DEPARTMENT OF MINES AND ENERGY

SOUTH AUSTRALIA

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ORGANIC CARBON AND TRACE ELEMENT INVESTIGATIONS COOPER BASIN SEDIMENTS PROGRESS REPORT: MUNKARIE NO. 1

GEOLOGICAL SURVEY

BY

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G.S. No. 6151
D.M. No. 225/78

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ABSTRACT

Preliminary investigations suggest that shales within conventionally-defined rock units in Munkarie No. 1 exhibit characteristic trace-element signatures. It appears moreover that the Toolachee Formation here can be subdivided into three chemostratigraphic units not otherwise recognisable from well logs.

There is no consistent correlation between trace element and organic carbon contents of the analysed samples; although exhaustive correlations are not yet completed, it seems therefore that a major initial aim of this investigation already has been achieved.

Potential stratigraphic applications of these geochemical data warrant further work.

INTRODUCTION

In April 1978 a joint project - "Organic carbon and trace element investigations" - was commenced by the S.A. Department of Mines and Energy and W.G. Shackleton of Salisbury College of Advanced Education (SCAE). The major purpose of the project is to identify possible relationships between the organic carbon (C_{org}) content and the trace metal content of sedimentary rocks.

Apart from contributing to the debate on the genesis of certain sedimentary mineral deposits, such an investigation may prove valuable to petroleum geology because:-

(a) if there is a significant relationship between metal and C_{org} contents of sediments, then it may be simpler and cheaper to analyse sediments for a suite of elements rather than for organic carbon, to identify those sediments worthy of further investigation as potential petroleum source rocks; and

(b) lateral variations in the distributions of metals may indicate source areas for the sediments.

To determine the applicability of such an approach, a pilot project was undertaken whereby 77 ten-foot-interval well cuttings samples (including 7 duplicates) were taken from 5750 to 6450 feet depth in Munkarie No. 1 well, southeastern Cooper Basin (all Depth measurements are retained as 'feet' because this is standard practice in the Cooper Basin area). This interval includes the Permian Toolachee and Daralingie formations, from which petroleum is produced elsewhere in the basin and portion of the Lower-Middle Triassic Nappamerri Formation.

PREPARATION AND TREATMENT OF SAMPLES

Cuttings representative of ten-foot intervals were scoop sampled and split to provide a working sample of approximately 50 g. A lithological log for the interval sampled was compiled by the author from wire-line logs and binocular microscope examination of the cuttings (Appendix I) independently of Munkarie completion-report lithologs.

Considerable contamination by bit shavings was removed by passing a bar magnet through the samples.

The samples were then numbered randomly and forwarded to the Australian Mineral Development Laboratories (AMDEL). After pulverising to pass 150 mesh BSS, 10 to 15 g were split from each sample for analytical work.

The following were determined at AMDEL:

(a) Carbonate carbon content

(b) Organic and elemental carbon content

(c) 32 elements by emission spectroscopic (ES) scan.

The results (initially reported as AMDEL Job AC3910/78) are presented as Appendix II. Note that with the exception of one value for Mo, the following elements were not detected: Mo, As, Bi, Cd, Ge, In, Sb, Ta, Th, W and Yb. Results from this analytical method are precise only to ± 50%.

On completion of the work at AMDEL, the remainder of the pulverised samples was sent to the Department of Earth Science, SCAE. 0.5 g of each sample was boiled in 2 ml of Aqua Regia for one hour. After cooling and dilution to 10 ml with distilled water, copper, lead, zinc, manganese and iron were determined on a Pye Unicam SP 191 atomic absorption spectrophotometer (AAS). The machine was recalibrated at frequent intervals, averaging once per ten samples. The results, precise to ± 5 percent at the 95 percent confidence level, also are included in Appendix II.

The results of the analytical work carried out at both AMDEL and SCAE are plotted against depth in Figure 1, which also includes two stratigraphic (lithological) columns: one compiled by the author's interpretation of wireline BHC-GR logs, using formation boundaries given in the well completion report, and the other compiled from the author's cuttings descriptions in conjunction with wireline logs.

DISCUSSION OF RESULTS

1. Raw Data - Refer to Figure 1

Carbonate carbon (C_{CO3}) There is little variation with lithology, except for slight decreases in sandy units. The lower portion of the Toolachee Formation contains significantly less carbonate carbon than the intervals above and below, and highest concentrations occur in the middle portion of the Toolachee Formation.

Organic and elemental carbon (C_{org}) Content varies markedly with lithology, the coaly units naturally exhibiting very high values. There is a sharp contrast in C_{org} concentrations between the Nappamerri Formation and the Toolachee Formation: these obviously formed in different environments. Although C_{org} content remains high through the Permian interval sampled, the lower portion of the Toolachee Formation contains slightly higher concentrations than the upper.

The carbon content decreases by about 50 percent from the lower Toolachee Formation to the Daralingie Beds.

Elements determined by ES at AMDEL These generally show variation in concentrations with lithology, especially evident by element concentrations in the basal sandstone unit of the Toolachee Formation and shales of the upper Daralingie Beds.

Some elements also vary in concentration within shales of different stratigraphic units. Zinc, for example, is "high and variable" in the Nappamerri Formation; "moderate and variable" in the upper Toolachee Formation; "very low" in the lower Toolachee Formation and "variable but high" in the Daralingie Beds.

To a lesser extent, but still significantly, lead and manganese also show this tendency.

Elements determined by AAS at SCAE The five elements, Cu, Pb, Zn, Mn and Fe, all show variation with lithology similar to those elements determined by ES. However, largely because of the higher precision of the AAS determinations, there is less apparent variation in element concentrations within a lithological unit.

The main difference between the results of the two analytical methods is that AAS shows no marked contrast in concentrations of any of the five elements between the lower Nappamerri Formation and the upper portion of the Toolachee Formation. However Fe, as the other metals, tends to occur at relatively lower concentrations in the lower portion of the Toolachee Formation.

2. Manipulated Data

Variations in element concentrations are due mainly to lithological variations. To minimise that influence upon the data, only analytical results from samples principally composed of shale, the most common lithology, were considered.

Because of the variation within lithological units, particularly as apparent by the imprecise ES method, results were evaluated by a rolling-mean technique. Zinc concentrations, which on initial inspection of the data appeared to show significant variation, were subjected to a range of averaging calculations from the raw data to the rolling mean calculated on seven consecutive values (n=7). Both ES and AAS results for Zn were treated in this manner (Figs 2 & 3)*.

After examination of these vertical "shale-only" profiles it was decided to adopt a five-consecutive-value rolling mean (n=5) in subsequent manipulations, since this mean appears to smooth variations in the raw data to a satisfactory level without rendering unrecognisable the main contrasts seen in these data. Raw values and rolling means (n=5) also were plotted for C_{CO3} and C_{org} (Fig. 4), manganese and iron (Fig. 5).

Carbonate carbon (C_{CO3}) The averaging technique emphasises consistent concentrations from Nappamerri Formation levels to the middle portion of the Toolachee Formation, where markedly higher values occur. The lower portion of the Toolachee Formation contains consistently lower concentrations, that increase slightly on entering the Daralingie Beds.

Organic and elemental carbon (C_{org}) As is apparent from the raw data, the most marked change in concentrations occurs at the Nappamerri - Toolachee formation boundary.

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* On Figures 2 and 3, and on subsequent figures, are shown three subdivisions of the Toolachee Formation interval. Bases for these subdivisions are explained in the ensuing discussion.

Concentrations within Toolachee Formation shales identify three units: an upper unit, containing lower concentrations than a lower unit, with an intervening "transitional zone". The Daralingie Beds exhibit C_{org} concentrations similar to the upper Toolachee unit.

Zinc Values for the Nappamerri Formation appear to depend on the efficiency of the analytical extraction technique. Emission spectroscopy produces much higher values than the aqua regia extraction for AAS, thus enabling a distinction to be made between the Nappamerri and Toolachee formations that is not apparent by the AAS results alone. Both sets of results however enable the Toolachee Formation to be subdivided into upper (with higher zinc content) and lower units. The boundary between these two units, at about 6030 feet depth, approximates a boundary recognised by both C_{CO3} and C_{org} data.

