COAL INTERPRETATION MANUAL

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1. INTERPRETATION OF LITHOLOGY

1.1 The Geologist's Tools

When making a hand identification of a rock sample, the geologist's tool is essentially his experience and he uses the following factors in making his assessment —

Colour
Grain size
Structure (bedded, cleved, etc.)
Feel
Hardness
Weight
Taste
Mineral composition
Plant and fossil remains

From this information he can normally always identify a basic lithology, certainly in terms of sedimentary, igneous and metamorphic rocks and usually he can go further into sub-divisions such as sandstone, shale, limestone, schist, gneiss, granite, basalt, etc. In addition certain very distinctive minerals like pyrite, calcite, quartz, gypsum and salt can usually be identified and, so can coal.

Geologists with experience in special lithologies and working in restricted areas can often sub-divide much further — for example recognition of types of shale bands, differentiation between siltstone and mudstone and recognition of different types of sandstone is usually straightforward with experience.

However, take a hard rock geologist and put him in a coal region and he will take some time before he is readjusted to interpret the new lithologies.

1.2 The Tools of the Well Log Interpreter

Like the geologist the interpreter has a certain number of tools on which to base his interpretation and similarly like the geologist he needs within any region and any type of geological deposition, a period of experience before he can adequately interpret the results. The essential tools for the interpreter are as follows:

Gamma radiation:	usually potasium or uranium.
Density:	more or less directly equivalent to the geologists weight.
Neutron thermalisation:	usually detection of hydrogen (i.e. water)
Resistivity:	usually an effect of water and the salinity of the water.
Sonic velocity:	a function of hardness and compaction.
Temperature:	essentially a thermal conductivity measurement.

To interpret a lithology, an assessment of many of the above facts is needed. However, as certain minerals are easy to identify in the geological hand specimen, so with wireline logs certain minerals are always obvious, such as salt, gypsum, potash and coal.

2. BASIC TOOL RESPONSES

2.1 Gamma Ray

Except where there are uranium concentrations and certain special effects in igenous rocks, the source of activity is potasium, or more specifically the associated isotope K40. The potasium is present in most shales in the form of mica and hence its measurement is usually an evaluation of shale content. In a typical sequence of logs in the coal environment a Shale Line can normally always be drawn on the gamma ray log. This line (Fig. 1) is the estimation of where the average 100% shale would respond on the log. Readings less than the value of the Shale Line mean increasing presence of sandstone, limestone and coal whilst readings above the Shale Line indicate marine bands or uranium concentrations.

It is usually possible in most areas to also draw a Sand Line which is the deflection caused by a typical sandstone. Deflections below this line usually represent coal and possibly limestone whilst deflections between the Shale and Sandstone Lines usually indicate gradations between sandstone and shale, i.e. mudstone, siltstone or even argillaceous limestone and in some cases inferior coal.

By way of a summary of the above, Fig. 1 shows an interpretation of a typical coal measure gamma ray response.

2.2 Density Measurement

The wireline tool actually measures electron density which is related in a complex way with bulk density. The complexity of this relationship is taken into account in the presentation of the log and for practical purposes is calibrated directly into formation bulk density. The volume of rock examined by a density tool depends upon source to detector spacing and as lithology does not require high resolution it is advantageous to use the long density spacing log in the evaluation. Density is, of course, a direct measurable rock property of a sample and one with which the geologist is familiar as weight. In certain cases the density measurement is diagnostic in its own right but usually it is necessary to study it in conjunction with a gamma ray log.

The density response over coal is unique owing to the low density of coal. This is even true when coal is of poor quality and a shale impurity increases the gamma ray deflection. The gamma deflections in coal and sandstone are similar but the strong density change is shown clearly on the density log allowing the true material to be distinguished. Apart from coal the density can give a unique answer for one or two other minerals in the evaporite sequence and for completeness these are also shown in Fig. 2.

GAMMA RAY

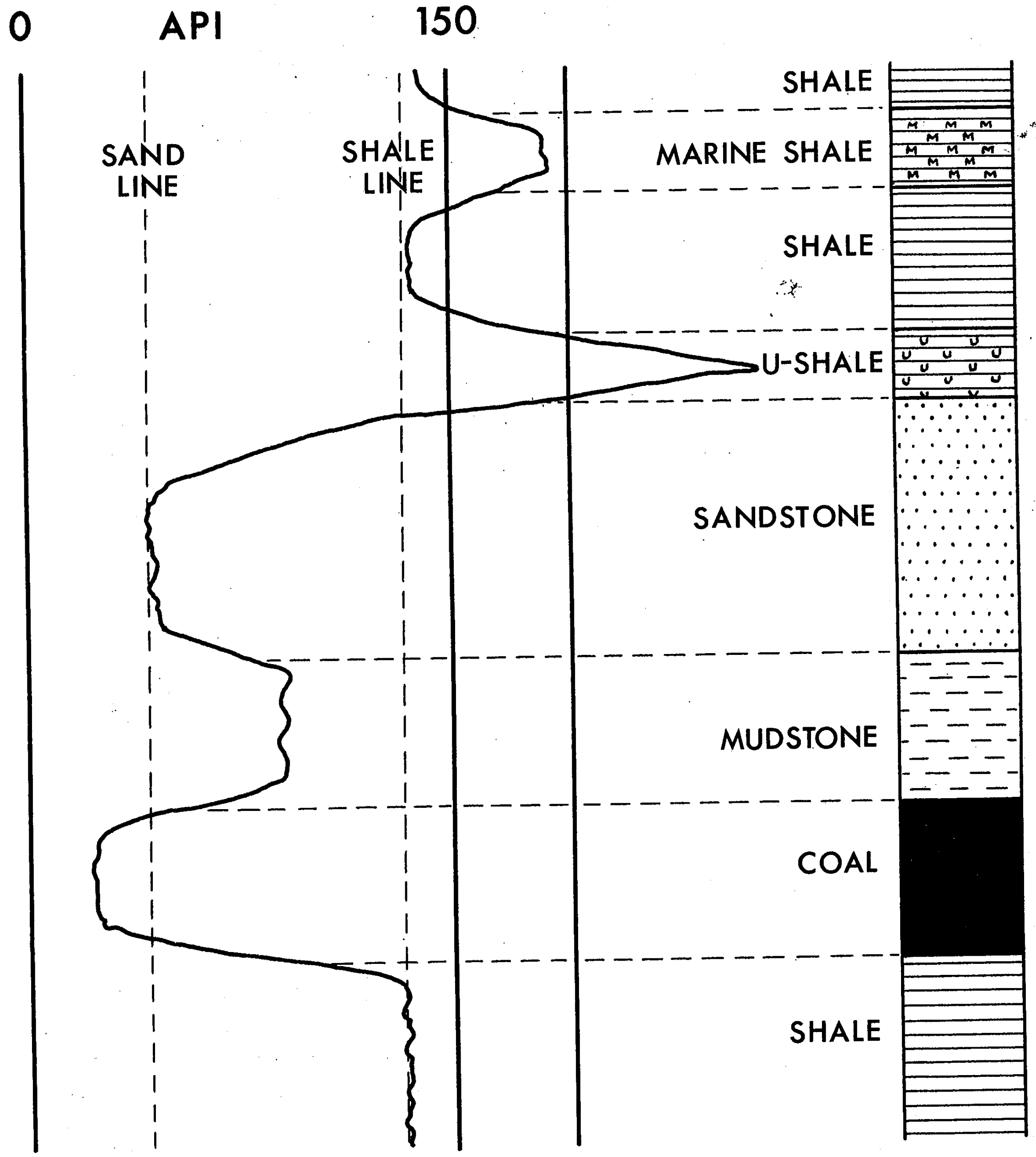

fig 1

BASIC COAL MEASURE LITHOLOGY FROM GAMMA RAY

The gamma ray and density log together are usually sufficient for basic coal lithology analysis — shale, sandstone, mudstone, marine bands and coal — and for this reason in the practical logging of a borehole they are combined in one presentation called the Coal Lithology Log. Included also in this log is a caliper because if a caliper of the borehole is poor then identification can be difficult (see section 3 on Coal Identification). Similarly, if the borehole is cased or without fluid, more care is needed (again see Coal Identification section).

The one area not covered satisfactorily by the Coal Lithology Log is the differentiation between sandstone and limestone. This is dealt with at the end of this section.

2.3 The Neutron Log

This log essentially responds to hydrogen and to a lesser extent carbon and is in many ways a confirmation of the gamma ray log.

Typical response of this measurement over the coal sequence is shown in Fig. 3.

It can be seen that shale reads high porosity due to the OH content in mica and possibly some free water in the parting planes. Coal reads high because of the hydrogen and carbon, and is invariably higher than the shale. Note, however, that sandstone can vary due to the effect of water in sandstone of different porosity. This variation is obviously very useful and a similar variation can be expected in limestone.

For interest, the neutron log is spectacular in evaporite sequences and this is shown in Fig. 4.

2.4 Resistivity Log

Although because of its simplicity this log has been used in many areas for correlation and in many cases for identification, its use must be treated with great caution as its diagnostic properties are not consistent and can vary locally for a variety of reasons. In the ideal case shales basically read low and everything else high but at times both coal and sandstone can read low and this can cause serious errors. For example, coals in the form of lignite and anthracite read very low whilst sub-bituminous and bituminous coal can vary from low to high. Within a given province it is possible that the coals are consistent. Typical response of the resistivity log in the coal lithology is shown in Fig. 5.

