tools and interpretation procedures have one thing in common - the capacity to improve oil and gas production if used properly. In order to reduce dependency on imported oil in both the USA and Canada, it is necessary to exert maximum effort on many wells. A minimum well evaluation effort is no longer considered a cost saving, but is instead an expensive loss of potential reserves.

Single well studies as described above lead directly to field and pool studies, seismic modelling, mapping, contouring, reservoir modelling and simulations which are topics not normally associated with well log analysis. Such studies are becoming commonplace, and are far more successful when the log data has been properly processed for the specific end-use.

The state of the art in well logging has pitfalls as well as advantages. Too much data, poorly understood, is often worse than not enough data. It is too easy to catch the enthusiasm of the salesperson's latest example log, and neglect the basics. Proper attention to good data handling, thorough and appropriate interpretation methods, and of course common-sense will prevent a bad case of data overload.

Log Interpretation in the Future

The future? It will probably involve artificial intelligence - the darling of the academic world until recently. Computer based expert systems will learn from experts in the field of log analysis, and will subsequently advise and consult with less expert users. As the expert system is increasingly used, its cleverness will heighten, until it is more intelligent than any single expert. Such hardware and software already exists, albeit for much simpler situations than log analysis. However, it is known that major service companies, oil companies and consulting firms have embarked on research in this field, emphasizing on log interpretation.

The success of a log analysis is judged by how well the analysis predicts the future performance of the completed zone. Many analysts and their managers are aware if their results were good or bad. Artificial intelligence with a learning data base, should provide the kind of "perfect memory" and the unbiased question/answer sequence needed to keep track of success and failure. Hopefully we will learn how to do better work as time goes on, by studying the background to each success or failure, entered automatically by the expert system.

The future holds the promise of a long sought goal in well logging - an automatic, universal interpretation program that never fails and adapts to change.

---

National Mud Control Laboratories

Onshore or Offshore
Canadian Oilmen call on National Mud for the "Tough" Jobs

We provide the drilling fluid and we also provide the experience, the planning, the detailed "how to," needed to put it to work effectively. The National Mud Team are "Professionals" trained to get the job done.

In the Laboratory too, our skilled technicians are always available to find quick answers to tricky problems

- Complete drilling mud and laboratory services throughout Canada
- Drilling engineering consultants land and offshore
- Helicopter service
  Grand Cache — Grand Prairie
- Computer hydraulics — pressure plots
- Workover specialists
- Inhibited drilling systems

Suite 600, 910-7th Ave. S.W., Calgary, Alberta T2P 1A3
Telephone: (403) 237-0246 Telex 03 927719

35, Gurholt Drive, Burnside Industrial Park, P.O. Box 935, Dartmouth, N.S. B2Y 3Z6 Telephone: (902)469-7793 Telex: 019 31431

#3 Riverview Avenue, Mount Pearl St. John's, Newfoundland A1C 2S4 Telephone: (709) 755-9441 Telex 015-4702

OFFSHORE RESOURCES, Vol. 2, No. 4/5, Sept/Oct 1984, Page 113