Zn values by both ES and AAS are significantly higher in the Daralingie Beds than in the Toolachee Formation.

Manganese Concentrations of this element show little variation through most of the sampled interval, although a "lower Toolachee" unit can be identified where concentrations are only about 50% of those apparent elsewhere. The boundaries of this unit are seen also in C_{org} and C_{CO3} data.

Iron Values show variations similar to those for AAS zinc.

Combined element distribution All the above results suggest that element concentrations may be used to define major stratigraphic units, and more particularly to subdivide the Toolachee Formation. Unit boundaries are shown in Table 1, the intra-Toolachee boundaries being chosen from both the raw and rolling-mean plots (Figures 1 to 5). The element concentrations shown in this table are means (not rolling means) of all predominantly-shale samples from each of the chosen subdivisions.

TABLE 1

ROCK UNIT, Established terminology	SUBDIVISION Proposed here	DEPTH (Feet)	MEAN ASSAY VALUES (SHALE-ONLY BASIS)					
			C_{org} %	C_{CO3} %	Zn_{ES} ppm	Zn_{AAS} ppm	Mn_{AAS} ppm	Fe_{AAS} ppm
Nappamerri Fm.		-5860	0.53	0.85	297	86	641	38,640
Toolachee Fm.	Upper	5860-6030	5.43	0.83	108	81	578	37,140
	Middle	6030-?6150	4.44	1.28	40	49	475	36,430
	Lower	?6150-6370	6.75	0.53	32	51	263	21,800
Daralingie Beds		6370-	3.51	0.84	257	106	579	35,290

The boundary between the middle and lower Toolachee Formation units is problematic, since it may be placed above or below a coaly unit occurring near that depth.

To make clearer the variations in element concentrations summarised in Table 1, the above means are expressed in Table 2 as percentages of the highest mean value for each element.

TABLE 2

ROCK UNIT	SUBDIVISION Proposed here	DEPTH (Feet)	MEAN ASSAY VALUES (SHALE-ONLY BASIS), AS PERCENT OF HIGHEST VALUE					
			C_{org}	C_{CO3}	Zn_{ES}	Zn_{AAS}	Mn_{AAS}	Fe_{AAS}
Nappamerri Fm.		-5860	7.85	66.41	100.00	81.13	100.00	100.00
Toolachee Fm.	Upper	5860-6030	80.44	64.84	36.36	76.42	90.33	96.12
	Middle	6030-?6150	65.78	100.00	13.47	46.23	74.10	94.28
	Lower	?6150-6370	100.00	41.41	10.77	48.11	41.03	56.42
Daralingie Beds		6370-	52.00	65.63	86.53	100.00	90.33	91.33

These data are plotted as Figure 6.

Correlations between elements Table 3 illustrates correlation coefficients between each of (Mn, Fe, Zn) and (C_{org}, C_{CO3}) pairs. Correlation of the metals with C_{org} content is shown to be highly variable and although correlation with C_{CO3} is marginally better, it is too variable to be of practical value.

TABLE 3

Elemental Pairs-	C_{org} with				C_{CO_3} with			
Rock Unit (shale samples only)	Mn_{AAS}	Fe_{AAS}	Zn_{ES}	Zn_{AAS}	Mn_{AAS}	Fe_{AAS}	Zn_{ES}	Zn_{AAS}
All shales	-0.23	-0.12	-0.55	-0.43	0.52	0.64	-0.03	-0.01
Nappamerri Fm.	-0.34	-0.57	-0.29	-0.56	0.79	0.82	0.46	0.43
"Upper" Toolachee Fm.	0.25	0.34	-0.38	-0.52	0.47	0.51	-0.39	-0.52
"Middle" Toolachee Fm.	0.36	0.20	-0.73	0.04	0.39	0.51	-0.07	-0.01
"Lower" Toolachee Fm.	-0.15	-0.11	-0.74	-0.73	0.91	0.82	0.29	0.43
Daralingie Beds	0.63	0.72	-0.42	-0.15	0.94	0.95	-0.55	0.10

CONCLUSIONS & RECOMMENDATIONS

There is no consistent correlation of trace metals with organic and elemental carbon in the cuttings samples analysed. It is unlikely therefore that any estimation of organic carbon contents by correlation with trace metal analyses would be a success in this area, or probably in the Cooper Basin.

A potential value of this preliminary work is the possibility of recognising and defining rock units by their trace-element content. To further investigate these aspects, Munkarie cuttings from intervals above and below that discussed here will be analysed by ES and AAS, and results will be integrated in a subsequent review report.

It is proposed that cuttings from another Cooper Basin well be similarly analysed, to establish the potential for wider application of this chemostratigraphic tool within the basin. Big Lake No. 23 lies in a different province of the basin from Munkarie No. 1, but penetrated a comparable stratigraphic sequence with adequate well control, and cuttings from this well should be analysed for their trace-elements.

ACKNOWLEDGEMENTS

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W.G. SHACKLETON

APPENDIX 1

Munkarie No. 1

Summary Lithologic Log

APPENDIX I

Munkarie Number 1

Summary Lithologic Log

From	To	Description
5750'	5860'	Shale - silty. Fine to medium grained, quartz and lesser feldspar; traces organic matter. Traces of very fine pyrite in silty fraction Grey.
5860'	5870'	Shale - silty. Similar to above but frequent black coal fragments. Grey.
5870'	5880'	Coal - black, lustrous. Some silty shale as above.
5880'	6000'	Shale - silty. Similar to shales above but abundant organic material gives dark brown to black colour.
6000'	6020'	Coal - black, lustrous.
6020'	6080'	Shale - silty and sandy in parts some coal fragments. Grey to brown depending on amount of organic material. Coarser towards bottom.
6080'	6090'	Sandstone - coarse, angular - subangular clear quartz grains.
6090'	6130'	Shale - silty, as for 5880'-6000'.
6130'	6150'	Coal - as before, some quartz sand as for 6080'-6090'.
6150'	6180'	Shale - silty, as for 5880'-6000'.
6180'	6200'	Coal - as before.
6200'	6210'	Shale - silty, dark grey, organic rich.
6210'	6230'	Coal - black, less lustrous than above. Larger silty shale component.
6230'	6270'	Shale - silty, as for 6200'-6210'.
6270'	6280'	Coal - black, lustrous.
6280'	6300'	Shale - as above, 50% organic silty shale.
6300'	6310'	Coal - as above, 50% organic silty shale.
6310'	6370'	Sandstone - 1-2 mm dia. angular quartz grains. Traces organic silty shale and coal fragments.

From	To	Description
6370'	6430'	Shale - dark grey, highly organic, suggestion of bedding in other section.
6430'	6440'	Coal - black, lustrous.
6440'	6450'	Shale - as for 6370'-6430'.

APPENDIX II

MUNKARIE NUMBER 1

TABULATED ANALYTICAL RESULTS

The following tables present the results of analysis of well cuttings from Munkarie Number 1.

Determinations of carbonate carbon, organic carbon and the multi element scan by emission spectroscopy for 32 elements were all carried out by the Australian Mineral Development Laboratories, South Australia.

Determinations of copper, lead, zinc, manganese and iron by atomic absorption spectroscopy were carried out by W. G. Shackleton, P. Dorsett and L. Halfpenny at Salisbury College of Advanced Education, South Australia, on a Pye Unicam atomic absorption spectrophotometer.

N.B.

1. X = not detected at the limits quoted.
2. Results are in ppm unless otherwise stated.
3. Detection limits in brackets.

* Duplicate sample.

