1953/66
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COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

RECORDS 1953 No. 66

ELECTRICAL WELL LOGGING TESTS MAITLAND COALFIELDS, NEW SOUTH WALES

by

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ABSTRACT

This report covers the results of the experimental electrical logging of eight bore holes in the Maitland Coalfields, New South Wales.

The theory of the single point resistance and self-potential logging methods is outlined and the reactions of coal and other formations are described. The experiments were inconclusive in deciding whether or not electrical logging can be used for correlation. Because there are many vertical and lateral gaps in the stratigraphical sequence of the coal measures it is considered unlikely that electrical logging could be used for correlation in the Maitland Coalfields.

However, electrical logging has been recommended for adoption as a routine procedure in the drilling programme to check the recovery of cores in the coal zone. This procedure may result in a saving on drilling costs.

1. INTRODUCTION

At the present time the Bureau of Mineral Resources, Geology and Geophysics is investigating some of the coal resources of the Maitland Coalfields. The coal reserves are proved by drilling which is conducted partly by the Bureau's and partly by contract drillers under the supervision of the Petroleum Technology Section of the Bureau. The drill cores are sent to the Joint Coal Board for chemical analysis which is required to judge the quality of the coal and thereby its future use. The correlation of geological logs is difficult because of pronounced lateral changes of the facies in the coal measures. Electrical logging, if successful would provide a possible means of improving correlation and a practical way of checking whether core losses are critical or not. For these reasons the Bureau decided to try out electrical logging and the writer was sent to Muswellbrook with well logging equipment.

The Maitland coal fields are situated west of Newcastle, N.S.W. The main towns in the district are Maitland, Singleton and Muswellbrook. During the period the writer visited the area (February 1952) the drilling operations were centered on the fringe of the Muswellbrook dome.

11. GEOLOGICAL SETTING

The geology of the Maitland Coalfields has been described by David (1950,1,p.337-342), who also gives references (1,p.403-405) to the extensive literature which exists about the area.

Mr. Bursill, the Bureau's geologist for the area, is at present preparing a report covering the latest results of the geological investigation of the coal basin.

The coal seams occur in Permian Sediments which have been subdivided as follows:

	feet
Upper Coal Measures -	
Newcastle Stage	1,500
Tomago Stage	3,000
Upper Marine Series	6,400
Lower or Greta Coal Measures	300
Lower Marine Series	5,900

The northern boundary of the Muswellbrook dome is formed by the Hunter overthrust. Going from the center of the Muswellbrook dome in westerly, southerly or easterly directions all the different Permian stages from old to young can be observed.

The present coal investigation is confined to the Tomago stage and possibly to the Newcastle stage of the Upper Coal Measures, in other words to the outer fringe of the Muswellbrook dome. It was already mentioned that correlation is difficult on account of pronounced lateral change of facies and gaps in the Tomago Stage. The present correlation technique consists of drilling to the bottom of the Tomago Stage until the Upper Marine series is reached. The top of the Upper Marine Series is a definite correlation horizon.

111. APPARATUS

A Widco shot hole logging unit, built by the Well Instrument Developing Co., Houston, Texas was used. The unit is designed for single point resistance logging of holes less than 500 feet deep. The unit is self-contained and may be transported in and operated from a Landrover.

The specifications are:-

Weight:	100 lbs.
Graphs:	Single point resistance only.
Recorder:	Fully automatic Esterline-Angus milliammeter.
Batteries:	One Burgess 4F 4H 6 volt, Three " 5308 45 "
Cable reel:	Hand cranked, 500 feet cable. Logging speed not critical, about one foot persecond.
Logging cable:	Stranded steel, neoprene covered, tensile strength 600 lbs. O.D. 0.143 inch
Dimensions:	25" L x 14" W x 25" H.
Resistance scale:	5, 10, 25, 50 and 100 ohms per inch deflections.
Logging electrode:	10" long, 1 ¼" O.D., weight 6 lbs.
Scale of records:	20 feet per inch.

A calibration of the recorder by means of a resistance box placed in series with the electrodes showed that the resistance scale is not linear but tends to be compressed towards the upper end of the scale.

In using the logger, one electrode is lowered down the bore hole filled with water or drilling mud. The second electrode is placed in the mudpit at the surface. An electric current is supplied by a low frequency oscillator and the potential difference between the electrodes is measured. The ratio between potential differences and electric current is a measure of the resistance. Variations in resistance are recorded when the moving electrode is raised in the bore hole through formations of different resistivity.

The Widco shot hole logger is designed for resistance loggin only and modifications were necessary to adapt it for self-potential logging. A hand-operated potentiometer was added and the potentials required to balance out the electrode potentials were recorded on the Esterline-Angus recorder. A voltage-divide circuit was incorporated to make the full scale deflection on the record correspond to 100 millivolts.

The arrangement was not very satisfactory for two reasons:-

1. It was impossible to avoid an appreciable lag in the adjustment of the potentiometer relative to the changes of the electrode potential. The tendency existed to over-run the correct setting, which resulted in a jagged curve on the record.
2. No adequate provision was made to vary the baseline value so as to maintain the recorder always on scale.

In the Muswellbrook work the time required to log one hole was between ½ and ¾ hour. Additional time was required for filling the hole with water or pulling out the drill rods. An improved self-potential recording arrangement and better installation of the equipment in a car or truck would probably reduce the actual logging time.

IV. OUTLINE OF METHODS USED

1. Single Point Resistance Method

In a homogeneous medium, the resistance of a single electrode to electric current is,

$$R = KP$$

in which, R = resistance in ohms,
K = constant depending on size and shape of electrode,
P = resistivity of the medium expressed in ohm-metres.

