COMPUTER LOGS IN DECISION MAKING

JOHN KOWALSKI
Dresser Atlas

Forty years ago there was little problem with the analysis of a well log. The only type of log that was available was an Electrolog. This survey was used to determine the depth of the pay zone, the thickness of the bed, and the location of the oil-water contact. As time went on, more and more different types of logs were developed and the analysis of each was fairly simple and straightforward. However, a problem was developing in the interpretation of wells. What could be done on a well which was logged with two, or three, or four different tools?

Each tool required a different method of analysis because of the different theories and types of data that were being measured. Log analysis was rapidly developing into a highly specialized discipline. At the present time, one of the most important people in any oil company is the log analyst. The exploration people depend on him for information about the rocks in a wildcat and the exploitation group depends on him to tell them about the reservoir characteristics. Now, instead of one or two types of logs, he has to contend with about forty of them. Each of these logs responds differently in a sequence of different lithologies. Because of this distinctive response, certain combinations of logs may be used to determine characteristics of the rock through which they are recorded. In most cases, these logs are recorded as a line trace on film in a camera (Fig. 1). There are, however, certain specialized logs which are recorded on special equipment to facilitate their interpretation (Fig. 2). The modern log analyst uses all methods of interpretation that are available to him, from simple charts to computers.

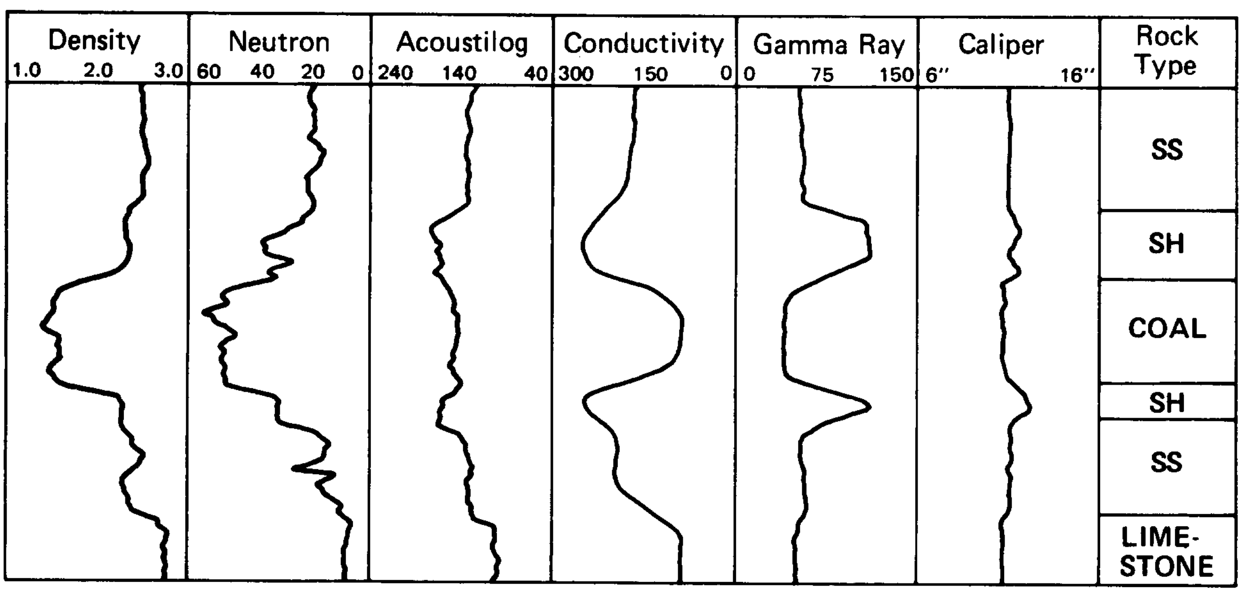

FIG. 1 GENERALIZED RESPONSE OF LOGS IN VARIOUS LITHOLOGIES

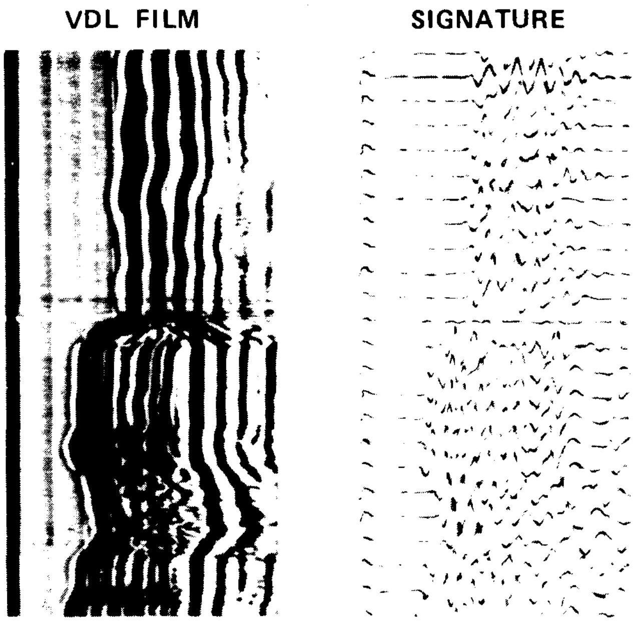

