GEOLOGICAL SURVEY OF CANADA

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THE UPPER DEVONIAN PALLISER FORMATION, ROCKY MOUNTAINS, B.C. AND ALBERTA: GEOCHEMISTRY AND GENERAL GEOLOGY

by

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I. INTRODUCTION

This Open File report results from a joint research project of the Geological Survey of Canada and Esso Minerals Canada. The broad objective of the project has been the study of the lithogeochemistry of a selected carbonate formation (Sangster and de Mille, 1980). The project aimed to provide a geological and geochemical data base to determine background geochemical abundances, and variances, of selected elements relative to certain sedimentological features. The data could perhaps also be used toward a better understanding of the distribution of base metal deposits (e.g. lead-zinc) relative to geochemical and geological parameters of carbonate rocks.

The report consists of two parts: (i) a computer diskette containg chemical and geological data on the 1277 samples collected and analyzed in this study; and (ii) a short text describing the background of the project, a geologcal description of the Palliser Formation, analytical techniques, and a few summary tables and diagrams to illustrate the nature and range of the data contained on the diskette. The Open File is essentially a presentation of data; an interpretive report may be published at some future date.

The Palliser Formation of Famennian age (late late Devonian) was selected for several reasons: 1. before a formal joint program was agreed upon, Esso Minerals had already collected several hundred samples from the unit; 2. the Geological Survey of Canada had plans underway to begin a detailed study of surface exposures of the Palliser Formation and it seemed advantageous to combine the geochemical sampling with the anticipated geological studies; 3. the Palliser is well exposed over a strike length of about 800 km providing an opportunity to investigate geochemical abundances over a large area; 4. the Palliser was known to contain a few small lead-zinc occurrences in its southern extremities whereas none were known in the northern portion. Thus the geochemistry of "barren" and "mineralised" test areas of the same stratigraphic unit could be compared and contrasted.

Subsequently, the Palliser Formation was sampled in two areas of the Front and Main Ranges of the Rocky Mountains (Fig.1). A decision was made, early in the project, to sample outcrop sections only, rather than drill cuttings, in order to avoid the problems of down-hole contamination, to ensure tight stratigraphic control, and because it was the only way that many sedimentological features could be seen.

In the northern area (Fig. 2), 17 outcrop sections of the Palliser Formation were measured and sampled by H. Geldsetzer. In the southern area (Fig. 3), G. de Mille supervised collection of samples from 23 outcrop sections of the Palliser Formation. Location data for the 40 sections are presented in Table I. A total of 1277 samples of the Palliser Formation and a few from adjacent formations were analyzed for 27 major, minor and selected trace elements. Illustrations of the relationships of some elements to geological parameters of several measured sections are given in the appendix. Geochemical and petrographic data for these samples are contained on a computer diskette under separate cover and available from the Geological Survey of Canada, Ottawa, Canada.

II. GEOLOGY OF THE PALLISER FORMATION

DISTRIBUTION AND RELATIONSHIPS

The Palliser Formation is a carbonate unit exposed in several thrust sheets of the Front and Main ranges of the northwest-trending Rocky Mountains. In Canada, the formation extends from the International Boundary for 820 km to 54°50' north latitude in the northern half of the Monkman Pass map area, east-central B.C. (NTS 93 I). The formation was systematically sampled from its northern limit southeastward for 260 km to the northern border of the Banff – Jasper National Park and again from the southern border of the park to the International Boundary, another 260 km (Fig. 1).

The Palliser Formation represents the surface outcrops of a widespread marine transgression during Famennian time (late Late Devonian). The carbonates continue to the east and north in the subsurface where they are referred to as the Wabamum Formation. These subsurface sediments become more and more restricted to the east and southeast where they are represented by a succession of carbonates and evaporites. To the north the subsurface sediments continue to be mostly carbonates but ultimately grade into fine-grained terrigenous clastics in the western part of the Northwest Territories.

In the southern and central parts of the outcrop belt the Palliser Formation overlies conformably the Sassenach Formation (previously the upper Alexo Formation) which, like the Palliser Formation, is of Famennian age. The Sassenach Formation rests unconformably on Frasnian (lower Upper Devonian) sediments of the Fairholme Group. In the northern area the Sassenach Formation is missing and the Palliser Formation rests directly on upper Frasnian carbonates of the Simla Formation which is roughly equivalent to the uppermost part of the Fairholme Group to the south (Geldsetzer, 1982). Throughout the outcrop area the Palliser Formation is unconformably overlain by the fine-grained clastics of the Exshaw or Banff Formations which grade in the northern area into the Besa River Formation. These fine-grained terrigenous sediments area of latest Devonian or early Tournaisian (early Mississippian) age.

THICKNESS

In Banff – Jasper National Park, between the northern and southern study areas (Fig. 1), the thickness of the Palliser Formation varies between 200 and 320 m and increases from east to west (McLaren, 1955). In the southern area (Fig. 3), thickness ranges from 140 m to 450 m, shows the same tendency to thicken from east to west, but varies considerably in thickness over rather short distances (Fig. 4). North of Phillips Peak (section 79 EMC 20; Fig. 3), the formation is reported to reach a thickness of 620 m (Gibson, 1979). Along the Front Ranges of the southern area, thickness of the Palliser Formation has been reduced in several sections by thrust faults in the lower part of the formation (Fig. 4). In the northern area (Fig. 2) the Palliser Formation reaches another high of 530 m near Mount Hanington (79 GCA 4, 5; Fig. 2) and wedges out to the northwest below the black shales of the Besa River Formation.

INTERNAL STRATIGRAPHY

The Palliser Formation in the Banff-Jasper National Park is subdivided into two members, a lower Morro Member and an upper Costigan Member (deWit and McLaren, 1950). Both members can generally be identified in the southern area, however, in the northern area, the Costigan-like lithology occurs only at and near Bone Mountain (80 GCA 01) wedging out rapidly from 40 metres to only a few metres in adjacent sections (Fig. 4).

The Morro Member consists of gray cliff-forming carbonates and represents the bulk of the Palliser Formation; the member ranges in thickness from 70 to 300 m, but averages 200 m. In the northern area, the Morro Member consists of three lithofacies (Facies 1 to 3). By contrast only Facies 1 has been recognized in the southern area except around and north of Phillips Peak (79 EMC 20) where all three lithofacies appear to be present (Fig. 4). In the northern area, the Morro Member changes gradually in a northerly direction from a cliff-former to a slightly recessive unit. This change reflects an increase in bioturbation which apparently causes the rock to crumble into small fragments. In the central part of the northern area, where the Palliser Formation is exceptionally well preserved, a strongly recessive interval of shaly carbonates with a basal black laminated micrite appears within the Morro Member and divides the member into two parts of approximately equal thickness (a lower 290 m and an upper 240 m). This excellent stratigraphic marker (Facies 2 in Fig. 4) can be traced laterally to the northwest and southeast for 40 km and, possibly, 100 km respectively. Over these distances the upper 240 m thick part of the Morro Member thins considerably; in sections beyond, the marker horizon cannot be identified (Fig. 4). This thinning had been interpreted as erosional truncation below the black shales of the overlying Banff and Besa River formations (Geldsetzer, 1982).

There is a remarkable similarity between the Palliser Formation in the central portion of the northern area and that described by Gibson (1979) from the southern area near Phillips Peak (north of 79 EMC 20; Fig. 3). The Morro Member near Phillips Peak contains a 100 m thick recessive interval of shaly, laterally discontinuous laminated carbonate. It is likely that the abrupt appearance of dark, laminated carbonates, both here and in the northern area, record the same event, be it tectonic or climatic. Precise biostratigraphic control is needed to document the time-equivalence of these shaly laminated beds. This horizon has been assigned to Facies 2 in both areas.

The Costigan Member is made up of recessive, dark, thin-bedded, fossiliferous, locally brecciated and sometimes silty carbonates, between 20 and 130 m thick and averaging 75 m. The distinct lithology of this member is referred to as Facies 4 on Figure 4. The four lithofacies are described in more detail below.

LITHOLOGY

This section is a brief summary of the four major lithofacies which are identifiable in the field. There are, of course, minor variations within these major facies the description of which goes beyond the scope of this paper. A more detailed account is given elsewhere (Geldsetzer, in press).

Facies 1

Facies 1 is the thickest facies and represents the bulk of the Morrow Member of the Palliser Formation. In outcrop it consists of a monotonous succession of ledges and recesses. The ledges are pellet-intraclast lime-grainstones whereas the recessive lithology is made up of lime-mud and lime-wackestones. Facies 1 is characterized by bioturbation which appears to intensify in the northern area. The burrow fill is commonly recrystallized and, in the southern area, occasionally dolomitized. Stylolites are a common feature of the thicker bedded strata. Skeletal fossil debris is sparse except near the base where fragments of brachiopods and crinoids are locally abundant.

Facies 2

The base of this facies is defined by a thin, black, laminated, unfossiliferous lime-mudstone which occurs throughout the central part of the northern area. This "black band" grades upsection into gray calcareous shales with interbeds of limestone that display algal structures and trace fossil markings.

Facies 3

The contact between Facies 2 and Facies 3 is gradational. The shaly component slowly disappears upsection and thin, evenly bedded limestones become increasingly brown-gray mottled, a lithology which, in some sections, continues to the upper contact of the Palliser Formation. Black chert nodules may occur at various stratigraphic levels. Macrofossils are crinoid ossicles and rare brachiopods. The dominant lithology seen in thin section is a pellet grainstone.

Both Facies 2 and 3 appear to be present near Phillips Peak (north of 79 EMC 20; Fig. 3) of the southern area.

Facies 4

This facies is widespread in the southern area and represents the Costigan Member. The basal unit in the Phillips Peak area is an intraformational carbonate conglomerate. The bulk of the member consists of wavy to nodular or boudinage-like, medium to thin-bedded limestones that form buff to orange, recessive slopes covered by a platy klinker-like talus.

Individual "nodular" strata are separated by thin and laminar shale-like lime mudstone. Ripple marks, flame structures and roll masses are present together with small slump and pull-apart features, especially in sections to the southwest. In the northeast (79 EMC 03; Fig. 3), gypsum occurs at two levels within the mid-Costigan interval. Macrofossils are not common with the exception of crinoids and sparse brachiopoda in the lowermost strata.

In the northern area, the Costigan Member appears to occur near Bone Mountain (80 GCA 01; Fig. 2) where the uppermost 40 metres of the Palliser Formation area yellowish gray, slightly argillaceous platy limestones which display crossbedding, channelling and imbricated pebble horizons.

MINERALIZATION

Base metal occurrences have been found within the Palliser Formation at three localities in the southern area (Fig. 3; Table II). Galena occurs within a few metres of the base of the Morro Member near Section 79 EMC 01. The mineralization occupies a narrow shear zone at the edge of a cirque. Galena, with traces of silver, and minor sphalerite, also occur in a fault-brecciated portion of the Costigan Member a short interval below the Costigan-Exshaw contact near Section 79 EMC 06. Sphalerite was found in "zebra rock" and pseudobreccia in the upper part of the Morro Member, a few miles north of Section 79 EMC 20. No sulphide minerals other than pyrite have been reported from the northern area. Pyrite is common in finely disseminated form in the basal beds of Facies 2 of the Palliser Formation (Fig. 4).

III. SAMPLING AND ANALYTICAL PROCEDURES

SAMPLING

Outcrop stratigraphic sections were selected to provide as complete a section of the Palliser as possible. In the northern area, the Palliser Formation was sampled at 7.5 m intervals, fist-size rock specimens or, if lithology was crumbly, rock chips were collected over an area of 0.5 m^2. In the southern area, rock chip samples were collected at 8 m intervals from an area of 1 m^2. Samples were collected along a direct line between formation contacts. In some instances a lateral shift along bedding was required because of cover or difficult access. Collections were also taken in overlying and underlying formations as near the contacts as possible.

Geographic location, sample and section number, distance above base of formation, and several field criteria (colour, texture, lithology, etc.) were recorded in the field on cards in computer-compatible format.

Approximately one-half of each sample was retained for thin sectioning. Most of the thin sections form the northern area have been analyzed for petrographic data, whereas such data for the southern area are forthcoming as part of a M.Sc. thesis by Mr. D. Kaylor at McGill University. Thus, a petrographic description is, or will be, available for every sample that was chemically analyzed. The other half of each sample was crushed, ground, and milled to -200 mesh. A split of the powder was taken and submitted to the analyzing labs. An internal standard was included after every tenth sample submitted by the Geological Survey of Canada. Results of the replicate analyses of this standard are presented in Table III.

ANALYSIS

Samples from both Geological Survey of Canada and Esso Minerals Canada sampling programs were sent to the same labs for analysis. In the case of G.S.C. samples, separate splits of powdered material were sent to the two analytical labs. Esso, in contrast, had the same aliquot analyzed sequentially by the two labs.

MAJOR ELEMENTS

Major elements were analyzed by X-Ray Laboratories Ltd. of Toronto, Canada. Results were reported as percent oxide with a detection limit of 0.01%.

MINOR ELEMENTS

X-Ray Laboratories also determined the suite of minor elements Rb, Sr, Zr, Ba, and Cr_2O_3 with detection limits as shown in Table IV. The same lab performed a determination of loss on ignition (LOI) at 850°C.

A further pair of minor elements (S and organic C) were analyzed by Bondar-Clegg and Co. Ltd., Ottawa, Canada, using a Leco furnace technique.

TRACE ELEMENTS

A selection of trace elements (Cu, Pb, Zn, Ni, Mn, V, Ag, As, Sb, and F) were selected for this study and were determined by Bondar-Clegg and Co. Ltd. Metals were analyzed by atomic absorption methods, with appropriate background correction, following total decomposition of the sample in HF-$HClO_4$-HNO_3. Arsenic was determined by colorimetry (Ag-diethyldithiocarbamate), F by specific ion electrode following fusion of the sample with sodium carbonate, and Sb by XRF.

GENERAL RELATIONSHIPS

A comparison of the stratigraphy with the distribution of elements yields the following observations:

The value of strontium (Sr) in the northern area is about twice the value of the southern area (Appendix C). A further sharp increase in strontium occurs in facies 3 and 4 of the northern area, whereas a similar strontium increase in the southern area is restricted to the Costigan Member (Facies 4) in the Main Range only, i.e. in the westerly sections (Esso 79-18, 19, 20).