The theory shows that practically the whole resistance is in the immediate surroundings of the electrode. One electrode is stationary and its resistance does not change. The changes in resistance recorded are therefore due to changes in the immediate vicinity of the moving electrode. In practice the apparent resistivity P_T, is used. The numerical value of P_T is a weighted average of the resistivities of the materials in the neighbourhood of the moving electrode and the nearer the material is to the electrode the larger is its influence on the average. Neglecting the effect of the stationary electrode, the relation $P_T = C\,Rm$ holds in which Rm represents the measured resistance of the moving electrode and P_T the combined resistivity of the drilling fluid and the surrounding rock.

The single point resistance method has a few disadvantages:-

1. Non-linear response: high resistivity beds show a rather flat response because of the preponderant influence of the mud. The larger the bore hole diameter the flatter the response.
2. Lack of penetration power because only the material immediately surrounding of the electrode influences the resistance.

Advantages of the method are:-

1. Sharp definition of geological boundaries due to its limited penetration power.
2. Ease of correlations.

The flatness of response results in a log in which the high resistance sections seem to be compressed whereas multiple point logging methods show an undesirably large range of values. Multiple point logs of salt water sands often lack character. On the other hand, single point logs mostly still show sufficient character because the main contribution to resistance variation comes from the mud-contaminated rock zone adjacent to the bore hole.
These reasons make the single point logging method particularly suitable for correlation work.

3. In general, beds of 6"-12" thickness show up if the hole diameter is not too large and their resistivity contrasts sufficiently with that of the neighbouring rocks. However, for very thin beds a micro-logging method should be used.

4. Changes on the single point resistance log can almost invariably be ascribed to lithological changes occurring at the level of the measuring electrode and consequently depth measurements of strata boundaries are reliable. Multiple point logs are liable to show distortions which have no connection with the formations situated opposite the pick-up electrodes.

2. Self-potential Method

The potentials in bore holes may be classified as natural potentials or secondary potentials.

Natural potentials are the potentials found in the ground, even when no bore hole exists. They are considered to be contact potentials occurring between dissimilar beds; the dissimilarity may be in the chemical composition of the solid particles constituting the beds or in the nature or concentration of the solutions which the beds contain. The natural potentials cannot be measured in a bore hole unless the hole is dry and the measuring electrodes are brought into close contact with the wall rock.

Secondary potentials in a bore hole are caused by the introduction of drilling mud. These potentials may be explained by considering the effects produced where a bed of shale is in contact with a bed of salt water sands and the bore hole is full of fresh water mud. Laboratory experiments have shown that in an annular cell consisting of salt water, fresh water and shale, the different materials being separated by porous partitions, a current flow is produced by the electro-chemical reactions at or near the contact of the shale and salt water. (Mounce and Rust, 1945). In the bore hole a similar current chain is formed around the common point of contact of the shale, salt water sands and drilling mud. The direction of current flow is in the sense, shale - fresh water mud - salt water sands - shale. If the mud is more saline than the solutions in the sands, the current flows in the opposite direction. In self-potential logging, the potentials measured are those due tothe current flow in the mud section of the current chain. The potential recorded with the electrode opposite the salt water sands will be negative with respect to that recorded with the electrode opposite the shale.

It is now generally accepted that the potentials recorded in bore holes are mainly of electro-chemical origin, produced in a manner similar to that just described and that electro-filtration potentials are of minor importance.

The reactions of the coal seams on the potential logs recorded at Muswellbrook will be described, but as yet, the causes of these reactions are not well understood. It is believed that more extensive potential logging data, carefully correlated with the petrological characteristics of individual coal seams, may yield an adequate explanation of the reactions of coal seams on self-potential logs and that it may be possible to judge the quality of the coal from the logs.

V. DISCUSSION OF RESULTS

1. Details of Work Done

A list of the eight bore holes logged is given below:-

Date Logged 1953	Name		Fig. No. (Plate1)	Depth of Bore Logged feet	Elevation at surface (Approximate) feet
Feby 23	Blakefield	2S	1	496	760
" 23	"	7S	2	133	580
" 24	Saddler's Ck.	3S	3	135	525
" 24	" "	4S	4	145	600
" 24	" "	5S	5	140	500
" 25	Parnell's Cks	75T	6	100	400
" 25	Ponds Creek	8T	7	133	350
", 26	State Reserve, Ravensworth	IS	8	245	490

The resistance and potential logs which were recorded are reproduced in Plate 1, together with the geological core logs provided by the Petroleum Technology Section.

2. Character of the Electrical Logs

From the logs shown in figures 1,2,5,7 and 8, it is seen that, as a fairly general rule, the coal bands were recorded by their high resistance peaks and small positive or negative potentials "kicks".

In some coal zones, the resistance log shows alternate high resistance peaks and low resistance values. This characteristic is due to the presence of shale beds within the coal zone, for example in Pond's Creek 8T bore hole, (fig.7A). The resistance log may be useful therefore in indicating the quality of a coal zone or coal seam.

In Blakefield 2S (fig.1), cindered coal seams (cindered or coked by intrusives) at 284'-292' and 388'-392' show up as large negative potential anomalies and low resistance anomalies. This is in remarkable contrast with coal beds showing positive potential "kicks" and high resistance values. The geological log refers to abundant calcite in both seams; the first mentioned is described also as highly pyritiferous. Furthermore the cindered coals have a high permeability. It appears likely that the solutions contained in these coal seams have a high mineral content. This would probably account for the low electrical resistivity. No adequate explanation however can be offered at present for the existence of the potentials. The sharpness of the negative potential anomalies is a characteristic effect produced by low resistivity beds and results from the tendency of the potential drop in the current circuit to be concentrated in the relatively high resistivity mud column section of the circuit.

The thickness of the coal zones can be estimated with an accuracy of $\pm \frac{1}{2}$ foot. Thin beds (thickness less than 6") generally do not show up on the resistance log. Beds of 6"-12" will generally be indicated on the resistance log when the resistivity contrast with the surrounding formation is large enough, for example in Saddler's Creek 5S (fig.5) and Pond's Creek 8T (fig.7A).