FIG. 2 VARIABLE DENSITY ACOUSTILOG

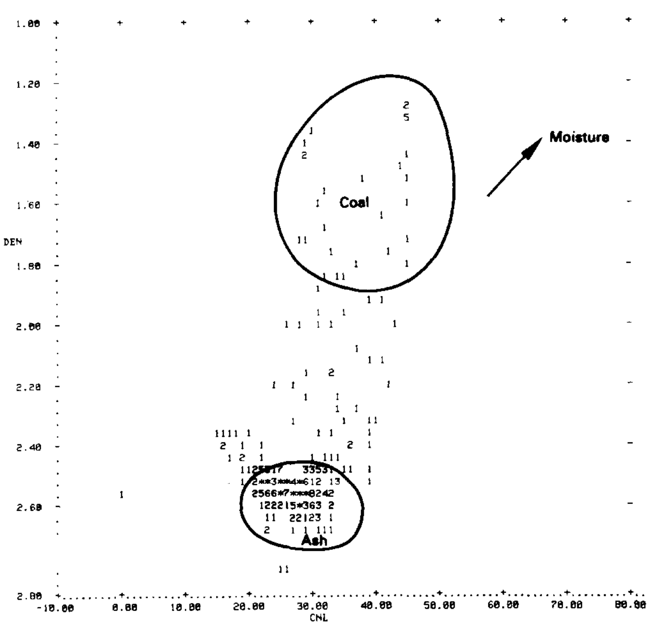

FIG. 3 CROSSPLOT OF COMPENSATED NEUTRON & COMPENSATED DENSILOG.

In today's oil field most wells are high cost, high risk ventures. A single zone can make the difference between putting a well on production and abandoning it. The responsibility of deciding on the location and quality of pay zones places such a burden on the log analyst that he cannot afford to leave anything to chance. The advent of computers has given him a tool which he can depend on giving a total uniform analysis of any section.

At the present time there are many different types of programs, a great many of which are highly specialized. However, there are six programs which are in widespread usage — Shaly-Sand, Complex (carbonates), Elastic Properties, Coal, Diplog and Cased Hole Analyses. Each of these computer programs requires certain input data to calculate all of the output information. After the data has been converted to magnetic tape it is plotted on a graph-like chart. Because of the characteristics of the logs, distinctive patterns, which depend on the rock, are formed in these crossplots (Fig. 3). The log analyst then uses these crossplots to determine parameters for the computed log.

SHALY-SAND ANALYSIS

This is used in sequences of sand, shale and shaly-sand. The required input is a deep resistivity, shallow resistivity, and two porosity measurements. Through the use of established relationships between this data, water resistivity and lithology, the computer program calculates percent bulk volume of sand, shale, clay and porosity water saturation, hydrocarbon density, permeability, water-filled porosity and fluid-filled porosity. This information is plotted on a four-track paper for easy comparison to the openhole logs (Fig. 4) and a listing of the data is also furnished to the customer.