An anomalous pattern is displayed by the Zn/Pb ratio. Generally zinc exceeds lead throughout the Palliser Formation except in the northernmost sections of the Front Range (GSC 80-1, 2, 3, 4), and in the lower Morro Member of those sections in the southern area where Pb-Zn mineralization is known to occur, i.e. in sections Esso 79-6-Oldham and Esso 79-20-Phillips Peak.

There is a fairly strong SiO_2 component in the basal 20 to 40 metres of the Morro Member in the northern sections of the northern area. This trend disappears to the south and is not evident at all in the southern area. This high SiO_2 content is visible in thin sections of the lower Morro Member as silt-size quartz grains, probably of aeolian origin.

An even stronger influx of SiO_2 occurs in facies 2 and 4 of the northern area and in the Costigan Member (Facies 4) of the southern area. All increases in SiO_2 are generally associated with an increase in manganese (Mn).

The Palliser Formation in both areas is essentially a limestone; none of the samples from the northern area is a dolomite and only 5 samples from the southern area were identified as dolomite. The only exception is the dolomitization of limestone immediately above and below a series of gypsum beds in the Costigan Member at section Esso 79-3.

The underlying Sassenach Formation in the south is completely dolomitized whereas in the north the underlying Simla and Mount Hawk formations are, like the Palliser Formation, limestone. Minor and trace elements in the underlying units are within normal background values.

The overlying Exshaw and Besa River formations are easily recognized by significant enrichment, especially in the basal part, of all metals. In addition, organic carbon (C), sulphur (S), fluorine (F) and barium (Ba) are consistently high, whereas shales of the Banff Formation are surprisingly low in these elements.

ACKNOWLEDGMENTS

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Table I. Locations of the forty stratigraphic sections used in this study. "GCA" refers to sections sampled by Geological Survey of Canada; "EMC" refers to sections sampled by Esso Minerals Canada. NTS = National Topographic System co-ordinates

		UNIVERSAL TRANSVERSE MERCATOR (UTM) CO-ORDINATES		
SECTION	NTS	ZONE	EASTING	NORTHING
79 GCA 03	93 H 16E	10	69600	597350
79 GCA 04	93 I 01E	10	68370	600070
79 GCA 06	93 I 08W	10	66440	603240
79 GCA 05	93 I 01E	10	68200	600430
81 GCA 05	83 E 11E	11	35480	594595
81 GCA 07	83 E 10E	11	39820	594170
81 GCA 08	83 E 11W	11	34560	595680
80 GCA 02	93 I 10W	10	63705	606365
80 GCA 03	93 I 10W	10	63275	606840
80 GCA 01	93 I 10W	10	64430	605620
80 GCA 04	93 I 10E	10	65320	604530
81 GCA 06	83 E 07E	11	39810	592620
80 GCA 06	93 I 10E	10	61430	606150
80 GCA 08	93 I 10W	10	57430	609265
80 GCA 10	93 I 10W	10	60870	607020
80 GCA 11	93 I 10W	10	63910	604475
80 GCA 13	93 I 10W	10	63040	605445
79 EMC 23	82 G 06W	11	61460	547340
80 EMC 22	82 G 06W	11	61780	548000
80 EMC 21	82 J 14W	11	61820	564920
79 EMC 20	82 J 03E	11	64080	553850
79 EMC 19	82 G 14E	11	63550	552220
79 EMC 18	82 G 11E	11	63500	549360
79 EMC 17	82 G 06E	11	64400	545945
79 EMC 16	82 G 07E	11	67560	546460
79 EMC 15	82 G 07E	11	67500	547450
79 EMC 14	82 G 07E	11	67400	547850
79 EMC 13	82 G 07E	11	67500	548300
79 EMC 12	82 G 10E	11	67600	549140
79 EMC 11	82 G 10E	11	67040	549980
79 EMC 10	82 G 15E	11	67100	551900
79 EMC 09	82 G 15E	11	66770	552880
79 EMC 08	82 J 02E	11	66850	554400
79 EMC 07	82 J 02E	11	66520	555200
79 EMC 06	82 J 02E	11	66300	555480
79 EMC 05	82 J 02E	11	66250	556220
79 EMC 04	82 J 02E	11	66180	556450
79 EMC 03	82 J 07E	11	66665	559110
79 EMC 02	82 O 03E	11	63008	566100
79 EMC 01	82 G 03W	11	61140	565840

Table II. Lead-zinc occurrences in Palliser Formation, southern Rocky Mountains, Canada.

Occurrence number	Name	Location	Description	Reference
1	Oldman	50°7'30"N 114°43'W	Galena in shear zone, Morro Mbr.	Holter, 1977
2	Canmore	50°49'N 115°18'W	Galena replacement in Costigan Mbr.	Esso Minerals, internal report
3	Rock Creek	50°7'N 115°4'30"W	Sphalerite in "zebra-rock", Morro Mbr.	Gibson, 1979

Table III. Results of analyses of 65 splits of a standard, homogenized carbonate analysed at the same time and by the same methods as the Geological Survey of Canada samples. Values below the detection limit (Table IV) have been set to the detection limit for calculating means and standard deviations. Negative sign indicates values below the detection limit. "Best value" refers to values determined by repeated analysis in G.S.C. laboratories, Ottawa.

%

	SiO_2	TiO_2	Al_2O_3	FeO	MgO	CaO	Na_2O	K_2O	P_2O_5	S (total)	C-org.	LOI
5th percentile	1.20	-0.01	-0.01	0.26	2.59	50.0	-0.01	-0.01	0.20	0.11	0.06	42.4
50th percentile (median)	1.32	-0.01	-0.01	0.33	2.69	51.1	-0.01	-0.01	0.21	0.19	0.09	43.2
95th percentile	1.78	-0.01	0.05	0.48	2.86	52.2	-0.01	0.01	0.23	0.28	0.25	43.5
Mean	1.43	0.01	0.02	0.35	2.72	51.2	0.02	0.01	0.22	0.19	0.12	43.1
Standard deviation	0.22	0.00	0.02	0.07	0.10	0.78	0.05	0.01	0.01	0.04	0.07	0.33
Best value	1.30	0.01	0.15	0.33	2.75	52.8	0.01	0.09	0.22	-	-	43.1

ppm

	Ba	Rb	Sr	Zr	Mn	Pb	Zn	Cu	Ni	Cr_2O_3	V	As	Sb	Ag	F
5th percentile	-10	-10	520	-10	368	-2	4	3	-2	-10	8	-2	-1	-0.1	370
50th percentile (median)	-10	-10	570	-10	440	8	7	4	-2	-10	16	-2	-1	-0.1	445
95th percentile	38	10	640	30	570	20	20	7	4	-10	24	1	-1	-0.1	672
Mean	13	10	570	14	450	9	9	5	2	-10	17	-2	-1	-0.1	467
Standard deviation	14	1	45	8	50	6	5	1	1	0	5	0	0	0	112

Table IV. Analytical methods and analyzing labs. XRF = X-ray fluorescence; AAS = atomic absorption spectrometry; XRAL = X-Ray Laboratories Ltd.; BCC = Bondar-Clegg Co. Ltd.

Element	Units	Method	Laboratory	Detection Limits
SiO_2	%	XRF	XRAL	0.01
TiO_2	%	XRF	XRAL	0.01
Al_2O_3	%	XRF	XRAL	0.01
FeO	%	XRF	XRAL	0.01
MgO	%	XRF	XRAL	0.01
CaO	%	XRF	XRAL	0.01
Na_2O	%	XRF	XRAL	0.01
K_2O	%	XRF	XRAL	0.01
P_2O_5	%	XRF	XRAL	0.01
S(total)	%	Leco furnace; titration	BCC	0.02
C-org	%	HCl pre-treatment; Leco furnace	BCC	0.01
LOI	%	Leco furnace	XRAL	0.1
Ba	ppm	XRF	XRAL	50 and 10
Rb	ppm	XRF	XRAL	10
Sr	ppm	XRF	XRAL	10
Zr	ppm	XRF	XRAL	10
Mn	ppm	AAS total decomposition	BCC	5
Pb	ppm	AAS total decomposition	BCC	2
Zn	ppm	AAS total decomposition	BCC	1
Cu	ppm	AAS total decomposition	BCC	1
Ni	ppm	AAS total decomposition	BCC	2
Cr_2O_3	ppm	XRF	XRAL	10
V	ppm	AAS total decomposition	BCC	2
As	ppm	Colorimetry; HNO_3-$HClO_4$ decomp.	BCC	2
Sb	ppm	XRF	BCC	1
Ag	ppm	AAS total decomposition	BCC	0.1
F	ppm	Specific ion electrode	BCC	20

FIGURE CAPTIONS

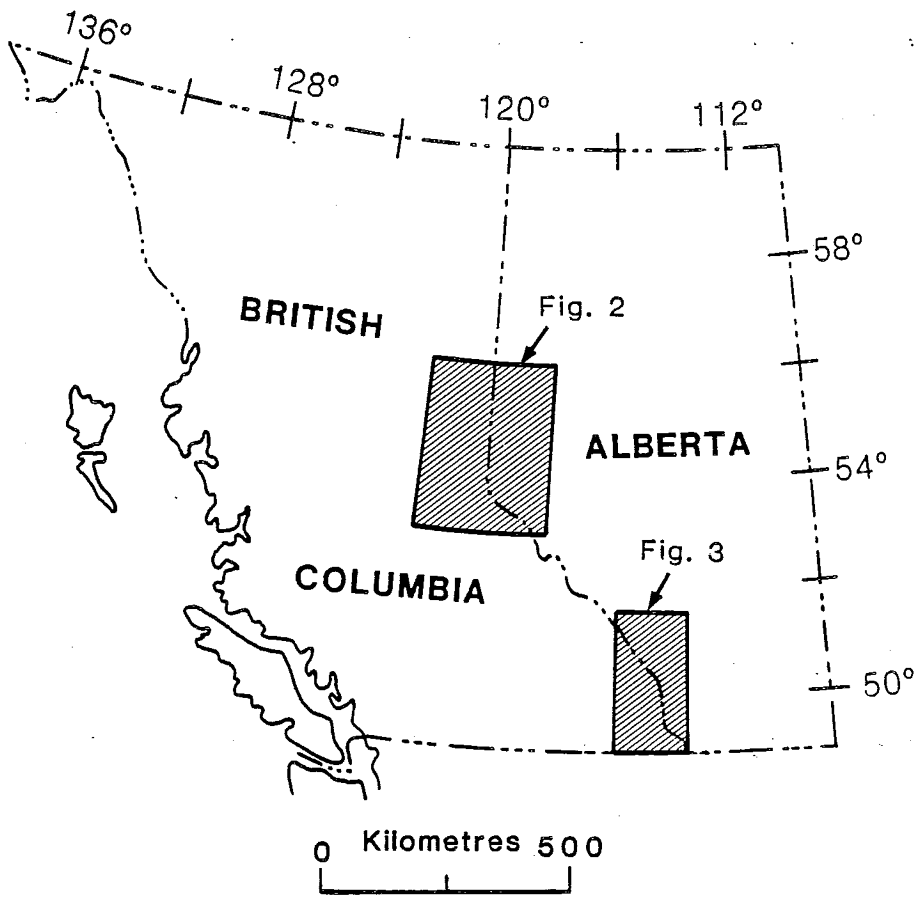
Figure 1 - Index map.

Figure 2 - Northern outcrop belt of Palliser Formation and distribution of sections sampled. Section is shown on Figure 4.

Figure 3 - Southern outcrop belt of Palliser Formation and distribution of sections sampled. Section is shown on Figure 4.

Figure 4 - Facies distribution and geochemical sampling of Palliser Formation, southern Rocky Mountains, Canada.

Fig. 5-14 - Profiles of selected stratigraphic sections displaying six chemical elements and five geological parameters (Appendix A).



136°
128°
120°
112°
58°
54°
50°
BRITISH
COLUMBIA
ALBERTA
Fig. 2
Fig. 3
0 Kilometres 500

