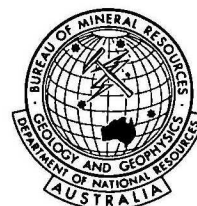


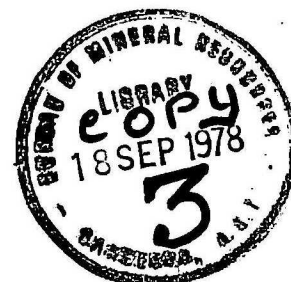
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BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

RECORD 1978/15



GEOCHEMICAL STUDY OF CORE MATERIAL
FROM THE ARRINTHRUNGA FORMATION,
NORTHERN TERRITORY

001329

by

J.J. DRAPER

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SUMMARY

As part of a continuing geochemical study of carbonate rocks, core from four stratigraphic drillholes has been analysed. The four holes studied are BMR Elkedra Nos 4 & 5, and BMR Huckitta Nos 7 & 8. Elkedra No. 4 was drilled in the Meeta Beds and the other three in the Arrinthrunga Formation which is, in part, laterally equivalent to the Meeta Beds. Within each well, geochemical units are recognised, and they generally correspond to lithological variation. F and Organic C are consistent discriminators between geochemical units, while the other elements are of variable importance. Sr, Fe, and Mn - whilst reflecting the specific mineralogy of the carbonate mineral are influenced by other factors. P and Ba are strongly associated with the non-carbonate phase of the rocks. F shows little relationship to phosphorus, has quite high values (up to 0.640 percent), and is probably present as fluorite associated with either an evaporative environment or algal material. Organic C would be derived mainly from algal material but some may have been oxidised during early diagenetic alteration.

INTRODUCTION

As part of a multidisciplinary study of the Georgina Basin (Druce, 1974), the geochemistry of carbonate rocks is being investigated. Progress reports (Draper, 1976; in prep.) have outlined the geochemistry of carbonate rocks in the Burke River Structural Belt, the Toko Syncline, and company work on drillholes. This report outlines the results of sampling carried out on core from four stratigraphic wells in the Huckitta-Elkedra area.

The four holes sampled are BMR Elkedra Nos 4 & 5 (formerly GRG 4 & 5), and BMR Huckitta Nos 7 & 8 (formerly GRG 7 & 8) (Fig. 1). Elkedra No. 5, and Huckitta Nos 7 & 8, are within the Arrinthrunga Formation, and Elkedra No. 4 is within the Meeta Beds, a partial lateral equivalent of the Arrinthrunga Formation (Smith, 1972). Descriptions of all the core are given by Milligan (1962) and, additionally, of Elkedra No. 4 by Fehr & Nichols (1963). A detailed study of the Arrinthrunga Formation is currently being undertaken as part of the Georgina Basin Project. Samples were taken at approximately 3 metre intervals; the analytical methods used (by Australian Mineral Development Laboratory) are those outlined in Draper (1976), except that Pb and Zn values were not determined, and Si and Al values were obtained by gravimetric methods. Pb and Zn values for the holes are reported in Draper (in prep.), the analyses having been carried out by Broken Hill Company Proprietary. The sample interval for Pb and Zn varied from that used here. The results are tabulated in Appendix 1.

Acknowledgements

Stimulating discussions on the Arrinthrunga Formation were held with J.M. Kennard. Sampling was carried out by K. Heighway, J. Price, and S. Schmidt.

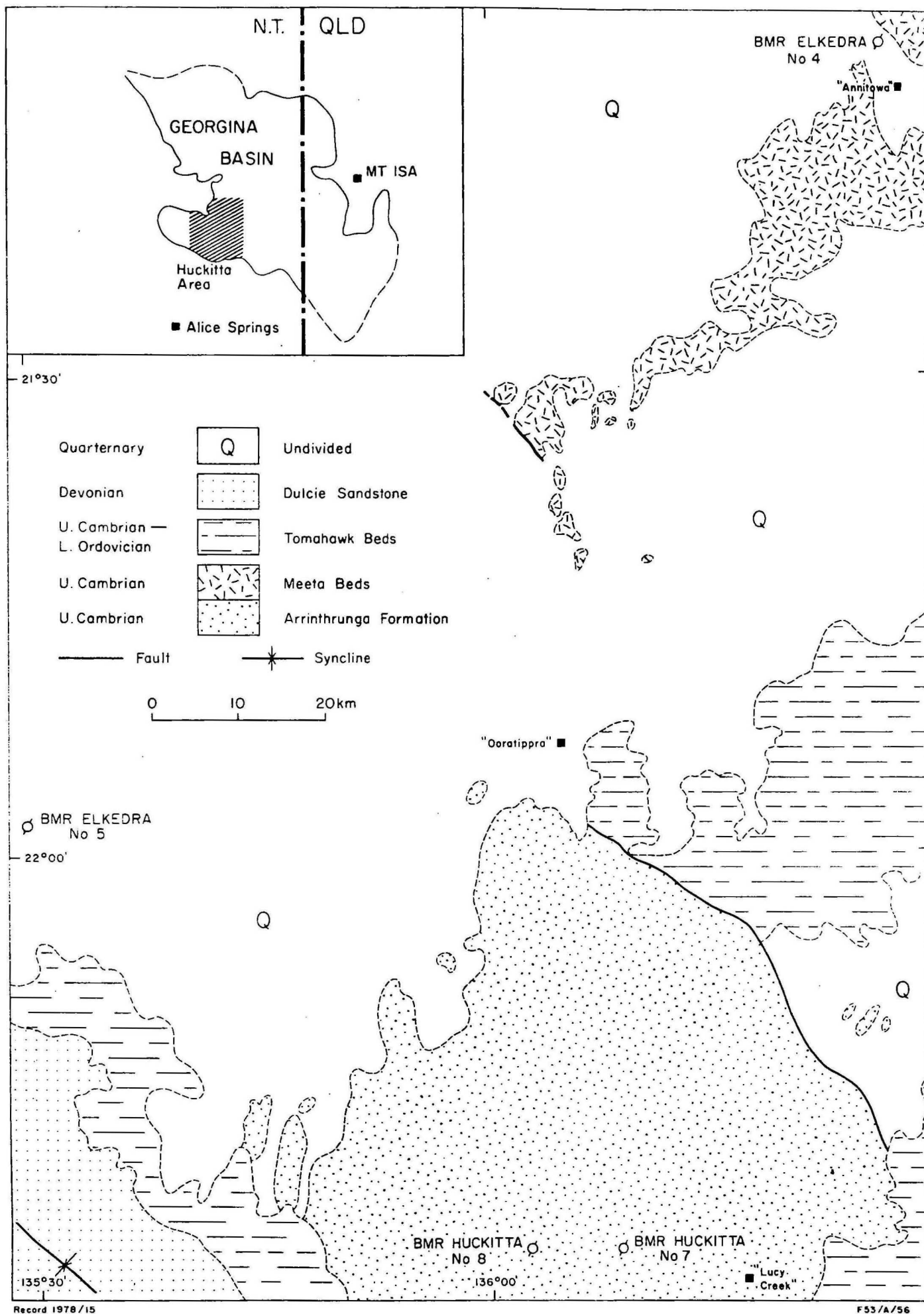


Fig.1 Locality map of stratigraphic holes on which geochemistry was carried out.