COMPLEX RESERVOIR ANALYSIS

This program is normally run through carbonate reservoirs that typically contain limestone, dolomite, anhydrite, and relatively minor amounts of siliceous materials, all in varying amounts. The computed curves include secondary porosity, apparent grain density, a permeability estimate, water saturation, the caliper, the lithology determination and the fluid and porosity analysis including an estimate of moveable hydrocarbons. The primary reason for carbonates being treated with a separate computer program is the lithologic characteristics of this type of rock. It is denser than sandstone and contains minerals not usually associated with sands and shales. In addition, it is crystalline in structure and generally, lower porosity makes it easier to treat separately. Although it is run on a different computer program the format for presentation is similar to that of the shaly sand analysis (Fig. 5), and it also includes a list of the data.

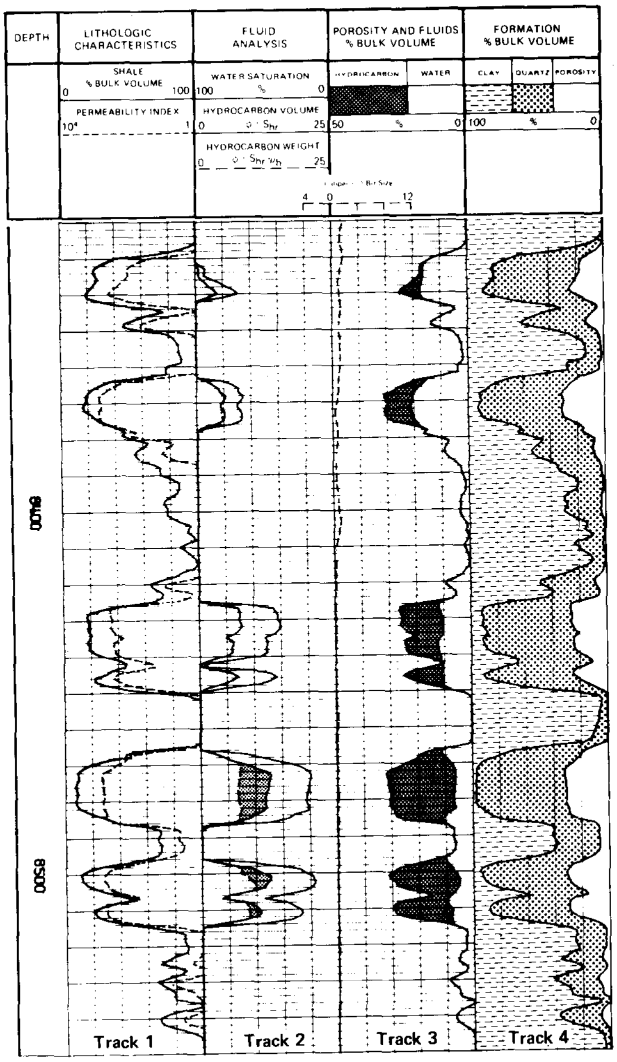

FIG. 4—SANDSTONE ANALYSIS

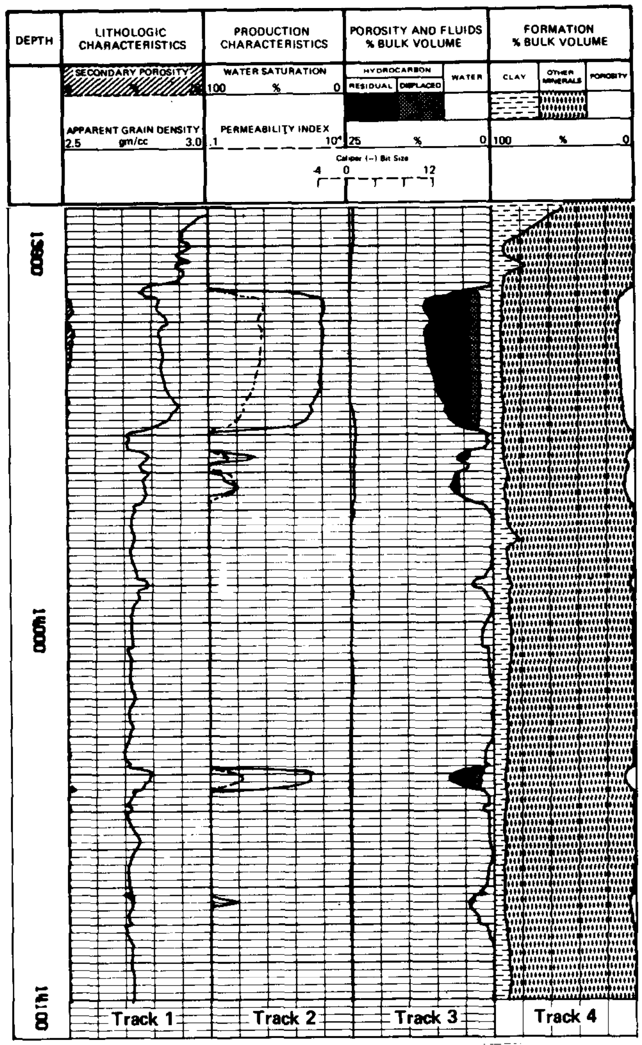

FIG. 5—COMPLEX RESERVOIR ANALYSIS

COAL ANALYSIS

Both shaly sand and the Complex Reservoir Analysis are oriented toward hydrocarbon detection and evaluation. The Coal Analysis program is primarily designed for evaluation of coal seams, as well as other characteristics necessary in mine construction. The Coal Program is designed around a lithologic analysis which will handle shaly sands and carbonates with equal ease. This can be done because the fluid is not a primary concern in this interpretation. When the program determines a coal seam to be present, it automatically calculates carbon, ash and moisture in weight percent, which furnishes the coal company with a relative quality of the seam. In addition, when the Acoustic Log has been recorded, the elastic parameters are also calculated over the entire interval. These furnish the customer with the properties described under the Elastic Properties Epilog which allows him to consider the overburden and floor strength surrounding the coal seams. This information is presented in a standard four-track format (Fig. 6). The listings furnished to the coal company give a printout of the data every quarter foot.

CASED HOLE EXPLORATION SERVICE

This program combines a number of cased hole services, including the C/O log, Si/Ca ratios, the Neutron Lifetime Log and the Compensated Neutron Log, with openhole data to produce an Epilog that looks very much like the Sandstone Analysis. The major difference is that two fluid saturations are calculated using the C/O and NLL logs to facilitate comparison with the original