MUNKARIE NO. 1

	FROM (FEET)	TO	CARBONATE CARBON %	ORGANIC CARBON %	BA (200)	BE (1)	CE (300)	CO (5)	CR (20)	LA (100)	MN (10)	MO (3)	NB (20)	NI (5)	SC (3)	SR (50)	TA (100)
	****	****	*****	*****	****	****	****	****	****	****	****	****	****	****	****	****	****
NAPPMERRI FORMATION	5750	5760	0.55	0.62	700	1	X	50	100	X	1500	X	20	80	10	80	X
	5760	5770	1.15	0.41	300	2	X	30	100	X	1000	X	X	70	7	70	X
	5770	5780	0.92	0.43	300	1	X	50	100	50	1000	X	40	100	10	70	X
	5780	5790	0.65	0.37	700	2	X	40	150	50	2000	X	30	80	15	80	X
	* 5780	5790	0.84	0.47	500	2	X	70	150	70	1500	X	20	150	10	80	X
	5790	5800	0.87	0.43	500	2	X	30	100	X	1500	X	X	70	15	80	X
	5800	5810	0.65	0.40	1000	2	X	50	100	X	2000	X	X	150	10	70	X
	5810	5820	0.65	0.56	500	1	X	10	100	X	1000	X	X	80	5	X	X
	5820	5830	0.62	0.58	500	1	X	15	80	X	1000	X	X	50	7	70	X
	5830	5840	0.78	0.64	300	2	X	40	100	X	1500	X	X	70	7	70	X
	5840	5850	0.94	0.63	700	1	X	60	150	70	1500	X	40	60	15	80	X
	5850	5860	0.85	0.69	300	2	X	50	100	X	2000	X	X	70	10	80	X
TOOLACHEE FORMATION	5860	5870	0.91	11.49	500	2	X	15	100	X	1000	X	X	50	7	70	X
	5870	5880	1.00	18.45	700	2	X	40	100	X	1000	X	X	150	10	70	X
	5880	5890	1.15	11.15	800	1	X	15	100	X	1000	X	X	80	7	70	X
	5890	5900	0.71	4.38	300	1	X	X	70	X	300	X	X	20	3	X	X
	5900	5910	0.71	4.42	500	2	X	20	100	50	700	X	X	70	10	50	X
	5910	5920	0.61	8.30	700	2	X	10	100	X	500	X	X	70	10	80	X
	5920	5930	0.79	4.74	700	2	X	40	150	X	1500	X	X	100	10	70	X
	5930	5940	0.61	2.70	700	2	X	40	100	X	1500	X	X	80	10	70	X
	5940	5950	0.76	6.05	700	2	X	50	150	X	1000	X	X	100	10	50	X
	5950	5960	1.43	2.00	800	2	X	30	100	X	2000	X	X	80	10	50	X
	5960	5970	0.92	2.88	500	2	X	40	100	X	1000	X	X	100	10	50	X
	5970	5980	0.59	2.63	500	3	X	50	100	X	1000	X	X	150	10	50	X
	5980	5990	0.62	2.18	200	1	X	30	100	X	1000	X	X	70	10	50	X
	* 5980	5990	0.79	2.17	700	2	X	20	80	X	1000	X	X	70	7	X	X
	5990	6000	0.62	2.50	500	3	X	30	150	100	1500	X	X	100	15	70	X
	6000	6010	0.91	42.60	300	X	X	10	80	X	500	X	X	50	7	X	X
	6010	6020	0.21	18.90	300	1	X	10	100	X	1000	10	X	70	3	X	X
	6020	6030	0.96	7.65	300	1	X	10	100	X	1500	X	X	70	5	X	X
	6030	6040	1.43	1.66	300	X	X	10	100	X	700	X	X	30	X	X	X
	6040	6050	0.90	2.82	X	2	X	30	100	X	1000	X	20	80	5	X	X
	6050	6060	2.05	0.59	200	1	X	15	80	X	800	X	X	70	7	X	X
	6060	6070	1.23	2.94	X	1	X	10	80	X	1000	X	X	50	5	X	X
	* 6060	6070	1.16	3.36	300	1	X	20	70	X	1500	X	X	50	5	X	X
	6070	6080	2.02	7.35	200	2	X	15	100	X	1000	X	X	80	5	X	X
	6080	6090	0.33	1.60	500	1	X	10	100	X	300	X	X	70	X	X	X
	6090	6100	1.21	3.20	300	2	X	10	100	X	1000	X	X	70	10	X	X
	6100	6110	0.71	5.35	300	2	X	40	100	X	800	X	20	100	10	X	X
	* 6100	6110	0.75	5.60	300	2	X	30	100	X	1000	X	X	70	5	X	X
	6110	6120	0.62	9.75	700	1	X	50	200	X	1000	X	40	100	10	70	X
	6120	6130	0.34	17.00	300	1	X	X	100	X	1000	X	X	50	7	X	X
	6130	6140	0.12	15.35	800	1	X	10	100	X	300	X	X	100	5	50	X
	6140	6150	0.39	32.40	300	1	X	X	70	X	80	X	X	50	5	X	X
	6150	6160	0.21	9.65	1500	1	X	40	150	X	700	X	20	100	10	50	X
	6160	6170	0.32	4.74	1000	1	X	10	100	X	1000	X	X	70	7	70	X
	6170	6180	0.61	5.80	1000	1	X	10	100	X	800	X	X	100	7	50	X
	6180	6190	0.49	15.65	1000	2	X	15	100	X	1000	X	X	100	7	70	X
	6190	6200	0.34	42.50	X	1	X	X	70	X	100	X	X	70	5	X	X
	6200	6210	0.64	6.62	300	X	X	X	100	X	500	X	X	50	5	X	X
	6210	6220	0.39	26.00	800	5	X	40	150	100	300	X	50	150	15	100	X
	6220	6230	0.43	4.90	1000	2	X	10	100	50	500	X	20	80	10	50	X
	6230	6240	0.60	6.30	500	1	X	5	100	X	800	X	X	70	5	50	X

MUNKARIE NO. 1

	FROM (FEET)	TO	CARBONATE CARBON %	ORGANIC CARBON %	BA (200)	BE (1)	CE (300)	CO (5)	CR (20)	LA (100)	MN (10)	MO (3)	NB (20)	NI (5)	SC (3)	SR (50)	TA (100)
	****	****	*****	*****	****	****	****	****	****	****	****	****	****	****	****	****	****
	6240	6250	0.26	7.05	500	1	X	5	150	X	500	X	20	50	10	X	X
	6250	6260	0.55	6.25	300	2	X	5	150	X	700	X	20	80	5	X	X
	6260	6270	0.55	4.94	700	2	X	10	100	50	500	X	20	80	15	50	X
	* 6260	6270	0.56	4.96	700	3	X	15	150	150	500	X	20	80	20	70	X
	6270	6280	0.71	61.10	X	2	X	10	80	X	600	X	X	80	7	X	X
	6280	6290	0.85	7.45	700	3	X	5	100	X	1000	X	X	80	10	X	X
	6290	6300	0.66	6.70	500	2	X	10	100	50	800	X	X	100	10	50	X
	6300	6310	0.31	27.90	300	1	X	5	100	X	500	X	X	70	5	50	X
	6310	6320	0.20	3.60	300	2	X	40	150	50	300	X	20	100	10	X	X
	6320	6330	0.14	4.16	700	2	X	20	200	70	300	X	20	100	15	X	X
	6330	6340	0.23	1.35	200	1	X	10	100	X	200	X	X	30	3	X	X
	6340	6350	0.12	2.03	X	1	X	10	100	X	300	X	X	70	3	X	X
	6350	6360	0.06	0.66	X	X	X	20	80	X	200	X	X	80	X	X	X
	* 6350	6360	0.36	0.49	X	X	X	30	70	X	200	X	X	60	3	X	X
	6360	6370	0.06	0.65	300	X	X	50	70	X	200	X	X	80	3	X	X
DARALINGIE FORMATION	6370	6380	0.24	2.40	700	3	X	70	200	50	700	X	50	150	15	80	X
	6380	6390	0.38	2.64	500	3	X	40	100	50	1000	X	20	80	10	80	X
	6390	6400	0.61	3.78	700	2	X	50	150	100	3000	X	30	80	15	70	X
	* 6390	6400	1.10	3.39	1500	3	X	50	200	70	1500	X	50	200	20	80	X
	6400	6410	0.97	3.56	800	2	X	40	150	X	1500	X	30	80	15	70	X
	6410	6420	0.93	2.88	300	2	X	20	100	X	1000	X	X	100	5	X	X
	6420	6430	0.70	3.55	800	2	X	50	150	100	1000	X	50	150	20	100	X
	6430	6440	0.27	8.60	300	1	X	X	80	X	300	X	X	50	3	X	X
	6440	6450	1.20	5.50	500	3	X	50	150	50	1500	X	20	100	10	X	X