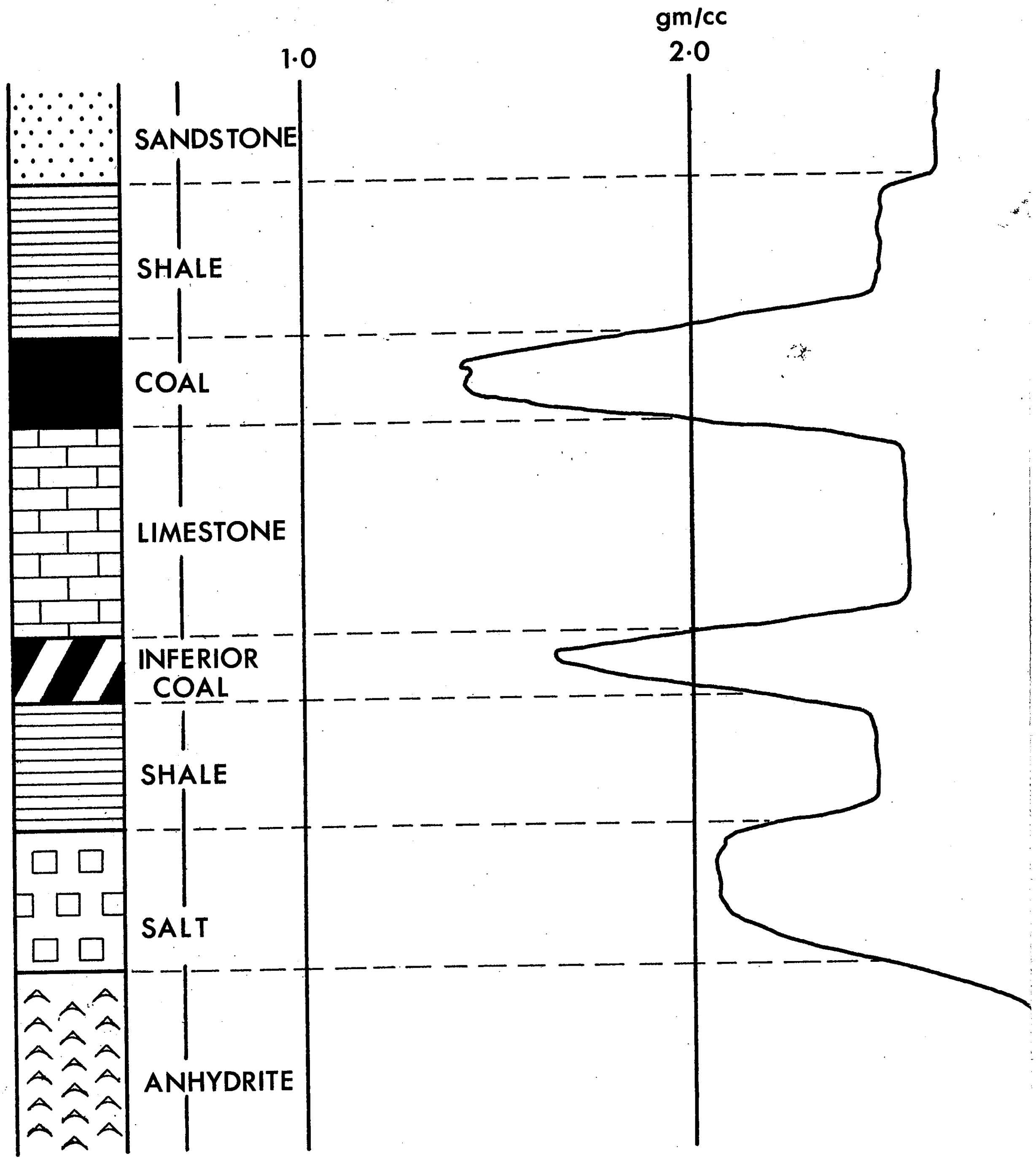

fig 2

BASIC LITHOLOGY FROM LS DENSITY LOG

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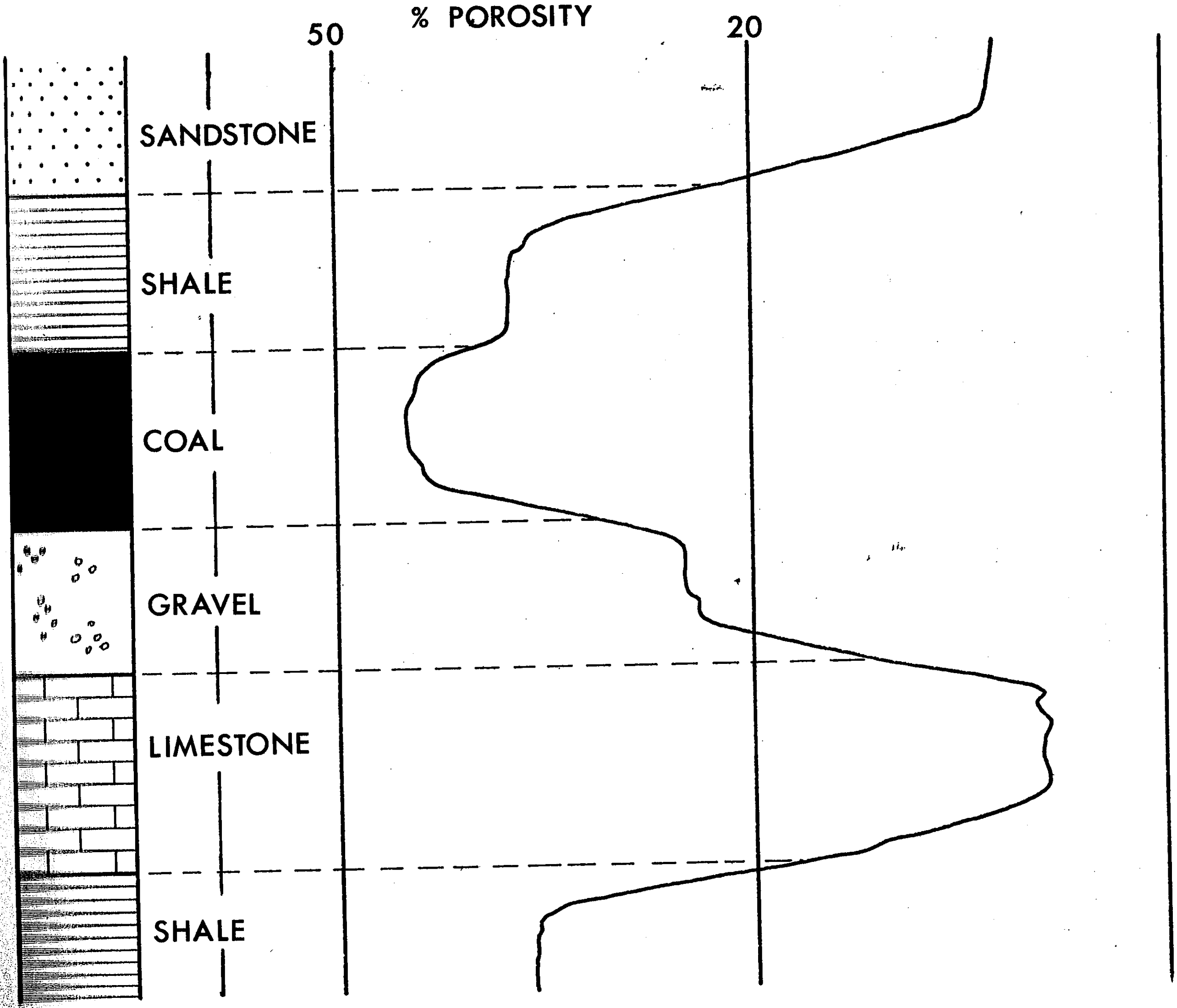


fig 3

LITHOLOGY FROM NEUTRON LOG

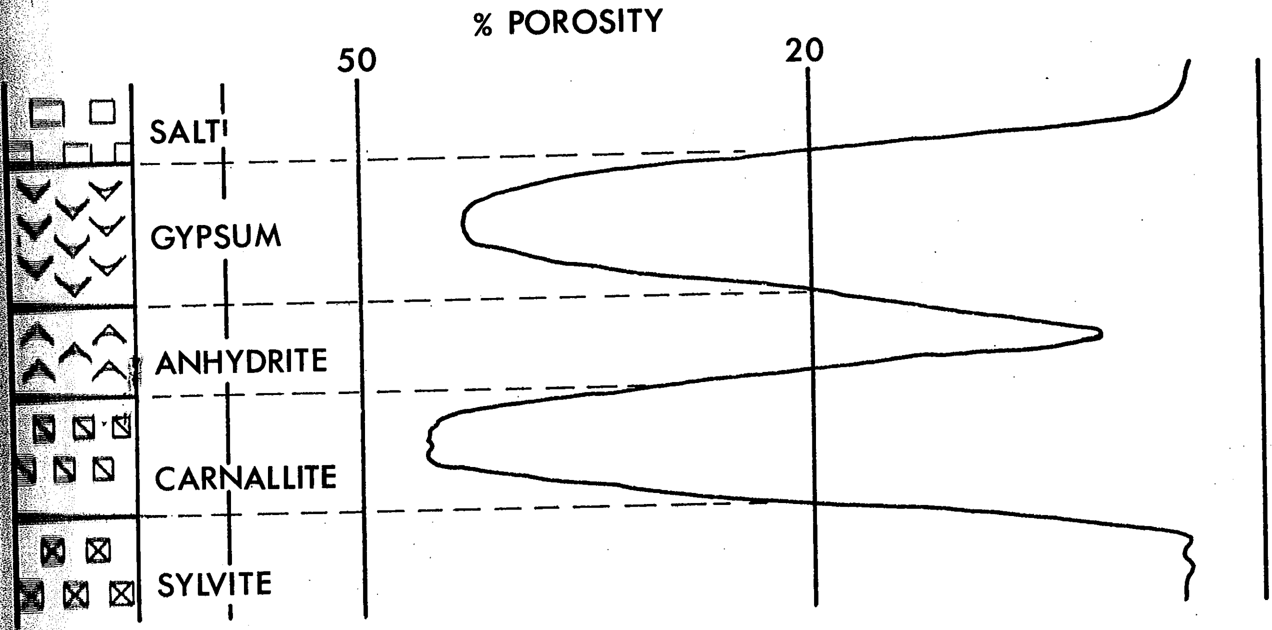


fig 4

NEUTRON IN EVAPORITES

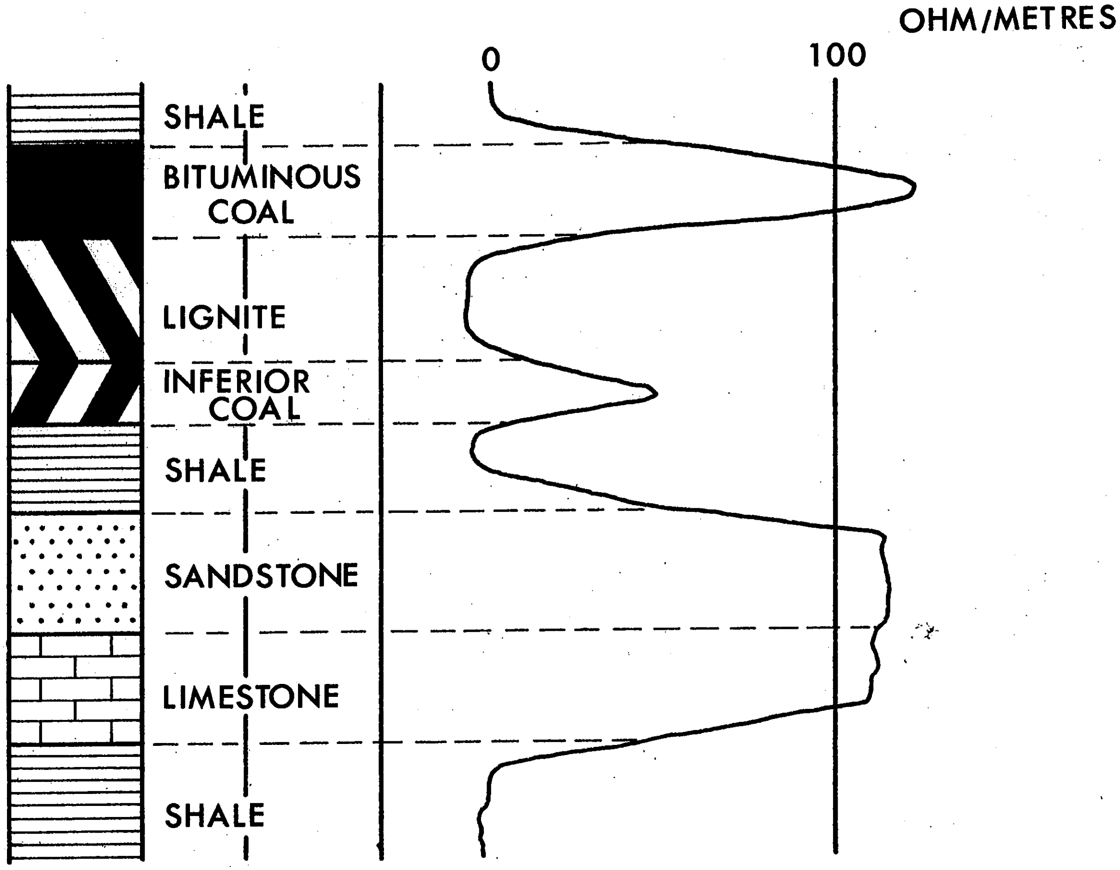


fig 5

RESISTIVITY RESPONSE IN COAL MEASURES

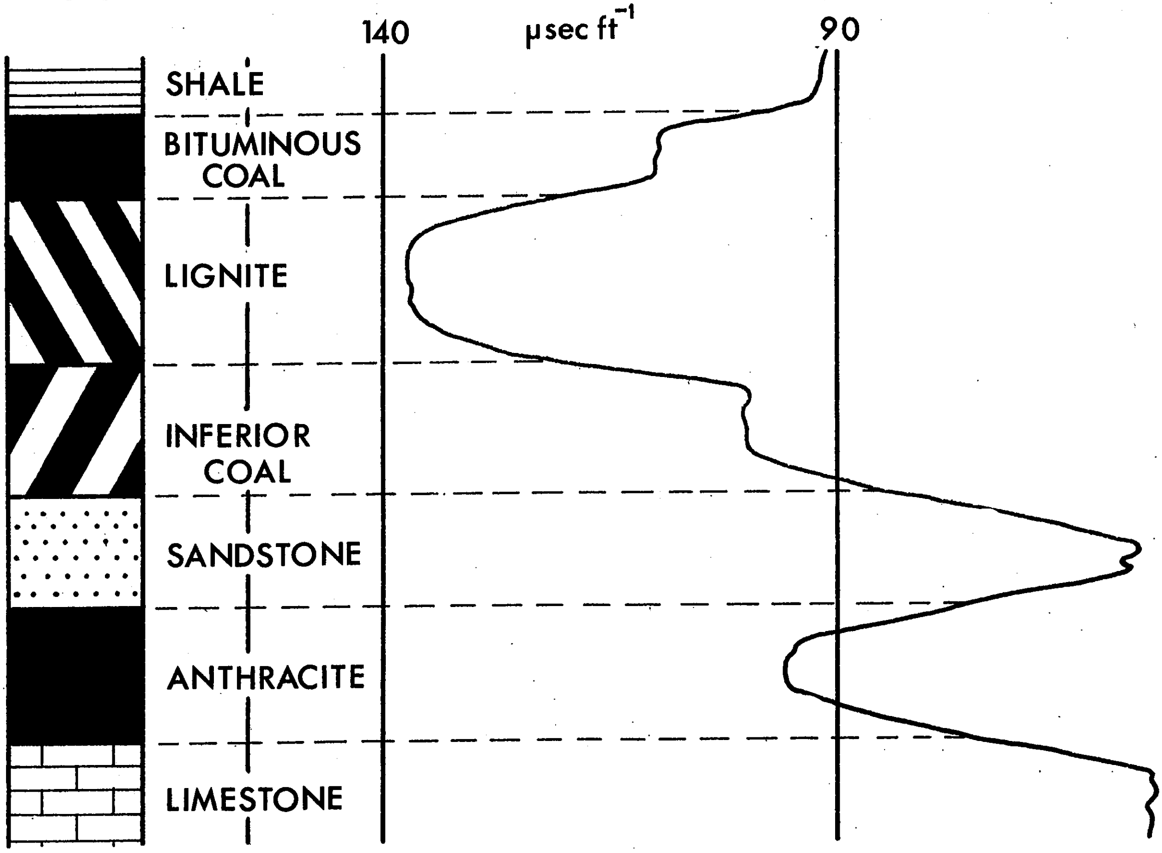


fig 6

SONIC RESPONSE IN COAL MEASURES

2.5 Sonic Log

In many ways this log has a similar response to the density which is not surprising in view of the close relationship between compaction and density. Consequently it is usually very good for defining coal and indeed may have the potential to be used as a coal rank indicator. In lithological interpretations it rarely shows more than a density log and thus is not usually justified to be run as a simple lithology tool. Typical responses are shown in Fig. 6.

2.6. Temperature

Although at present of very little use for lithology, it is important for the record to note that a differential temperature response can usually be seen over coal sections, thus indicating a higher thermal conductivity over coal than most other rocks.

2.7 Limestone v. Sandstone

In a simple evaluation programme it is quite difficult to distinguish between these two rock types and if indeed there are shale impurities it is almost impossible without very sophisticated tools.