Figure 1

Figure 2

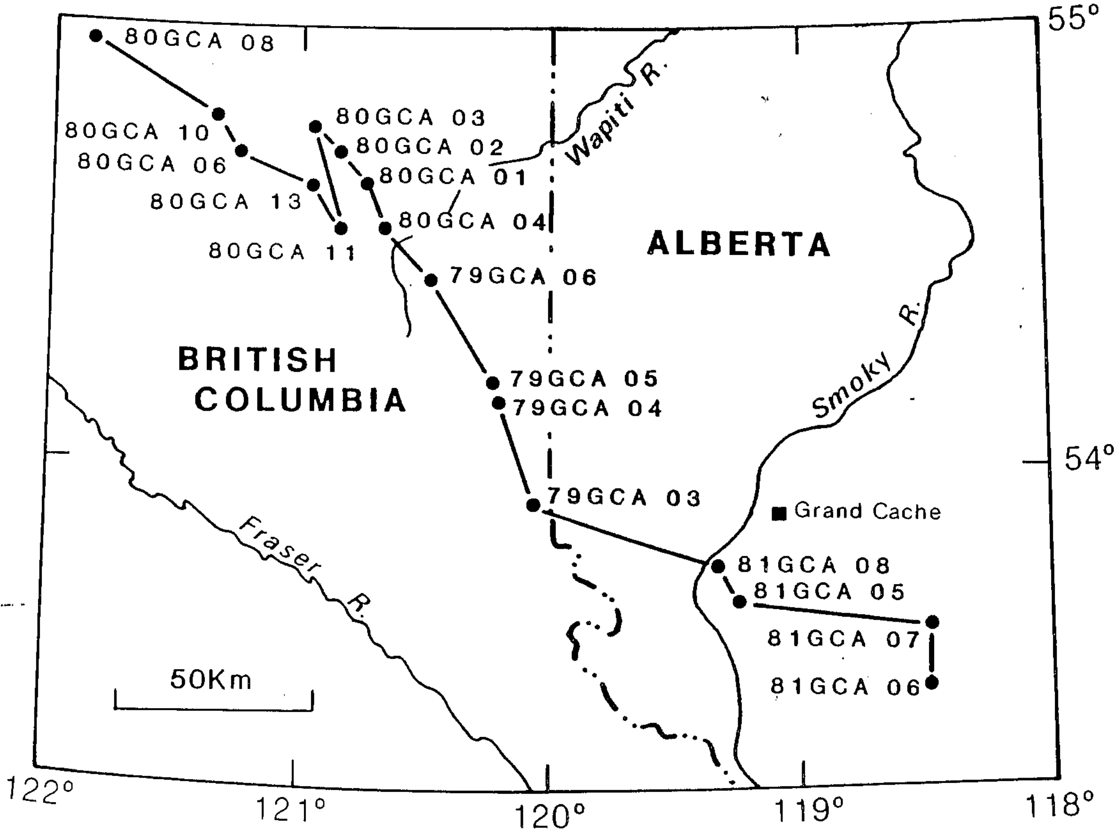
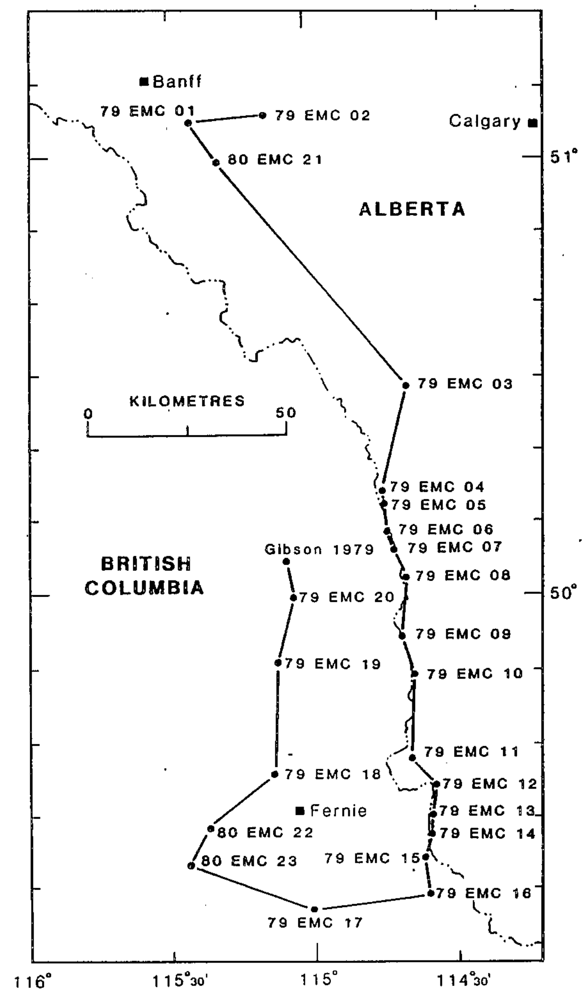
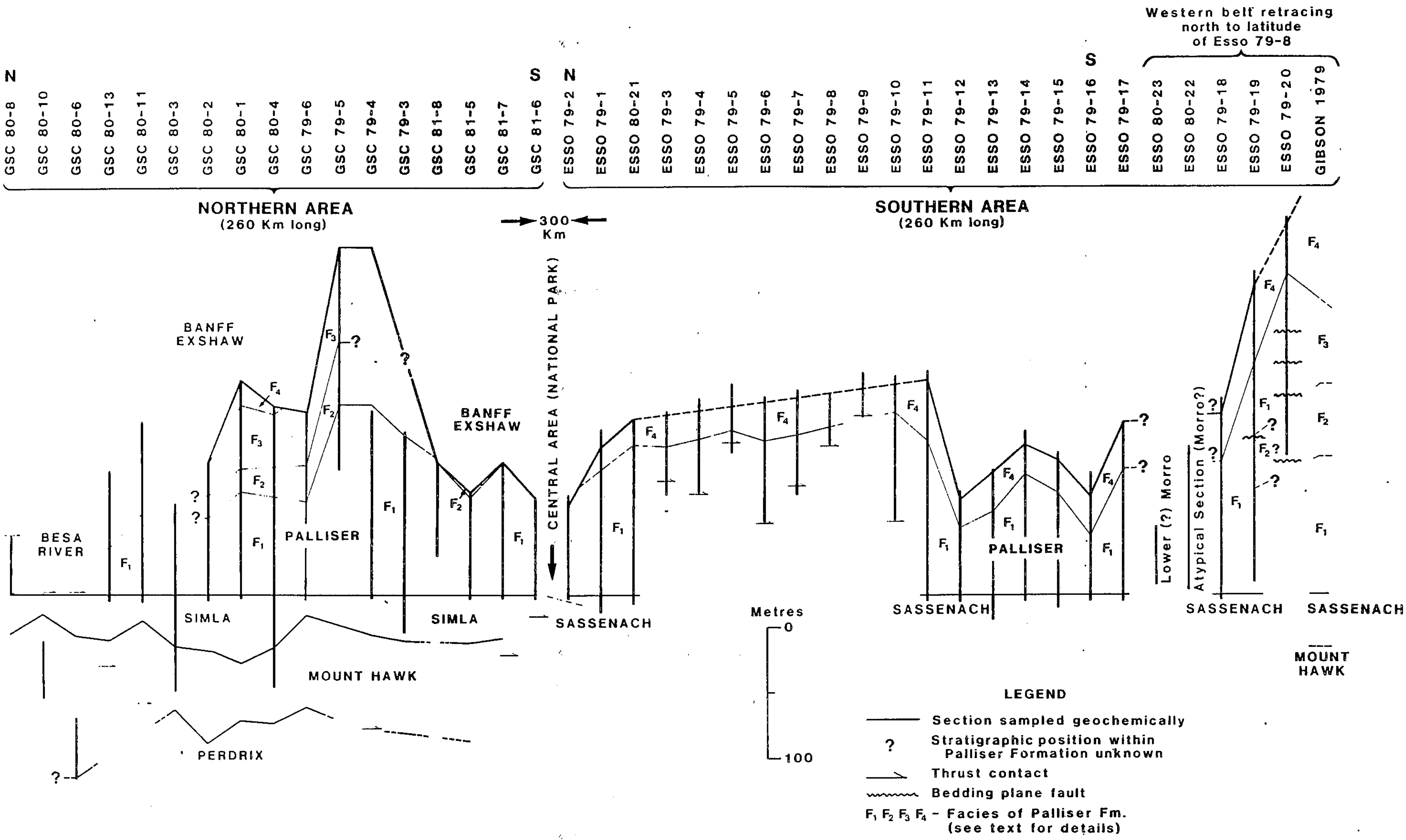


Figure 3





Western belt retracing north to latitude of Esso 79-8
N
S
N
S
GSC 80-8
GSC 80-10
GSC 80-6
GSC 80-13
GSC 80-11
GSC 80-3
GSC 80-2
GSC 80-1
GSC 80-4
GSC 79-6
GSC 79-5
GSC 79-4
GSC 79-3
GSC 81-8
GSC 81-5
GSC 81-7
GSC 81-6
ESSO 79-2
ESSO 79-1
ESSO 80-21
ESSO 79-3
ESSO 79-4
ESSO 79-5
ESSO 79-6
ESSO 79-7
ESSO 79-8
ESSO 79-9
ESSO 79-10
ESSO 79-11
ESSO 79-12
ESSO 79-13
ESSO 79-14
ESSO 79-15
ESSO 79-16
ESSO 79-17
ESSO 80-23
ESSO 80-22
ESSO 79-18
ESSO 79-19
ESSO 79-20
GIBSON 1979
NORTHERN AREA
(260 Km long)
300 Km
SOUTHERN AREA
(260 Km long)
CENTRAL AREA (NATIONAL PARK)
BANFF EXSHAW
BANFF EXSHAW
BESA RIVER
PALLISER
PALLISER
SIMLA
SIMLA
MOUNT HAWK
PERDRIX
SASSENACH
SASSENACH
SASSENACH
SASSENACH
MOUNT HAWK
Lower (?) Morro
Atypical Section (Morro?)
Metres
0
100
LEGEND
Section sampled geochemically
? Stratigraphic position within Palliser Formation unknown
Thrust contact
Bedding plane fault
F1 F2 F3 F4 - Facies of Palliser Fm. (see text for details)

Figure 4

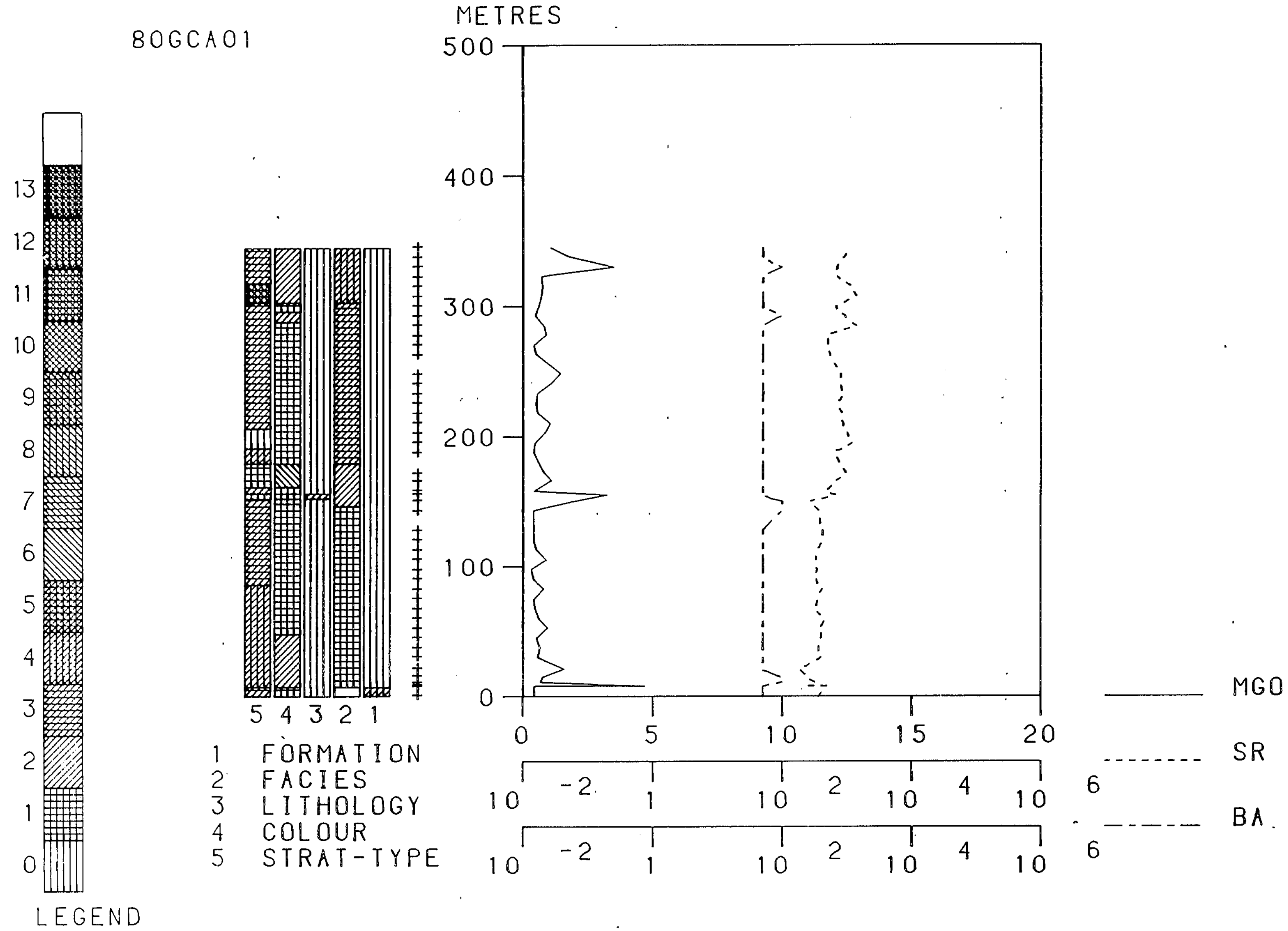

80GCA01
LEGEND
0
1
2
3
4
5
6
7
8
9
10
11
12
13
5 4 3 2 1
1 FORMATION
2 FACIES
3 LITHOLOGY
4 COLOUR
5 STRAT-TYPE
METRES
500
400
300
200
100
0
0 5 10 15 20
10 -2 1 10 2 10 4 10 6
10 -2 1 10 2 10 4 10 6
MGO
SR
BA