DESCRIPTION OF GEOCHEMICAL LOGS

Plots of the various elements against depth have been prepared for each hole (Fig. 2, 3, 4 & 5). These geochemical logs are described and compared with general lithological logs taken from the literature. When the detailed study of the Arrinthrunga Formation is completed the geochemical logs will be compared against revised, detailed lithological logs and the interpreted depositional environments. In this report the term geochemical units refers to a geochemical sequence that differs significantly from an adjacent sequence. The term lithological units refers to a lithological entity which differs from adjacent lithological entities.

BMR Elkedra No. 4

(a) HCl soluble fraction. The insoluble residue log (Fig. 2) confirms that the rocks are carbonates with a variable insoluble content. The Ca and Mg logs indicate that the rocks are predominantly dolomite, but with some limestone in the lower part. Sr values reflect the mineralogy closely with above background values corresponding to the limestone. Fe values, in general, reflect the mineralogy, being significantly higher in dolomites than in adjacent limestones, but the Fe log suggests that factors other than mineralogy influence the Fe content. Mn values are relatively constant, and unrelated to carbonate mineralogy.

(b) Whole rock fraction. P values are quite variable, although the P log does parallel the insoluble residue log, indicating that P is associated with the terrigenous components of the rocks. Cu values are variable, but an increase in Cu values is associated with an increase in Organic C values. Si and Al values reflect the variability of the terrigenous component, and the low constant Si/Al ratio indicates that it is predominantly clay. The high Si/Al ratios indicate quartz-rich sandy horizons (or, alternatively, zones of silicification). The Ba log parallels those for insoluble residues, Si, and Al, indicating that Ba is associated with the clay component of the rock. The F log parallels that for P (apatite) at the top,