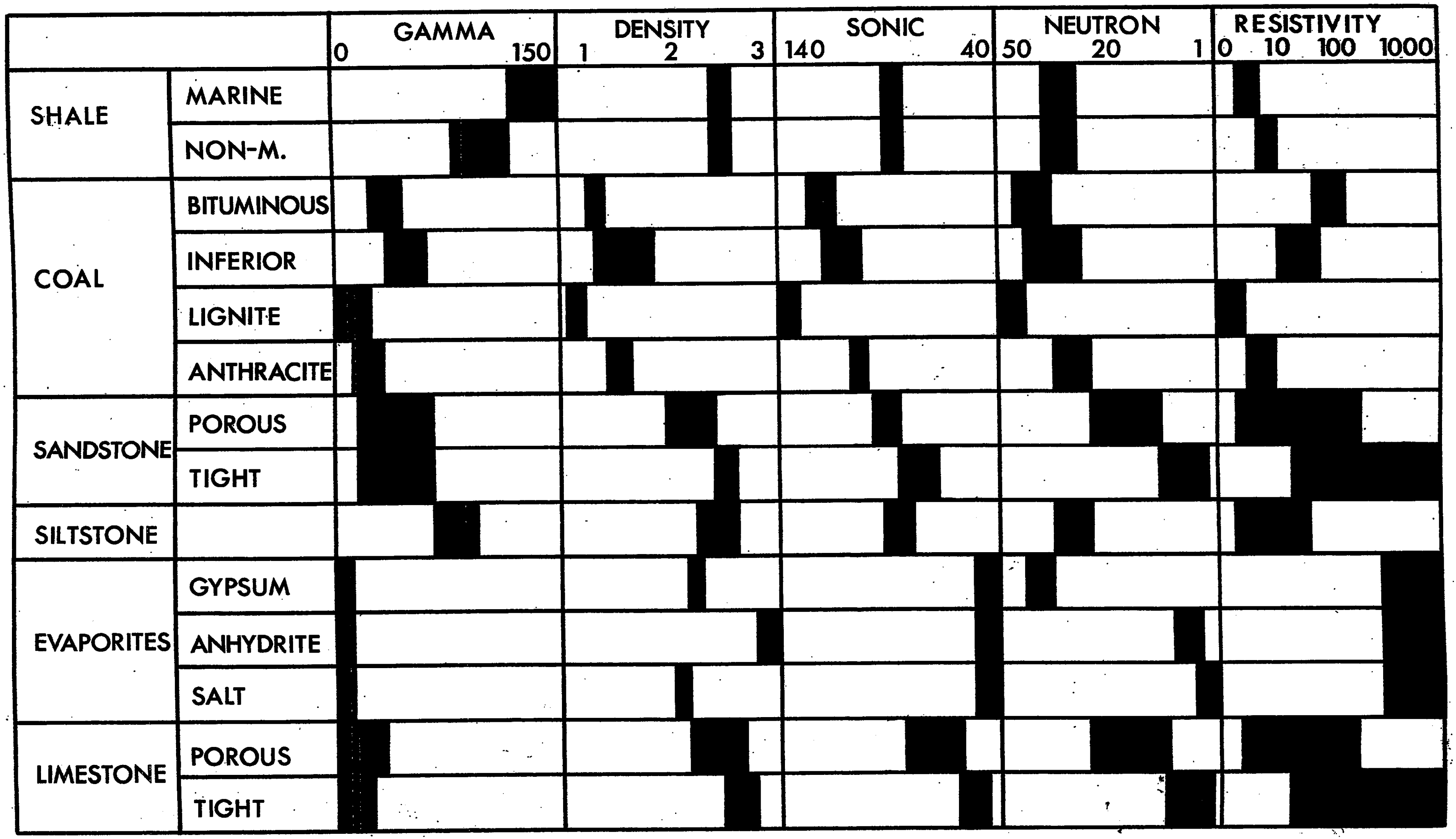
Properties in both are similar and vary only by degree and the notes below show the type of effects which may help to distinguish between them. Although it has been noticed over the years that because of the very stable geological conditions associated with the formation of limestone, a limestone response tends to have a consistent signature which once the geologist is familiar with the lithology he can often learn to identify.

The slight difference in log response between these two types of formation is as follows:

Gamma Ray:	both low but limestone usually lower and when the reading is below 15% of the Shale Line limestone is almost a certainty.
Density:	both very similar — look for constant signature.
Neutron:	limestone usually shows lower porosity.
Sonic:	limestone usually faster and with less cycle skipping.

fig 7

LITHOLOGY V. TOOL RESPONSE (SUMMARY)



2.8 Summary

i. In most cases coal lithology can be directly deduced using the gamma ray/density combination as shown in the Coal Lithology Log.

ii. Although widely used, resistivity may not be as reliable as generally thought.

iii. If limestone is present great care is needed in interpretation.

iv. Fig. 7 is a general diagram summarising all the responses mentioned in this section and may be a useful guide for those undertaking interpretation.

2.9 Hints on interpretating coal lithology

i. Look for low gammas and mark out those which have low density (coal).

ii. Mark out any very high gamma ray peaks (Marine bands or Uranium shales).

iii. Draw a Shale Line and block out the shale section.

iv. Draw a Sand Line and block out the sandstone bands.

v. Examine the remaining material carefully as it will be a mixture of rock types.

3. COAL IDENTIFICATION

It is possible to identify coal with certainty in nearly all possible hole conditions. However, where hole conditions are difficult and there is caving or drill stems are left in the hole, care is necessary. The following cases are considered:

3.1 Open hole — fluid filled
3.2 Open hole — no fluid
3.3 Cased hole — fluid filled
4.4 Cased hole — no fluid

3.1 Open Hole — Fluid Filled

This is the most usual and easiest condition for coal identification and can be done positively with the combination of the caliper and density log and usually with a caliper and sonic log. In both cases the principle is for the caliper log to define that the hole is consistent, thus confirming that the measurement of either the density or sonic is reading rock formation and not hole abnormality. As a back-up, since most gamma rays read low over a coal section, it is always useful to confirm a low gamma ray. Fig. 8 shows a good quality response of the three logs.

Effect of Caving

Development of caves which do not permit the coal combination sonde to sidewall against the borehole cause erroneous results since the area immediately adjacent to the tool is replaced by fluid and not rock. In the case of caved coal with the density of 1.3 and fluid with a density of 1.1, the effect may not be startling. Against normal sedimentary rocks the effect is to lower significantly the apparent density and in the limit when the cave exceeds the depth of penetration of the tool a response similar to coal could be read.

In such conditions it is important to use the deepest penetration tool available — the long spacing density. Unless the cave is very large the LSD tool will read and detect the presence of coal. Where the cave is extensive great care is necessary in identification but it is usually possible to resolve the problem by considering both the short spacing and long spacing density logs and by considering the relative deflection of each with respect to the base line. If the BRD reads a lower density than the LSD, this indicates that cave is non-coal. If both logs respond similarly then coal is present. The condition would of course also happen if the cave was extremely large. Fig. 9 shows how the above principle is employed.

Obviously the caliper should be studied closely.

The sonic log gives very indifferent results in caving and, therefore, is not to be trusted.

3.2 Open Hole — No Fluid

As the sonic log will not work without fluid the density log is the only possibility, although some indication can also be gained from the neutron and gamma ray.

The response is virtually the same as 3.1 except that densities read at a lower value (absence of the fluid) and caving effects are more pronounced, especially with the short spaced logs.

Where caliper is good interpretaion is straightforward but in very large caves where there is no material other than air to scatter back the density radiation, a peculiar effect happens where the density appears to increase (as count rate drops). Because in the absence of fluid and formation there is no medium to scatter back the radiation.

This effect will occur first on the BRD log which will tend to show a higher density than the LSD (the reverse of condition 3.1). Thus when the LSD reads lower than the BRD, coal is present, but when both logs read the same, non-coal or extremely large caving is present (presumably extensive caving is not associated with coal). Fig. 10 summarises these effects.

It is worth noting that old workings which are dry show up with a very high density.

The gamma ray log is not very much affected by fluid, reading perhaps 10/20% higher due to lack of fluid absorption so this can be used in relatively well known areas to help identify coal.

An interesting feature which should be noted with the gamma ray is that when it is run with a combined density sonde when fluid is absent the radiation from the density source will always cause an increase in the gamma ray. This effect is caliper dependent (the effect increasing with hole diameter) and typically in the order of 20% in average diameter coal boreholes. In view of this effect a discontinuity feature occurs when a sonde passes between the water/air interface since once the source is cleared of water there will be an immediate stepped increase on the gamma ray detector which is situated some 6 feet further up the sonde. This effect is shown in Fig. 11. It is now possible to have certain sondes in which this space is increased and the log remains unaffected by the density source (this is known as the dry hole CCS).

Both the neutron and temperature logs can be run without fluid but the neutron's response is extremely difficult and must be watched carefully, and the temperature will lack definition.

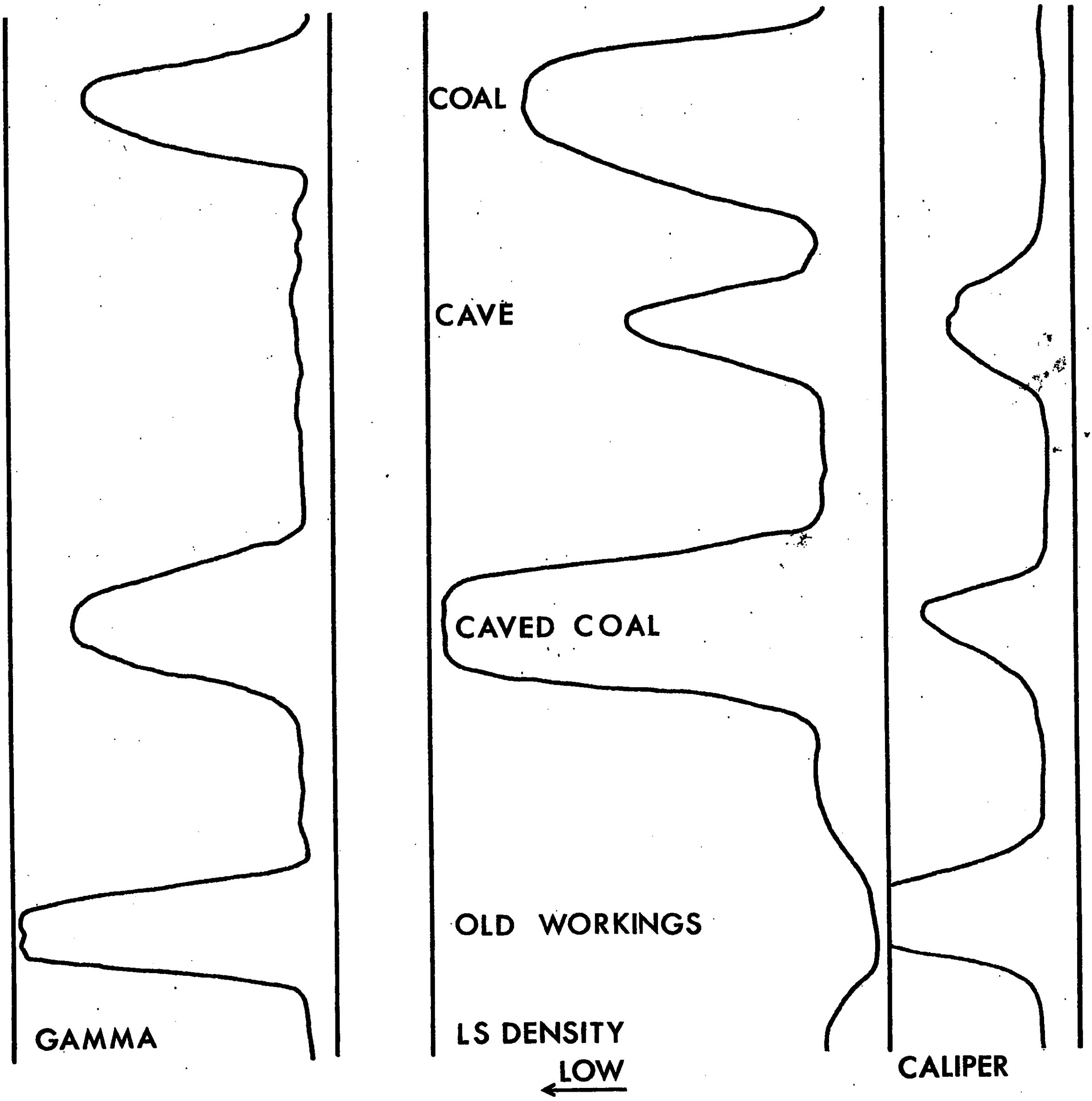


fig 10

DRY HOLE IDENTIFICATION

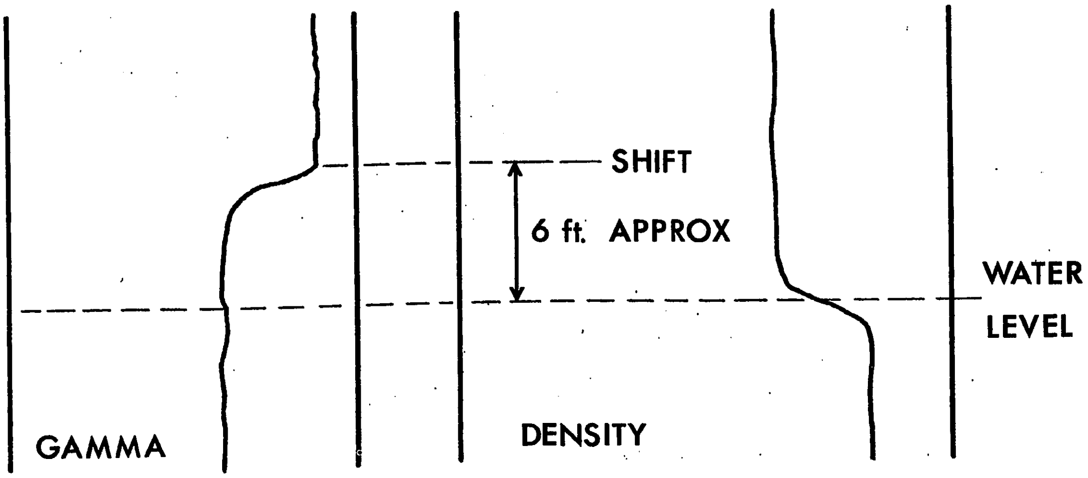


fig 11

DRY HOLE GAMMA SHIFT

3.3 Cased Hole — Fluid Filled

Density, gamma and neutron are the only logs which can be run in this condition and the effect of casing is two-fold.

i. It means there is no caliper.

ii. The gamma and density measurements suffer a degree of absorption due to the iron (the neutron is much less affected).

The absence of a caliper means that in all interpretations we are now uncertain as to the degree of variation in the borehole walls and thus any interpretation is subject to this proviso.

In any case it is usually possible to make reasonable deductions regarding the caliper by looking at the LSD trace throughout the borehole and to see if it has a fairly consistent response. Fig. 12 shows a split response illustrating what may be expected in a good section compared with a badly caved borehole.

Fig. 12 also shows how the BRD log reflects the changes in caliper due to the shallow penetration of this tool. strong variations in the BRD response, particularly if it appears to exaggerate the LSD features, is some indication of caving.

A caved coal section behind rods may not be identifiable. The best clue will come from the gamma which, if very low in a caved section, is most likely to be coal as sandstone does not usually cave. Beware, however, as in a very caved area a shale will show a low gamma.

3.4 Cased Hole — No Fluid

Very similar conditions as in 3.3 above except the effects of caving are more exaggerated and the reversal effect described in 3.2 will ultimately take place.

3.5 Summary

i. In open hole dry or wet with good caliper the density log can be used with 100% certainty to define coal.

ii. In open hole dry or wet density will give 100% identification except where a really massive caving exists.

iii. In cased holes where good caliper can be deduced, interpretation using the density log is again nearly 100% certain.

iv. In cased holes dry or wet where caliper is bad, great care is necessary but it is usually possible to identify coal.

v. Good coal does not usually cave and it is extremely rare for a condition to arise where caving is so extensive that the LSD does not make some response to the formation.