Figure 5

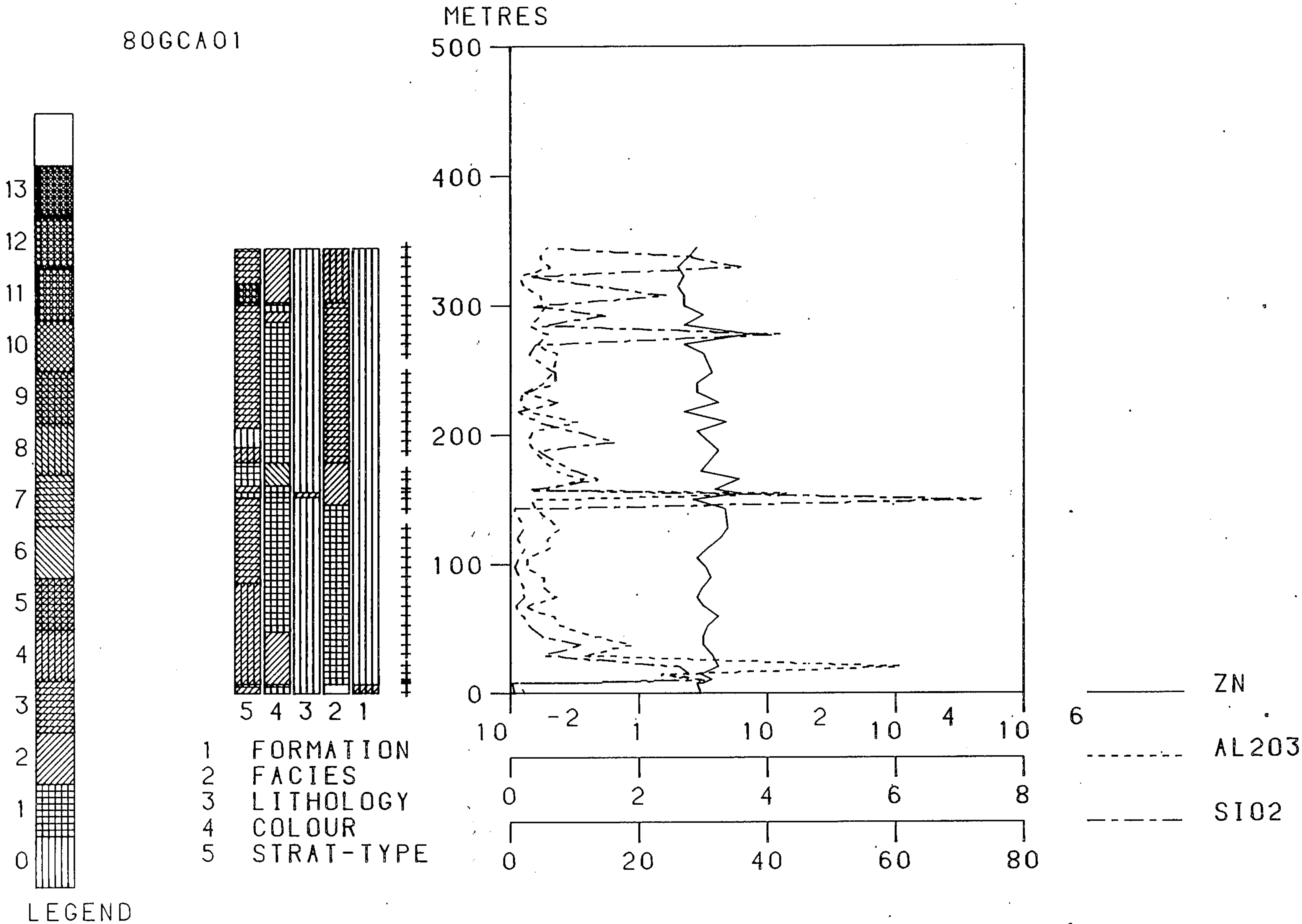
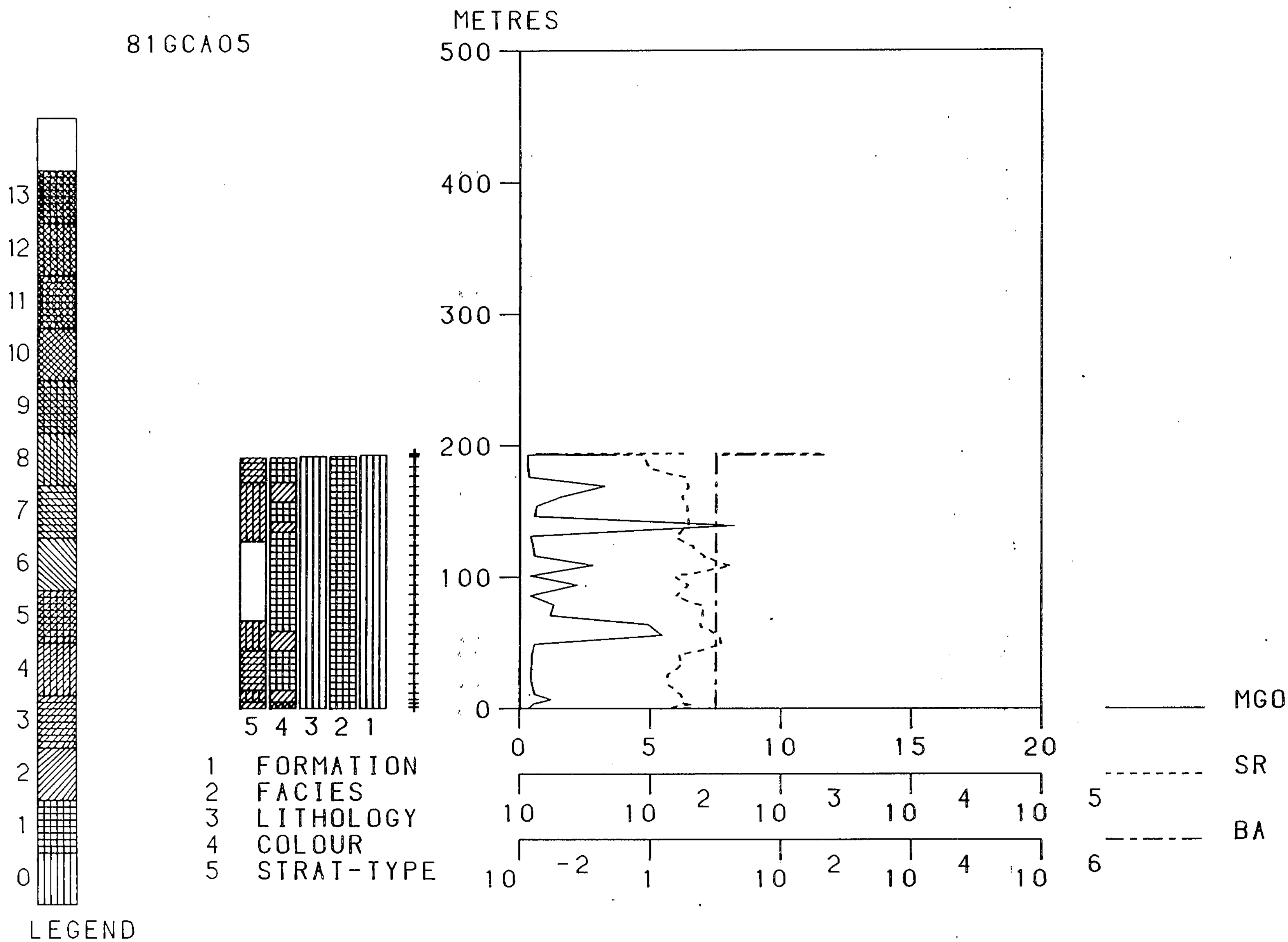

80GCA01
METRES
500
400
300
200
100
0
13
12
11
10
9
8
7
6
5
4
3
2
1
0
LEGEND
5 4 3 2 1
1 FORMATION
2 FACIES
3 LITHOLOGY
4 COLOUR
5 STRAT-TYPE
10 -2
1
10 2
10 4
10 6
0
2
4
6
8
0
20
40
60
80
ZN
AL2O3
SIO2

Figure 6

-18-



81GCA05
METRES
500
400
300
200
100
0
0
5
10
15
20
10
10 2
10 3
10 4
10 5
10 -2
1
10 2
10 4
10 6
MGO
SR
BA
13
12
11
10
9
8
7
6
5
4
3
2
1
0
LEGEND
5 4 3 2 1
1 FORMATION
2 FACIES
3 LITHOLOGY
4 COLOUR
5 STRAT-TYPE

Figure 7

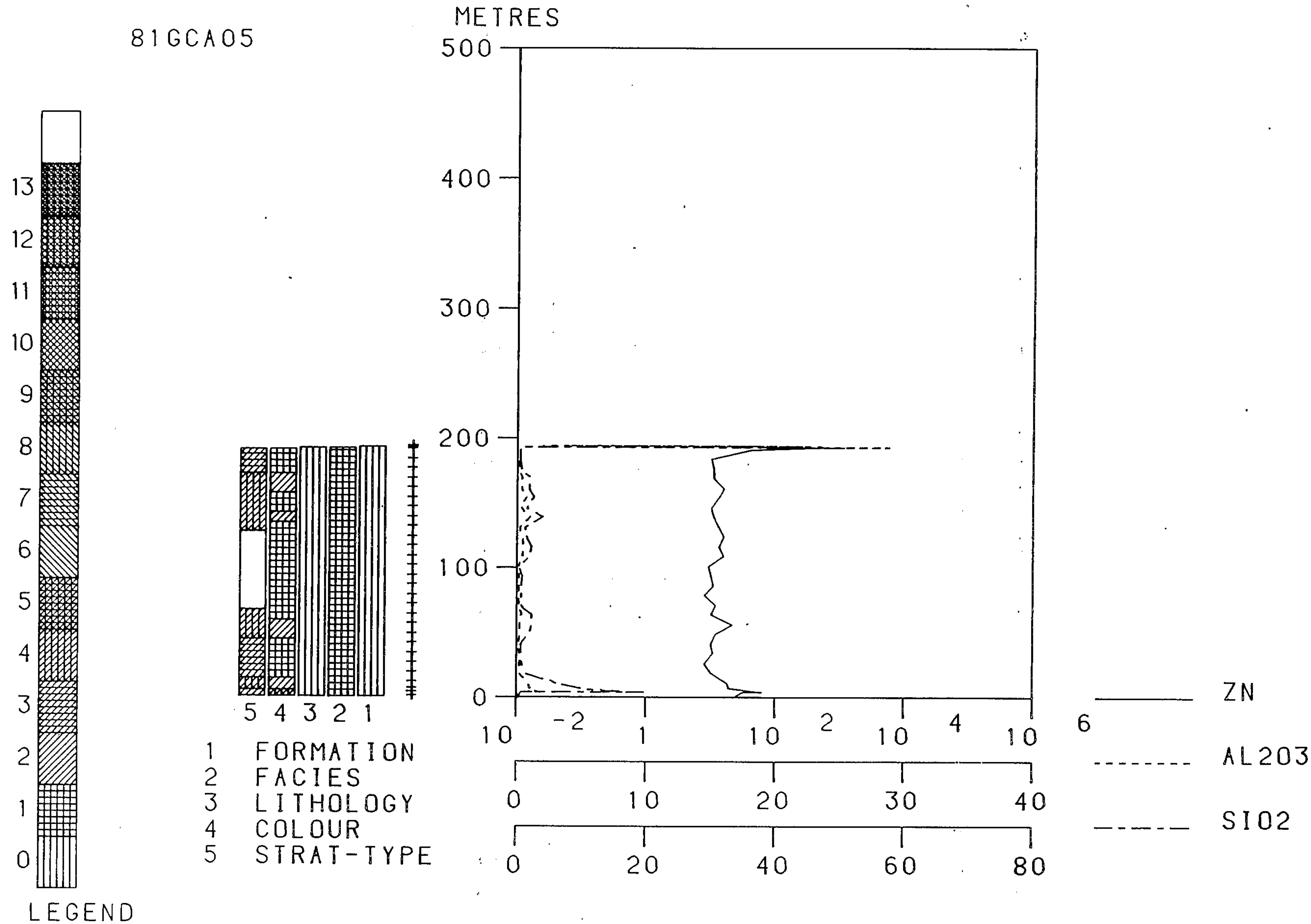

81GCA05
METRES
500
400
300
200
100
0
13
12
11
10
9
8
7
6
5
4
3
2
1
0
LEGEND
5 4 3 2 1
1 FORMATION
2 FACIES
3 LITHOLOGY
4 COLOUR
5 STRAT-TYPE
10 -2
1
10 2
10 4
10 6
0 10 20 30 40
0 20 40 60 80
ZN
AL203
SI02

Figure 8

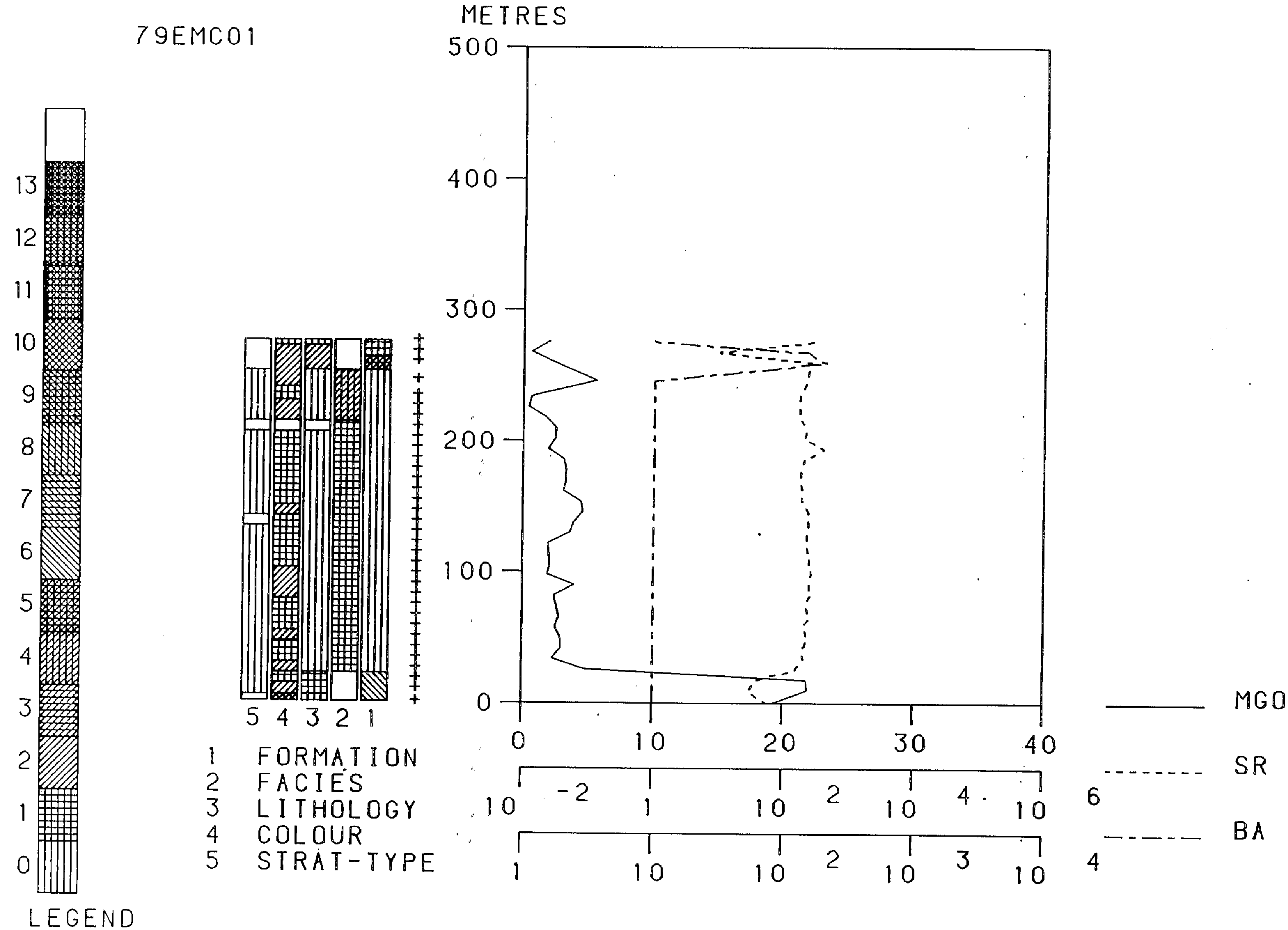

79EMC01
METRES
500
400
300
200
100
0
13
12
11
10
9
8
7
6
5
4
3
2
1
0
LEGEND
5 4 3 2 1
1 FORMATION
2 FACIES
3 LITHOLOGY
4 COLOUR
5 STRAT-TYPE
0 10 20 30 40
10^{-2} 1 10^{2} 10^{4} 10^{6}
1 10 10^{2} 10^{3} 10^{4}
MGO
SR
BA