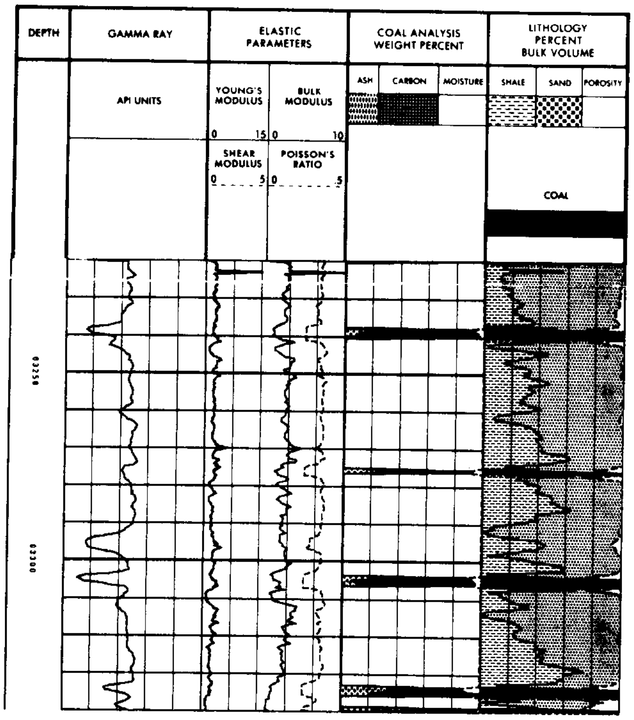

FIG. 6—COAL ANALYSIS

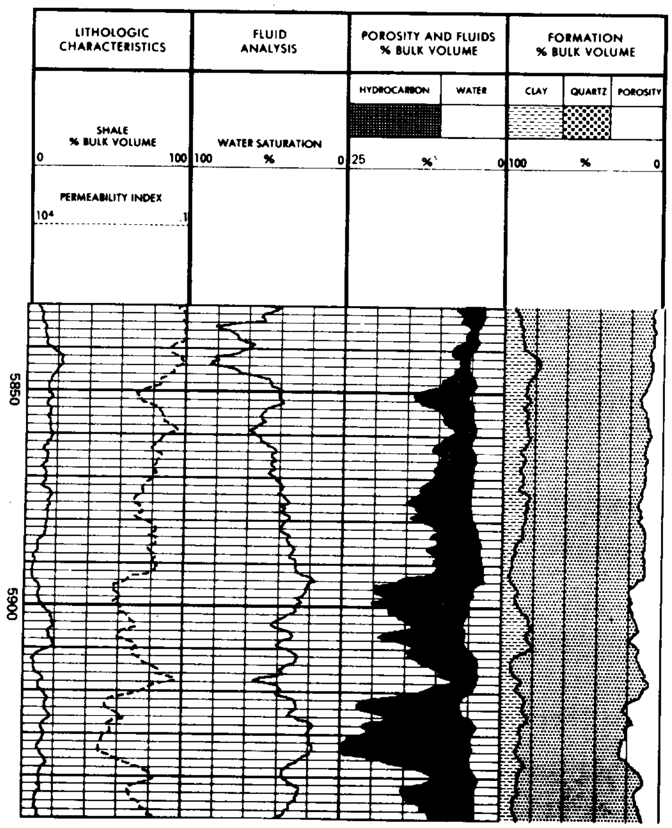

FIG. 7—SANDSTONE ANALYSIS

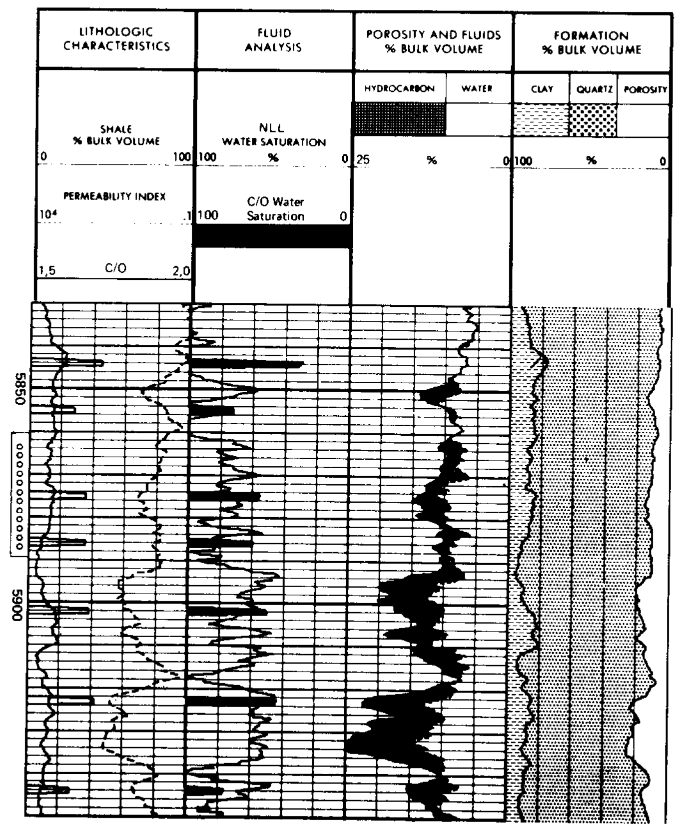

FIG. 8—CASED HOLE EXPLORATION SERVICE

openhole data. The Sandstone Analysis (shaly sand) exhibits the hydrocarbon content of the virgin formation (Fig. 7). The Cased Hole Exploration Service Analysis gives a hydrocarbon content at the time the logs were run during the depletion of the formation (Fig. 8). It is easy then for an oil company to compare the two logs and determine if they are getting an adequate hydrocarbon recovery, or if they are not, to determine a method of treatment for the well.