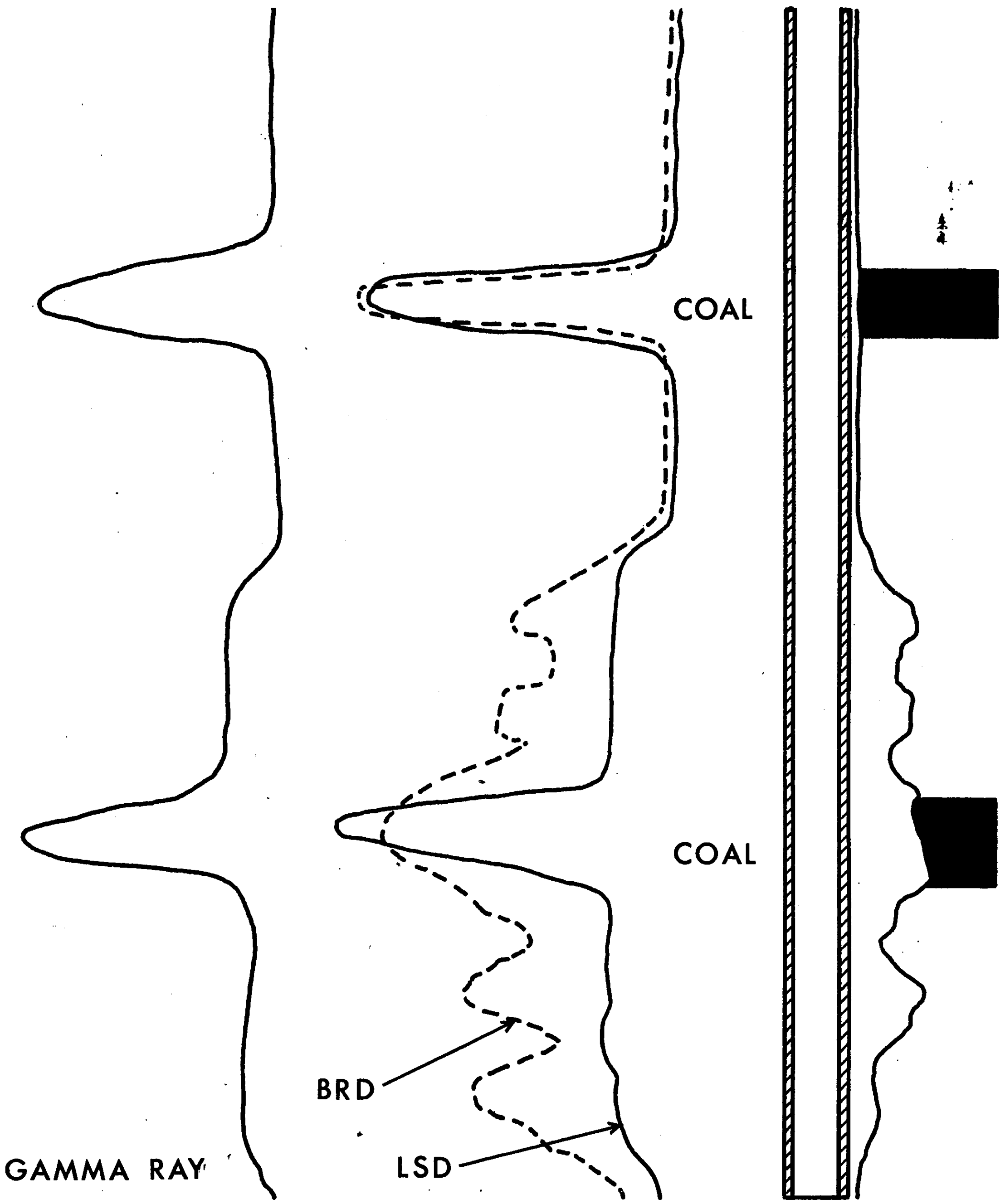


fig 12

COAL IDENTIFICATION CASED HOLE

3

4. SEAM THICKNESS

Seam thickness can be measured from the following logs:

Density
Gamma Ray
Neutron
Micro Resistivity
Sonic
Caliper

In all normal conditions by far the best and most reliable thickness determination can be made by using the density together with the caliper log. The shorter the spacing on the density is theoretically better, but as density spacings get too short complications arise and nullify the advantage.

The presentation in the Coal Thickness Log which uses the Bed Resolution Density and the Caliper on expanded scales of 20:1 has been specifically designed to give the best and most reliable thickness determination.

4.1 Coal Thickness Log Interpretation

i. First of all note the 'coal deflection' and see if the caliper response is consistent. If the caliper shows no more than marginal deviation then interpretation is simple. The correct interpretation point is the mid point on the BRD curve which, because this log is linear is the half density point, see Fig. 14. It is possible also to get a good thickness value from the LSD log as shown on the Coal Quality Log, see section 4.2.

ii. If the caliper shows significant variations then more caution is needed and the first stage is to compare the caliper response carefully with the 'coal deflections' on the BRD. It can usually be seen that the cave deflections give a similar response on the BRD log and in fact these sections are not coal at all. Coal normally does not cave and therefore the next step is to eliminate from the BRD log the cave areas. The flat parts of the caliper with coal type deflections on the BRD are now coal and deflections here can be interpreted at the half way point. Sometimes the cave is associated with the top of the coal and the half way point is taken between the root and the peak of the graph as far as the cave is concerned. Fig. 15 shows how caves may be identified and coal interpreted.

iii. Because coal does not usually cave it is often quite possible to measure accurately the thickness of the coal seam in a difficult section by examining the caliper log. The interpretation points are shown in Fig. 16, the top point being where the arms of the caliper immediately open into the cave, the bottom point being at the top of the gradation caused by the arms being closed as the caliper moves in to the coal area.

Coal thicknesses using the above method in reasonable conditions should be interpreted to ± ½ inch, in some cases even better.

4.2 Using the Coal Quality Log

Reasonable thickness can also be deduced from the Coal Quality Log, using the LSD and the gamma ray. LSD has deeper penetration and is less affected by the caves but has a more gradual slope and thus the interpretation point is more difficult to tie down. The correct procedure is to measure from the log heading the density of the peak of the deflection and the density of the root of the deflection, calculate the mean density of these two points, locate the position on the log heading and read the thickness of this position. Fig. 17 shows how this is done.

In normal conditions this position is approximately ⅕th along the curve from the root of the graph. Not, however, that if a processed density is given (see Log Processor Section) the LSD is linear and interpretation point is midway.

The gamma ray can also give an indication, particularly when the coal is sandwiched between shale and mudstone. The interpretation
* point on the gamma ray is ⅓rd down from the base level of the shale. *
The reason why the gamma ray interpretation is not symmetrical is that gamma rays travel further in the less dense coal medium, see Fig. 18.

4.3 Cave Boundaries

Often boundaries to coal show caving. The best way to examine this is via the caliper but if for some reason this log is absent, effects of caving can usually be seen on the density log. Fig. 19 shows the effects of a thin cave using the LSD log and the easiest method of interpreting is to draw an imaginary boundary as shown and interpret normally. Fig. 20 shows the same cave as seen on the BRD log and here the interpretation point would be half way between the cave boundary and the peak, as shown on the diagram.