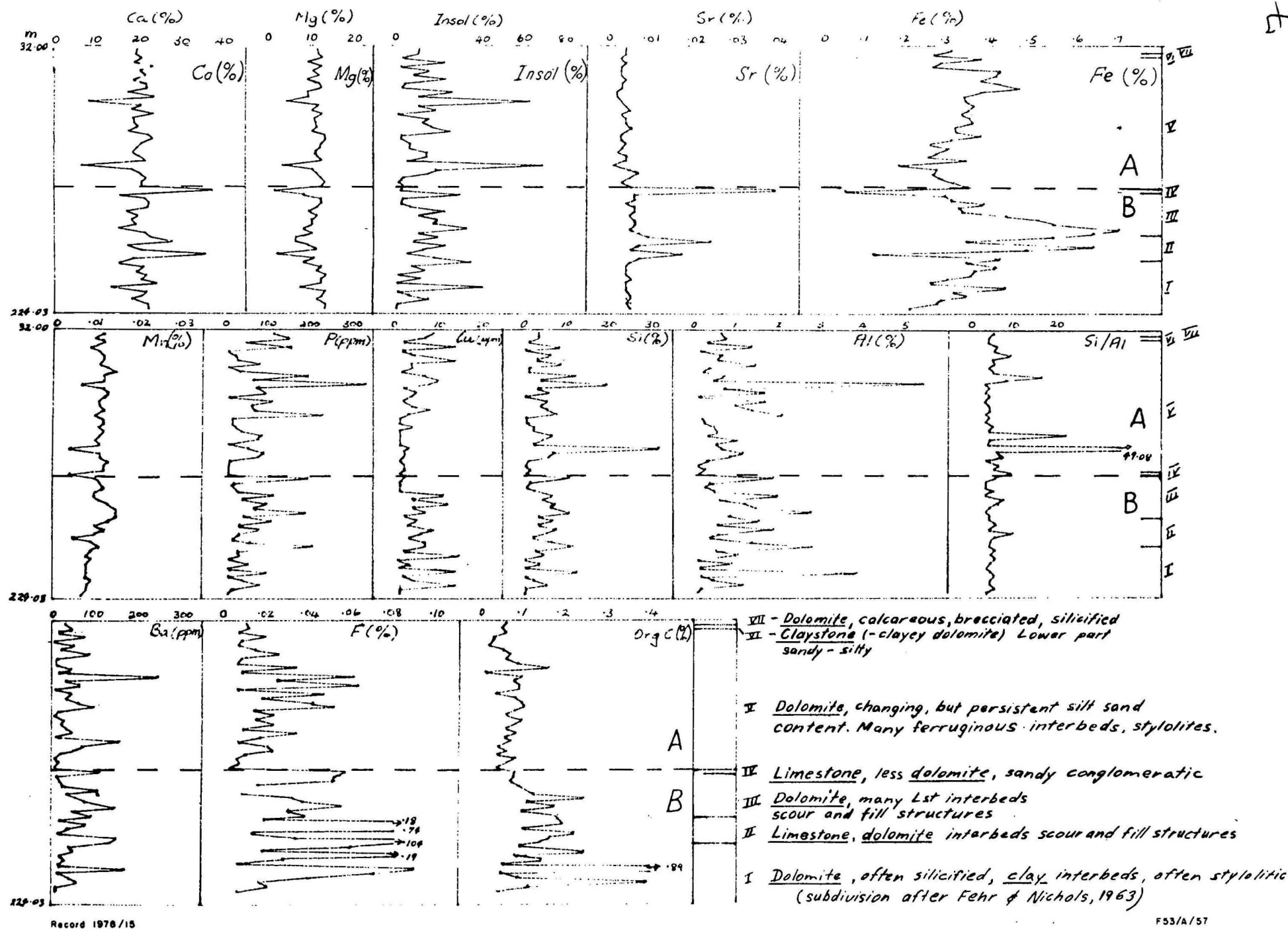


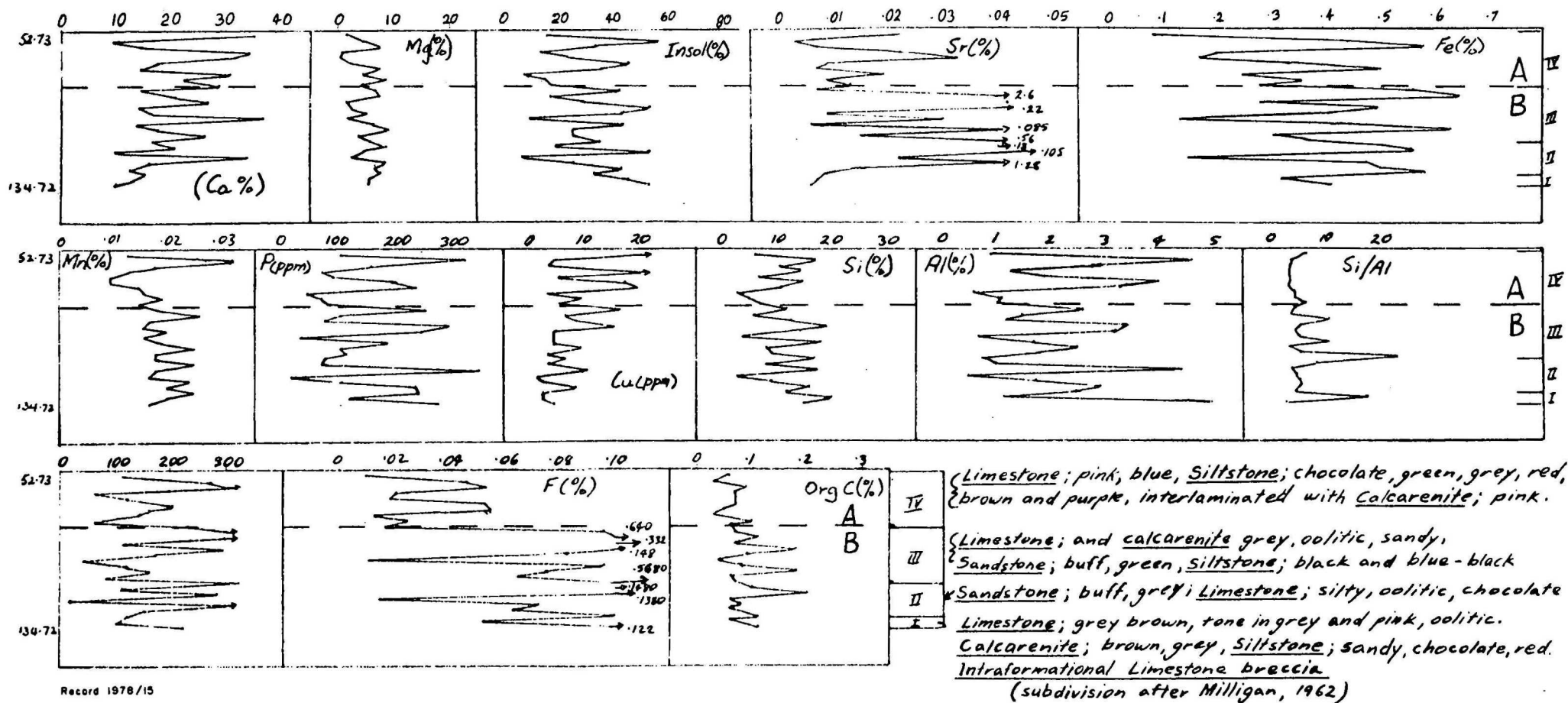
Fig. 2. Plot of element versus depth - B.M.R. Elkedra No 4

but F values become high and variable down the hole. F may be present sorbed on clays or as a fluorite mineral. Organic C values show no correlation with insoluble residues or Al.

(c) Comparison with lithology. Fehr & Nichols (1963) divided Elkedra No. 4 into seven lithological units (Fig. 2). Two of the lithological units (VI & VII) are too narrow to be covered by the sampling. Lithological unit VI, which is predominantly limestone, is represented by one sample (refer to highest Ca and Sr peaks). The sequence is divisible into two geochemical units (Fig. 2), the upper geochemical unit (A) corresponding to lithological unit V and the lower geochemical unit (B), lithological units I, II and III combined. The major change in lithology is from dolomites in lithological unit V to interbedded limestone and dolomite in lithological unit I, II & III. Stylolites are present throughout, indicating significant removal of carbonate with a relative increase in the insoluble residue content. Geochemical unit B is separated from A on the basis of consistently higher organic C, F, Cu and Sr (minor but significant) values and changes in the log pattern of Al, Si, P, Fe and insoluble residues. High Ca values occur in geochemical unit B (reflecting the limestone) and high Si/Al values in geochemical unit A (reflecting the sandstone). Pb and Zn values (Draper, in prep.) do not reflect the geochemical units.

BMR Elkedra No. 5

(a) HCl-soluble fraction. The geochemical plot (Fig. 3) indicates that Elkedra No. 5 contains a sequence of limestones, dolomitic limestones and dolomites, with variable quantities of insoluble residues. In the upper part of the sequence, Sr content in dolomite is higher than in limestones, but in the lower part of the hole there are some very anomalous Sr values (up to 2.6 percent). Fe values basically reflect the mineralogy, being higher in dolomites and lower in limestones. Mn values also reflect mineralogy, being higher in dolomites except in the upper part of the hole.

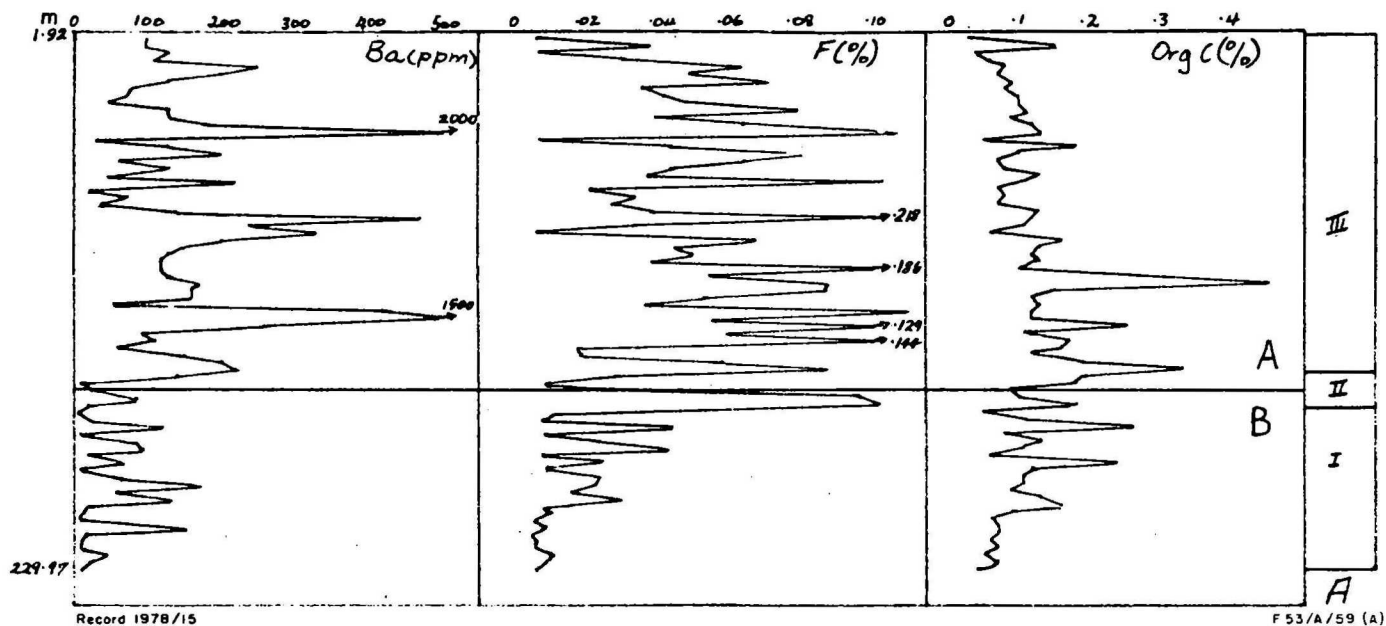


(b) Whole-rock fraction. The P log parallels that for insoluble residues, indicating that P is associated with the non-carbonate phase. Cu values are variable, and show a progressive decrease with depth. Si/Al ratios indicate clay-rich terrigenous material in the upper part and siliceous horizons in the lower part of the hole. The Ba log generally parallels that for insoluble residues, but there is an enrichment of Ba to 1700 ppm in some samples, a feature found in many other carbonates in the Georgina Basin (Draper, 1976; in prep.). F values initially parallel those for P, but, in the lower part of the hole, excessively high values are present (up to 0.64 percent). Organic C values show an overall increase in the lower part of the hole.