MUNKARIE NO.1

<--- ANALYSIS BY EMISSION SPECTROSCOPY --->

	FROM (FEET)	TO	TH (100)	TI (100)	V (10)	W (50)	Y (10)	YB (1)	ZR (10)	AG (0.1)	AS (50)	BI (1)	CD (3)	CU (1)	GA (1)	GE (3)	IN (10)	PB (1)
	****	****	****	*****	****	****	****	****	****	****	****	****	****	****	****	****	****	****
NAPPMERRI FORMATION	5750	5760	X	10000	150	X	70	X	200	0.30	X	X	X	100	30	X	X	100
	5760	5770	X	3000	100	X	50	X	200	0.30	X	X	X	80	50	X	X	100
	5770	5780	X	10000	150	X	80	X	300	0.20	X	X	X	80	30	X	X	100
	5760	5790	X	5000	150	X	100	X	300	0.30	X	X	X	100	50	X	X	100
	* 5780	5790	X	10000	150	X	70	X	300	0.20	X	X	X	100	40	X	X	100
	5790	5800	X	10000	150	X	100	X	30	0.30	X	X	X	80	50	X	X	150
	5800	5810	X	3000	150	X	70	X	300	0.20	X	X	X	60	20	X	X	300
	5810	5820	X	3000	100	X	50	X	100	0.20	X	X	X	100	15	X	X	100
	5620	5830	X	5000	100	X	80	X	200	0.10	X	X	X	50	20	X	X	70
	5830	5840	X	3000	100	X	70	X	100	0.20	X	X	X	70	30	X	X	100
	5840	5850	X	10000	200	X	10	X	500	0.30	X	X	X	100	40	X	X	80
	5850	5860	X	10000	100	X	70	X	200	0.10	X	X	X	80	20	X	X	50
TOOLACHEE FORMATION	5860	5870	X	2000	150	X	30	X	80	0.20	X	X	X	80	40	X	X	100
	5670	5880	X	3000	150	X	50	X	100	0.20	X	X	X	60	20	X	X	70
	5860	5890	X	3000	100	X	50	X	100	0.40	X	X	X	50	25	X	X	30
	5890	5900	X	1000	60	X	X	X	30	0.40	X	X	X	30	30	X	X	100
	5900	5910	X	5000	150	X	70	X	100	0.30	X	X	X	50	30	X	X	70
	5910	5920	X	3000	100	X	50	X	100	0.20	X	X	X	30	40	X	X	20
	5920	5930	X	5000	150	X	50	X	100	0.30	X	X	X	60	10	X	X	70
	5930	5940	X	5000	150	X	70	X	100	0.30	X	X	X	80	30	X	X	100
	5940	5950	X	10000	200	X	70	X	100	0.30	X	X	X	80	30	X	X	100
	5950	5960	X	5000	200	X	70	X	200	0.30	X	X	X	100	30	X	X	200
	5960	5970	X	5000	100	X	70	X	100	0.30	X	X	X	70	50	X	X	80
	5971	5980	X	5000	100	X	50	X	200	0.20	X	X	X	50	20	X	X	100
	5980	5990	X	3000	100	X	70	X	100	0.20	X	X	X	50	50	X	X	70
	* 5980	5990	X	10000	100	X	30	X	100	0.20	X	X	X	30	30	X	X	30
	5990	6000	X	10000	150	X	70	X	200	0.10	X	X	X	70	20	X	X	70
	6000	6010	X	2000	100	X	30	X	100	0.30	X	X	X	30	20	X	X	70
	6010	6020	X	2000	150	X	10	X	70	0.20	X	X	X	30	20	X	X	30
	6020	6030	X	2000	100	X	30	X	100	0.30	X	X	X	50	30	X	X	30
	6030	6040	X	2000	100	X	X	X	70	0.20	X	X	X	30	20	X	X	30
	6040	6050	X	3000	100	X	70	X	300	0.30	X	X	X	70	20	X	X	80
	6050	6060	X	2000	100	X	30	X	100	0.30	X	X	X	30	20	X	X	70
	6060	6070	X	3000	100	X	X	X	100	0.30	X	X	X	30	20	X	X	30
	* 6060	6070	X	2000	100	X	30	X	200	0.20	X	X	X	30	15	X	X	50
	6070	6080	X	2000	150	X	30	X	100	0.30	X	X	X	80	20	X	X	80
	6080	6090	X	1000	100	X	20	X	80	0.30	X	X	X	40	10	X	X	50
	6090	6100	X	3000	100	X	50	X	100	0.20	X	X	X	80	20	X	X	70
	6100	6110	X	3000	150	X	30	X	100	0.30	X	X	X	100	30	X	X	30
	* 6100	6110	X	5000	150	X	30	X	100	0.30	X	X	X	80	50	X	X	100
	6110	6120	X	10000	200	X	70	X	500	0.20	X	X	X	100	5	X	X	50
	6120	6130	X	2000	100	X	30	X	100	0.20	X	X	X	25	25	X	X	50
	6130	6140	X	3000	100	X	20	X	100	0.20	X	X	X	70	20	X	X	70
	6140	6150	X	2000	80	X	30	X	80	0.20	X	X	X	50	10	X	X	30
	6150	6160	X	10000	150	X	50	X	200	0.20	X	X	X	80	25	X	X	70
	6160	6170	X	10000	100	X	30	X	200	0.10	X	X	X	60	20	X	X	70
	6170	6180	X	3000	100	X	30	X	300	0.20	X	X	X	50	30	X	X	100
	6180	6190	X	3000	100	X	30	X	200	0.20	X	X	X	50	20	X	X	100
	6190	6200	X	2000	70	X	30	X	70	0.30	X	X	X	30	10	X	X	10
	6200	6210	X	2000	100	X	30	X	100	0.30	X	X	X	70	30	X	X	30
	6210	6220	X	10000	150	X	100	X	200	0.40	X	X	X	100	25	X	X	100
	6220	6230	X	5000	100	X	70	X	100	0.30	X	X	X	80	30	X	X	80
	6230	6240	X	3000	150	X	30	X	200	0.20	X	X	X	70	25	X	X	80