LITHO-ELASTIC PROPERTIES

This program uses two, sometimes three, porosity devices and the gamma ray to determine four engineering properties of the rock at each level. These are Poisson's ratio, bulk modulus, shear modulus, and Young's modulus. These strength parameters are used for a number of engineering applications. In oil or gas wells, the most common uses are to try to determine the fracturability and sand producing potential of individual formations. These curves are derivations of the four original calculations mentioned. A correlation between the lithology and the four original calculations (Fig. 9) shows the strength characteristics of the various rocks. It is obvious from this that although the formation is lithologically uniform, its elastic properties can exhibit a wide range of values which is important in designing the completion of a well or the construction of a mine.

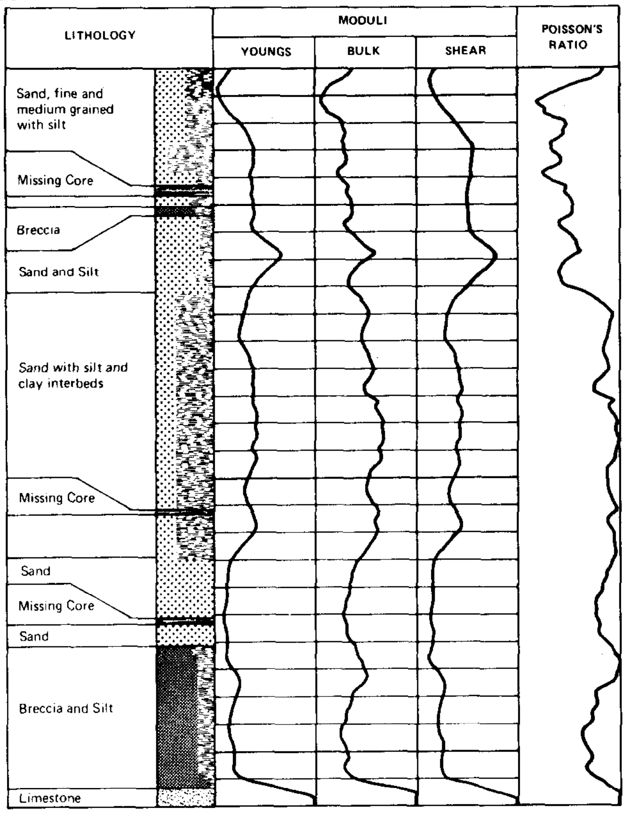

FIG. 9—ELASTIC PROPERTIES

DIPLOG ANALYSIS

The strike and dip of formations is a prime concern when working on an oil prospect. Unfortunately, when the rocks of interest are below the surface of the earth this measurement is difficult to determine. Well logging companies have devised a tool which will furnish a geologist with the strike and dip of formations encountered in a well. The Diplog is recorded in two ways, optically (Fig. 10) and on magnetic tape. The analysis is accomplished on a computer which furnishes the oil company with a printout (Fig. 11) of the formation dip and a vector plot of the well (Fig. 12). The vector plot shows arrows indicating the angle and direction of dip as well as the borehole deviation. Certain patterns of the dip may be associated with certain geological features as illustrated. A geologist who has knowledge of the lithology and the dip patterns can make a determination about the geologic history which aids him in the placement of other wells.