(c) Comparison with lithology. Milligan (1962) divided the sequence in Elkedra No. 5 into four lithological units (Fig. 3). The geochemical logs seem to reflect two geochemical units. Geochemical unit A corresponds to lithological unit IV, and geochemical unit B to lithological units I, II & III. Lithological unit IV contains considerably more siltstone than the other three lithological units which contain sandstone and ooids, not present in lithological unit IV. The geochemical units are separated on the basis of higher values of organic C, F, Si/Al, and Sr in geochemical unit B, and changes in the log patterns of Mn and Si. Pb and Zn values (Draper, in prep.) do reflect the geochemical units, Zn values being higher in geochemical unit B, and Pb in geochemical unit A.

BMR Huckitta No. 7

(a) HCl-soluble fraction. The rocks consist of limestone and dolomitic limestone in the upper part and dolomite with rare limestone in the lower part (Fig. 4). Insoluble residue values vary, but tend to be lower in the lower part of the hole. Sr values, as previously, reflect the mineralogy. Fe and Mn values partly reflect mineralogy, but it is apparent that they are influenced by other factors (outlined below).



A (subdivision after Milligan, 1962)

III Limestone and siltstone. - almost equal amounts, interbedded and intergrading.
Limestone, aphanitic to silty, grey brown and greenish. Siltstone, calcareous -
 very calcareous, grey, green grey, blue grey, brown, red and chocolate
 occ. Intraformational breccia, minor sandstone

II Dolomite, aphanitic, to crystalline, grey and brown, often silty, minor siltstone, black

I Dolomite, as previous, with dolarenite and pellety dolomite

Fig. 4. Plot of element versus depth - BMR Huckitta No 7.

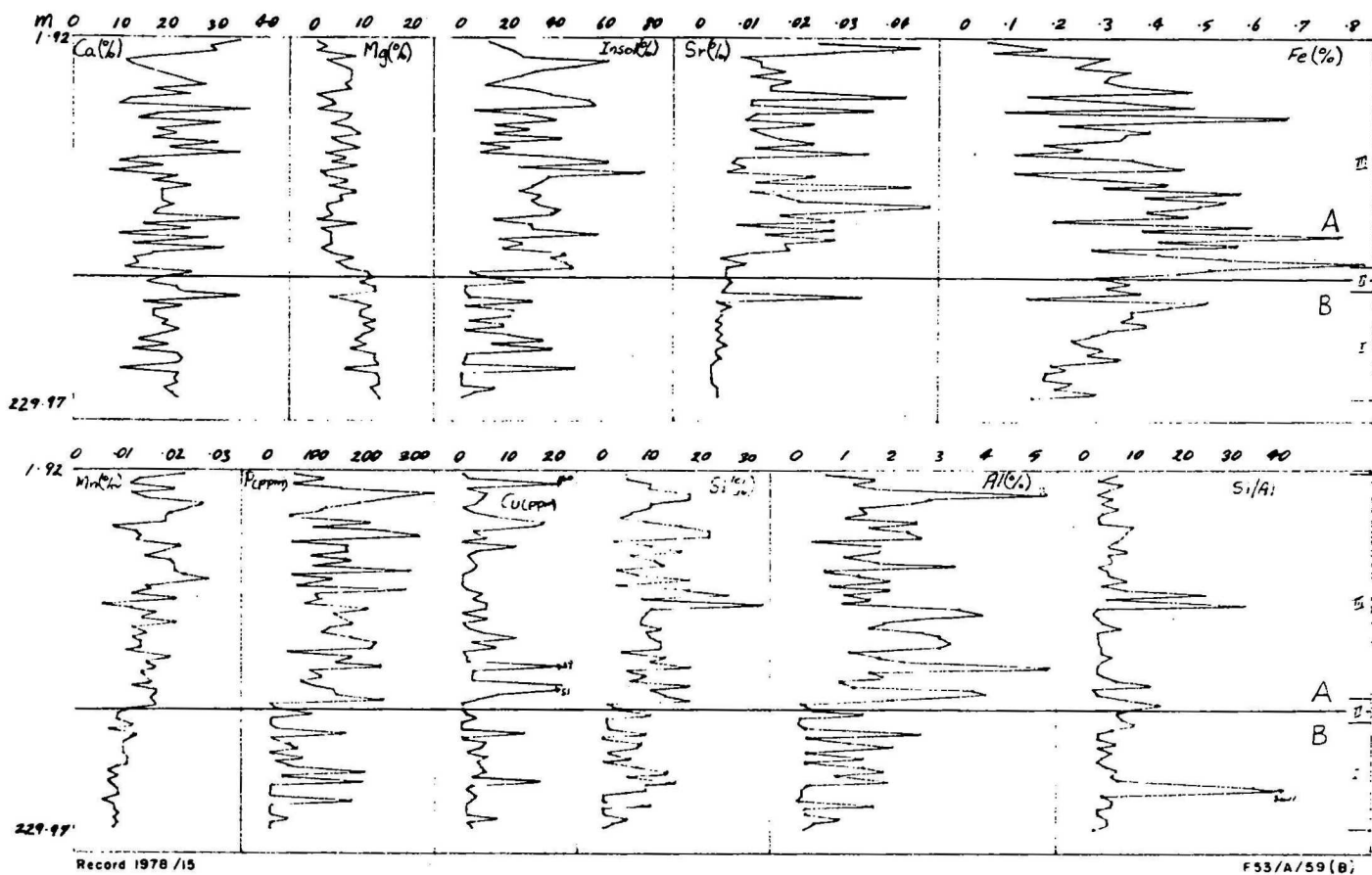


Fig.4. (continued)

(b) Whole-rock fraction. P values tend to parallel those for insoluble residues. Cu values are variable and include some anomalous values. Si and Al values reflect the variation in the terrigenous component. The Si/Al ratio indicates that the terrigenous component tends to be silicon-rich with several very silicon-rich beds. Ba values reflect an association with insoluble residues, but there is some enrichment in the upper part. F values are variable and very high (up to 0.218 percent) in the upper part, but are lower in the lower part of the hole. Organic C values are variable with values increasing and then decreasing with depth.

(c) Comparison with lithology. Three lithological units have been recognised by Milligan (1962). Lithological units I & II are basically dolomites with minor siltstone. Lithological unit III is interbedded limestone and siltstone, with minor intraformational breccia and sandstone. Two geochemical units are discernable - geochemical unit A representing the interbedded limestone (some of which is dolomitic) and siltstone, and geochemical unit B, the dolomite of lithological unit I and part of II. Geochemical unit B has higher Mg values, and lower values of insoluble residues, Sr, Fe, Mn, P, Si, Al, Ba and F. Zn values but not Pb (Draper, in prep.) do reflect the geochemical units.

BMR Huckitta No. 8

(a) HCl-soluble fraction. The sequence consists of limestone and dolomitic limestone with variable insoluble residue content (Fig. 5). Sr values tend to reflect the mineralogy. Fe tends to reflect the Mg content, but is influenced by other factors. Changes in the Mn content also mirror changes in the Mg content.

(b) Whole rock fraction. P values reflect the insoluble residue content. Cu values are variable, but low. Si and Al values are variable, while Si/Al ratios indicate that the terrigenous component is mainly clay with occasional silicon-rich beds. Ba content generally mirrors the insoluble residue content. F values tend to parallel P values, but there are some anomalous values at the base of the hole. Organic C values are relatively constant.