MUNKARIE NO.1

<--- ANALYSIS BY EMISSION SPECTROSCOPY --->

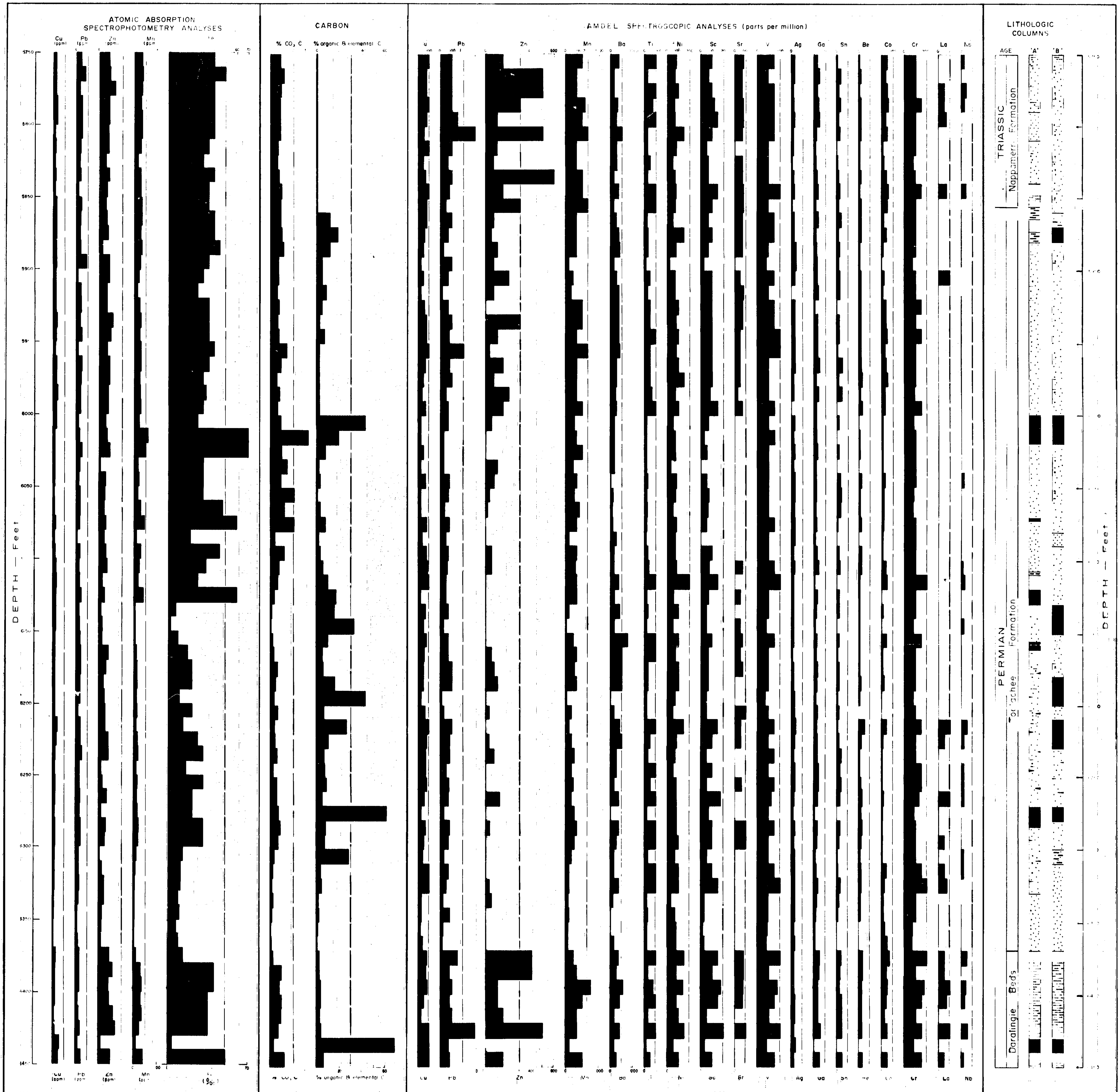
	FROM (FEET)	TO	TH (100)	TI (100)	V (10)	W (50)	Y (10)	YB (1)	ZR (10)	AG (0.1)	AS (50)	BI (1)	CD (3)	CU (1)	GA (1)	GE (3)	IN (10)	PB (1)
	****	****	****	*****	****	****	****	****	****	****	****	****	****	****	****	****	****	****
	6240	6250	X	10000	100	X	70	X	200	0.30	X	X	X	70	40	X	X	50
	6250	6260	X	5000	150	X	30	X	200	0.30	X	X	X	80	40	X	X	70
	6260	6270	X	10000	100	X	70	X	300	0.20	X	X	X	60	30	X	X	70
	* 6260	6270	X	10000	150	X	100	X	200	0.20	X	X	X	50	30	X	X	80
	6270	6280	X	2000	100	X	50	X	100	0.10	X	X	X	25	3	X	X	30
	6280	6290	X	10000	150	X	50	X	200	0.30	X	X	X	70	30	X	X	80
	6290	6300	X	10000	100	X	70	X	200	0.20	X	X	X	50	25	X	X	70
	6300	6310	X	3000	100	X	30	X	200	0.30	X	X	X	40	10	X	X	30
	6310	6320	X	10000	150	X	50	X	500	0.30	X	X	X	100	20	X	X	70
	6320	6330	X	10000	200	X	70	X	500	0.30	X	X	X	100	30	X	X	50
	6330	6340	X	2000	100	X	50	X	200	0.30	X	X	X	30	25	X	X	20
	6340	6350	X	3000	100	X	30	X	200	0.30	X	X	X	30	20	X	X	80
	6350	6360	X	2000	80	X	10	X	100	0.30	X	X	X	20	10	X	X	20
	* 6350	6360	X	2000	100	X	20	X	200	0.10	X	X	X	30	5	X	X	30
	6360	6370	X	2000	80	X	X	X	100	0.30	X	X	X	40	5	X	X	20
DARALINGIE FORMATION	6370	6380	X	10000	200	X	80	X	300	0.20	X	X	X	80	50	X	X	150
	6380	6390	X	3000	100	X	70	X	200	0.20	X	X	X	70	40	X	X	80
	6390	6400	X	10000	200	X	70	X	300	0.30	X	X	X	100	30	X	X	100
	* 6390	6400	X	5000	150	X	80	X	300	0.10	X	X	X	70	20	X	X	100
	6400	6410	X	10000	150	X	100	X	200	0.30	X	X	X	50	30	X	X	80
	6410	6420	X	3000	100	X	30	X	100	0.30	X	X	X	30	30	X	X	100
	6420	6430	X	10000	200	X	100	X	300	0.20	X	X	X	100	60	X	X	300
	6430	6440	X	1000	80	X	20	X	70	0.40	X	X	X	100	5	X	X	70
	6440	6450	X	5000	150	X	70	X	100	0.20	X	X	X	100	50	X	X	80

MUNKARIE NO.1

	FROM	TO	<- ANALYSIS BY ES ->			<-------- ANALYSIS BY AAS -------->				
	(FEET)		SB (30)	SN (1)	ZN (20)	CU	PB	ZN	MN	FE
	****	****	****	****	****	****	****	****	****	*****
NAPPAMERRI FORMATION	5750	5760	X	1	150	30	45	90	700	40000
	5760	5770	X	4	500	30	80	100	800	50000
	5770	5780	X	2	500	30	30	140	700	40000
	5780	5790	X	4	400	40	50	100	600	40000
	* 5780	5790	X	3	200	30	50	80	600	40000
	5790	5800	X	2	100	35	50	90	700	40000
	5800	5810	X	3	500	20	50	60	700	40000
	5810	5820	X	X	100	25	40	80	600	35000
	5820	5830	X	1	70	20	30	60	350	30000
	5830	5840	X	2	500	25	40	90	600	40000
	5840	5850	X	3	150	20	18	70	600	35000
	5850	5860	X	2	300	30	35	60	700	35000
TOOLACHEE FORMATION	5860	5870	X	4	70	30	40	70	700	40000
	5870	5880	X	2	50	30	35	80	600	40000
	5880	5890	X	3	100	30	40	30	700	45000
	5890	5900	X	2	70	30	90	90	500	35000
	5900	5910	X	3	200	25	25	90	450	30000
	5910	5920	X	3	70	25	40	70	300	25000
	5920	5930	X	X	X	30	40	70	500	35000
	5930	5940	X	2	300	35	35	120	600	35000
	5940	5950	X	2	100	30	50	100	500	35000
	5950	5960	X	1	30	18	20	70	600	40000
	5960	5970	X	5	150	30	50	90	600	35000
	5970	5980	X	2	70	30	45	90	500	30000
	5980	5990	X	4	150	30	40	70	600	35000
	* 5980	5990	X	5	250	55	40	90	500	30000
	5990	6000	X	X	150	30	40	80	600	30000
	6000	6010	X	2	50	30	20	60	450	25000
	6010	6020	X	X	X	20	30	70	1200	70000
	6020	6030	X	2	X	20	50	90	1000	70000
	6030	6040	X	1	100	14	30	10	350	30000
	6040	6050	X	3	70	14	25	60	400	30000
	6050	6060	X	4	30	12	35	50	300	30000
	6060	6070	X	4	30	16	35	50	600	50000
	* 6060	6070	X	2	X	10	30	40	500	45000
	6070	6080	X	1	X	25	30	60	900	50000
	6080	6090	X	X	X	14	10	45	200	18000
	6090	6100	X	2	50	20	35	60	600	45000
	6100	6110	X	3	30	25	25	70	400	30000
	* 6100	6110	X	3	70	30	30	70	450	35000
	6110	6120	X	X	X	20	30	30	350	25000
	6120	6130	X	2	X	20	45	50	800	60000
	6130	6140	X	2	X	20	25	18	80	6000
	6140	6150	X	X	X	25	30	30	50	2000
	6150	6160	X	2	X	18	35	25	120	8000
	6160	6170	X	1	50	20	40	80	200	16000
	6170	6180	X	2	70	18	40	60	250	20000
	6180	6190	X	2	100	16	30	35	250	20000
	6190	6200	X	1	X	20	30	45	180	9000
	6200	6210	X	2	30	18	12	50	250	20000
	6210	6220	X	1	X	40	35	50	160	12000
	6220	6230	X	2	30	30	35	80	300	25000
	6230	6240	X	4	70	20	50	80	350	30000