Figure 9

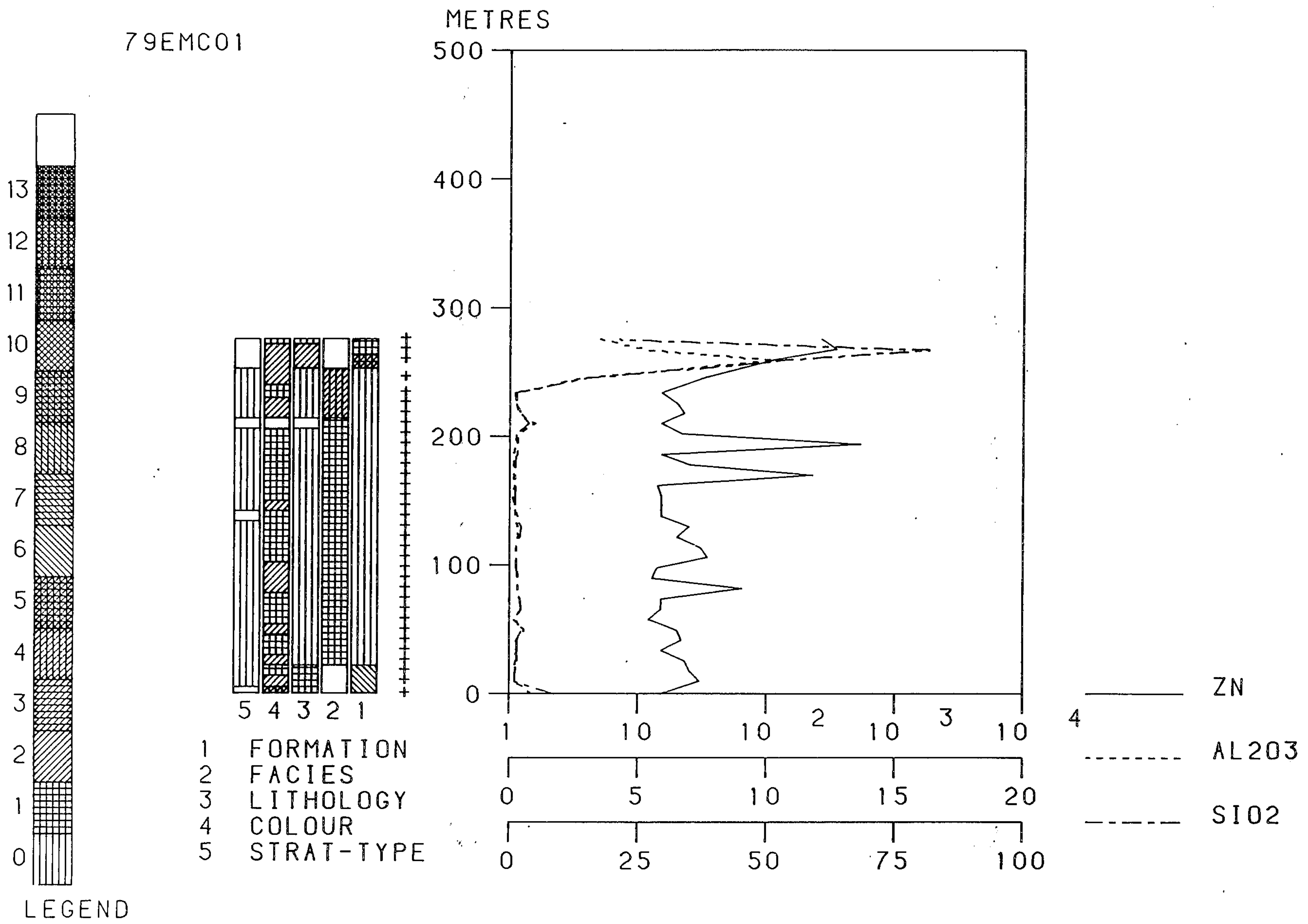

79EMC01
LEGEND
0
1
2
3
4
5
6
7
8
9
10
11
12
13
5 4 3 2 1
1 FORMATION
2 FACIES
3 LITHOLOGY
4 COLOUR
5 STRAT-TYPE
METRES
500
400
300
200
100
0
1
10
10 2
10 3
10 4
0 5 10 15 20
0 25 50 75 100
ZN
AL2O3
SIO2

Figure 10

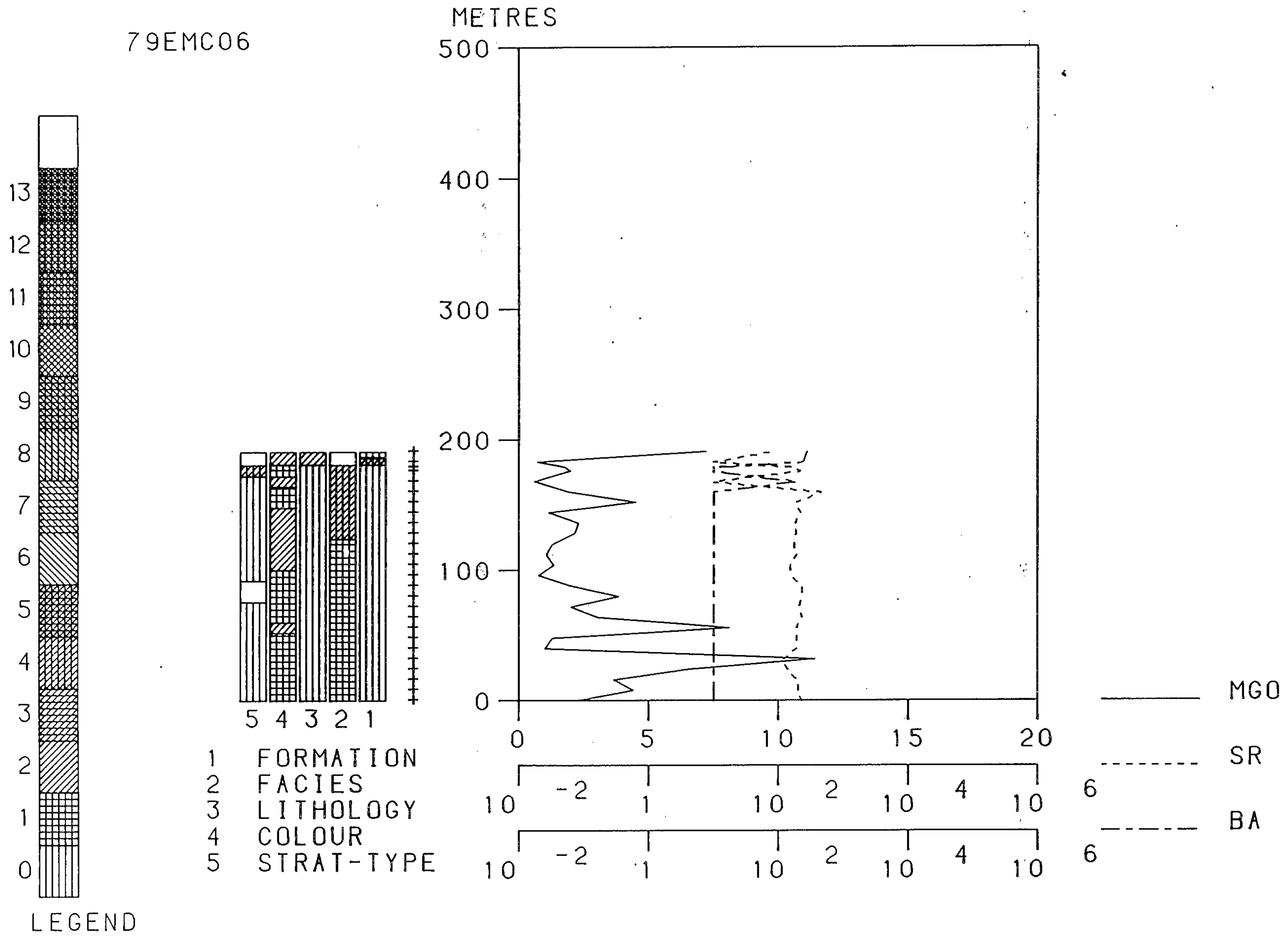

79EMC06
METRES
500
400
300
200
100
0
0
5
10
15
20
13
12
11
10
9
8
7
6
5
4
3
2
1
0
LEGEND
5 4 3 2 1
1 FORMATION
2 FACIES
3 LITHOLOGY
4 COLOUR
5 STRAT-TYPE
MGO
SR
BA

Figure 11

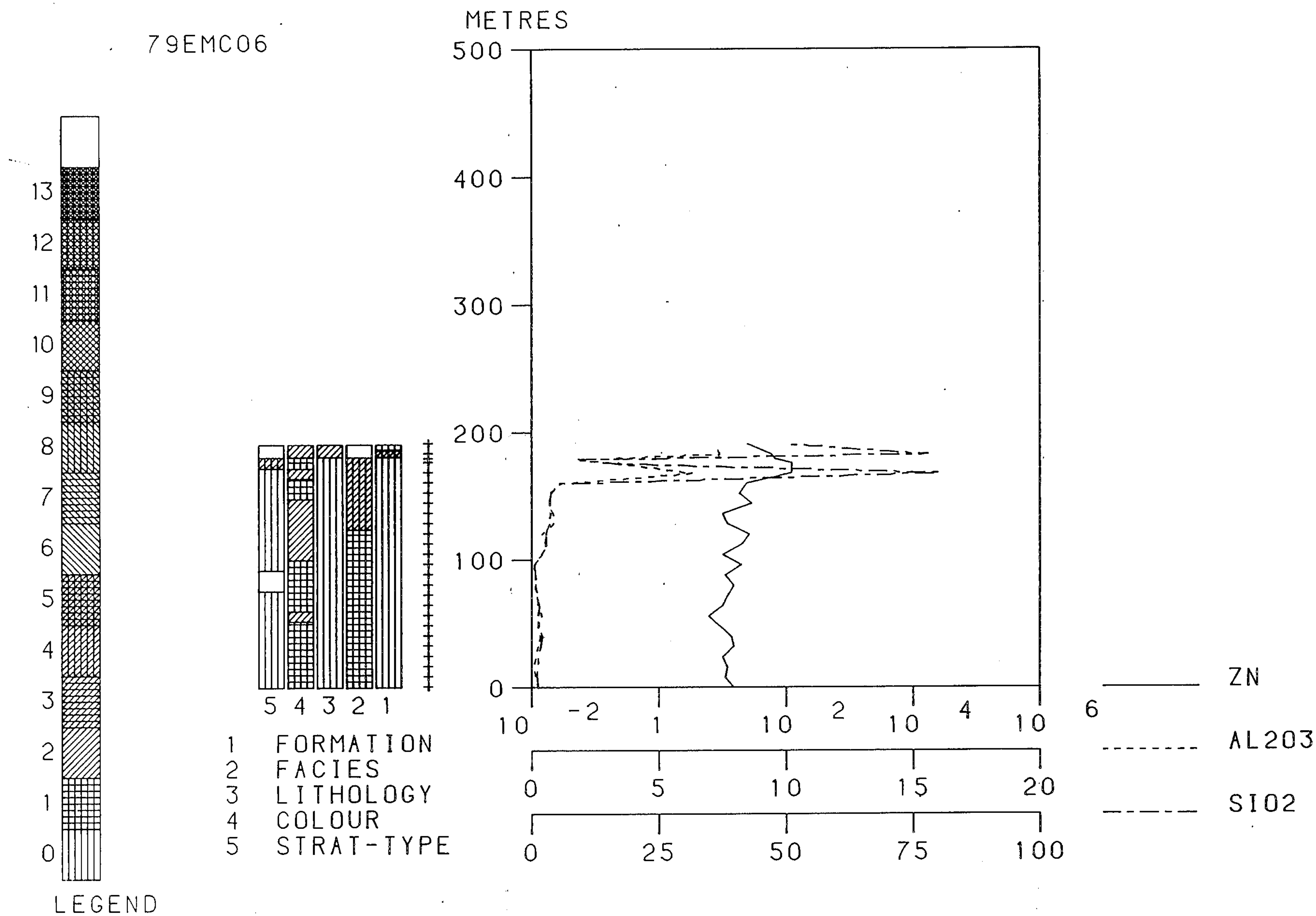
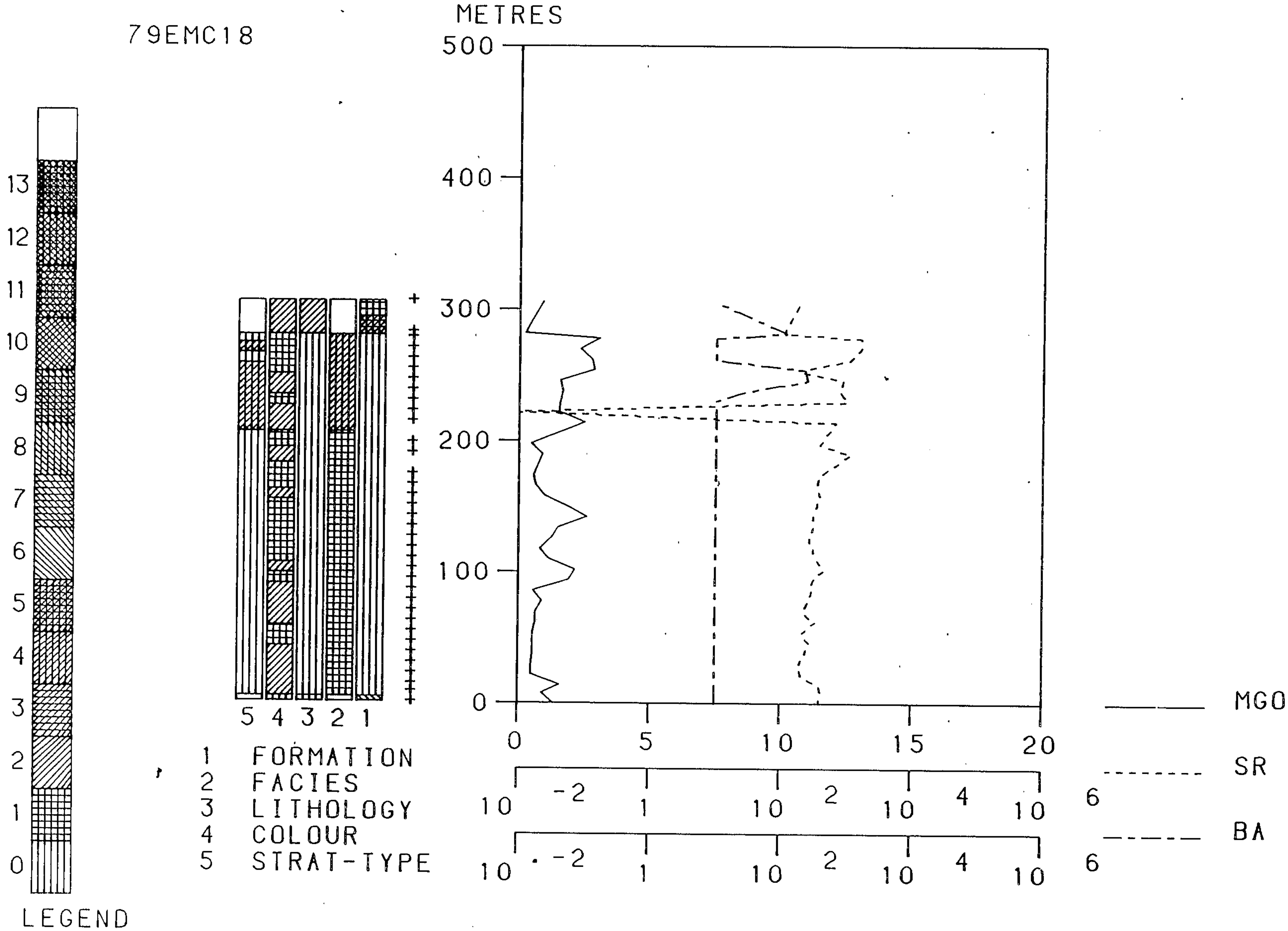