High resistance values may be recprded in some graywacke and intrusive sections. With some experience, most of the high resistance anomalies in graywacke and intrusives could be distinguished from those due to coal seams by the following considerations:

1. The drilling speed in coal beds is much higher than in graywackes and intrusives.

2. The high resistance anomalies in graywackes and intrusives in general show gradual transitions and lack the sharpness of the coal maxima. This is shown by the logs for the graywacke zones at 310'-380', 400'-425' and the coal zones in Blakefield 2S (fig.1); the teschenite zone in Saddler's Creek 4S (fig.4) and the graywacke zones at 80'-165' and 180'-225' in State Reserve Ravensworth IS (fig.8)

The depth of the weathered zone is sometimes well indicated by the self-potential log. At Saddler's Creek 3S (fig.3) iron-stained shales in the top section correlate with a sharp negative potential at 45 feet depth at the bottom of the weathering zone. The potential probably originates from the oxidation of sulphides and is the same phenomenon as associated with the formation of gossan above a sulphide ore-body. The weathered coal seam at 40 feet depth does not show up in the electrical log. The same explanation may be given for a sharp negative potential at a depth of 53 feet at Saddler's Creek 4S (fig.4). However, in this instance the potential may be due to the nearby shale-graywacke contact.

3. Correlation

The bores logged at Muswellbrook did not show sufficient overlaps in the stratigraphical column to judge whether or not correlation by electrical logging is possible. Abrupt lateral facies changes and local gaps in the sequence should make correlation by electrical logging as difficult as by the use of cores. The electrical characteristics of a formation change with the lithological characteristics. However, there is a remote chance that some of the graywacke sections which cannot be correlated by visual inspection of the rocks, may disclose electrical characteristics which can be used for correlation.

4. Minimum thickness of beds disclosed by electrical logging.

At Muswellbrook, with a bore hole diameter of about 4" and fresh water drilling liquids, coal beds of 6"-12" can generally be detected on the resistivity logs if sufficient resistivity contrast exists with the surrounding rock.

If it is desired to log thin beds of say 1" thick, then a recent refinement of electric logging technique makes it possible to detect much thinner formations than can be resolved by standard instruments. This development, known as micro-logging makes use of very small closely spaced electrodes which are held in contact with the wall of the hole.

5. Well logging as an economical tool.

In drilling, the core recovery is often poor and it is not always easy to decide whether or not a bore should be redrilled. An electrical log will show whether a core was lost in a coal zone and thus make a decision easy. Also, it will provide checks for depth and thickness measurements of coal seams.

VI. CONCLUSIONS AND RECOMMENDATIONS

Only eight holes were available for the well logging tests, and these holes did not show sufficient overlaps in the stratigraphical column to determine whether or not electrical logging could be used for correlation in the Muswellbrook area. The geology of the coal measures does not warrant optimism on this point.

The electrical logs enable the thickness of coal zones to be estimated to an accuracy of $\pm \frac{1}{4}$ foot. Electrical logging would be an extemely useful tool in checking drilling operations and recovery of cores in the coal zones. As such, it may save on drilling costs by reducing the necessity for redrilling. Well logging can be recommended also for its cheapness and the speed of operation.

There seems no likelihood, at least at the present time, of replacing ordinary coring by electrical logging. Coal sections could not always be readily distinguished from graywacke or intrusive rock sections and furthermore, coal cores are required for chemical analysis.

It is considered that electrical well logging would provide valuable assistance in the drilling operations in the Muswellbrook area. The most suitable type of equipment would probably be a 1000 foot logging unit built for both resistance and self-potential recording.

References

David, T.W.E., 1950 - THE GEOLOGY OF THE COMMONWEALTH OF AUSTRALIA, Arnold, London. 1.

Mounce, W.D. and Rust, W.M., 1945 - Natural potentials in well logging, Trans. A.I.M.E., 164 (Geophysics), 288-294.

Melbourne
August 19th, 1953.