MUNKARIE NO.1

	FROM	TO	<- ANALYSIS BY ES ->			<-------- ANALYSIS BY AAS -------->				
	(FEET)		SB (30)	SN (1)	ZN (20)	CU	PB	ZN	MN	FE
	****	****	****	****	****	****	****	****	****	*****
	6240	6250	X	3	X	18	30	14	160	14000
	6250	6260	X	4	X	20	30	30	300	30000
	6260	6270	X	3	70	20	30	60	250	20000
	* 6260	6270	X	3	70	20	35	70	250	20000
	6270	6280	X	X	X	14	30	18	300	20000
	6280	6290	X	3	30	20	40	60	400	30000
	6290	6300	X	2	X	20	40	50	350	30000
	6300	6310	X	X	X	18	25	6	200	12000
	6310	6320	X	1	X	14	25	25	120	10000
	6320	6330	X	3	30	16	30	45	90	10000
	6330	6340	X	2	50	12	25	45	70	8000
	6340	6350	X	1	X	12	12	25	70	9000
	6350	6360	X	X	X	10	8	25	40	6000
	* 6350	6360	X	X	X	5	20	18	70	7000
	6360	6370	X	X	X	8	18	20	45	8000
DAFALINGIE FORMATION	6370	6380	X	4	400	30	30	90	200	12000
	6380	6390	X	3	400	20	30	120	600	40000
	6390	6400	X	3	100	20	25	90	700	40000
	* 6390	6400	X	1	100	18	35	80	700	40000
	6400	6410	X	4	100	18	18	90	600	35000
	6410	6420	X	4	150	16	25	120	700	35000
	6420	6430	X	4	500	20	35	140	450	35000
	6430	6440	X	X	X	60	18	16	190	3000
	6440	6450	X	5	150	50	45	130	800	50000



LITHOLOGIC COLUMN 'A' – Lithologies inferred from well logs
LITHOLOGIC COLUMN 'B' – Lithologies by cuttings descriptions and logs

LITHOLOGIC LEGEND

Sandy silty · Coaly shale · Minor coal seams · Sandstone · Shaley · Coal

FIG 1

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

MUNKARIE No 1

GEOCHEMISTRY OF CUTTINGS

FEB 1979 79-146

1154

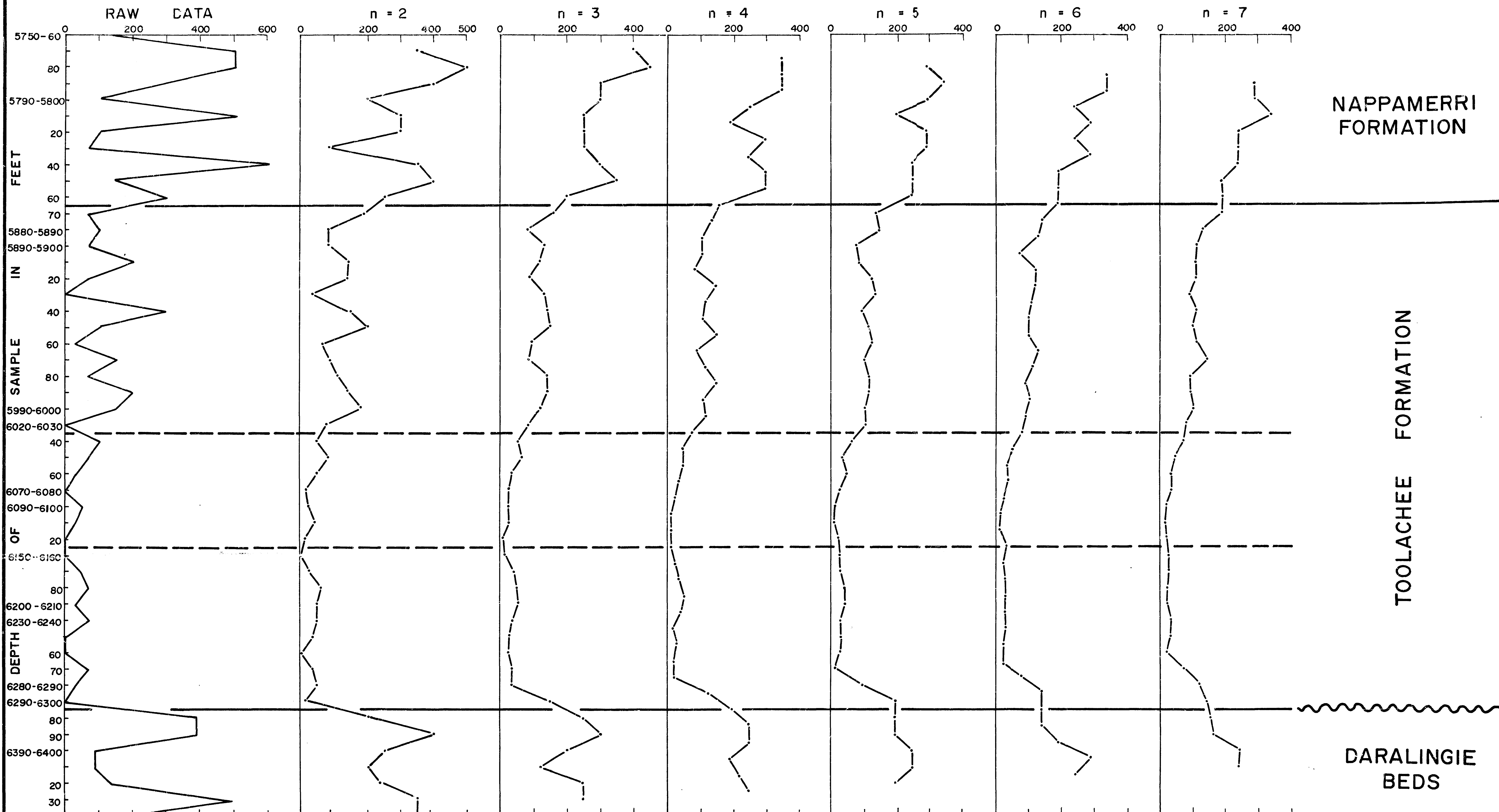


Fig. 2

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA		SCALE. —
COMPILED W. G. S.	MUNKARIE No. 1 CUTTINGS		DATE: FEB. 1979
DRN M.R.	CKD	ZINC CONTENT OF SHALES EMISSION SPECTROSCOPY	PLAN NUMBER
	RAW DATA & ROLLING MEANS n = 2 TO n = 7		79 - 147