79EMC06
METRES
500
400
300
200
100
0
13
12
11
10
9
8
7
6
5
4
3
2
1
0
LEGEND
5 4 3 2 1
1 FORMATION
2 FACIES
3 LITHOLOGY
4 COLOUR
5 STRAT-TYPE
10 -2
1
10 2
10 4
10 6
0 5 10 15 20
0 25 50 75 100
ZN
AL2O3
SIO2

Figure 12



79EMC18
LEGEND
0
1
2
3
4
5
6
7
8
9
10
11
12
13
5 4 3 2 1
1 FORMATION
2 FACIES
3 LITHOLOGY
4 COLOUR
5 STRAT-TYPE
METRES
500
400
300
200
100
0
0
5
10
15
20
10 -2
1
10 2
10 4
10 6
MGO
SR
BA

Figure 13

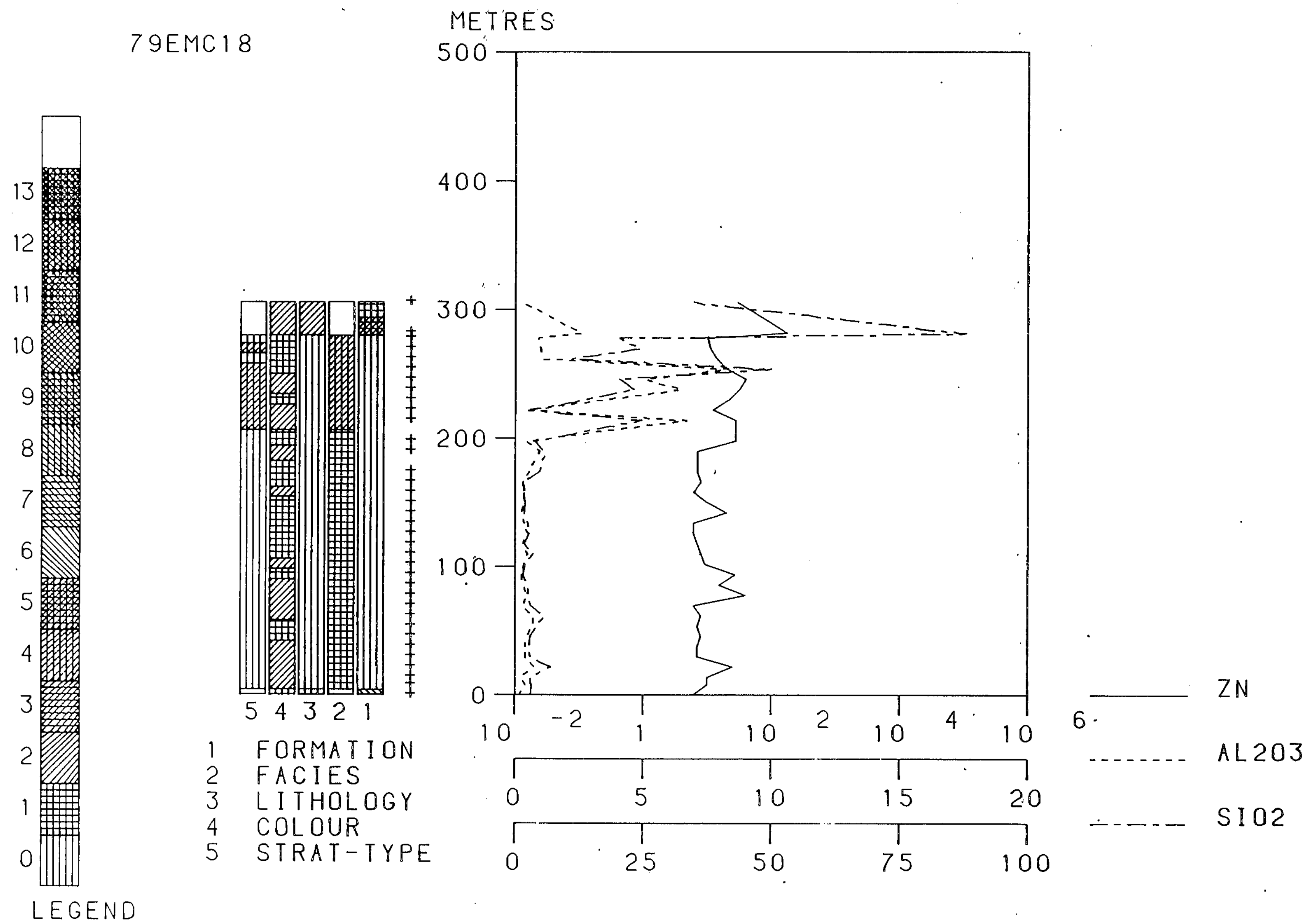

79EMC18
LEGEND
0
1
2
3
4
5
6
7
8
9
10
11
12
13
5 4 3 2 1
1 FORMATION
2 FACIES
3 LITHOLOGY
4 COLOUR
5 STRAT-TYPE
METRES
500
400
300
200
100
0
10 -2
1
10 2
10 4
10 6
0
5
10
15
20
0
25
50
75
100
ZN
AL2O3
SIO2

Figure 14

APPENDIX A

Six chemical elements and five geological parameters displayed in profiles for five stratigraphic sections.

The large data set collected in this study (1277 samples, 27 chemical elements, 40 stratigraphic sections, and many geological features) is contained on a computer diskette available from the Geological Survey of Canada, Ottawa, Canada. To illustrate the nature and range of these data, however, a few summary tables and diagrams are presented here.

Figures 5-14 display profiles for six elements (Zn, SiO_2, Al_2O_3, MgO, Sr, Ba) in five stratigraphic sections. The figures also present information on five geological features (formation name, Palliser facies, lithology, rock colour, and stratification type).

The five sections selected for presentation from the forty available were chosen for a variety of reasons. Section 79 EMC 06, for example, was selected because it is the section closest to a known lead-zinc occurrence in the Palliser (i.e. the Oldman occurrence; Table II). Section 80 GCA 01 is one of the few sections sampled that contains all four facies of the Palliser Formation. Section 81 GCA 05 is the Winnifred Pass section, well-known to western Canadian sedimentologists. Sections 79 EMC 01 and 79 EMC 18 were selected because the former is in the northern part of the southern area and in the Front Ranges of the Rocky Mountains; the latter section is in the southern part of the same area and in the Main Ranges.

In the diagrams that follow, "metres" refers to thickness upward from the base of the section being sampled, the small crosses indicate positions of individual samples. Note that Zn, Sr, and Ba are in ppm; Al_2O_3, SiO_2 and MgO are in %. Also presented in the diagrams are the five geological parameters mentioned above. The legend for the pattern numbers follows:

FORMATION	PATTERN NUMBER
Palliser	0
Banff	1
Besa River	2
Mount Hawk	3
Simla	4
Exshaw	5
Sassenach	6
Belly River	7
Rundle	8
FACIES	
Palliser Facies 1	1
Palliser Facies 2	2
Palliser Facies 3	3
Palliser Facies 4	4
LITHOLOGY	
Limestone	0
Dolostone	1
Siltstone/Shale	2
Sandstone	3
Conglomerate	4
Evaporite	5
Breccia	6
Tuff	7
Other (Metamorphic; Igneous; Volcanic flows)	8
COLOUR	
White to yellow	0
Light to medium grey	1
Dark grey or brown to black	2
Aternating light and dark bands	3
Reddish	4
Greenish	5
Varicoloured	6
STRATIFICATION TYPE	
Planar, parallel, horizontal stratification	0
Laminates, rhythmites	1
Corrugated, crinkly bedding	2
Wavy bedding	3
Nodular bedding	4
Nodular and wavy bedding	5
Cross stratification	6
Trough-shaped, festoon, channel-shaped, scour-and-fill cross stratification	8
Small scale cross stratification	11

APPENDIX B

Statistical summary of six elements (Al, Ba, Mg, Si, Sr, Zn) from all sections in northern and southern areas. Elements are the same as illustrated on profiles of Appendix A. Data are listed per element by section.

PALLISER PROJECT (SOUTH)
** ESSO DATA **

------------------------- ELEMENT/COMPOUND=SIO2 ; MEASURE=PCT ; LIMIT=0.01 -------------------------

SECTION	MIN	MEDIAN	MAX	PRESENT	SAMPLES
79EMC01	0.920	1.535	81.800	34	34
79EMC02	0.640	1.590	75.700	24	24
79EMC03	0.630	2.090	74.900	23	23
79EMC04	0.930	3.940	74.500	19	19
79EMC05	2.560	11.550	80.800	14	14
79EMC06	0.540	2.165	80.300	26	26
79EMC07	1.100	3.420	76.500	21	21
79EMC08	0.740	4.390	62.200	11	11
79EMC09	1.720	4.790	75.200	9	9
79EMC10	0.760	1.350	74.500	30	30
79EMC11	0.090	0.990	75.100	47	47
79EMC12	0.190	1.330	81.320	21	22
79EMC13	0.430	1.550	52.400	29	29
79EMC14	0.110	1.020	89.100	32	32
79EMC15	0.150	0.870	53.300	30	30
79EMC16	0.120	0.715	34.000	20	20
79EMC17	0.370	0.970	33.700	35	36
79EMC18	1.430	3.220	87.900	36	36
79EMC19	1.150	3.120	83.900	57	57
79EMC20	0.650	2.215	91.300	46	46
79EMC23	0.710	2.290	4.480	12	12
80EMC21	0.230	0.920	3.060	47	47
80EMC22	1.070	4.030	13.040	29	29

PALLISER PROJECT (NORTH)
** G.S.C. DATA **

------------------------- ELEMENT/COMPOUND=SIO2 ; MEASURE=PCT ; LIMIT=0.01 -------------------------

SECTION	MIN	MEDIAN	MAX	PRESENT	SAMPLES
79GCA03	0.250	2.830	69.190	43	43
79GCA04	0.730	3.335	20.790	52	52
79GCA05	0.630	3.675	63.100	62	62
79GCA06	0.570	2.930	78.000	69	69
80GCA01	0.210	4.850	73.320	47	47
80GCA02	0.250	3.450	50.800	49	49
80GCA03	0.560	1.810	28.610	40	40
80GCA04	0.700	3.000	77.340	67	67
80GCA06	2.370	3.790	36.930	17	17
80GCA08	1.220	53.525	58.970	4	4
80GCA10	0.260	4.060	13.710	12	12
80GCA11	0.810	4.360	81.160	29	29
80GCA13	0.300	2.970	85.660	19	20
81GCA05	0.250	1.410	47.170	34	34
81GCA06	0.270	1.160	24.080	27	27
81GCA07	0.280	0.995	7.390	32	32
81GCA08	0.230	1.210	3.340	19	19

PALLISER PROJECT (SOUTH)
** ESSO DATA **

------------------------ ELEMENT/COMPOUND=AL2O3 ; MEASURE=PCT ; LIMIT=0.01 --------------------------

SECTION	MIN	MEDIAN	MAX	PRESENT	SAMPLES
79EMC01	0.110	0.270	10.300	34	34
79EMC02	0.040	0.260	11.900	24	24
79EMC03	0.020	0.305	10.200	22	23
79EMC04	0.170	0.710	9.150	19	19
79EMC05	0.560	1.340	8.890	14	14
79EMC06	0.120	0.385	7.420	26	26
79EMC07	0.190	0.640	8.730	21	21
79EMC08	0.170	0.740	1.710	11	11
79EMC09	0.340	0.830	8.330	9	9
79EMC10	0.110	0.245	8.640	30	30
79EMC11	0.020	0.210	12.400	47	47
79EMC12	0.010	0.290	3.070	22	22
79EMC13	0.060	0.230	5.780	26	29
79EMC14	0.030	0.260	4.680	32	32
79EMC15	0.020	0.230	5.120	29	30
79EMC16	0.010	0.155	0.670	20	20
79EMC17	0.010	0.275	5.160	36	36
79EMC18	0.140	0.475	8.310	36	36
79EMC19	0.100	0.450	7.330	57	57
79EMC20	0.080	0.300	3.690	46	46
79EMC23	0.130	0.330	0.570	12	12
80EMC21	0.090	0.280	0.710	47	47
80EMC22	0.180	0.520	1.450	29	29

PALLISER PROJECT (NORTH)
** G.S.C. DATA **

------------------------ ELEMENT/COMPOUND=AL2O3 ; MEASURE=PCT ; LIMIT=0.01 --------------------------

SECTION	MIN	MEDIAN	MAX	PRESENT	SAMPLES
79GCA03	0.060	0.470	2.490	43	43
79GCA04	0.130	0.560	4.800	52	52
79GCA05	0.060	0.445	6.600	62	62
79GCA06	0.130	0.570	5.270	69	69
80GCA01	0.150	0.550	6.080	47	47
80GCA02	0.110	0.520	1.800	49	49
80GCA03	0.110	0.605	2.720	40	40
80GCA04	0.130	0.590	5.360	65	67
80GCA06	0.380	0.690	3.380	17	17
80GCA08	10.110	19.450	19.740	3	4
80GCA10	0.050	0.855	4.390	12	12
80GCA11	0.250	0.700	14.880	29	29
80GCA13	0.040	0.685	15.190	20	20
81GCA05	0.040	0.330	28.840	34	34
81GCA06	0.040	0.290	2.180	27	27
81GCA07	0.040	0.210	0.840	32	32
81GCA08	0.040	0.320	0.720	19	19