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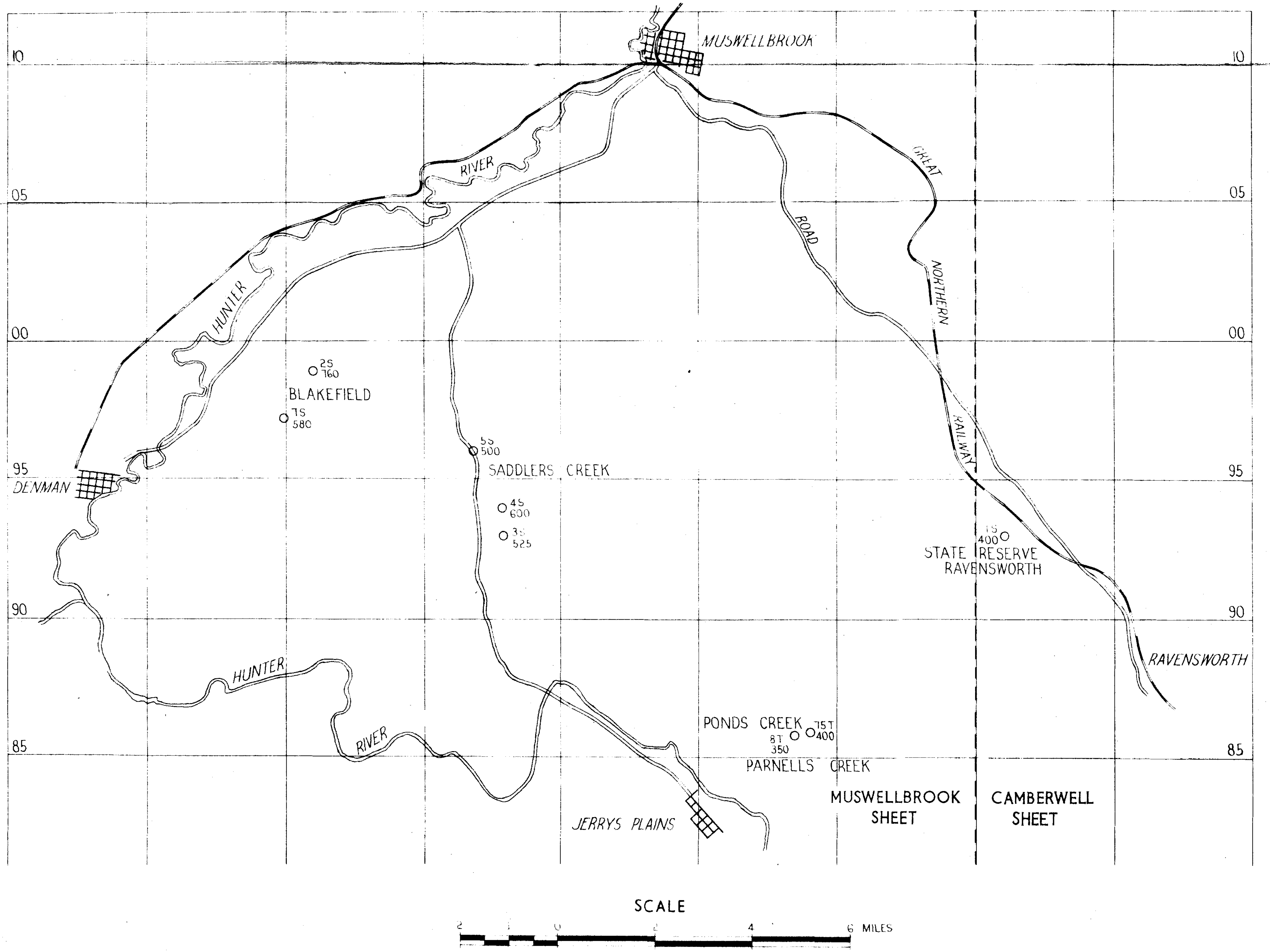
Distribution

1. Chief Geologist, Canberra.
2. Chief Petroleum Technologist, Melbourne.
3. Under Secretary, Department of Mines, Sydney.
4. Joint Coal Board.
5. Geophysical Library, Melbourne.
6. " " "
7. " " "

PLATE I



ELECTRICAL WELL LOGGING TEST

MAITLAND COALFIELDS N.S.W

LOCALITY MAP

SHOWING

LOGGED BORE LOCATIONS

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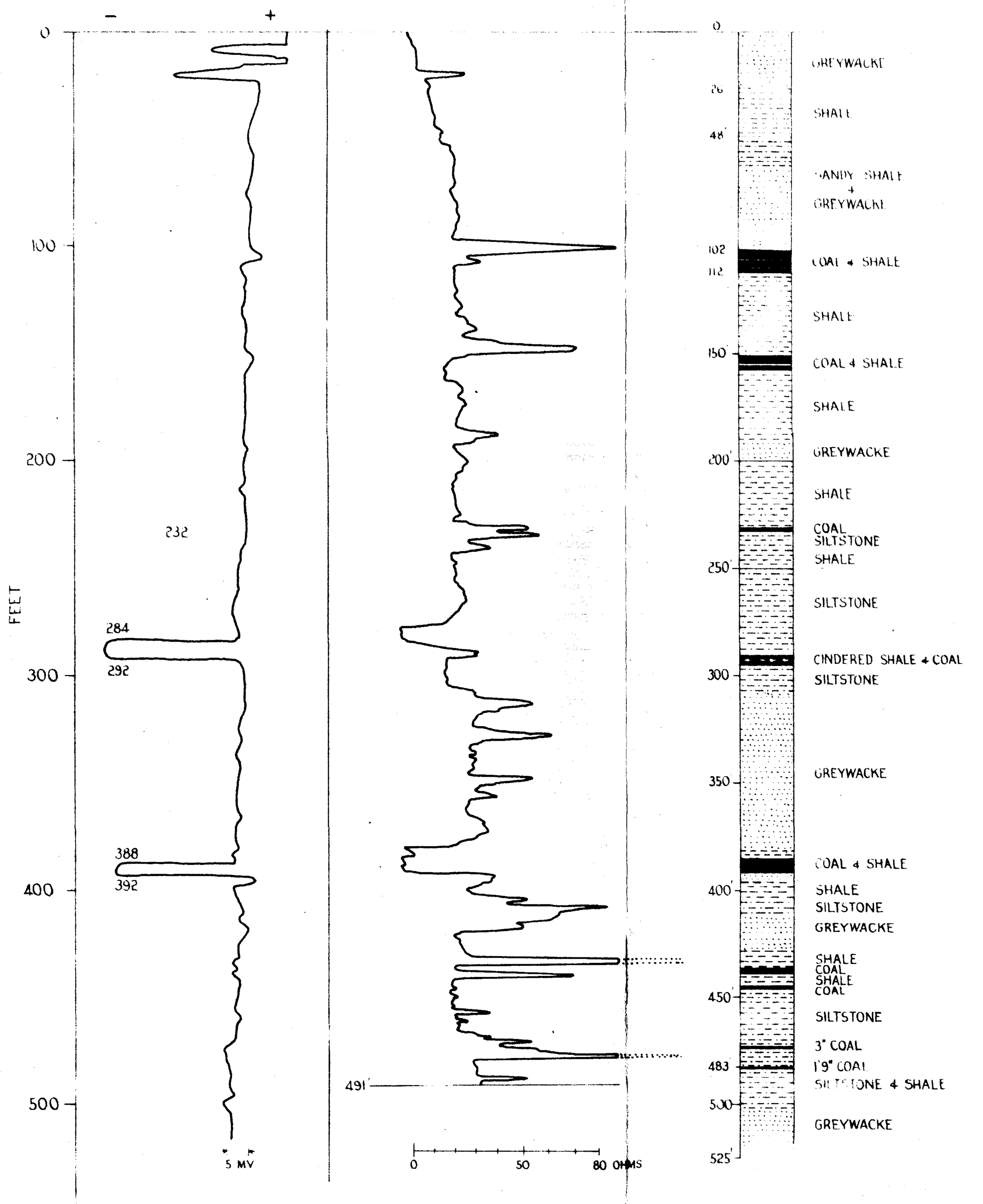