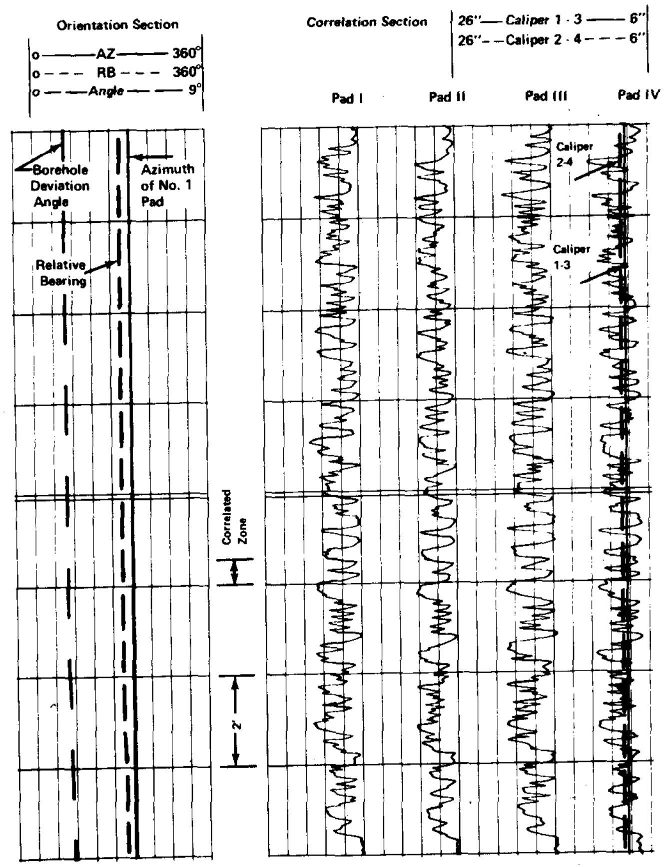

FIG. 10—FOUR-ARM DIPLOG ORIENTATION AND CORRELATION CURVES

SUMMARY

Computed logs have become common in the oil industry in the last five years. Almost every wildcat well or important well will be analyzed by computer interpretation. The purpose of this, of course, is to keep from misinterpreting the data, that is to eliminate as much human error as possible. A second purpose is to keep the format of the interpretation uniform, thus allowing a log analyst to look at logs from any geological province and compare them to each other. A third purpose is one which is not readily apparent as an aid to managerial decisions. In the modern oil company, a great number of managers and supervisors do not have a logging background. Because of this, they find it difficult to study the raw data and mentally evaluate

DEPTHS		• • FORMATION DIP • •			• • • • BOREHOLE • • • •			
UPPER	LOWER	ANGLE	AZI	BEARING	DRIFT	AZI	BEARING	GRADE
4711	4719	2.0	151	S 29 E	0.8	58	N 58 E	100
4713	4721	2.0	148	S 32 E	0.4	62	N 62 E	100
4715	4723	2.0	147	S 33 E	0.4	59	N 59 E	100
4717	4725	1.9	121	S 59 E	0.4	50	N 50 E	100
4719	4727	1.9	116	S 64 E	0.4	60	N 60 E	100
4721	4729	1.1	80	N 80 E	0.4	40	N 40 E	100
4723	4731	2.5	61	N 61 E	0.4	46	N 46 E	100
4725	4733	2.2	92	S 88 E	0.9	57	N 57 E	100
4727	4735	1.1	82	N 82 E	0.4	56	N 56 E	100
4729	4737	1.7	92	S 88 E	0.5	51	N 51 E	100
4731	4739	1.7	88	N 88 E	0.5	47	N 47 E	100
4733	4741	1.6	81	N 81 E	0.5	48	N 48 E	100
4735	4743	2.8	40	N 40 E	0.5	50	N 50 E	100
4737	4745	2.5	11	N 11 E	0.5	47	N 47 E	90
4739	4747	2.5	42	N 42 E	0.4	48	N 48 E	55
4741	4749	3.8	275	N 85 W	0.5	52	N 52 E	25
4743	4751	13.2	211	S 31 W	0.5	52	N 52 E	1
4745	4753	17.3	193	S 13 W	0.5	55	N 55 E	37
4747	4755	10.7	214	S 34 W	0.5	51	N 51 E	77
4749	4757	10.7	208	S 28 W	0.5	54	N 54 E	53
4751	4759	8.5	74	N 74 E	0.5	54	N 54 E	62
4753	4761	7.9	80	N 80 E	0.6	51	N 51 E	100
4755	4763	7.4	15	N 15 E	0.5	56	N 56 E	100
4757	4765	7.4	6	N 6 E	0.5	55	N 55 E	100
4759	4767	7.4	357	N 3 W	0.5	54	N 54 E	100
4761	4769	5.6	354	N 6 W	0.6	52	N 52 E	100
4763	4771	4.1	38	N 38 E	0.5	48	N 48 E	100
4765	4773	4.1	29	N 29 E	0.5	51	N 51 E	100
4767	4775	4.4	320	N 40 W	0.6	44	N 44 E	100
4769	4777	4.1	328	N 32 W	0.6	42	N 42 E	55
4771	4779	7.1	332	N 28 W	0.6	41	N 41 E	53
4773	4781	7.2	326	N 34 W	0.6	42	N 42 E	64
4775	4783	5.4	23	N 23 E	0.6	49	N 49 E	68
4777	4785	5.8	24	N 24 E	0.6	49	N 49 E	72
4779	4787	5.4	6	N 6 E	0.6	39	N 39 E	77
4781	4789	5.1	1	N 1 E	0.9	37	N 37 E	100
4783	4791	4.6	352	N 8 W	1.7	36	N 36 E	100
4785	4793	4.6	339	N 21 W	2.2	43	N 43 E	100
4787	4795	4.6	340	N 20 W	2.0	35	N 35 E	100
4789	4797	4.6	44	N 44 E	0.5	41	N 41 E	100