(c) Comparison with lithology. Milligan (1962) recognised two lithological units (Fig. 5), which are distinguished by the presence of siltstone, and the sand and ooid content of the carbonates. Two geochemical units are recognised, but they do not reflect the lithological changes. The geochemical units are recognised by pattern change, although organic C, F and Si/Al do show changes in overall value. Pb and Zn values (Draper, in prep.) are uniform throughout.

DISCUSSION

Element behaviour

Calcium, Magnesium, and insoluble residues. The rocks are predominantly carbonate: limestone, dolomitic limestone, and dolomite. The insoluble residues generally reflect the original terrigenous component although pressure solution and silicification may have had some influence, particularly in Elkedra No. 4.

Strontium. Sr values generally reflect the mineralogy; the more dolomitic (Mg-rich) the carbonate, the lower the Sr content. This reduction in Sr values results mainly from the fact that Sr (Sr^{2+} ionic radius, $1.10\text{\AA}$) substitutes readily for Ca (Ca^{2+} ionic radius, $0.94\text{\AA}$) in carbonate minerals, but does not usually substitute for Mg (ionic radius, $0.65\text{\AA}$). As the amount of Mg increases in the carbonate rock, the relative amount of Ca decreases and hence the actual Sr content must decrease. Ca constitutes 40 percent (by weight) of calcite but only 21.7 percent (by weight) of dolomite, so that, assuming there is no substitution of Sr for Mg, dolomites should have half the quantity of Sr that limestones have.

Other factors affect the strontium content of the rocks. The high values (up to 2.6 percent) in Elkedra No. 5 may be associated with discrete Sr minerals (such as celestite). Strontium minerals in carbonate rocks occur as secondary void filling, nodular and replacement deposits, or are associated with primary evaporites (Graf, 1960). Strontium can also substitute for Ca in gypsum, pseudomorphs of which have been recognised in Huckitta No. 7 (J. Kennard, personal communication, 1978).

The Sr content could also be influenced by original mineralogy (aragonite versus calcite), secondary mineralogy, diagenetic affects (including leaching) and initial supply of Sr to the environment of deposition.

Iron. Ferrous Fe (Fe^{++} ionic radius, $0.76\text{\AA}$) can substitute readily for Mg (Mg^{++} ionic radius, $0.65\text{\AA}$). This is reflected in these rocks, where the Fe content of Mg-rich carbonates is higher than in adjacent Ca-rich rocks. However it is apparent that other factors influence the Fe content (e.g., in Huckitta No. 7 Fe values are generally lower in dolomites than dolomitic limestones, although within each geochemical unit the Fe content does reflect the mineralogy). Factors which could influence the Fe content are: (a) supply (affected by climate, tectonism, currents, and volcanism), (b) mineralogy (primary and secondary), (c) original salinity, and (d) diagenetic effects.

Manganese. With an ionic radius of $0.80\text{\AA}$ (Mn^{2+}), Mn can substitute readily for Mg, and, hence, shows similar behaviour to Fe. Generally Mn reflects the Mg content, but is influenced by other factors, which would be similar to those for Fe.

Phosphorus. The manner in which the P log mirrors the insoluble residue log indicates that P is associated almost entirely with the non-carbonate fraction of the rock, either as apatite or associated with clays.

Copper. Cu has no obvious pattern of behaviour. Possible modes of presence for Cu are: (a) substitution in carbonate minerals, (b) sorbed on clays, (c) sorbed or complexed with organic matter, (d) discrete minerals and (e) substitution in detrital minerals. In Elkedra No. 4, there is a possible association between Cu and organic matter.

Silicon, Aluminium, Si/Al. The Si and Al values reflect the insoluble residues, and the Si/Al ratio indicates whether these residues are clay or quartz rich. Secondary silica would also show up in high Si/Al ratios, but reference to the lithological logs indicate silica is a constituent only in Elkedra No. 4.

Barium shows a pattern similar to that of insoluble residues, indicating that Ba is associated with the non-carbonate fraction. It is generally associated with clays or discrete minerals.

Fluoride is present in quantities in excess of what would be present in phosphate minerals. In most carbonate rocks in the Georgina Basin, F is normally present in phosphate minerals (Draper, 1976; in prep.) and rarely as fluorite. F can be sorbed on clays or held in clay and mica lattices, but no obvious association can be recognised between F and insoluble residues or Al content, so it seems likely that F is present as fluorite. High F values may be associated with an evaporative environment (Graf, 1960; Moore and others, 1972) or algal matter (Graf, 1960).

Organic carbon. Since higher plants did not exist in the Upper Cambrian and invertebrate fossils are very rare in the Arrinthrungra Formation, the major contributor to organic matter was probably algae. Early diagenetic alteration of algal bodies would result in oxidation of organic matter.

Environmental implications

Draper (in prep.) found that the acid-soluble fraction elements are useful in defining differences between rock units in the Georgina Basin, and that whole-rock fraction elements, except for Organic C, are of limited value. In this report, differences within a rock unit are examined. In Table 1, the elements contributing most to the separation of geochemical units are shown: F and Organic C are most important. However, the significance of the geochemical differences cannot be determined until detailed studies of the Arrinthrungra and its depositional environments are complete.

TABLE 1. ELEMENTS WHICH HELP DISTINGUISH GEOCHEMICAL UNITS

Stratigraphic Hole	Difference in values	Difference in geochemical log pattern
BMR ELKEDRA NO. 4	F, Organic C	Al, Si, Si/Al, Cu, P, Insol Res., (Fe) ^(a)
BMR ELKEDRA NO. 5	F, Organic C, Sr	Mn, Si, Si/Al, (Cu)
BMR HUCKITTA NO. 7	F, Mg, Sr, Ba, Insol Res.	Fe, Mn, P, Cu, Si, Al
BMR HUCKITTA NO. 8	F, Organic C, Si/Al	Fe, Cu, Al

(a) bracketed elements are those where difference is minimal.