PALLISER PROJECT (SOUTH)
** ESSO DATA **

---------------------- ELEMENT/COMPOUND=MGO ; MEASURE=PCT ; LIMIT=0.01 ----------------------

SECTION	MIN	MEDIAN	MAX	PRESENT	SAMPLES
79EMC01	0.400	2.700	21.900	34	34
79EMC02	0.630	2.725	21.100	24	24
79EMC03	0.140	5.190	20.900	23	23
79EMC04	0.740	1.940	6.980	19	19
79EMC05	0.750	1.935	7.100	14	14
79EMC06	0.580	1.995	11.400	26	26
79EMC07	0.580	1.430	6.430	21	21
79EMC08	1.120	1.890	5.950	11	11
79EMC09	0.390	0.950	3.820	9	9
79EMC10	0.500	2.050	11.100	30	30
79EMC11	0.460	1.650	20.100	47	47
79EMC12	0.590	2.595	17.750	22	22
79EMC13	0.500	2.460	20.600	29	29
79EMC14	0.570	4.665	21.300	32	32
79EMC15	0.630	3.430	20.000	30	30
79EMC16	0.490	1.070	20.900	20	20
79EMC17	0.610	1.525	11.640	36	36
79EMC18	0.220	1.075	3.050	36	36
79EMC19	0.230	2.630	7.100	57	57
79EMC20	0.090	1.675	21.500	46	46
79EMC23	0.600	0.985	18.200	12	12
80EMC21	0.710	2.770	23.250	47	47
80EMC22	0.590	0.750	2.940	29	29

PALLISER PROJECT (NORTH)
** G.S.C. DATA **

---------------------- ELEMENT/COMPOUND=MGO ; MEASURE=PCT ; LIMIT=0.01 ----------------------

SECTION	MIN	MEDIAN	MAX	PRESENT	SAMPLES
79GCA03	0.080	0.730	3.920	43	43
79GCA04	0.290	1.280	13.060	52	52
79GCA05	0.270	0.645	4.040	62	62
79GCA06	0.280	0.760	5.670	69	69
80GCA01	0.300	0.640	4.700	47	47
80GCA02	0.290	0.500	4.120	49	49
80GCA03	0.210	0.490	2.380	40	40
80GCA04	0.260	0.610	7.970	67	67
80GCA06	0.550	0.780	2.240	17	17
80GCA08	1.360	2.365	2.670	4	4
80GCA10	0.280	0.590	0.830	12	12
80GCA11	0.210	0.610	4.000	29	29
80GCA13	0.170	0.415	18.030	20	20
81GCA05	0.280	0.555	8.220	34	34
81GCA06	0.440	0.860	11.320	27	27
81GCA07	0.400	0.540	1.800	32	32
81GCA08	0.360	1.460	8.880	19	19

PALLISER PROJECT (SOUTH)
** ESSO DATA **

ELEMENT/COMPOUND=BA ; MEASURE=PPM ; LIMIT=10.00

SECTION	MIN	MEDIAN	MAX	PRESENT	SAMPLES
79EMC01	150.000	180.000	210.000	2	34
79EMC02	120.000	225.000	350.000	4	24
79EMC03	80.000	130.000	470.000	5	23
79EMC04	250.000	250.000	250.000	1	19
79EMC05	230.000	345.000	1380.000	4	14
79EMC06	200.000	240.000	270.000	3	26
79EMC07	320.000	380.000	690.000	3	21
79EMC08	90.000	90.000	90.000	1	11
79EMC09	350.000	795.000	1240.000	2	9
79EMC10	50.000	210.000	310.000	3	30
79EMC11	240.000	245.000	250.000	2	47
79EMC12	150.000	150.000	150.000	1	22
79EMC13	130.000	130.000	130.000	1	29
79EMC14	120.000	130.000	170.000	3	32
79EMC15	100.000	100.000	100.000	1	30
79EMC16	.	.	.	0	20
79EMC17	30.000	40.000	200.000	3	36
79EMC18	10.000	120.000	250.000	5	36
79EMC19	10.000	115.000	500.000	14	57
79EMC20	10.000	40.000	270.000	4	46
79EMC23	.	.	.	0	12
80EMC21	.	.	.	0	47
80EMC22	.	.	.	0	29

PALLISER PROJECT (NORTH)
** G.S.C. DATA **

ELEMENT/COMPOUND=BA ; MEASURE=PPM ; LIMIT=10.00

SECTION	MIN	MEDIAN	MAX	PRESENT	SAMPLES
79GCA03	50.000	50.000	100.000	4	43
79GCA04	16.870	50.000	200.000	12	52
79GCA05	50.000	50.000	228.860	28	62
79GCA06	50.000	50.000	2100.000	27	69
80GCA01	50.000	50.000	100.000	47	47
80GCA02	50.000	50.000	500.000	49	49
80GCA03	50.000	50.000	100.000	40	40
80GCA04	50.000	50.000	500.000	67	67
80GCA06	50.000	50.000	100.000	17	17
80GCA08	50.000	250.000	350.000	4	4
80GCA10	50.000	75.000	200.000	12	12
80GCA11	50.000	100.000	600.000	29	29
80GCA13	50.000	275.000	1300.000	20	20
81GCA05	381.630	394.140	449.680	3	34
81GCA06	.	.	.	0	27
81GCA07	.	.	.	0	32
81GCA08	.	.	.	0	19

PALLISER PROJECT (SOUTH)
** ESSO DATA **

------------------------- ELEMENT/COMPOUND=SR ; MEASURE=PPM ; LIMIT=10.00 -------------------------

SECTION	MIN	MEDIAN	MAX	PRESENT	SAMPLES
79EMC01	10.000	220.000	410.000	34	34
79EMC02	30.000	205.000	360.000	24	24
79EMC03	60.000	170.000	1860.000	23	23
79EMC04	20.000	170.000	240.000	19	19
79EMC05	20.000	175.000	340.000	14	14
79EMC06	10.000	190.000	450.000	26	26
79EMC07	30.000	190.000	240.000	21	21
79EMC08	80.000	180.000	260.000	11	11
79EMC09	30.000	180.000	240.000	9	9
79EMC10	40.000	180.000	250.000	29	30
79EMC11	60.000	180.000	250.000	47	47
79EMC12	60.000	210.000	240.000	22	22
79EMC13	80.000	180.000	250.000	29	29
79EMC14	40.000	190.000	310.000	32	32
79EMC15	130.000	220.000	440.000	30	30
79EMC16	40.000	150.000	230.000	20	20
79EMC17	110.000	195.000	390.000	36	36
79EMC18	110.000	360.000	1690.000	35	36
79EMC19	20.000	360.000	1330.000	55	57
79EMC20	20.000	230.000	860.000	46	46
79EMC23	20.000	230.000	610.000	12	12
80EMC21	20.000	240.000	370.000	47	47
80EMC22	130.000	330.000	570.000	29	29

PALLISER PROJECT (NORTH)
** G.S.C. DATA **

------------------------- ELEMENT/COMPOUND=SR ; MEASURE=PPM ; LIMIT=10.00 -------------------------

SECTION	MIN	MEDIAN	MAX	PRESENT	SAMPLES
79GCA03	157.170	334.560	869.480	43	43
79GCA04	200.130	343.775	640.000	52	52
79GCA05	182.940	550.840	2000.000	62	62
79GCA06	113.700	273.640	960.000	69	69
80GCA01	190.000	510.000	1410.000	47	47
80GCA02	220.000	390.000	1210.000	49	49
80GCA03	230.000	380.000	730.000	40	40
80GCA04	120.000	410.000	1110.000	67	67
80GCA06	450.000	540.000	890.000	17	17
80GCA08	100.000	200.000	660.000	4	4
80GCA10	420.000	545.000	930.000	12	12
80GCA11	90.000	430.000	740.000	29	29
80GCA13	50.000	395.000	610.000	20	20
81GCA05	22.180	178.520	418.740	34	34
81GCA06	79.910	218.980	408.060	27	27
81GCA07	181.280	220.525	350.050	32	32
81GCA08	130.340	258.600	393.920	19	19

PALLISER PROJECT (SOUTH)
** ESSO DATA **

--- ELEMENT/COMPOUND=ZN ; MEASURE=PPM ; LIMIT=1.00 ---

SECTION	MIN	MEDIAN	MAX	PRESENT	SAMPLES
79EMC01	12.000	21.000	540.000	34	34
79EMC02	7.000	15.000	350.000	24	24
79EMC03	6.000	14.000	54.000	23	23
79EMC04	10.000	15.000	600.000	19	19
79EMC05	19.000	40.500	322.000	14	14
79EMC06	6.000	15.000	120.000	26	26
79EMC07	11.000	20.000	470.000	21	21
79EMC08	16.000	38.000	240.000	11	11
79EMC09	8.000	30.000	625.000	9	9
79EMC10	5.000	9.500	380.000	30	30
79EMC11	8.000	12.000	775.000	47	47
79EMC12	8.000	14.000	172.000	22	22
79EMC13	7.000	14.000	50.000	29	29
79EMC14	7.000	11.000	280.000	32	32
79EMC15	7.000	12.000	285.000	30	30
79EMC16	3.000	10.000	74.000	20	20
79EMC17	7.000	16.500	117.000	36	36
79EMC18	6.000	10.000	175.000	36	36
79EMC19	9.000	16.000	185.000	57	57
79EMC20	10.000	14.500	69.000	46	46
79EMC23	12.000	16.000	47.000	12	12
80EMC21	6.000	10.000	32.000	47	47
80EMC22	8.000	10.000	20.000	29	29

PALLISER PROJECT (NORTH)
** G.S.C. DATA **

--- ELEMENT/COMPOUND=ZN ; MEASURE=PPM ; LIMIT=1.00 ---

SECTION	MIN	MEDIAN	MAX	PRESENT	SAMPLES
79GCA03	11.000	15.000	225.000	43	43
79GCA04	12.000	21.500	158.000	52	52
79GCA05	2.000	20.000	380.000	62	62
79GCA06	13.000	24.000	200.000	69	69
80GCA01	4.000	10.000	52.000	47	47
80GCA02	4.000	7.000	212.000	49	49
80GCA03	5.000	9.000	32.000	40	40
80GCA04	4.000	7.000	125.000	67	67
80GCA06	5.000	10.000	47.000	17	17
80GCA08	11.000	114.000	228.000	4	4
80GCA10	13.000	16.500	69.000	12	12
80GCA11	12.000	44.000	200.000	29	29
80GCA13	18.000	32.000	185.000	20	20
81GCA05	8.000	13.000	1160.000	34	34
81GCA06	12.000	14.000	600.000	27	27
81GCA07	10.000	12.000	180.000	32	32
81GCA08	8.000	10.000	30.000	19	19

APPENDIX C

Statistical summary of chemical data from all sections in northern and southern areas. Data are presented as a summary of all sections, listed per element.

PALLISER PROJECT (SOUTH)
** ESSO DATA - SUMMARY **

MEASURE=(PCT) - MAJOR ELEMENTS

ELEM	MIN	MEDIAN	MAX	PRESENT	SAMPLES
SIO2	0.090	1.870	91.300	652	654
TIO2	0.010	0.020	0.540	304	654
AL2O3	0.010	0.320	12.400	649	654
FEO(TOT)	0.030	0.190	4.570	654	654
MGO	0.090	1.990	23.250	654	654
CAO	0.530	51.610	56.400	654	654
NA2O	0.010	0.160	1.700	650	654
K2O	0.010	0.120	5.610	653	654
P2O5	0.010	0.020	4.890	654	654
CORG	0.010	0.160	5.660	654	654
LOI	3.620	42.600	46.460	654	654
S	0.010	0.100	44.600	654	654

MEASURE=(PPM) - TRACE ELEMENTS

ELEM	MIN	MEDIAN	MAX	PRESENT	SAMPLES
BA	10.000	180.000	1380.000	62	654
RB	10.000	10.000	160.000	221	654
SR	10.000	200.000	1860.000	650	654
ZR	10.000	40.000	380.000	89	654
MN	2.000	88.000	2210.000	654	654
PB	2.000	10.000	58.000	525	654
ZN	3.000	14.000	775.000	654	654
CU	1.000	4.000	68.000	654	654
NI	2.000	6.000	200.000	474	654
CR	10.000	70.000	230.000	67	654
V	5.000	20.000	4000.000	653	654
AS	2.000	3.000	55.000	128	654
SB	1.000	6.000	45.000	393	654
AG	0.100	0.600	4.000	58	654
F	5.000	200.000	5100.000	654	654

PALLISER PROJECT (NORTH)
** G.S.C. DATA - SUMMARY **

MEASURE=(PCT) - MAJOR ELEMENTS

ELEM	MIN	MEDIAN	MAX	PRESENT	SAMPLES
SIO2	0.210	2.665	85.660	622	623
TIO2	0.020	0.030	1.750	375	623
AL2O3	0.040	0.500	28.840	620	623
FEO(TOT)	0.040	0.230	21.920	623	623
MGO	0.080	0.630	18.030	623	623
CAO	0.100	52.200	55.890	623	623
NA2O	0.020	0.070	2.540	43	623
K2O	0.020	0.110	6.640	554	623
P2O5	0.020	0.020	1.000	270	623
CORG	0.020	0.120	4.100	614	623
LOI	6.160	42.390	45.310	623	623
S	0.020	0.090	3.590	585	623

MEASURE=(PPM) - TRACE ELEMENTS

ELEM	MIN	MEDIAN	MAX	PRESENT	SAMPLES
BA	16.870	50.000	2100.000	359	623
RB	10.110	20.000	151.130	72	623
SR	22.180	354.180	2000.000	623	623
ZR	10.580	30.000	360.180	129	623
MN	4.000	90.000	1500.000	623	623
PB	3.000	9.500	44.000	480	623
ZN	2.000	15.000	1160.000	623	623
CU	2.000	5.000	74.000	623	623
NI	3.000	6.000	164.000	254	623
CR	11.100	90.000	293.230	27	623
V	4.000	20.000	1800.000	621	623
AS	3.000	4.000	53.000	51	623
SB	2.000	3.000	12.000	29	623
AG	0.200	0.300	1.200	61	623
F	27.000	230.000	4600.000	623	623

APPENDIX D

Statistical summary of all chemical data collected in this study. Listed by element.