FIG. 1 BLAKEFIELD Nº2 S

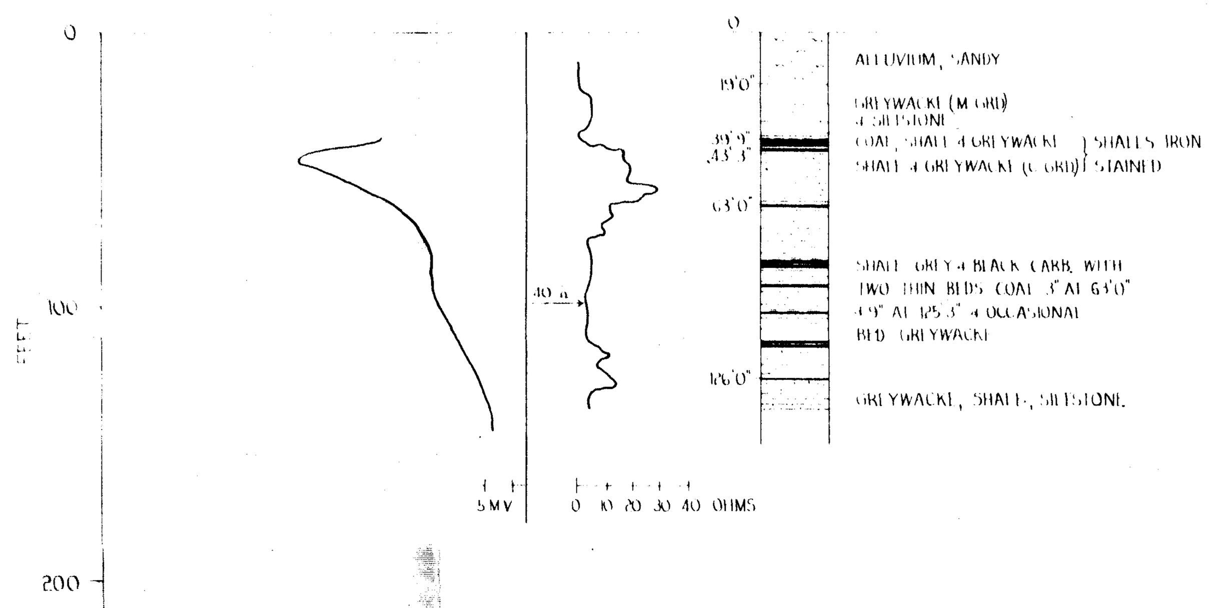


FIG. 3 SADDLER'S CREEK 3S

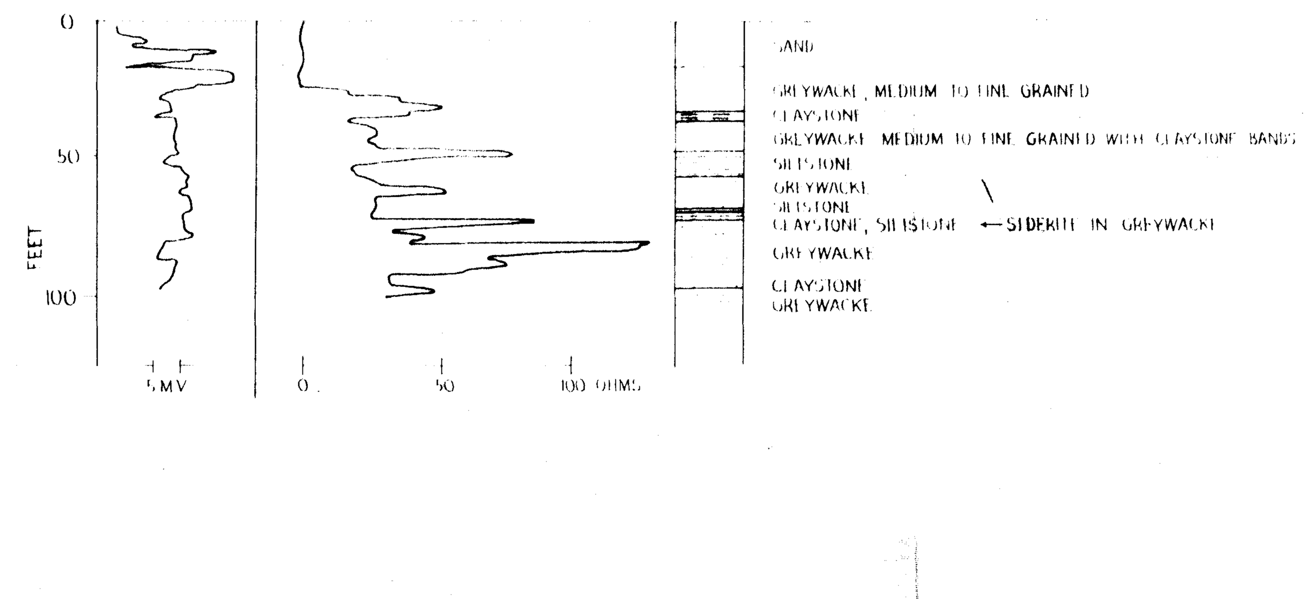
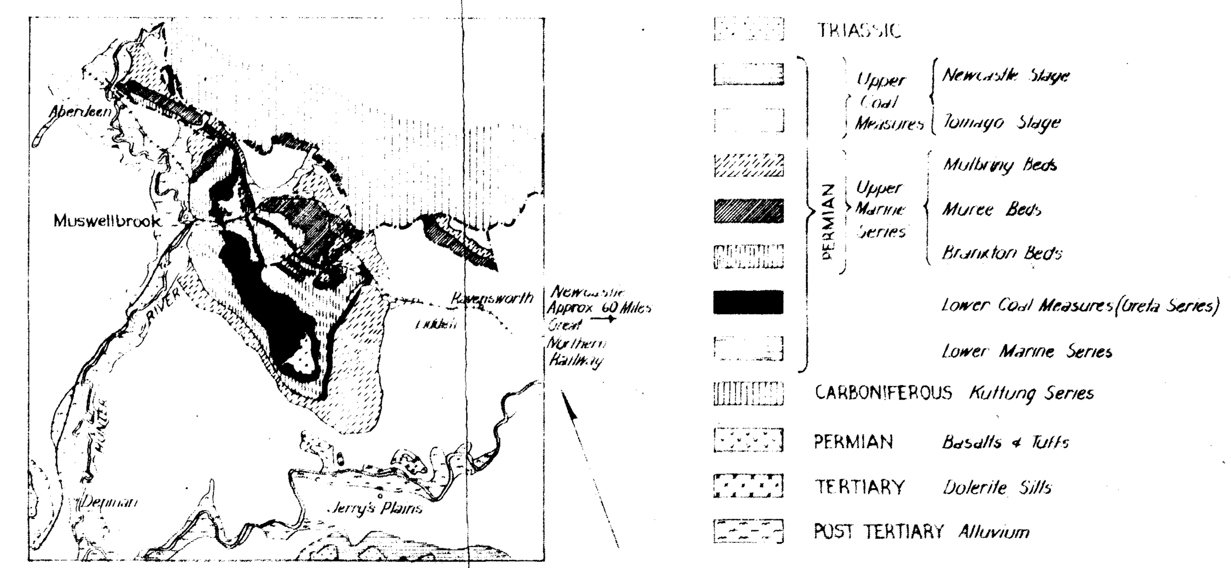