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APPENDIX I

GEOCHEMICAL DATA

Sample

No.	Depth (m)	Hole	Ca	Mg	Insol	Sr	Fe	Mn	P	Cu	Si (sill- con)	Al	Si/Al	Ba	F	Org C	Ca/Mg	Sr/Ca	Fe/Mn	Pb/Zn
74715314	32.00	Elkedra No. 4	19.7	11.4	10.8	0.004	0.305	0.012	115	9	3.60	0.63	5.71	35	.011	0.06				
315	38.40		19.2	11.8	10.3	0.004	0.265	0.010	150	7	3.60	0.77	4.68	50	.012	0.05				
316	44.19		20.5	12.5	3.55	0.003	0.375	0.012	50	2	1.22	0.30	4.07	20	.0075	0.06				
317	47.24		19.0	9.70	22.4	0.004	0.28	0.009	155	14	8.05	1.33	6.02	80	.020	0.03				
318	50.29		23.0	12.5	2.10	0.003	0.26	0.011	<10	2	0.75	0.13	5.77	<10	.009	0.03				
319	53.34		20.1	10.9	15.5	0.003	0.42	0.012	25	4	6.20	0.67	9.25	55	.0075	0.02				
320	56.39		21.5	12.0	8.25	0.003	0.41	0.012	30	14	3.10	0.59	5.25	25	.015	0.05				
321	59.44		18.8	9.15	23.3	0.004	0.375	0.011	80	4	8.62	1.45	5.94	90	.026	0.07				
322	62.48		21.7	11.9	4.50	0.003	0.42	0.013	<10	4	1.68	0.36	4.67	15	.009	0.06				
323	65.53		21.9	12.3	3.25	0.003	0.465	0.015	35	2	1.15	0.21	5.48	15	.0075	0.09				
324	68.58		17.3	9.40	26.1	0.002	0.375	0.012	195	7	12.0	0.71	16.90	50	.034	0.16				
325	71.63		23.4	9.65	10.2	0.002	0.335	0.012	65	10	4.20	0.48	8.75	20	.009	<0.01				
326	74.68		8.15	4.15	62.7	0.003	0.34	0.007	330	8	19.2	5.40	3.56	250	.061	0.10				
327	77.72		20.3	11.8	10.3	0.004	0.36	0.012	75	2	3.40	0.70	4.86	35	.025	0.08				
328	80.77		18.3	10.5	18.3	0.005	0.345	0.013	95	5	5.95	1.63	3.65	65	.063	0.09				
329	83.82		23.2	12.8	1.26	0.003	0.33	0.012	10	4	0.41	0.10	4.10	10	.0065	0.09				
330	86.87		18.6	11.0	15.7	0.004	0.35	0.011	110	2	5.50	1.66	3.31	50	.047	0.04				
331	89.92		18.9	11.2	12.6	0.004	0.355	0.011	65	4	4.08	0.98	4.16	35	.018	0.08				
332	92.96		19.9	11.5	16.2	0.005	0.315	0.012	70	8	5.85	1.33	4.40	65	.042	0.10				

Sample No.	Depth (m)	Hole	Ca	Mg	Insol	Sr	Fe	Mn	P	Cu	Si (Si11-con)	Al	Si/Al	Ba	F	Org C	Ca/Mg	Sr/Ca	Fe/Mn	Pb/Zn
74715333	96.01	Elkedra No. 4	17.7	10.5	24.7	0.004	0.315	0.010	230	3	7.90	2.08	3.80	100	0.052	0.10				
334	99.06		22.1	13.1	2.20	0.003	0.375	0.012	20	1	0.82	0.20	4.10	20	.014	0.08				
335	102.11		23.1	13.6	2.20	0.003	0.305	0.012	20	1	0.92	0.26	3.54	<10	.023	0.06				
336	105.16		20.8	12.7	6.92	0.004	0.255	0.011	25	4	2.46	0.48	5.13	30	.015	0.10				
337	108.20		19.7	12.1	6.30	0.003	0.30	0.012	40	1	2.18	0.53	4.11	25	.023	0.08				
338	111.25		18.7	11.2	14.7	0.002	0.27	0.011	85	1	6.95	0.31	22.42	35	.0095	0.06				
339	114.30		20.0	11.5	14.3	0.004	0.25	0.010	80	1	4.70	1.00	4.70	50	.034	0.08				
340	117.35		21.3	12.7	5.90	0.004	0.34	0.011	10	<1	2.10	0.50	4.20	10	.017	0.06				
341	120.40		6.60	3.25	68.8	0.001	0.180	0.004	55	3	31.9	0.65	49.08	160	.007	0.07				
342	123.44		18.1	10.4	18.6	0.005	0.27	0.011	90	2	6.90	1.13	6.11	70	.021	0.04				
343	126.49		20.1	11.5	15.8	0.007	0.26	0.011	80	2	6.00	0.82	7.32	50	.023	0.06				
344	129.54		21.8	12.1	3.85	0.005	0.28	0.013	15	1	1.18	0.30	3.93	20	.010	0.04				
345	132.59		20.6	13.4	1.48	0.003	0.31	0.012	<10	2	0.62	0.10	6.20	10	.006	0.08				
346	135.64		20.7	12.8	3.45	0.005	0.345	0.012	10	2	1.40	0.25	5.60	20	.0075	0.06				
347	138.68		37.0	1.56	2.20	0.039	0.055	0.004	<10	<1	0.93	0.10	9.30	<10	.0035	0.04				
348	141.73		15.90	8.50	30.0	0.006	0.29	0.010	195	2	10.8	1.86	5.81	110	.057	0.08				
349	144.78		21.2	12.3	3.65	0.006	0.305	0.011	20	1	1.30	0.36	3.61	15	.052	0.08				
350	147.83		22.2	12.5	2.70	0.004	0.38	0.012	20	<1	0.95	0.27	3.52	20	.052	0.07				
351	150.88		22.0	11.7	6.55	0.006	0.32	0.010	30	1	2.43	0.46	5.28	25	.016	0.09				

Sample No.	Depth (m)	Hole	Ca	Mg	Insol	Sr	Fe	Mn	P	Cu	Si (Silica)	Al	Si/Al	Ba	F	Org C	Ca/Mg	Sr/Ca	Fe/Mn	Pb/Zn
74715352	153.92	Elkedar No. 4	17.1	9.75	22.1	0.006	0.33	0.010	115	11	6.95	1.95	356	110		I.S.				
353	157.58		19.7	11.3	10.6	0.005	0.435	0.011	45	4	4.70	0.60	7.83	35	.0085	0.12				
354	160.63		18.1	10.1	19.6	0.006	0.51	0.013	100	12	7.35	1.20	6.13	60	.032	0.24				
355	163.37		19.1	10.2	17.9	0.006	0.545	0.015	70	4	6.30	1.45	4.34	80	.037	0.11				
356	166.12		15.2	8.30	33.0	0.005	0.70	0.015	190	7	10.8	2.74	3.94	150	.055	0.17				
357	169.16		21.3	10.2	10.1	0.007	0.64	0.015	45	2	3.70	0.80	4.63	50	.030	0.10				
358	172.21		22.7	6.75	19.9	0.009	0.545	0.013	110	5	6.80	1.50	4.53	95	.038	0.18				
359	175.56		27.7	6.40	8.95	0.024	0.34	0.010	35	3	3.30	0.55	6.00	20	.019	0.18				
360	178.31		17.2	9.40	22.9	0.007	0.64	0.012	80	9	7.60	1.85	4.11	80	.118	0.19				
361	181.36		20.1	11.2	12.4	0.005	0.48	0.010	35	6	5.50	0.55	10.00	35	.790	0.10				
362	184.40		35.4	2.10	5.15	0.017	0.12	0.005	20	3	2.20	0.38	5.79	15	.013	0.22				
363	187.45		18.5	10.9	18.0	0.007	0.42	0.009	60	7	6.50	1.33	4.89	150	.034	0.16				
364	190.50		15.1	8.45	35.4	0.005	0.34	0.011	205	7	11.6	2.78	4.17	140	.104	0.14				
365	193.85		21.0	12.2	7.60	0.004	0.41	0.009	30	2	2.96	0.50	5.92	40	.060	0.09				
366	196.60		19.2	11.4	13.90	0.004	0.36	0.008	35	15	4.88	1.00	4.88	50	.018	0.24				
367	199.64		21.5	13.7	1.42	0.004	0.35	0.009	10	1	0.53	0.09	5.89	20	.196	0.08				
368	202.69		20.3	12.2	11.4	0.005	0.295	0.008	55	3	3.98	0.88	4.52	30	.028	0.14				
369	205.74		24.0	12.2	1.18	0.004	0.255	0.008	10	1	0.47	0.13	3.62	15	.0075	0.05				
370	208.79		13.4	7.65	40.2	0.004	0.43	0.008	100	14	12.3	3.80	4.10	170	.089	0.89				

No.