PALLISER PROJECT (SOUTH & NORTH)
** ESSO & G.S.C. DATA - SUMMARY **

---------------------------------- MEASURE=(PCT) - MAJOR ELEMENTS ----------------------------------

ELEM	MIN	MEDIAN	MAX	PRESENT	SAMPLES
SIO2	0.090	2.205	91.300	1274	1277
TIO2	0.010	0.030	1.750	679	1277
AL2O3	0.010	0.410	28.840	1269	1277
FEO(TOT)	0.030	0.210	21.920	1277	1277
MGO	0.080	1.100	23.250	1277	1277
CAO	0.100	51.900	56.400	1277	1277
NA2O	0.010	0.160	2.540	693	1277
K2O	0.010	0.120	6.640	1207	1277
P2O5	0.010	0.020	4.890	924	1277
CORG	0.010	0.150	5.660	1268	1277
LOI	3.620	42.540	46.460	1277	1277
S	0.010	0.090	44.600	1239	1277

---------------------------------- MEASURE=(PPM) - TRACE ELEMENTS ----------------------------------

ELEM	MIN	MEDIAN	MAX	PRESENT	SAMPLES
BA	10.000	50.000	2100.000	421	1277
RB	10.000	13.100	160.000	293	1277
SR	10.000	252.760	2000.000	1273	1277
ZR	10.000	30.000	380.000	218	1277
MN	2.000	89.000	2210.000	1277	1277
PB	2.000	10.000	58.000	1005	1277
ZN	2.000	14.000	1160.000	1277	1277
CU	1.000	5.000	74.000	1277	1277
NI	2.000	6.000	200.000	728	1277
CR	10.000	75.000	293.230	94	1277
V	4.000	20.000	4000.000	1274	1277
AS	2.000	3.000	55.000	179	1277
SB	1.000	5.000	45.000	422	1277
AG	0.100	0.400	4.000	119	1277
F	5.000	220.000	5100.000	1277	1277

APPENDIX E

Key to codes used in data diskette

Column		
1-7	NTS map sheet	eg: 093 I 12 W
8-17	sample number	eg: 80 GCA 11 025 (year initials section sample)
18-23	GSC catalogue number	eg: 08536S
24-27	Metres above measured base of section	eg: 103.5
28-29	UTM Zone	eg: 10
30-34	UTM Easting	eg: 64580
34-50	UTM Northing	eg: 607560

NOTE: UTM coordinates refer to measured base of formation

41-42 **Formation**

- PL Palliser
- BF Banff
- BR Besa River
- MH Mount Hawk
- SI Simla
- EX Exshaw
- SA Sassenach
- BC Belly River
- RL Rundle

43 **Facies**

1 Palliser facies 1
2 Palliser facies 2
3 Palliser facies 3
4 Palliser facies 4

44-45 **Age**

01 Precambrian
02 Archean (2500 m.y.)
03 Archean-Proterozoic
04 Proterozoic (570-2500 m.y.)
05 Aphebian
06 Helikian
07 Hadrynian
08 Hadrynian-Cambrian
10 Paleozoic undivided
11 Proterozoic Paleozoic
12 Cambrain
13 Cambrain-Ordovician
14 Ordovician
15 Ordovician-Silurian
16 Silurian

17 Silurian-Devonian
18 Devonian
19 Devonian-Mississippian
20 Carboniferous
21 Mississippian
22 Pennsylvanian
23 Pennsylvanian-Permian
24 Permian
25 Permian-Triassic
30 Mesozoic undivided
31 Mesozoic-Paleozoic
32 Triassic
33 Triassic-Jurassic
34 Jurassic
35 Jurassic-Cretaceous
36 Cretaceous
37 Cretaceous-Tertiary
40 Cenozoic undivided
41 Mesozoic-Cenozoic
42 Tertiary
43 Tertiary-Quaternary
44 Quaternary
50 Unknown

46 **Age Modifier**

0-early
1-middle
2-late
3-unknown

47 **Dominant lithology**

0 limestone
1 dolostone
2 siltstone/shale
3 sandstone
4 conglomerate
5 evaporite
6 breccia
7 tuff
8 other (metamorphic, igneous, volcanic flows)
9 unknown

48 **Colour**

0 white to yellow
1 light to medium grey
2 dark grey or brown to black
3 alternating light and dark bands
4 reddish
5 greenish
6 varicoloured
7 not determined

49 **Impurities**

0 green, red, grey shaly inclusions
1 black shaly inclusions
2 shaly partings
3 disseminated shale
4 shaly partings and disseminated shale
5 carbonate inclusions
6 coarse clastic (sandstone, conglomerate) inclusions
7 organic inclusions (coal, kerogen)
8 no impurities
9 not determined

50 **Stratification**
- bedding thickness

0 thinly laminated <2 mm
1 laminated 2mm-1 cm
2 very thin beds 1 cm-5 cm
3 thin beds 5 cm-20 cm
4 medium beds 20 cm-60 cm
5 thick beds 60 cm-120 cm
6 very thick and massive beds >120 cm
7 not determined

51-52 **Stratification Types** (modified after Arnon, 1979)

00 planar, parallel, horizontal stratification
01 - laminites, rhythmites
02 - varved bedding
03 - graded bedding, fining upwards
04 - graded bedding, coarsening upwards
05 - partings, shale break
06 cross-stratification
07 - medium to large-scale cross-stratification
08 - trough-shaped, festoon, channel-shaped, scour and fill cross-stratification
09 - wedge-shaped cross-stratification
10 - tabular cross-stratification
11 - small-scale cross-stratification
12 - ripple bedding
13 - ripple bedding with flasers
14 - climbing ripple bedding
15 - zigzag or herringbone cross-stratification
16 - imbricated pebbles
17 corrugated, crinkly bedding
18 wavy bedding
19 nodular bedding
20 wavy and nodular bedding
21 contorted, convolute bedding (small-medium scale, mm-cm)
22 contorted, chaotic bedding (large-scale, metres)
23 not determined

53-54 **Sedimentary Structures**

00 ripple marks
01 - current, asymmetrical ripple marks
02 - linguoid, lunate ripple marks
03 - oscillation, symmetrical ripple marks
04 - interference ripple marks
05 - truncated ripple marks
06 - giant ripples, sand waves
07 parting or current lineation
08 sole marks
09 - groove, prod, rill marks
10 - flute molds
11 flame structures
12 desiccation or mud cracks, shrinkage polygons
13 tepee structures
14 cone-in-cone structures
15 rain and hail prints
16 gas pits
17 mud curls, stacked or imbricated as flat pebbles
18 slump structures
19 - load casts (cm scale)
20 - convolute lamination (cm shale)
21 - ball and pillow (usually metre scale)
22 bioturbation
23 - churned bedding
24 - burrows
25 - plant rootlets or stigmaria
26 biostructures
27 - bioclastic mounds or buildups (>1 m)
28 - algal structures, stromatolitic (laminated) or thrombolitic (not laminated)
29 - algal mounds or buildups (>1 m)
30 - isolated stromatolite heads (cabbage-shaped)
31 - linked stromatolite forms (heads and columns)
32 - heads only
33 - columns only
34 - stromatolite horizon (heads and columns not present or vaguely visible)
35 - isolated thrombolite heads (cabbage-shaped)
36 - linked thrombolite heads
37 - thrombolite horizon (heads not present or vaguely visible)
38 not determined

55 **Texture**

- **Carbonate classification (dominant type)**

0 mudstone
1 wackestone
2 packstone
3 grainstone
4 floatstone
5 rudstone
6 boundstone
7 recrystallized
8 not determined

56 - **Terrigenous classification (dominant type)**
0 clay silt <0.0625 mm
1 very fine - medium sand 0.0625-0.5 mm
2 coarse - very coarse sand 0.5-2.0 mm
3 granules 2-5 mm
4 pebbles 5-20 mm
5 cobbles, boulders above 20 mm
6 not determined

57 - **Sorting**
0 good
1 medium
2 poor
3 not determined

58 - **Rounding** of dominant size
0 good
1 medium
2 poor
3 not determined

59-60 **Composition of particles** (excludes cement)
- **dominant particles**
00 skeletal
01 nonskeletal
02 intraclasts
03 lithoclasts
04 pelletal (includes grapestones)
05 oncolitic
06 oolitic
07 clay or silt-sized
08 terrigenous
09 quartzose
10 arkosic
11 cherty
12 lithic
13 clay, silt or mud pellets
14 igneous
15 metamorphic
16 volcanic
17 evaporitic
18 not determined

61-62 - **minor particles** (second in abundance)
00 skeletal
01 non skeletal
02 intraclasts
03 lithoclasts
04 pelletal (includes grapestones)
05 oncolitic
06 oolitic
07 clay or silt-sized

08 terrigenous
09 quartzose
10 arkosic
11 cherty
12 lithic
13 clay, silt or mud pellets
14 igneous
15 metamorphic
16 volcanic
17 evaporite
18 not determined

63-64 **Fossil content**
- dominant type
00 bioclastic
01 pelecypods
02 gastropods
03 brachiopods
04 bryozoan
05 corals
06 stromatoporoids
07 crinoids
08 ostracods
09 foraminifera
10 plant fragments
11 calcispheres and charophytes
12 stromatolites
13 algal tubes
14 sponges
15 not present
16 not defined

65-66 **- minor type** (second in abundance)
00 bioclastic
01 pelecypods
02 gastropods
03 brachiopods
04 bryozoan
05 corals
06 stromatoporoids
07 crinoids
08 ostracods
09 foraminifera
10 plant fragments
11 calcispheres and charophytes
12 stromatolites
13 algal tubes
14 sponges
15 not present
16 not defined

67 **Porosity**
0 good
1 fair
2 poor
3 not determined

68 **Porosity type**
- **dominant**
  A interparticle
  B intraparticle, moldic
  C growth framework, shelter
  D intercrystalline
  E fenestral (vesicular, birdseye, shrinkage cracks)
  F large vugs, stromatactis
  G channels
  H fractured
  I brecciated
  J crackle breccia
  K zebra breccia
  L solution breccia
  M tectonic breccia
  N not determined

69 - **minor** (second in abundance)
  A interparticle
  B intraparticle, moldic
  C growth framework, shelter
  D intercrystalline
  E fenestral (vesicular, bird, shrinkage cracks)
  F large vugs, stromatactis
  G channels
  H fractured
  I brecciated
  J crackle breccia
  K zebra breccia
  L solution breccia
  M tectonic breccia
  N not determined

70 **Stylolites**
0 green, red residue
1 black residue
2 not present
3 not determined

71 **Cement**
- **Distribution**
  0 throughout
  1 laminated
  2 patchy
  3 mottled
  4 fracture controlled
  5 not determined

72 - **Composition**
- **dominant**
  0 calcite
  1 dolomite
  2 siliceous
  3 ferrugenous
  4 sulphides
  5 clayey
  6 organic
  7 evaporitic
  8 others
  9 not determined

73 - **minor** (second in abundance)
  0 calcite
  1 dolomite
  2 siliceous
  3 ferrugenous
  4 sulphides
  5 clayey
  6 organic
  7 evaporitic
  8 others
  9 not determined

74 **Dominant sulphide**
0 not present
1 pyrite
2 chalcopyrite
3 chalcocite
4 sphalerite
5 galena
6 unidentified

75 **Veins**
0 not present
1 calcitic
2 dolomitic
3 barite
4 siliceous
5 evaporitic
6 sulphides
7 others
8 not determined

76 **Abnormal weathering**
0 not present
1 gossan
2 leached zone
3 karsted surface
4 paleosol
5 undefined

77-78 **Depositional environments**

00 Carbonates (after Wilson, 1975)
01 basin (euxinic)
02 open shelf (below storm wave base)
03 toe of slope (below storm wave base)
04 foreslope (above storm wave base, below normal wave base)
05 organic reef (bioherm, biostrome)
06 sands on edge of platform (above normal wave base)
07 open platform (below normal wave base)
08 restricted platform (lagoonal, tidal)
09 platform evaporites (supratidal, sabkha)
10 lacustrine (carbonates)

11 Terrigenous, continental (after Arnon, 1979)
12 alluvial fans, debris flows
13 lacustrine - turbidites
14 - deltaic
15 - undetermined
16 eolian
17 fluvial - meandering
18 - braided
19 - undetermined

20 Terrigenous, marine (after Arnon, 1979)
21 beach
22 tidal (flat, marsh, channels)
23 deltaic - plain
24 - front
25 - prodelta
26 - undetermined
27 lagoonal
28 shallow marine (barrier islands, spits) platform
29 open platform
30 deep marine - turbidites
31 - proximal turbidites
32 - distal turbidites
33 - undetermined

79-80 **Associated facies** (stratigraphically above or below)

00 Carbonates (after Wilson, 1975)
01 basin (euxinic)
02 open shelf (below storm wave base)
03 toe of slope (below storm wave base)
04 foreslope (above storm wave base, below normal wave base)
05 organic reef (bioherm, biostrome)
06 sands on edge of platform (above normal wave base)
07 open platform (below normal wave base)
08 restricted platform (lagoonal, tidal)
09 platform evaporites (supratidal, sabkha)
10 lacustrine carbonates

11 Terrigenous, continental (after Arnon, 1979)

12 alluvial fans, debris flows
13 lacustrine - turbidites
14 - deltaic
15 - undetermined
16 eolian
17 fluvial - meandering
18 - braided
19 - undetermined

20 Terrigenous, marine (after Arnon, 1979)
21 beach
22 tidal (flat, marsh, channels)
23 deltaic - plain
24 - front
25 - prodelta
26 - undetermined
27 lagoonal
28 shallow marine (barrier islands, spits) platform
29 open platform
30 deep marine - turbidites
31 - proximal turbidites
32 - distal turbidites
33 - undetermined

The major, minor and selected trace elements and compounds appear in the following order:

1.	Cu	ppm	15.	CaO	pct
2.	Pb	"	16.	MgO	"
3.	Zn	"	17.	Na_2O	"
4.	Ni	"	18.	K_2O	"
5.	Mn	"	19.	FeO	"
6.	Ag	"	20.	MnO	"
7.	As	"	21.	TiO_2	"
8.	S	pct	22.	L.O.I.	"
9.	C (organic)	pct	23.	Ba	ppm
10.	F	ppm	24.	Cr_2O_3	"
11.	Sb	"	25	Zr	"
12.	V	"	26.	Sr	"
13.	SiO_2	pct	27.	Rb	"
14.	Al_2O_3	"	28.	P_2O_5	pct

Each value is a real number occupying seven character positions with the decimal point in the third place from the right.