FIG. 6 PARNELL'S CREEK 75T



GEOLOGICAL LOCALITY MAP

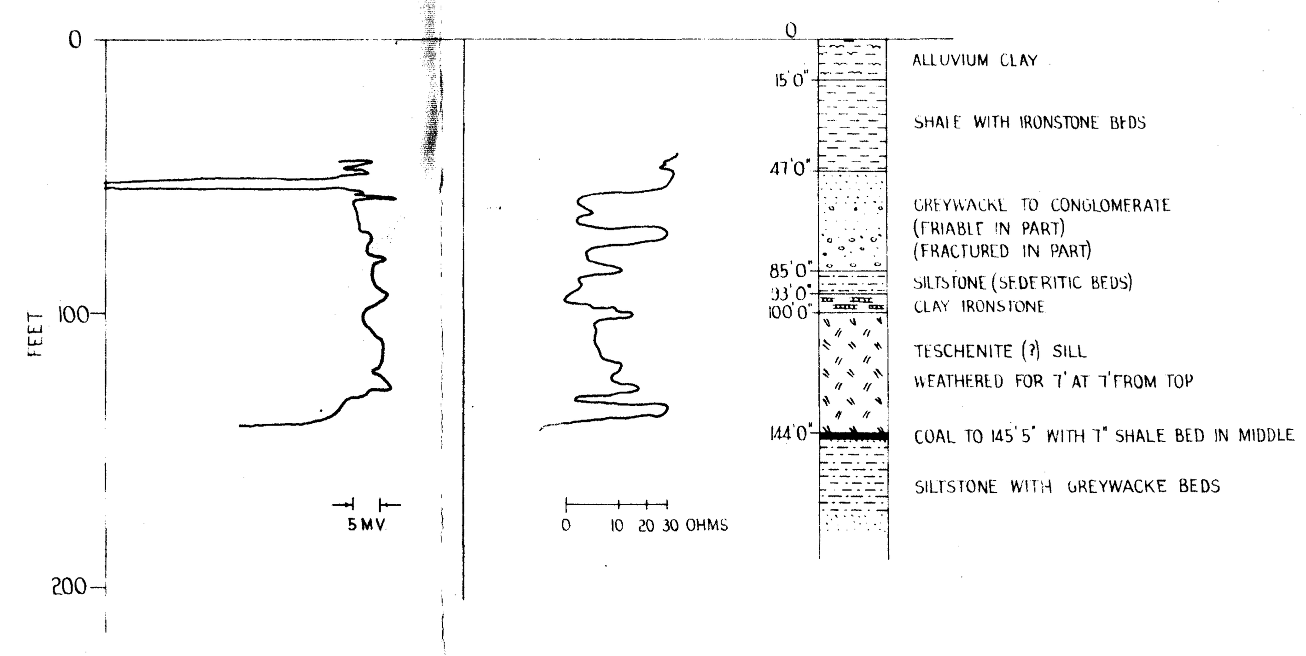


FIG. 4 SADDLER'S CREEK 4 S

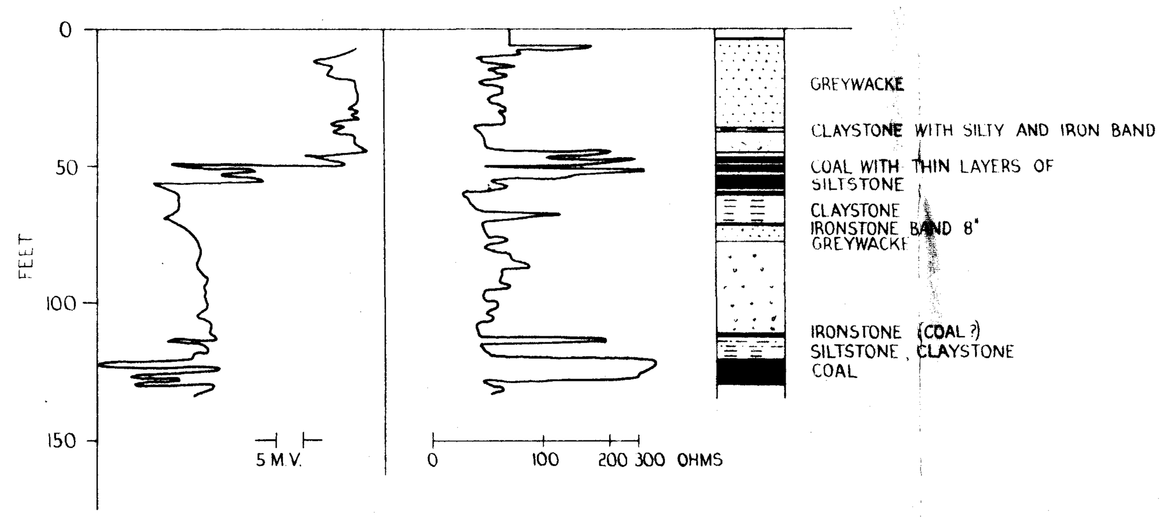


FIG. 7 PONDS CREEK 8T

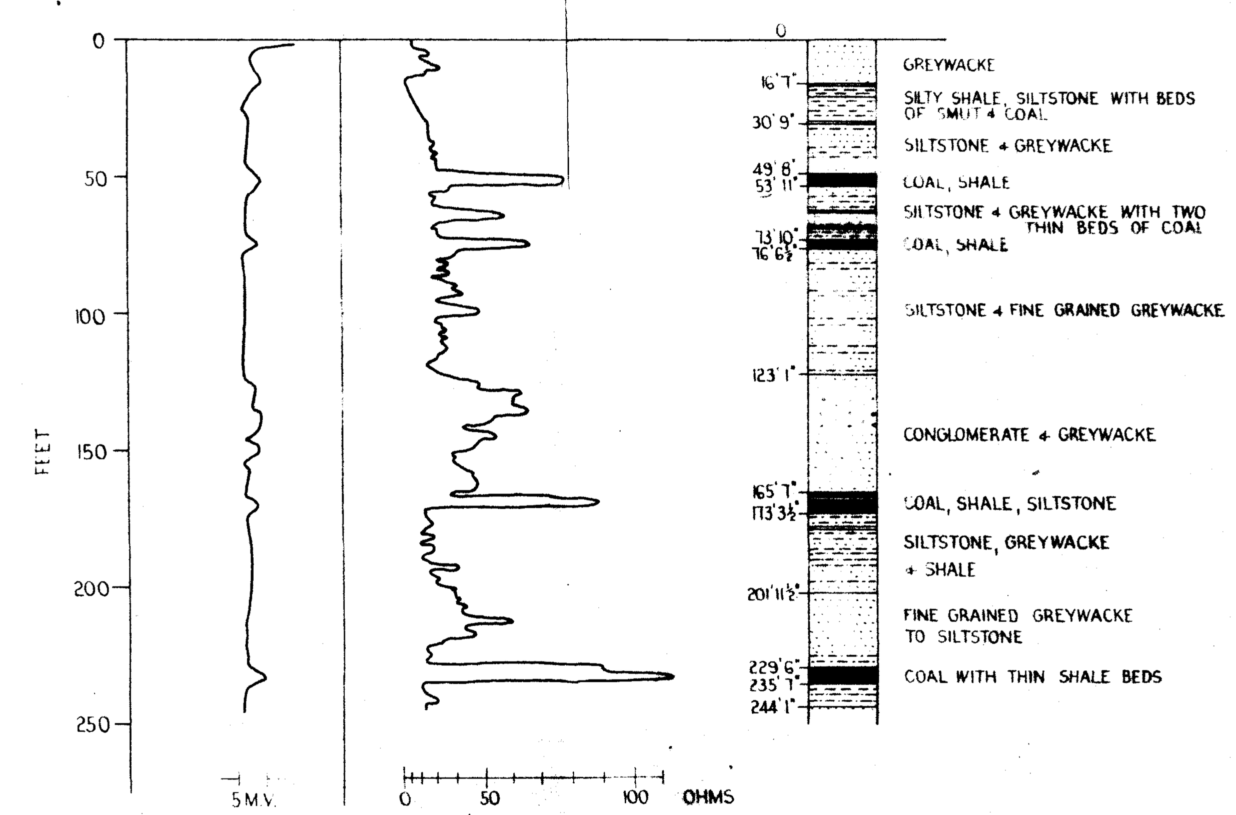