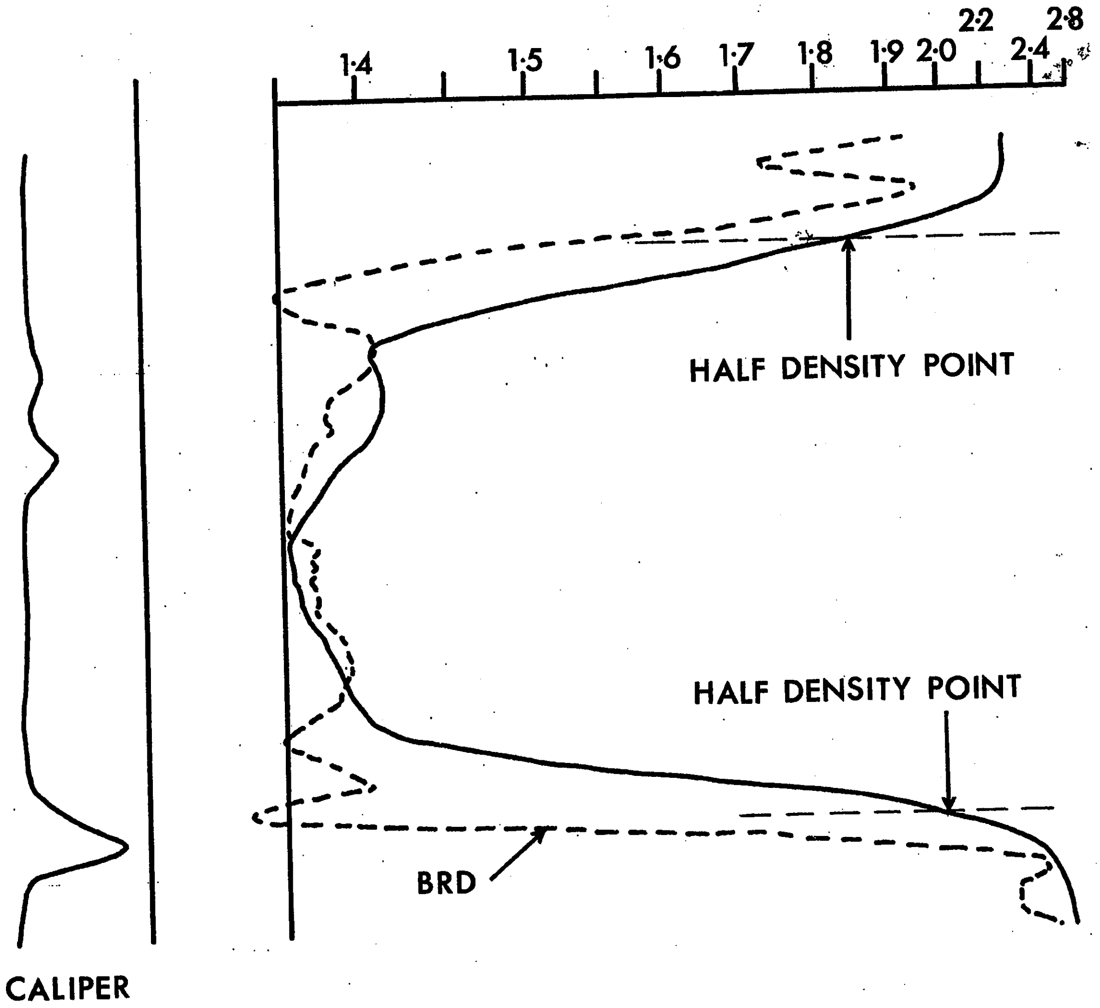


fig 17

SEAM THICKNESS LS DENSITY LOG

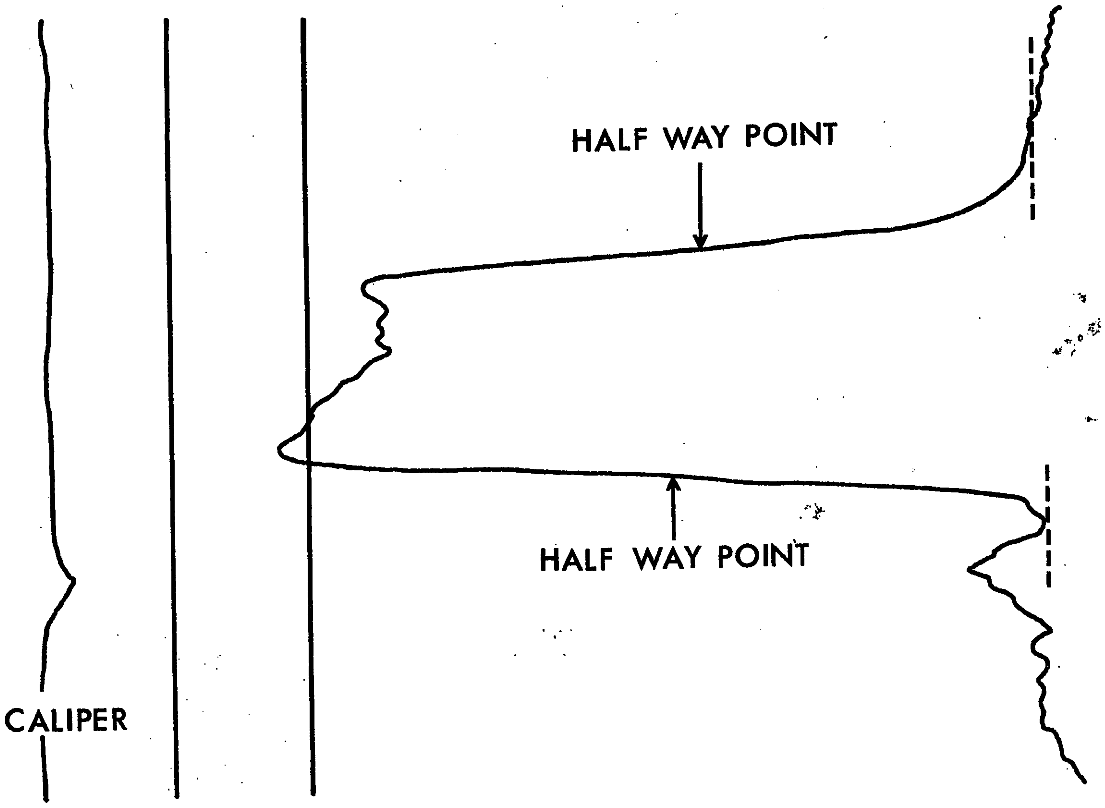


fig 14

SEAM THICKNESS BRD LOG

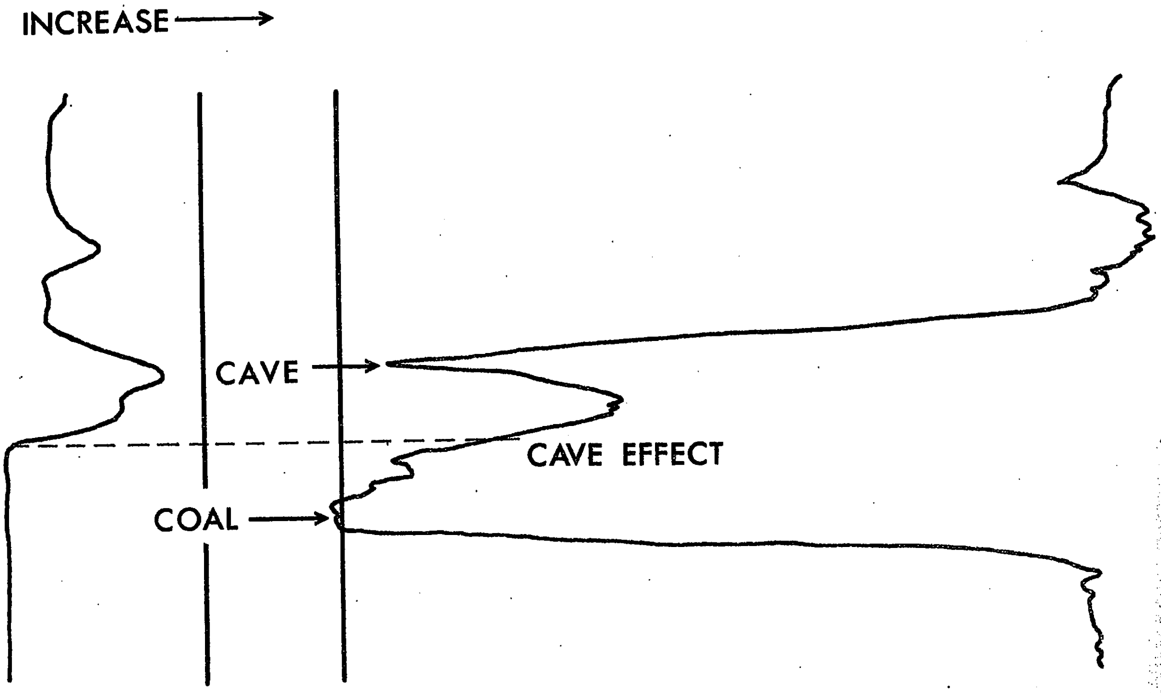


fig 15

BOUNDARY CAVING BRD

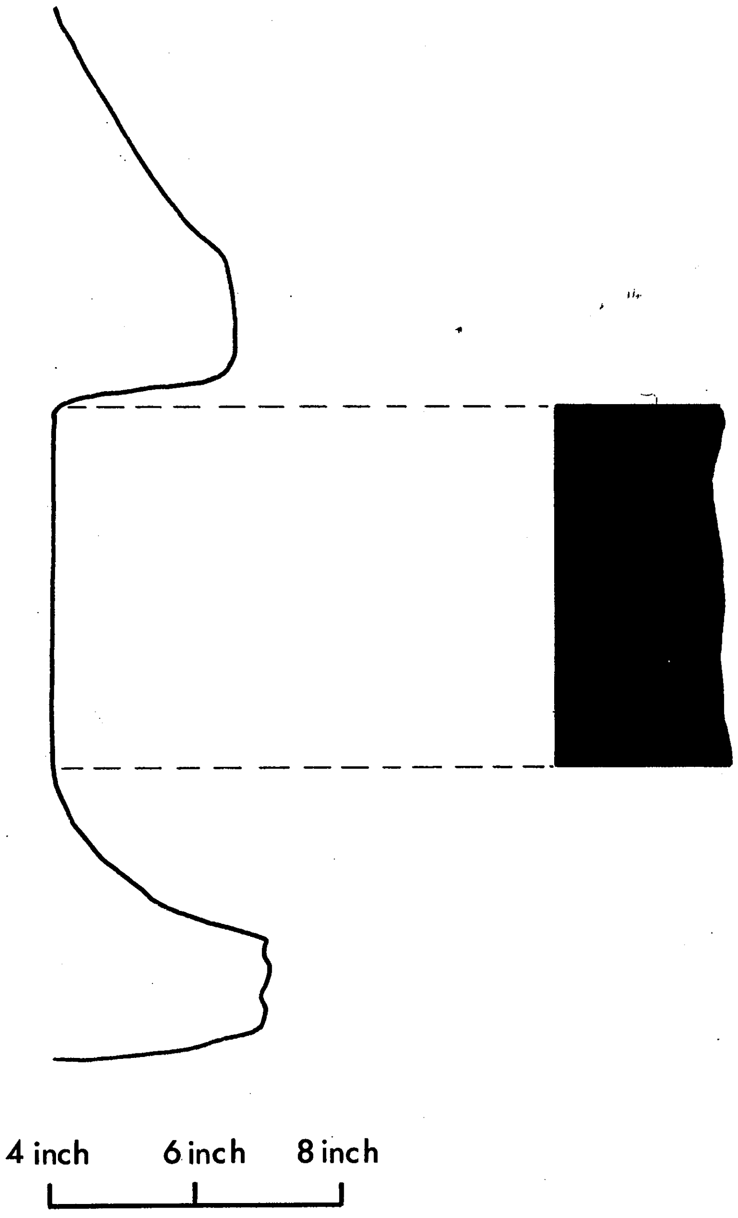


fig 16

SEAM THICKNESS FROM CALIPER LOG

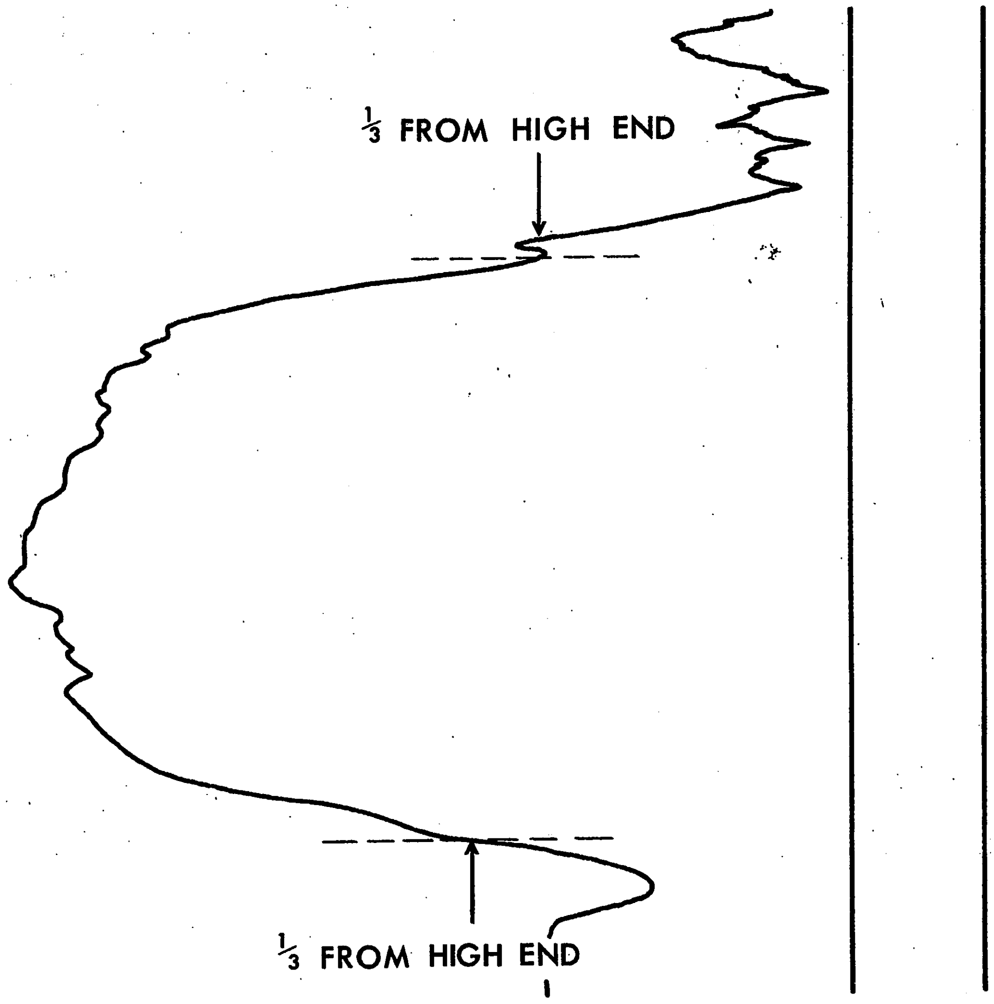


fig 18

SEAM THICKNESS FROM GAMMA RAY

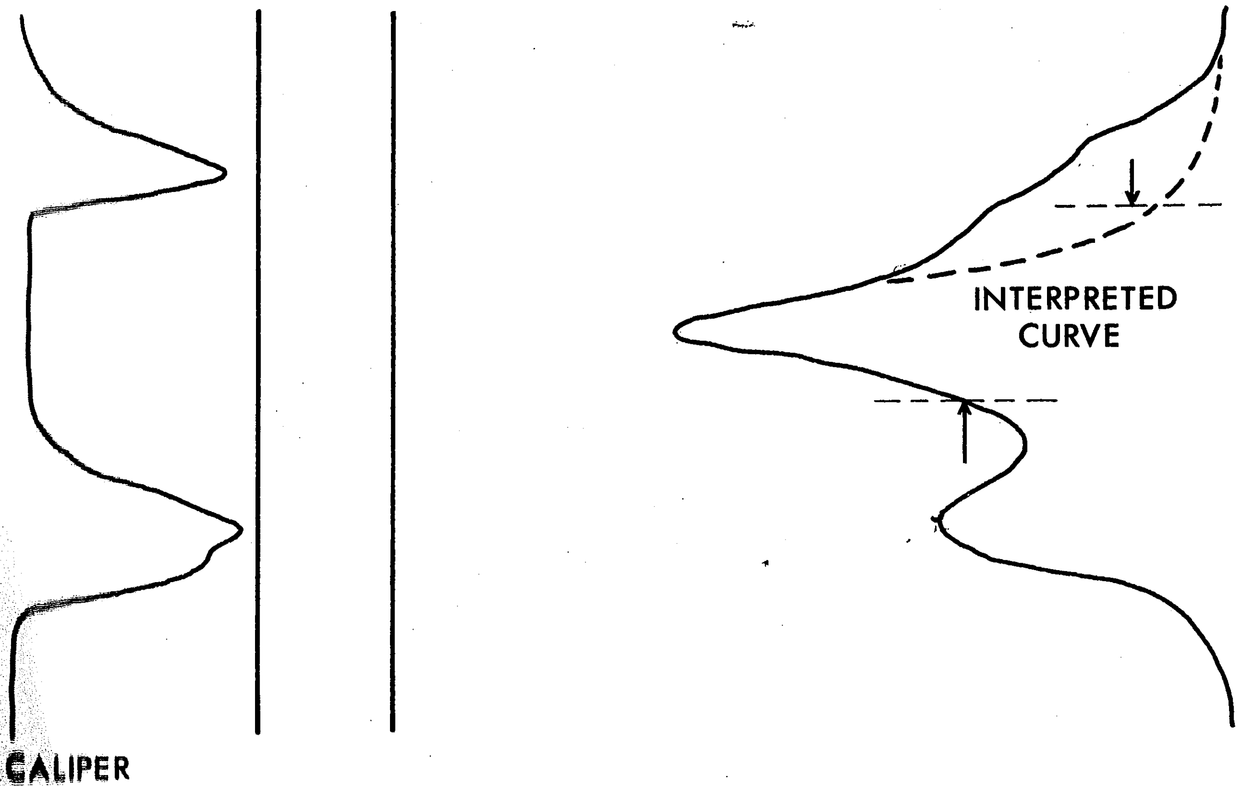


fig 19

CAVED BOUNDARY LS DENSITY

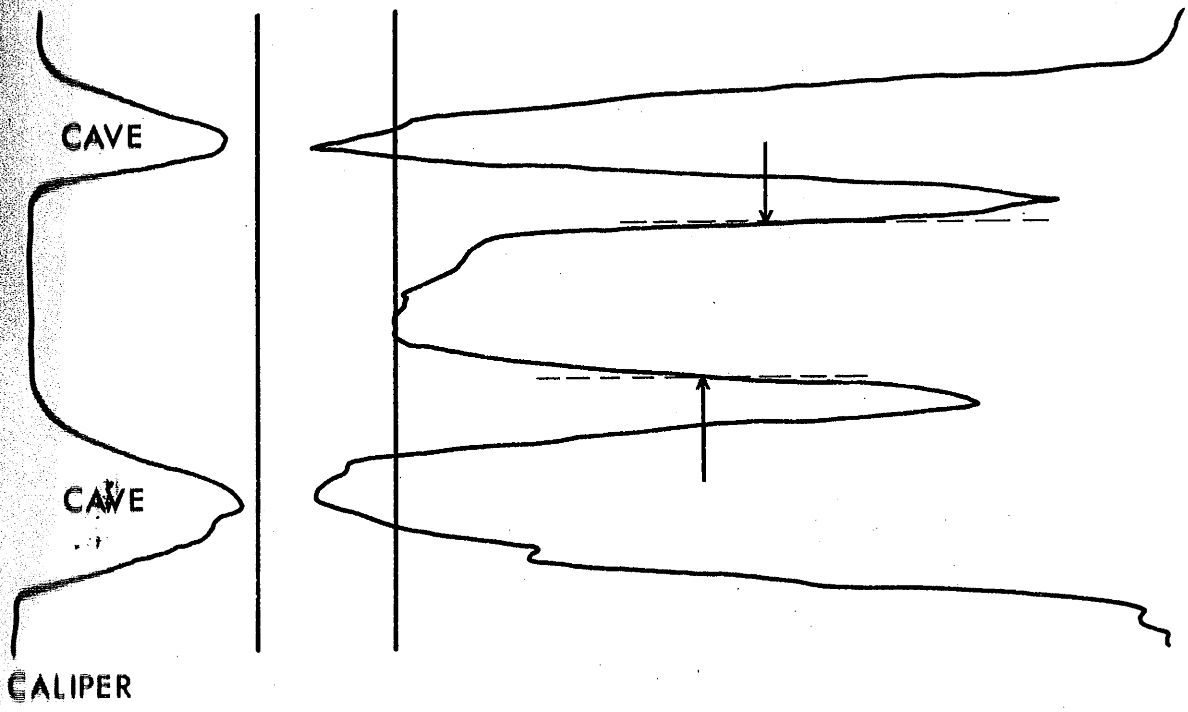


fig 20

BRD COAL V. CAVE

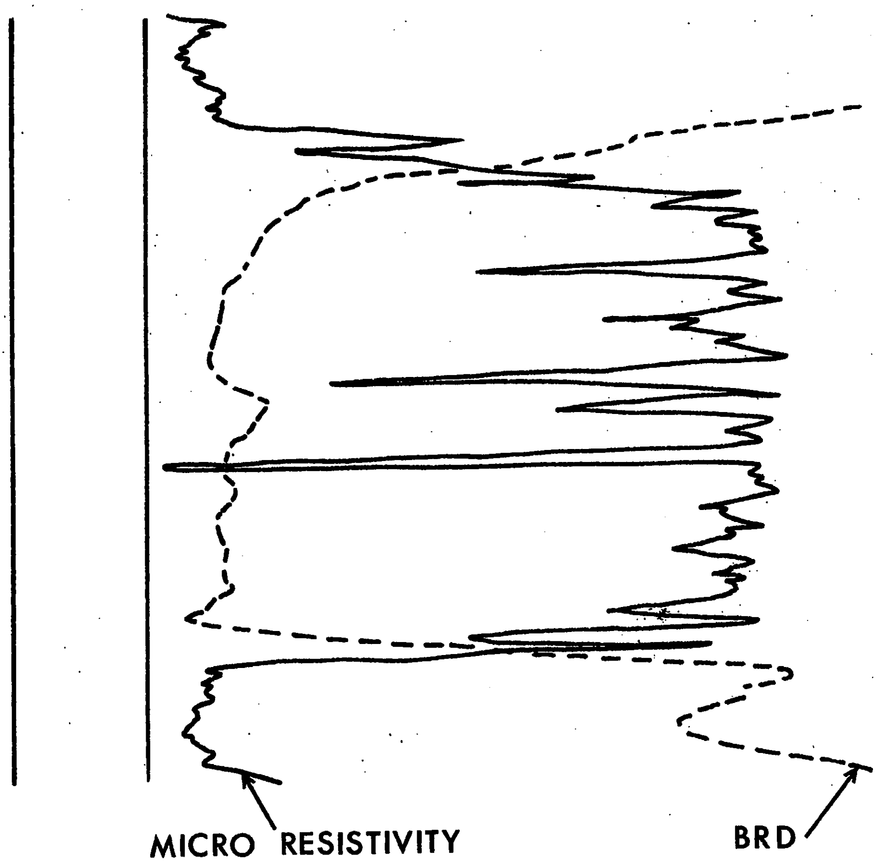


fig 21

MICRO RESISTIVITY DETAIL (V. BRD)