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Sample

No.	Depth (m)	Hole	Ca	Mg	Insol	Sr	Fe	Mn	P	Cu	Si (Silicon)	Al	Si/Al	Ba	F	Org C	Ca/Mg	Sr/Ca	Fe/Mn	Pb/Zn
74715286	52.73	Elkedra No. 5	35.0	0.17	15.6	0.022	0.085	0.012	105	66	5.75	0.87	6.61	110	0.010	0.06				
287	55.78		9.25	4.85	56.0	0.003	0.44	0.031	330	4	16.6	4.52	3.67	270	.046	0.03				
288	59.04		14.6	7.35	33.6	0.007	0.58	0.017	160	3	10.0	2.86	3.50	680	.053	0.09				
289	62.18		34.0	0.80	13.8	0.022	0.20	0.012	70	63	3.98	1.29	3.09	60	.021	0.07				
290	64.92		31.5	0.35	22.6	0.032	0.17	0.009	90	5	6.05	1.86	3.25	120	.019	0.07				
291	67.97		17.3	2.10	45.7	0.009	0.33	0.009	205	17	14.1	3.92	3.60	200	.053	0.07				
292	71.02		14.2	7.40	35.6	0.007	0.50	0.014	240	19	10.4	3.22	3.23	160	.055	0.05				
293	73.76		30.5	4.60	7.05	0.019	0.25	0.015	45	3	2.26	0.53	4.26	140	.013	0.03				
294	76.81		22.1	8.80	14.7	0.009	0.355	0.018	70	9	4.57	1.09	4.19	60	.025	0.10				
295	80.16		28.4	4.05	16.8	0.013	0.28	0.014	80	5	6.50	1.00	6.50	230	.017	0.06				
296	82.60		14.5	6.85	42.0	0.007	0.56	0.018	255	16	11.4	2.56	4.45	620	.096	0.07				
297	85.65		20.8	7.40	16.3	2.60	0.645	0.025	105	6	5.60	1.45	3.86	1700	.640	0.11				
298	89.00		26.6	1.27	28.7	0.042	0.28	0.016	75	8	12.2	1.13	10.80	110	.332	0.07				
299	92.35		14.0	2.25	52.7	0.22	0.495	0.015	300	15	18.5	3.38	5.47	290	.148	0.18				
300	95.10		16.1	5.0	42.8	0.009	0.405	0.019	250	4	13.9	3.14	4.43	170	.082	0.09				
301	98.15		36.5	1.75	9.15	0.030	0.135	0.015	30	4	3.07	0.61	5.03	40	.011	0.04				
302	101.19		13.8	6.20	43.1	0.006	0.42	0.018	190	4	17.3	1.66	10.42	120	.096	0.08				
303	104.24		17.6	9.00	25.2	0.085	0.63	0.024	105	9	7.80	2.46	3.17	160	.075	0.18				
304	107.29		26.0	3.65	25.1	0.015	0.305	0.017	115	3	8.85	1.74	5.09	80	.065	0.06				

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[illegible]

Sample No.	Depth (m)	Hole	Ca	Mg	Insol	Sr	Fe	Mn	P	Cu	Si (Silicon)	Al	Si/Al	Ba	F	Org C	Ca/Mg	Sr/Ca	Fe/Mn	Pb/Zn
74715376	1.92	Huckitta No. 7	34.5	0.31	12.5	0.025	0.055	.023	60	<1	5.15	0.67	7.69	100	0.006	0.03				
377	4.27		28.7	2.80	18.2	0.046	0.175	0.014	120	2	5.55	1.65	3.36	100	0.037	0.15				
378	7.32		30.0	0.28	23.8	0.028	0.065	0.012	60	160	10.2	1.23	8.29	130	0.0065	0.04				
379	10.55		18.1	8.45	26.8	0.009	0.305	0.021	155	2	10.0	1.68	5.95	110	0.030	0.06				
380	13.41		11.0	2.25	61.3	0.013	0.275	0.012	350	6	18.4	5.30	3.47	250	0.062	0.08				
381	16.46		12.2	5.30	49.1	0.013	0.235	0.015	260	5	18.1	2.80	6.46	200	0.048	0.07				
382	19.57		16.2	7.65	32.1	0.018	0.35	0.027	195	4	10.6	2.46	4.31	130	0.070	0.09				
383	22.65		19.5	7.80	26.2	0.011	0.305	0.024	125	2	10.0	1.33	7.52	80	0.035	0.08				
384	25.60		23.1	7.55	18.4	0.019	0.295	0.020	105	3	6.40	1.50	4.27	75	0.041	0.10				
385	28.65		27.7	6.20	11.6	0.015	0.34	0.019	50	8	4.05	1.08	3.75	50	0.047	0.10				
386	31.61		16.8	7.45	31.3	0.015	0.475	0.019	215	18	9.90	2.55	3.88	130	0.078	0.11				
387	34.69		24.2	0.59	39.4	0.043	0.135	0.008	100	16	16.6	1.53	10.85	130	0.039	0.09				
388	37.80		11.8	3.65	55.2	0.011	0.335	0.013	250	3	22.7	2.38	9.54	180	0.063	0.12				
389	40.75		9.60	4.25	57.3	0.011	0.48	0.014	320	6	22.9	2.64	8.67	2000	0.106	0.13				
390	43.77		36.7	0.95	6.35	0.036	0.090	0.013	55	1	2.78	0.39	7.13	35	0.0065	0.05				
391	46.94		17.4	7.75	28.7	0.012	0.675	0.022	170	12	10.7	1.79	5.98	130	0.043	0.18				
392	49.99		13.5	6.90	40.6	0.010	0.49	0.019	170	4	16.5	1.79	9.22	200	0.080	0.10				
393	53.03		30.5	3.20	15.8	0.024	0.20	0.015	95	2	6.05	1.02	5.93	65	0.063	0.07				
394	56.24		17.3	7.80	29.9	0.011	0.39	0.020	175	3	11.2	1.73	6.47	130	0.043	0.08				