FIG. 11—DIPLOG TABULAR PRINTOUT

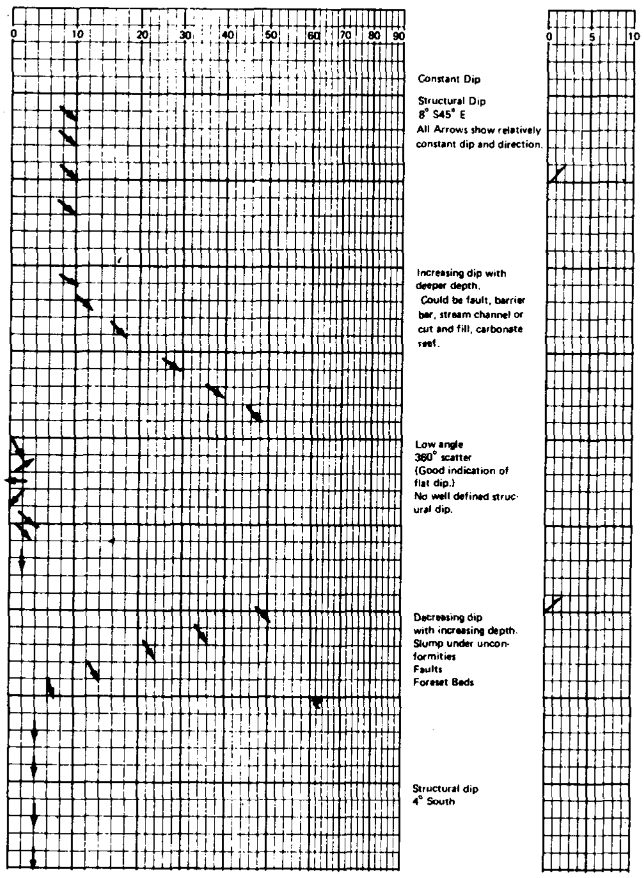

FIG. 12—DIPLOG VECTOR PLOT PATTERN

it. The computed log furnishes them with a tool which, although it requires some knowledge of logs, enables them to evaluate the importance of a well. In addition to allowing the manager to make decisions on the productivity potential of a specific well, there are now computed logs which allow him to determine problems before they occur. For example, zones which are rate-sensitive may be detected, and the completion may be tailored to allow these zones to attain maximum productivity. On certain types of completion where the well must be fractured, computed curves are available which will aid in deciding which zones to fracture first and the amount of pressure needed to break them down.

Some managers in large, diversified, energy-oriented companies are faced with having to evaluate coal and potential gas storage areas in addition to the normal hydrocarbon prospects. The major logging companies have developed computer programs which allow this evaluation to be performed with a minimum amount of effort.

It is apparent that a manager in a modern oil company can be faced with many problems for which computed logs offer solutions. The additional expense of having the logging companies compute the logs becomes negligible when compared with the time involved in making a decision and the cost of an erroneous one.