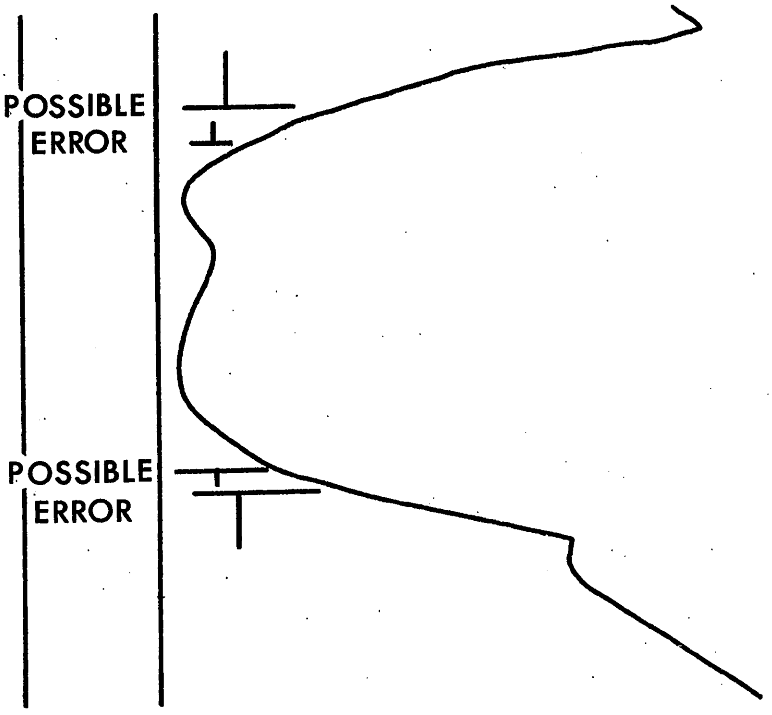


fig 22

NEUTRON RESPONSE OVER BOUNDARIES

4.4 Using the Micro Resistivity Log

The micro resistivity response of the dipmeter or the new CCS tool is extremely sharp and where resistivity contrasts are good it will show coal boundaries very distinctly. As the resistivity measurement is only relative, it is important to make sure by comparing with the density log that the boundaries are really coal/shale and not sandstone/shale, etc. Example of the micro resistivity response is shown in Fig. 21.

4.5 Neutron Log

Whilst the neutron log has a somewhat slower response and is difficult for accurate thickness determinations, it is useful when seam boundaries or types of coal seams contain high activity from uranium which effectively masks both the gamma ray and the density response and where, if sandstones are present or the hole is dry, resistivity is unlikely to help. The interpretation point of the neutron is very low down on the 'U' of the curve. An example of this condition is given in Fig. 22.

4.6 Seam Partings

With thick partings, i.e. more than 15 cm., the BRD gives a full response and interpretation is just the same as bed boundaries. However, when below 15 cm. it becomes very difficult to determine if the response is due to a thin bed of dirt or a slightly thicker bed of inferior coal. Fig. 23 shows how this confusion can arise.

To evaluate further it is necessary to use a very high resolution log such as the micro resistivity.

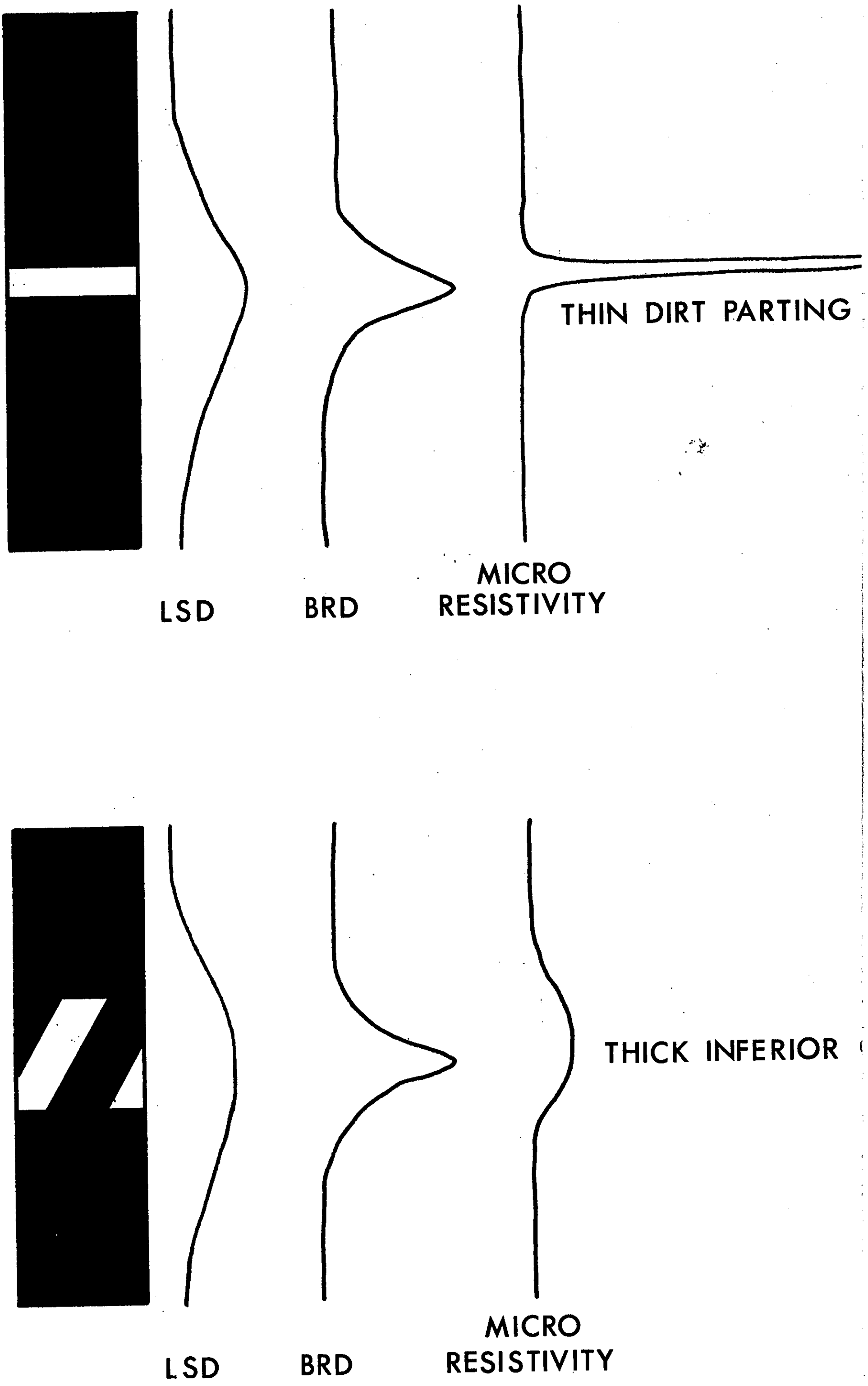


fig 23

THIN BED RESPONSE

7. STRATA DIP AND STRUCTURE

7.1 Preparation of Dip Measurement

The Dipmeter Sonde makes three continuous resistivity measurements equally disposed around the circumference of the borehole. If the resulting curves can be correlated then through the point of correlation a plane can be drawn and the attitude of this plane computed. If the resistivity markers can be assumed to have a geological significance representing resistivity changes between bedded formations, the correlation plane will be the dip of the formation.

Before using dip information it is necessary to understand how the information is processed. The first stage is to digitise each of the three curves in as high a vertical resolution as technically possible. The second stage is to pass the digital information into a computer and to program the computer in such a manner that the digitised curves can be compared. Obviously it is not sensible to compare the whole length of the curve throughout the borehole as this would preclude the dips changing. The technique therefore is to take a small section of one curve, say one metre, and compare it with the other two curves at a similar depth horizon. The length of the curve chosen is known technically as the *interval*. The next stage is to sweep the comparison range of this curve along the other two curves to within a prescribed limit. Obviously the length of sweep takes up computing time and it is usual to limit the range to within practical possibilities, bearing in mind that a 90° dip would mean infinite searching. This feature is known as the *search angle*. Having completed the correlation in this manner another section of curve is then used for correlation. The vertical distance between the start point of each curve is known as the *step*. Consult Fig. 33 which diagramatically shows the points mentioned here.

It can be seen that the operator of the computer has considerable control over the results by controlling the step, and search angle interval instructions given to the computer. If for example a very long interval is selected then the dip answer will be an average of that interval and thus the dip measured should show a dip associated with a strong regional lithology bedding plane. On the other hand, if the interval is very short, say 20 cm, then very small dips will be measured which could be false bedding planes.