FIG. 8 STATE RESERVE 1.S

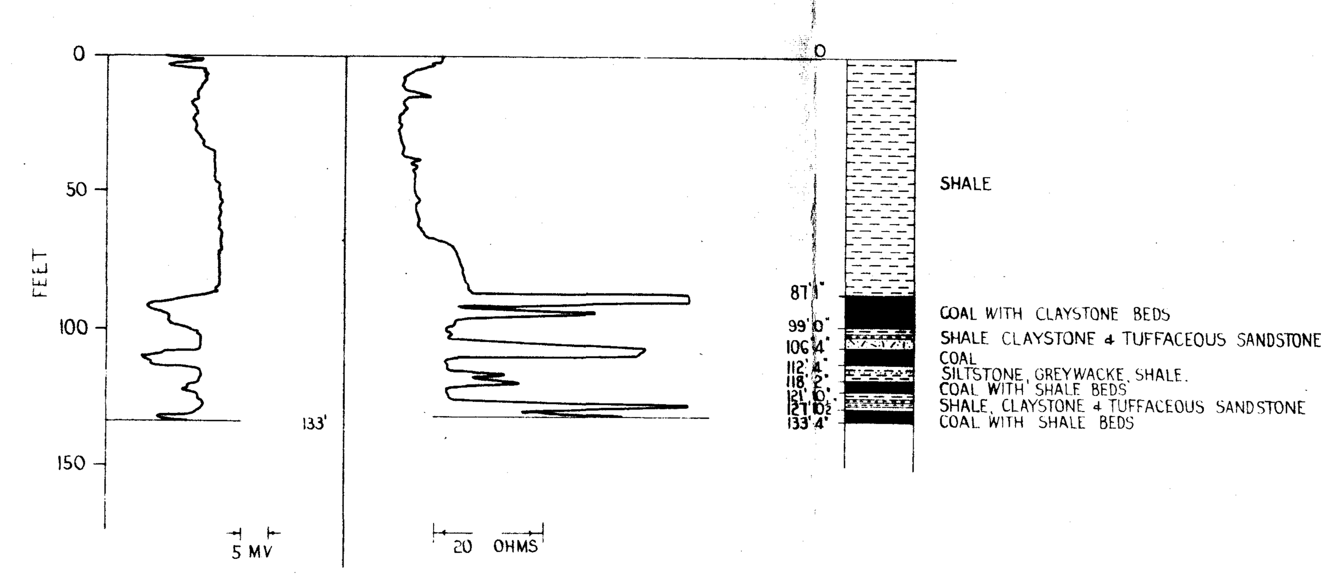


FIG. 2 BLAKEFIELD 7S

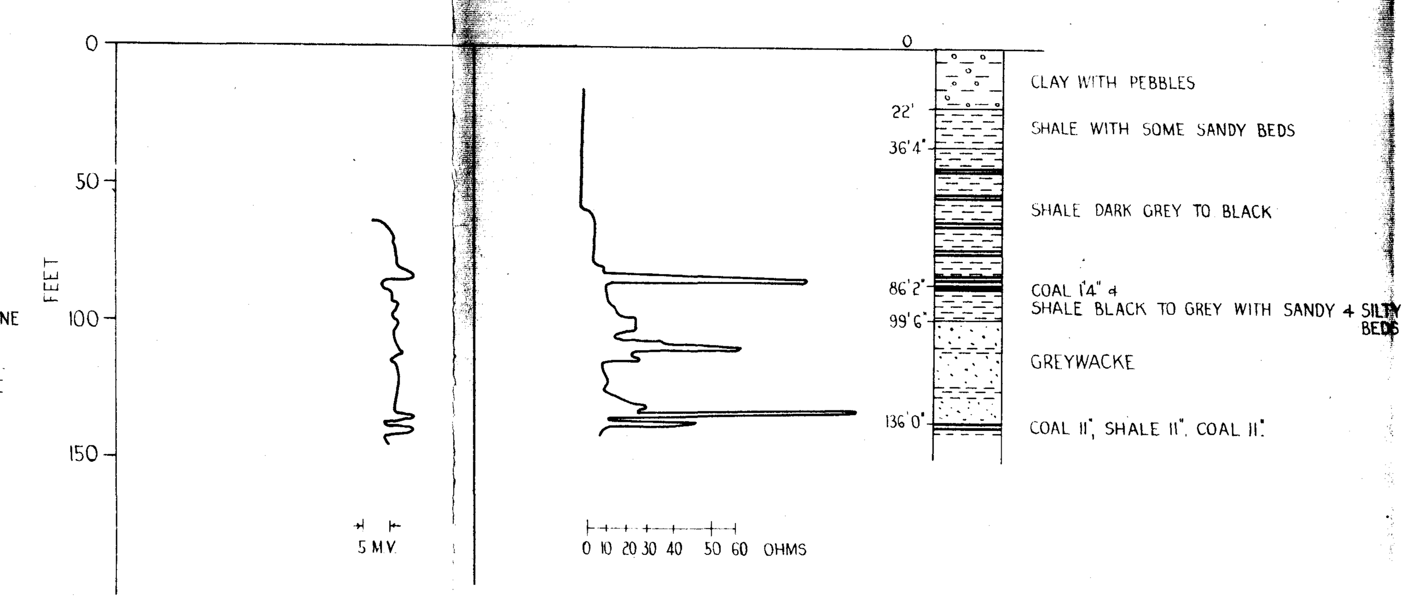
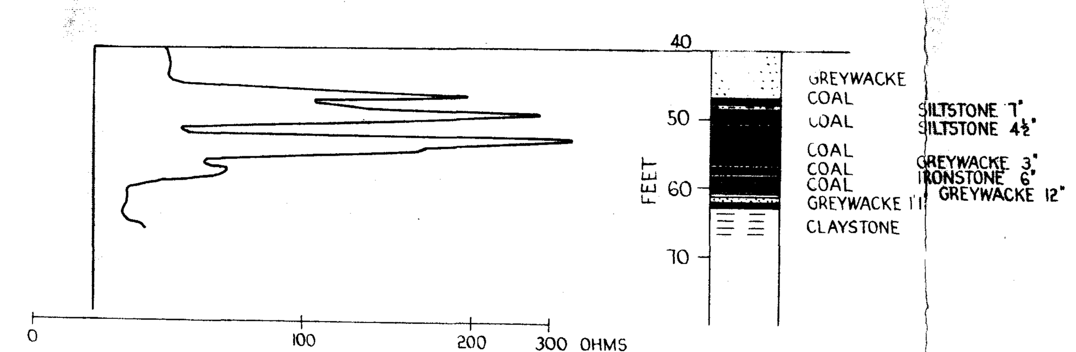


FIG. 5 SADDLER'S CREEK 5S



DETAIL RESISTIVITY LOG BETWEEN 40 AND 70 FEET

FIG. 7A PONDS CREEK 8T

ELECTRICAL WELL LOGGING TESTS
MAITLAND COALFIELDS N.S.W.

DIAGRAMS SHOWING

SELF-POTENTIAL LOGS, SINGLE POINT RESISTANCE LOGS, AND GEOLOGICAL LOGS.

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