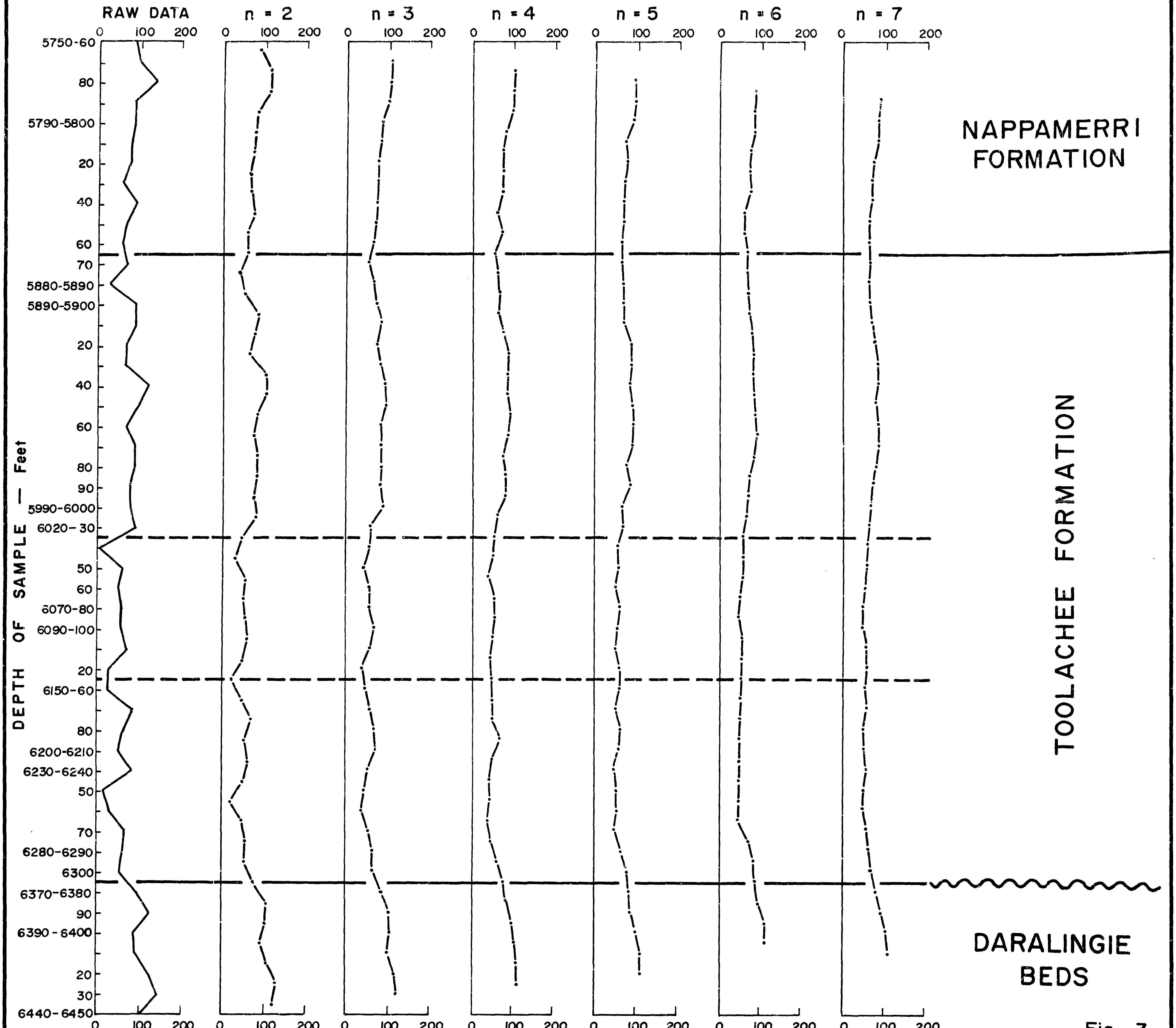


Fig. 3

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE —
COMPILED: W. G. S.	MUNKARIE No. 1 CUTTINGS	DATE FEB. 1979
DRN: M.R. CKD.	ZINC CONTENT OF SHALES BY ATOMIC ABSORPTION SPECTROSCOPY	PLAN NUMBER
	RAW DATA & ROLLING MEANS n = 2 TO n = 7	79 - 148

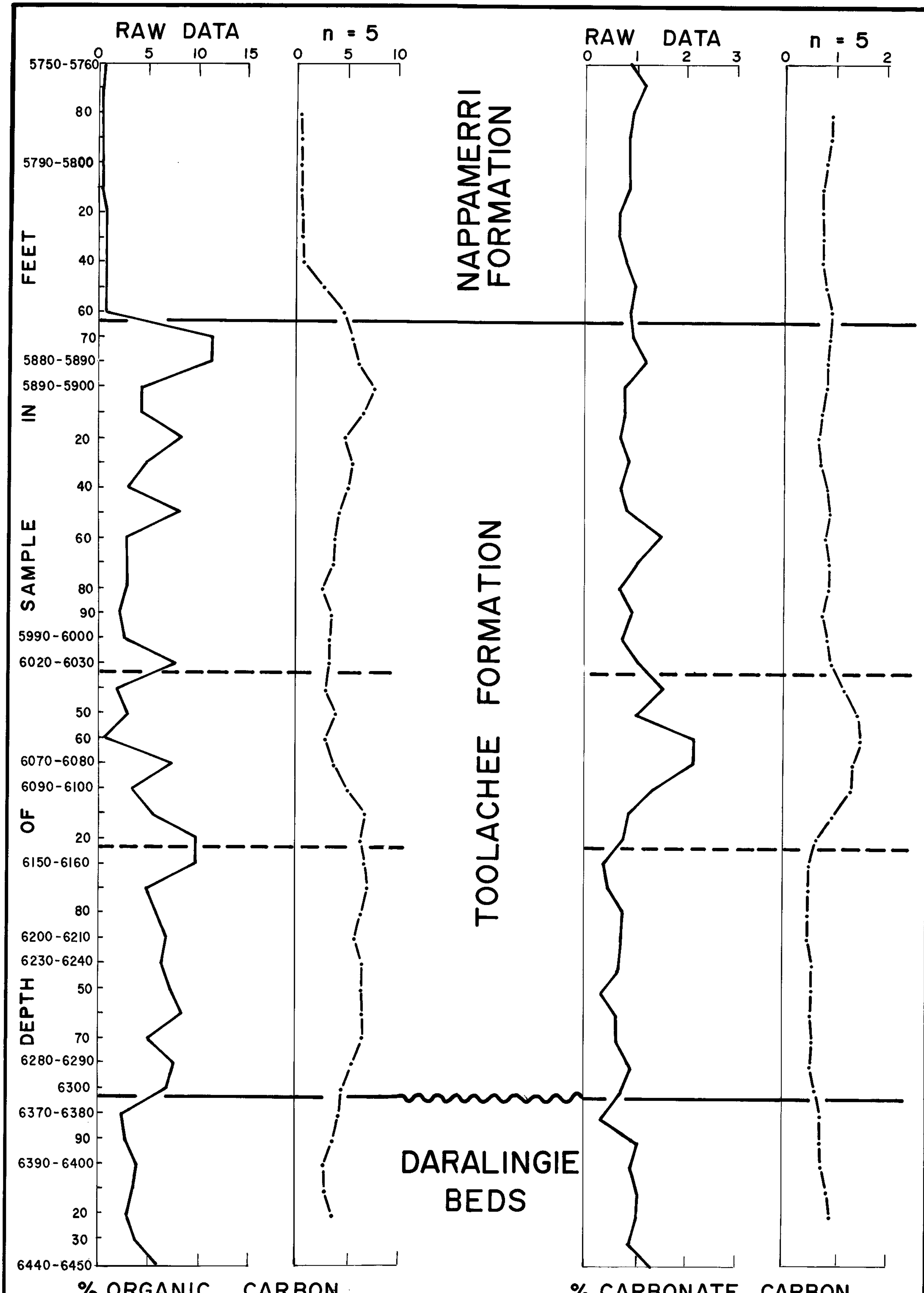


Fig. 4

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

MUNKARIE No. 1 CUTTINGS CARBON CONTENT OF SHALES

COMPILED: W. G. S.