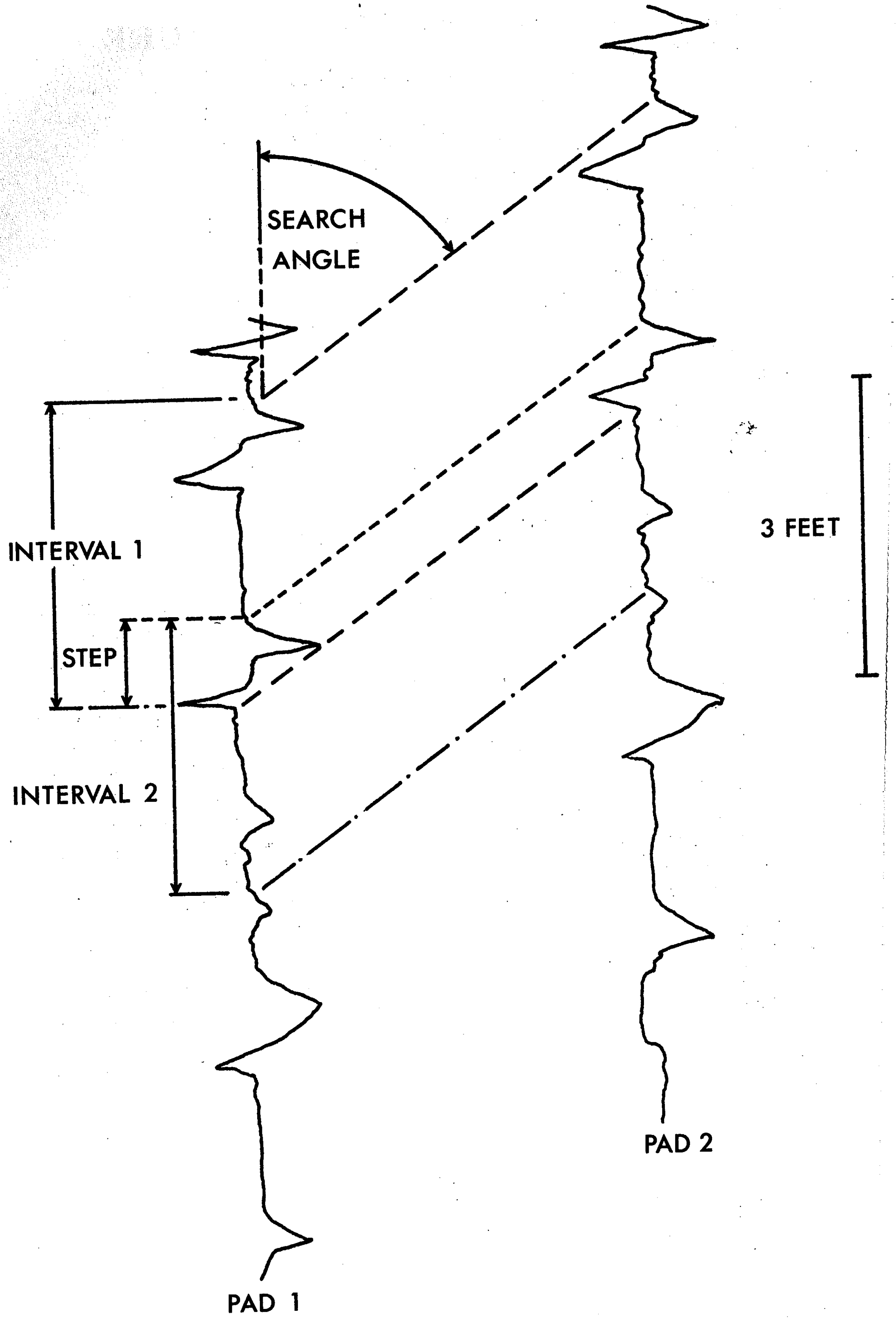


fig 33

DIPMETER TERMINOLOGY

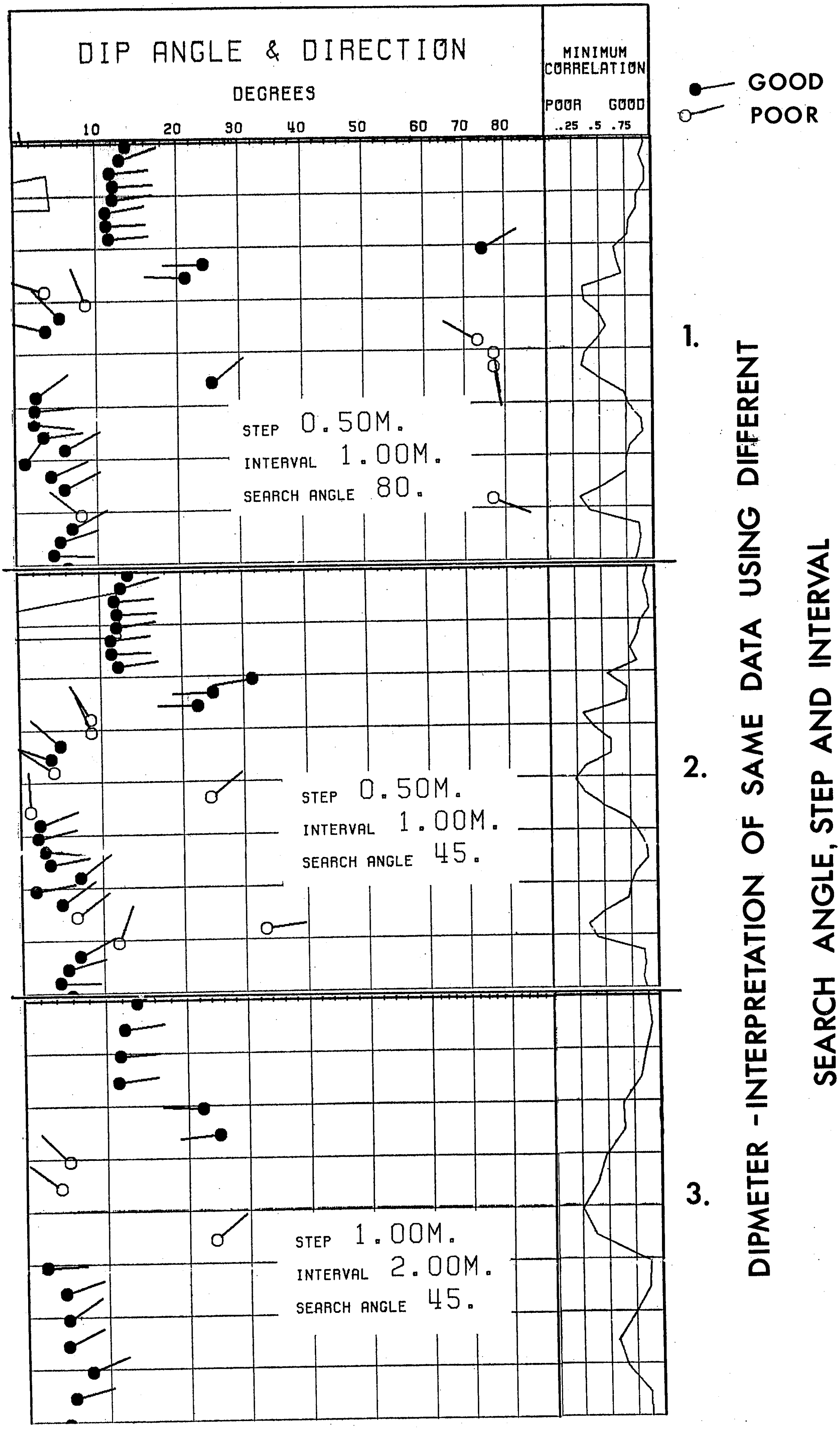
Similarly a change in the ratio of the *'step'* to the *'interval'* will affect the consistency of the result. The smaller this ratio the greater the overlap, i.e. the portion of the resistivity curves used again is the next correlation — and hence the greater the consistency between correlations. However, if a small ratio is selected a small actual step size can be involved and many correlations will be made — the program running time will increase and the picture could become confused. A reasonable compromise of 50% overlap is often seen to be advantageous.

The selection of the best step and interval for a geological area requires considerable experience. Fig 34. shows how the same information varies by giving a different step and interval presentation. Selection of the wrong step and interval does not lead to an erroneous answer but more to a difficult and unclear one. In most cases several steps and intervals are examined before the final presentation is produced.

7.2 Interpretation

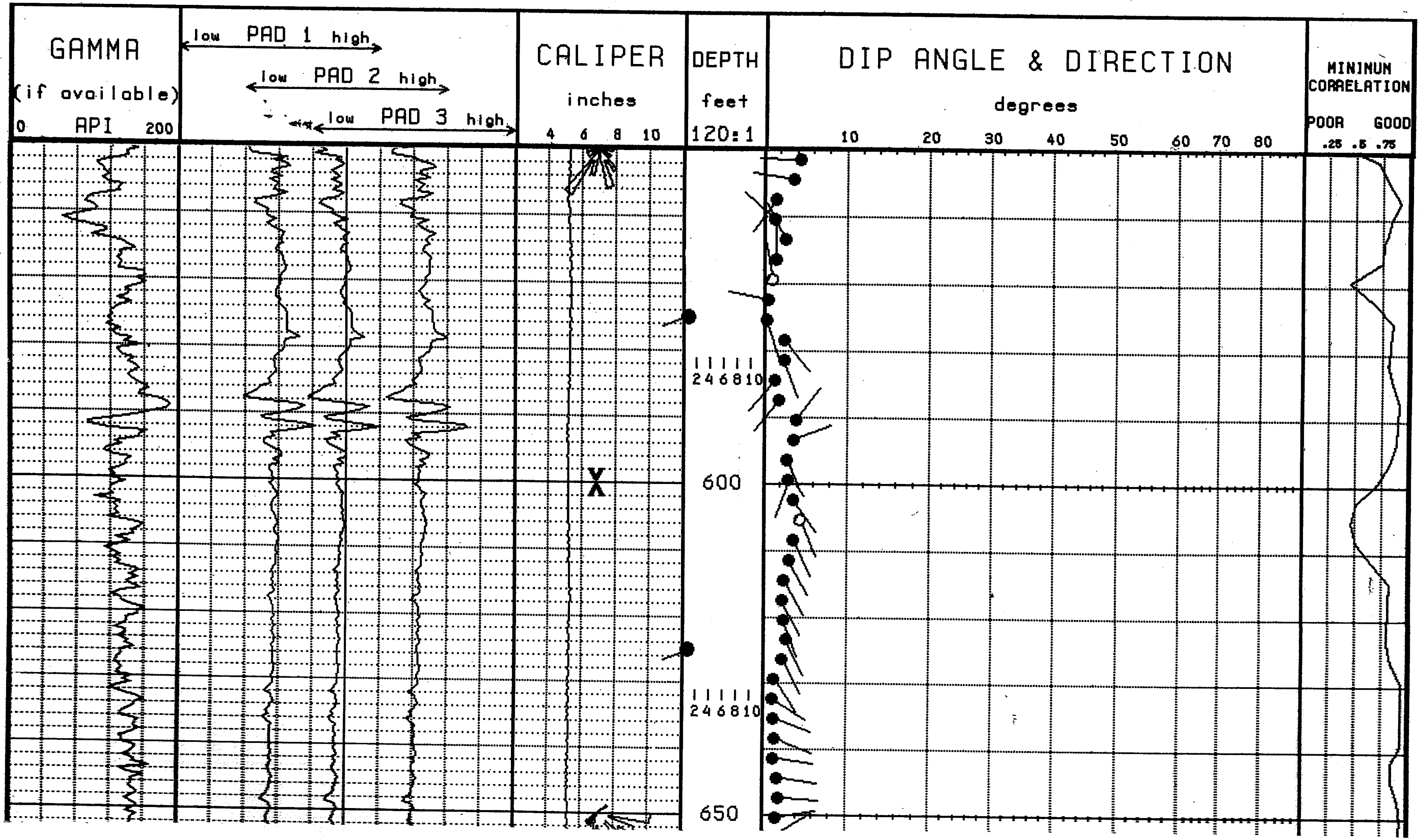
The interpretation of dip information is clearly a geological process which requires no explanation to the geologist. The examples given are of typical dipmeter results and the consequent geological interpretation. It perhaps should be noted that it may be exceptional to actually see a fault plane and it is more usual to deduce a position of faults by investigating the changes in dips. Even so, the frequent information available on dip usually means the fault plane can be determined quite accurately. Measurement of the fault plane is theoretically possible but will probably be masked by the length of the correlation interval taken by the computer. If the fault plane can be determined and indeed recognised on the resistivity traces, then the shortest *interval* with no *overstep* should be used. Note that hole deviations which must always be computed are shown in the centre trace.

Three examples of dipmeter logs, (example A — low dip, B — medium dip, C — high dip) are included for reference see pages 57, 58 and 59.

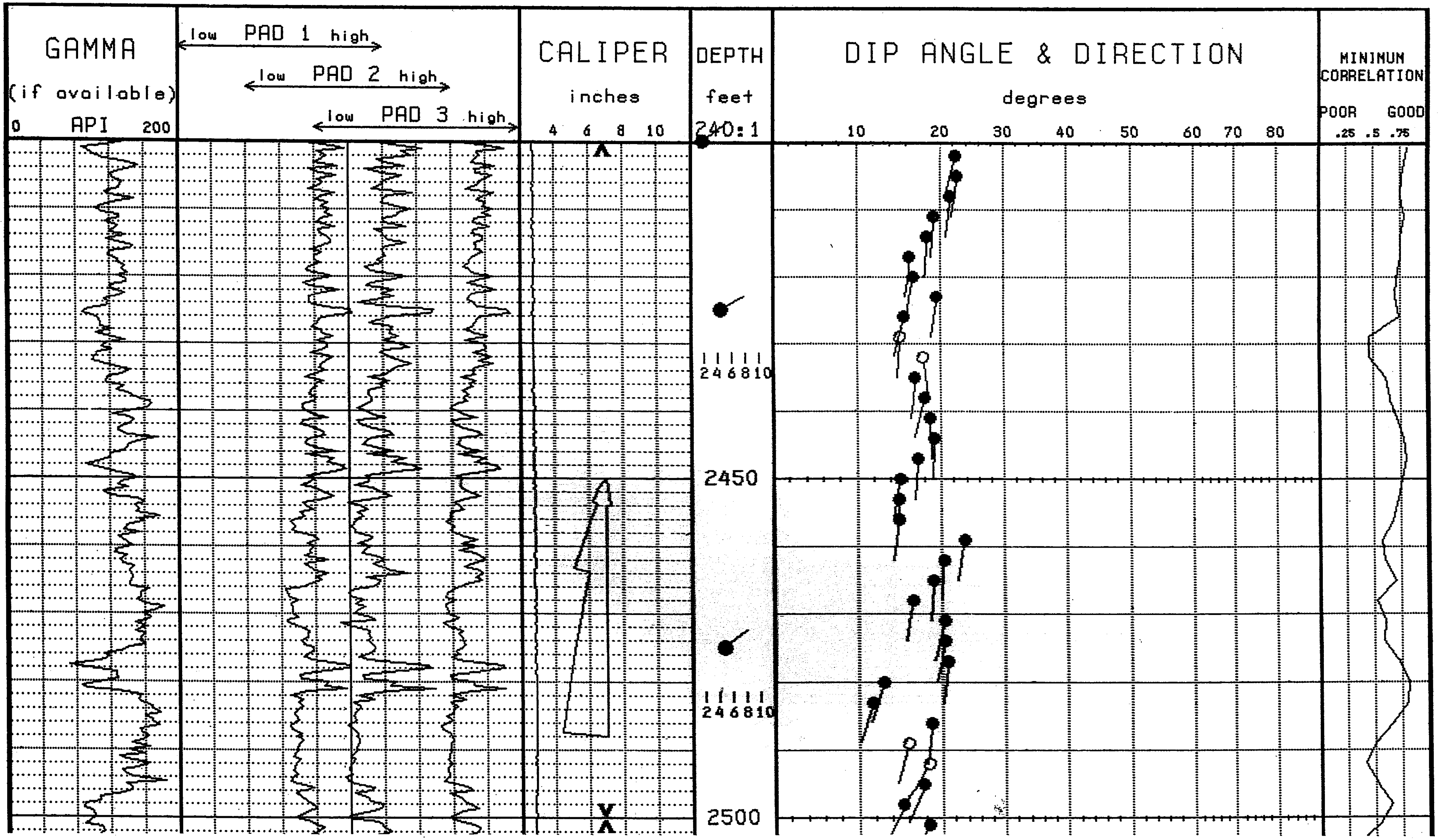


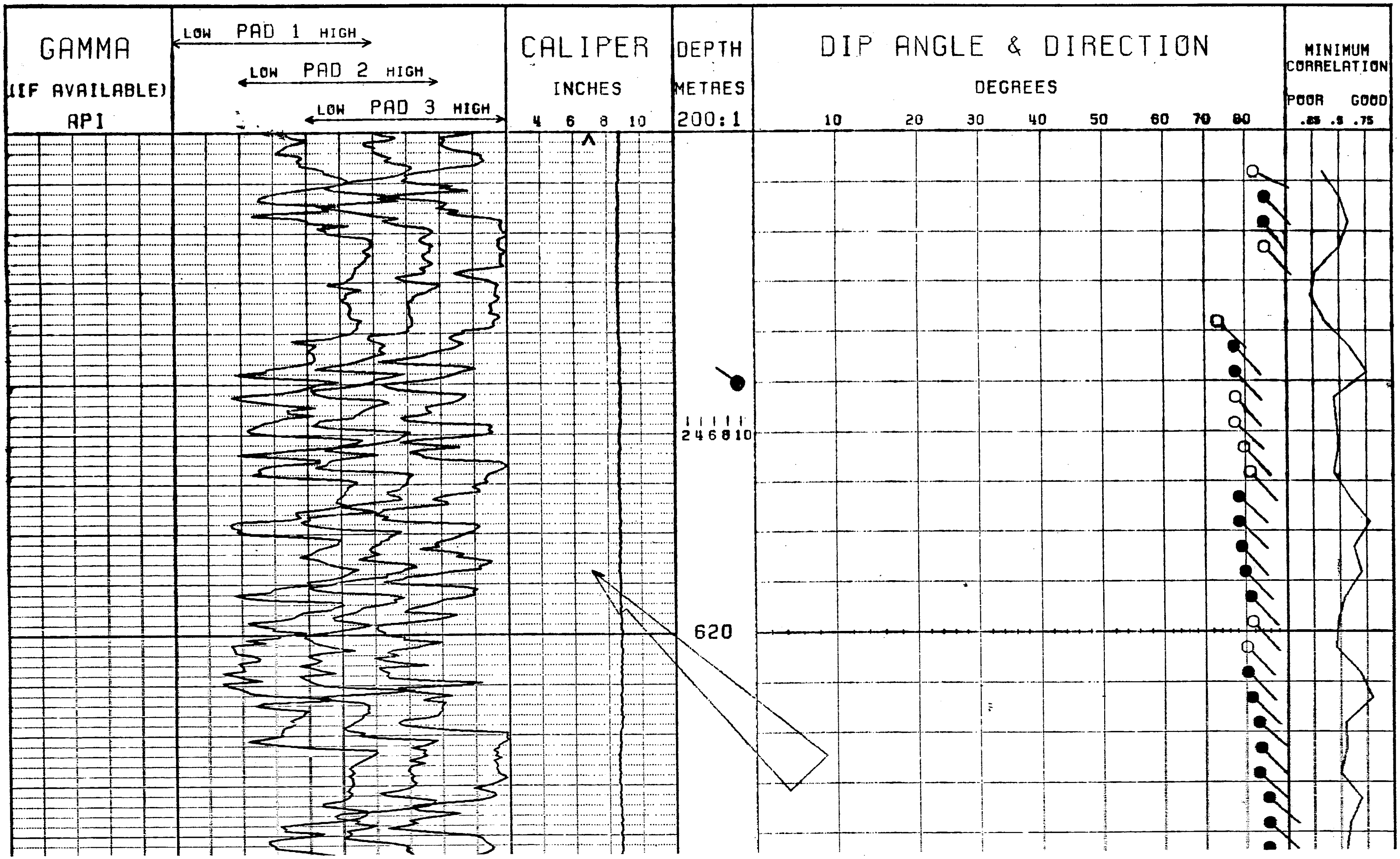
DIPMETER -INTERPRETATION OF SAME DATA USING DIFFERENT SEARCH ANGLE, STEP AND INTERVAL