DRN: M.R. CKD:

SCALE: —

DATE: JAN. 1979

PLAN NUMBER

S 13888

1154

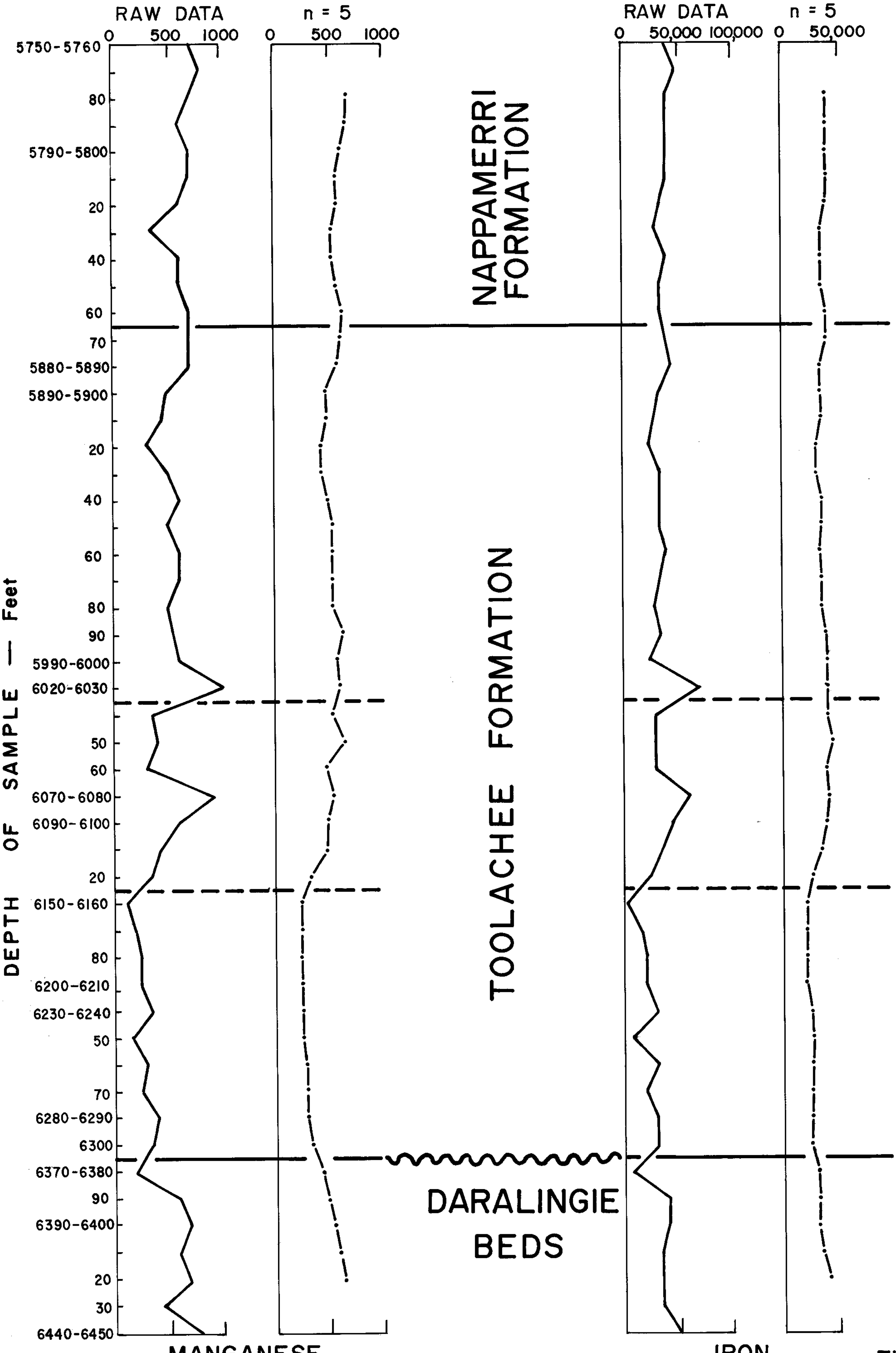


Fig. 5

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE: —
COMPILED: W. G. S.	MUNKARIE No. 1 CUTTINGS METAL CONTENT OF SHALES BY ATOMIC ABSORPTION SPECTROSCOPY	DATE: JAN. 1979
DRN: M.R. CKD:		PLAN NUMBER S 13889

1154

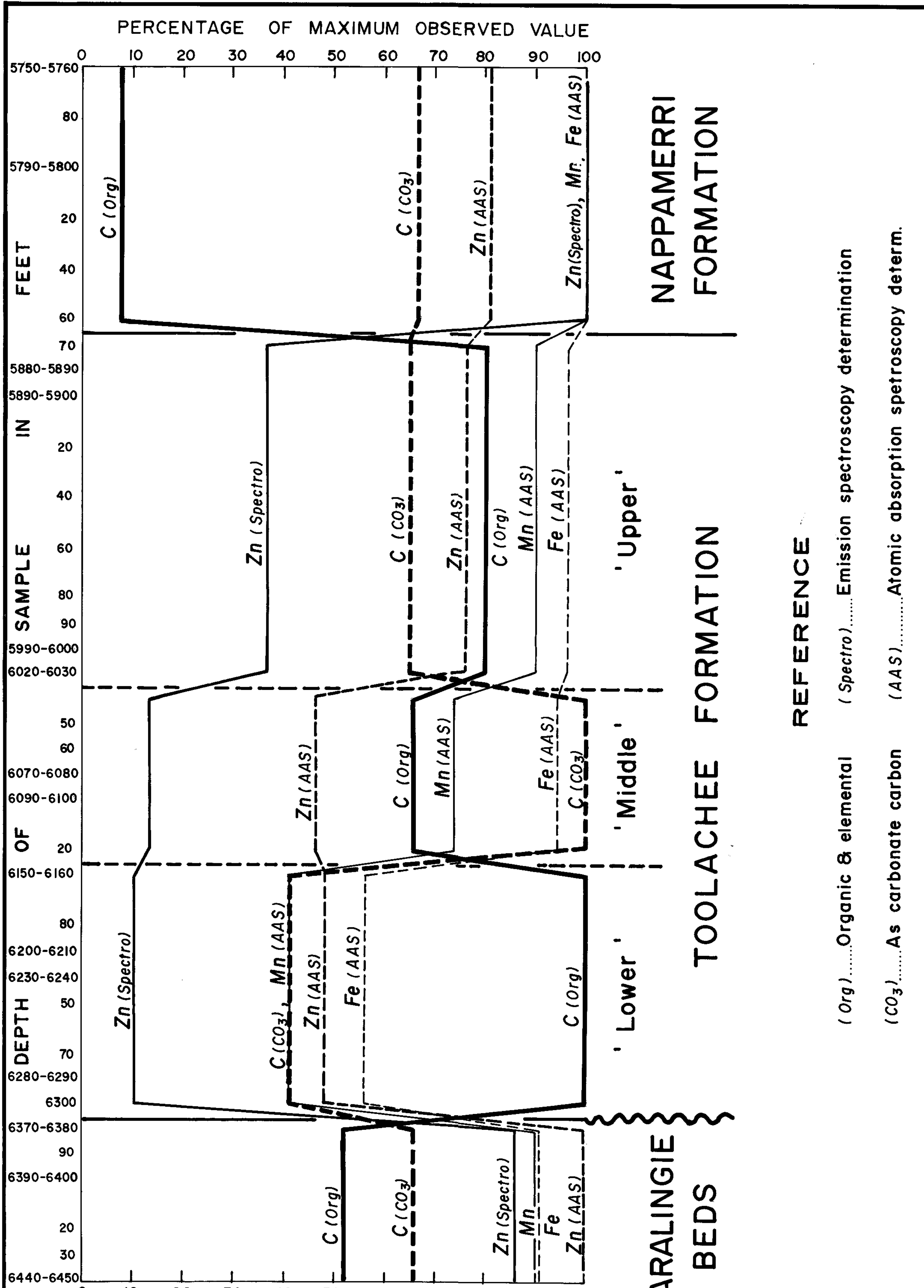


Fig. 6

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE: —
COMPILED: W. G. S.	MUNKARIE No. 1 CUTTINGS GEOCHEMISTRY OF SHALES SHOWING GEOCHEMICALLY IDENTIFIABLE UNIT BOUNDARIES	DATE: JAN. 1979
DRN: M. R. CKD:		PLAN NUMBER
		S 13890

1154