fig 34



DIPMETER EXAMPLE A - LOW DIPS


GAMMA
(if available)
0
API
200
low PAD 1 high
low PAD 2 high
low PAD 3 high
CALIPER
inches
4
6
8
10
DEPTH
feet
240:1
2 4 6 8 10
2450
2 4 6 8 10
2500
DIP ANGLE & DIRECTION
degrees
10
20
30
40
50
60
70
80
MININUN
CORRELATION
POOR
GOOD
.25
.5
.75



DIPMETER EXAMPLE C HIGH DIPS

8.2 Direct Measurement

The function of rock strength as reflected by the various well known moduli of elasticity is a function which combines the feature of rock density and the effect of compressive stress. Obviously the sonic log is measuring a form of compressive stress and thus the combination of this measurement, with the appropriate density determination, does give a useful indicator of rock strength.

The oil industry has for some years used a relationship relating rock strength to density and sonic log transit time. This relationship is:

$$SI = \frac{\rho b}{(\Delta t)^2} \times 1.35 \times 10^{10} \text{ psi}$$

where

ρb = rock density in gm/cc

Δt = sonic transit time in micro sec/ft

The answer is quoted in psi and this forms a reasonable basis for comparing strength performance. Fig. 36 is an example of a continuous plot of the strength index which has been derived from the density and sonic logs. The plot also shows the density log as this is always a valuable measurement to look at whenever considering rock strength.

The sonic log as configured at present measures the longitudinal pressure wave transit time. A shear wave is also produced but at present this is not measured. The sheer wave measurement, together with density, can be computed to give the well known moduli of elasticity and although shear waves can be measured with static logging equipment, no doubt a future development will see this measured continuously.

8.3 Dilatation

Coal seams frequently expand or dilatate when deloaded and this can usually be seen in cores. With the high accuracy of measuring insitu thickness from logs, comparison of the log thickness with a 100% core section will often show the amount of dilatation. Generally lower rank coals dilatate the most and as dilatation is an indication of low strength, it is often a guide to the most effective type of mechanical mining.

9.4 Washing Profile

The density log across a coal seam relates to ash content. It is, therefore, possible by using a density log to obtain an estimation of coal recovery and quality after washing (or floating) at different gravities. This is an important application for the washery in general, made more so by the fact that the log is an undestroyable sample.

In practice it is not simply sufficient to relate density directly with recovery since other factors such as friability can affect washing characteristics. With experience in particular areas and a known washing plant it is usually possible to make reasonable assumptions. Then a 'K' factor can be applied to relate rock density to recovery at a specific medium. Fig. 40 shows a density log analysed into a washing profile, indicating the recovery fractions.

SIDEWALL DENSITY GAMMA AND SIDEWALL DENSITY GUARD SONDE

The sidewall density gamma and sidewall density guard probes use multiple detectors to provide an accurate borehole-compensated density measurement with excellent bed-boundary resolution. The sidewall density guard probe provides an additonal focussed resistivity measurement with excellent vertical resolution and reasonable depth of investigation.

PRINCIPLE OF MEASUREMENT:

The probes contain a gamma source and two high-sensitivity scintillation gamma detectors. The detectors are protected against direct radiation from the source or via the borehole by extensive heavy-metal shielding. The active windows of source and detector are maintained firmly in contact with the borehole walls by a motorised back-up arm that also provides a borehole caliper measurement. Gamma radiation from the source is backscattered by the formation (Compton effect) and reaches the two detectors where the relative count-rates provide a measure of formation bulk density. The the sidewall density guard probe includes a central current-source electrode mounted between two guard electrodes, maintained at the same potential by internal electronics. Current from the central electrode is constrained to a thin disk by the presence of the guards and returns to the cable armour above a 10m insulated section. The potential of the central electrode with respect to a surface voltage-reference stake and the measured current are combined by a down-hole microprocessor to calculate the apparent formation resistivity.

FEATURES

- Compensated density output directly in engineering units (g/cc)
- Separate short-spacing detector(s) for accurate bed-boundary location
- Tungsten shielding reduces borehole influence on measurement
- Collimated source minimises mud-cake effect
- Powerful motorised caliper arm maintains good sidewall contact
- Standard calibration blocks available for field or base use
- Optional bed-resolution density (BRD) and temperature measurements

MEASUREMENTS

Compensated density
Natural gamma
Caliper
High-resolution density HRD
Bed-resolution density BRD
Temperature
Focussed resitivity

APPLICATIONS

Minerals
Lithology
Density and porosity
Correlation with other logs
Bed thickness and boundary location
Ash content in coal
Indication of fractures and permeable zones
Moisture determination in coal
Engineering
Rock strength and elasticity parameters (with sonic log)
Detection of weathered or fractured zones
Ground compaction studies
Water
Location of aquifer and aquitard
Porosity measurement
Detection of cavities and missing cement

OPERATING CONDITIONS

Borehole type: open-hole, water-filled
Qualitative measurements are possible in air-filled boreholes (excluding resitivity)

SPECIFICATIONS

Diameter:	50mm
Length:	2.88m
Weight:	20kg
Max. temperature:	70°C (extended range available)
Max. pressure:	20MPa (extended range available)
Density detectors:	NaI(Tl) scintillation crystal
Density spacings:	48cm (LSD) 24cm (HRD) 14 cm (BRD)
Calibrated density range (LSD):	1 to 3.0g/cc
Natural-gamma Detector:	50mm x 25mm NaI (Tl) scintillation crystal (larger sizes available)
Caliper range:	50mm to 300mm
Resitivity range:	1 - 10,000 ohm-m

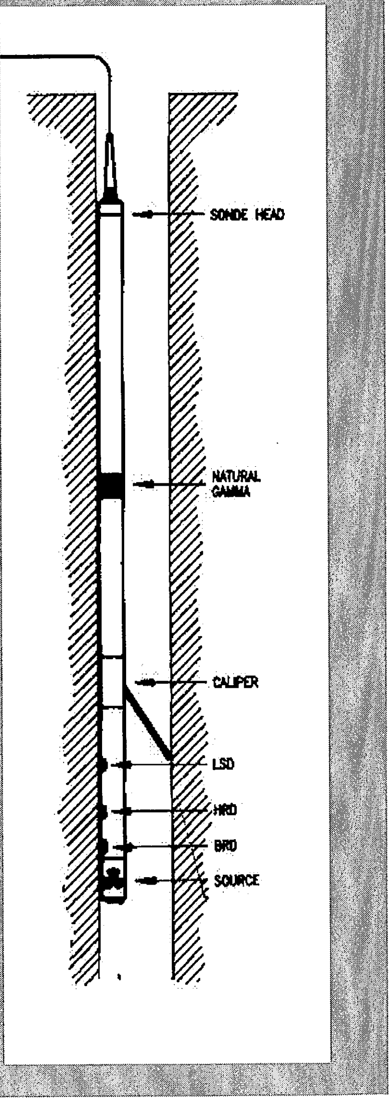
SALES INFORMATION

Probe:

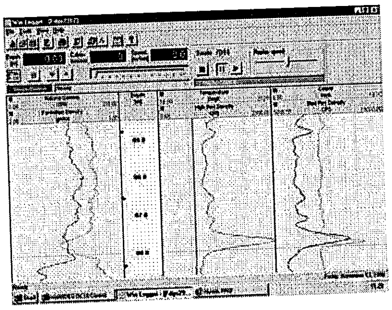
25 007 000	Sidewall density probe
25 008 000	-includes BRD
25 009 000	-includes BRD and temperature
25 011 000	Sidewall density guard probe
25 011 001	-includes BRD
25 011 002	-includes BRD and temperature

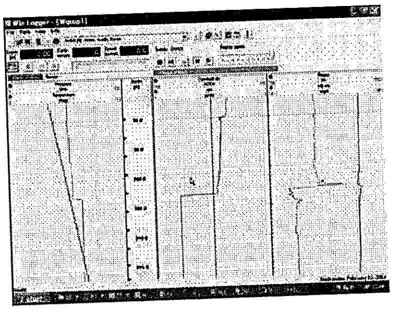
Accessories:

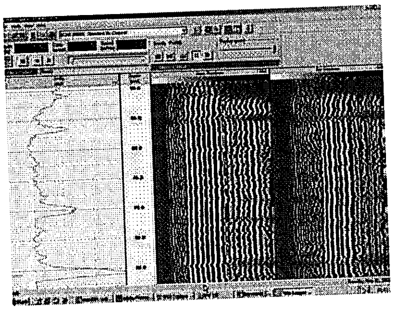
30 001 000	3.7GBq ^{137}Cs gamma source
20 081 000	Aluminium block field check jig
20 070 000	Natural-gamma API calibrator without source
30 010 000	3.7MBq ^{137}Cs source for natural-gamma calibrator



RG Winlogger Software







RG Winlogger is the operating software for the Micrologger2 surface system. The product of years of development, RG Winlogger provides data acquisition, processing and reporting for the standard RG probe range. Simple to operate, RG-Winlogger retains a standard Windows look and feel using familiar tool bars and drop-down menus for all frequently needed functions. The package incorporates some powerful features including a built in C-compiler to allow the more advanced user to construct custom 'user functions' to process multichannel data in real time during logging.

RG-Winlogger is supplied with a multi-user licence allowing free distribution of the software to any user of RG log data. This policy has proved popular with wireline service companies who may provide Winlogger to clients to allow them to replay or reprocess data in-house without resorting to 3rd-party packages.

FEATURES

- Support for RG digital probes
- Remote control of 'SMART' winch range
- 8, 16 and 32-bit data support
- Screen/printer log display in calibrated engineering units
- Selectable depth sample interval (1, 2, 5, 10cms etc)
- Metric and imperial logs in API format
- Custom logos and headers
- Data export in ASCII (LAS) format

SALES INFORMATION:

05 020 010	Winlogger software

RG Real-time Printer

High-speed 8.5" thermal plotter for printing with RG Winlogger software.

SPECIFICATIONS

Dimensions:	312mm(w) x 305mm(l) x 124mm (h)
Weight:	9.5kg

SALES INFORMATION

01 011 000	Thermal printer

Recommended Notebook PC Min. Specification

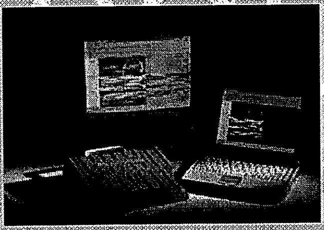
- Windows® XP operating system
- 1.5 GHz processor with 512 MB RAM
- 14.1" wide LCD screeen
- DVD RW Drive

SALES INFORMATION

01 006 001	Notebook PC

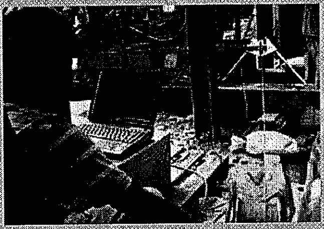
surface equipment

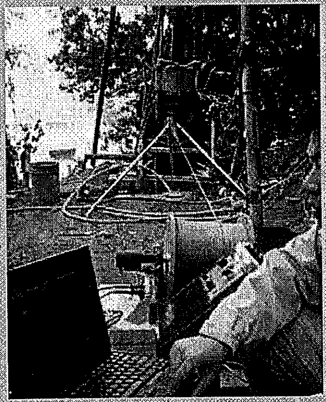
RG Micro Logger2 with USB



With a new USB interface for your laptop computer and built-in borehole video support, the Micrologger2 is probably the most powerful portable logging system on the market. This featherweight, smaller in size than the average notebook, packs a powerful punch and supports all RG probes and cameras, including the latest acoustic and imaging types. The Micrologger2 needs only a PC, probe and a RG or third-party supplied winch to provide high-quality logging and borehole television for every situation.

FEATURES





Logging

- Supports RG and many third-party probes
- USB high-speed link to PC
- Compatible with most winches/cables
- Remote control of SMART winch
- Real-time data display and printing
- Supports Windows™ printers
- Data output in LAS and RG formats
- Modular construction for easy field maintenance

Video

- Supports RG, Laval, Hytec and CCV cameras
- Uses same winch/cable for logging and video
- Full control of lighting, focus, iris, pan/tilt from PC
- Supports depth and text overlays
- Grabs and prints individual frames
- Optional booster supply for 150W external lighting

Imaging

- Direct support for High-resolution Digital Optical Televiewer (Hi-OPTV) and High-resolution Acoustic Televiewer (HRAT) probes

SALES INFORMATION

01 005 001	RG USB Micrologger2
01 005 002	110/220VAC power supply for ML2 and winch
01 005 030	150W lighting booster power supply
01 005 022	Canvas bag for Micrologger2

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