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Sample No.	Depth (m)	Hole	Ca	Mg	Insol	Sr	Fe	Mn	P	Cu	Si (Si11con)	Al	Si/Al	Ba	F	Org C	Ca/Mg	Sr/Ca	Fe/Mn	Pb/Zn
74715395	59.16	Huckitta No. 7	21.1	9.10	15.1	0.014	0.34	0.021	100	4	13.1	3.35	3.91	50	0.037	0.13				
396	62.21		16.7	3.50	43.4	0.017	0.33	0.021	300	3	3.42	0.83	5.43	220	0.102	0.11				
397	65.30		30.0	5.20	9.20	0.024	0.17	0.023	55	<1	7.55	1.32	5.72	25	0.021	0.07				
398	68.28		20.0	9.05	21.2	0.012	0.25	0.028	135	1	18.5	2.00	9.25	75	0.033	0.08				
399	71.38		34.5	2.10	9.05	0.035	0.11	0.015	65	<1	3.20	0.76	4.21	40	0.027	0.07				
400	74.45		13.5	6.20	47.1	0.008	0.355	0.016	290	2	18.3	1.99	9.20	140	0.038	0.13				
401	77.75		9.85	3.50	62.7	0.007	0.39	0.012	105	5	26.8	1.05	25.52	470	0.218	0.12				
402	80.52		18.6	8.75	25.0	0.010	0.46	0.021	115	3	8.65	1.59	5.44	240	0.033	0.11				
403	83.82		7.40	1.06	78.0	0.006	0.11	0.006	80	6	33.8	1.00	33.80	330	0.006	0.06				
404	87.10		21.5	2.40	37.9	0.024	0.255	0.012	210	6	10.9	3.46	3.15	200	0.066	0.16				
405	89.76		16.3	6.90	34.4	0.012	0.415	0.017	140	1	9.90	3.98	2.49	150	0.044	0.13				
406	92.79		24.2	3.00	30.4	0.044	0.295	0.014	155	6	8.85	2.50	3.54	130	0.049	0.12				
407	95.96		18.4	8.40	25.5	0.011	0.575	0.021	180	1	8.40	1.89	4.44	120	0.038	0.13				
408	98.83		18.7	5.05	34.4	0.017	0.380	0.012	130	2	12.80	1.55	8.26	120	0.186	0.10				
409	101.86		18.6	5.70	30.9	0.021	0.545	0.015	115	5	9.70	2.70	3.59	130	0.054	0.27				
410	104.98		20.9	2.55	33.7	0.048	0.49	0.012	175	12	10.1	3.02	3.34	170	0.087	0.45				
411	107.90		17.5	2.35	42.6	0.034	0.385	0.014	230	3	12.4	3.25	3.82	160	0.086	0.15				
412	110.95		16.8	3.95	39.5	0.017	0.465	0.014	220	8	12.8	3.02	4.20	160	0.052	0.12				
413	114.12		34.1	0.91	14.3	0.028	0.19	0.011	45	1	4.62	1.15	4.02	55	0.036	0.13				

Sample No.	Depth (m)	Hole	Ca	Mg	Insol	Sr	Fe	Mn	P	Cu	Si (Si111)- con	Al	Si/Al	Ba	F	Org C	Ca/Mg	Sr/Ca	Fe/Mn	Pb/Zn
74715414	117.20	Huckitta No. 7	14.9	8.80	30.9	0.008	0.60	0.020	175	2	11.3	1.79	6.31	420	0.109	0.12				
415	120.24		24.1	1.53	31.1	0.028	0.375	0.015	145	2	10.2	2.30	4.43	1500	0.054	0.12				
416	123.11		9.55	3.40	58.6	0.014	0.785	0.017	240	39	18.6	5.35	3.48	260	0.129	0.25				
417	126.19		28.0	3.20	17.5	0.028	0.41	0.014	90	3	5.55	1.55	3.58	95	0.058	0.11				
418	129.23		22.4	3.80	26.4	0.018	0.57	0.015	115	3	9.15	1.85	4.95	110	0.144	0.17				
419	132.44		31.0	1.73	18.8	0.019	0.27	0.016	70	3	6.70	0.95	7.05	60	0.017	0.16				
420	135.43		16.5	3.65	44.1	0.010	0.41	0.012	100	22	18.7	1.26	14.84	150	0.018	0.12				
421	138.63		12.2	8.00	39.1	0.005	0.545	0.017	140	51	10.6	3.78	2.80	200	0.057	0.19				
422	141.56		13.2	4.75	44.4	0.010	0.83	0.017	150	8	13.3	4.02	3.31	220	0.086	0.33				
423	144.58		10.9	6.85	47.1	0.006	0.51	0.016	245	4	18.5	1.95	9.49	140	0.028	0.19				
424	147.93		24.4	11.0	4.50	0.006	0.45	0.017	<10	<1	1.98	0.12	16.5	10	0.008	0.18				
425	150.75		19.5	12.2	10.4	0.006	0.28	0.011	20	1	4.14	0.45	9.20	25	0.037	0.09				
426	153.82		15.6	9.45	27.5	0.007	0.30	0.009	95	2	10.5	1.43	7.34	85	0.095	0.10				
427	156.77		21.5	12.9	3.00	0.006	0.25	0.009	10	4	1.27	0.15	8.47	20	0.1010	0.18				
428	159.90		22.4	12.9	2.55	0.005	0.32	0.012	<10	1	1.10	0.10	11.00	<10	0.010	0.05				
429	162.86		34.3	3.10	4.55	0.034	0.135	0.007	20	1	1.80	0.27	6.67	25	0.007	0.11				
430	165.91		14.5	8.80	30.4	0.004	0.51	0.013	165	14	9.95	2.66	3.74	120	0.043	0.26				
431	169.09		22.5	11.9	2.50	0.007	0.43	0.012	10	1	0.84	0.25	3.36	10	0.0075	0.08				
432	172.00		16.4	9.90	23.0	0.005	0.35	0.010	50	6	8.50	1.19	7.14	85	0.023	0.13				

Sample No.	Depth (m)	Hole	Ca	Mg	Insol	Sr	Fe	Mn	P	Cu	Si (Silicon)	Al	Si/Al	Ba	F	Org C	Ca/Mg	Sr/Ca	Fe/Mn	Pb/Zn
74715433	175.00	Huckitta No. 7	16.5	9.60	21.8	0.005	0.355	0.010	65	5	7.70	2.04	3.77	95	0.042	0.11				
434	181.10		19.4	12.5	4.55	0.004	0.33	0.010	<10	2	1.78	0.27	6.59	20	0.007	0.06				
435	184.12		18.5	10.1	18.7	0.005	0.38	0.011	75	6	6.05	1.45	4.17	65	0.024	0.24				
436	187.20		21.9	12.2	2.90	0.004	0.305	0.011	20	4	0.90	0.25	3.60	10	0.008	0.12				
437	190.42		17.9	10.0	21.0	0.005	0.27	0.009	55	5	7.55	1.43	5.28	65	0.023	0.11				
438	193.24		13.4	8.25	35.4	0.004	0.23	0.007	205	6	14.0	1.84	7.61	170	0.022	0.11				
439	196.42		19.2	10.8	14.0	0.006	0.25	0.009	35	3	5.50	0.90	6.11	60	0.015	0.09				
440	199.47		12.1	7.50	39.7	0.004	0.29	0.007	200	17	15.8	1.99	7.94	130	0.029	0.13				
441	202.52		21.3	12.6	3.30	0.004	0.26	0.008	<10	3	9.75	0.30	35.52	20	0.007	0.16				
442	205.46		22.5	12.5	2.55	0.005	0.33	0.009	10	2	9.75	0.18	54.17	15	0.0095	0.09				
443	208.54		21.5	13.1	2.00	0.003	0.185	0.009	<10	4	0.69	0.17	4.06	<10	0.005	0.06				
444	211.61		9.85	6.55	48.4	0.003	0.215	0.006	175	3	0.54	0.08	6.75	150	0.008	0.07				
445	214.80		21.9	13.0	1.38	0.003	0.175	0.008	<10	2	10.4	1.65	6.30	15	0.004	0.07				
446	217.80		20.9	13.4	1.68	0.003	0.17	0.008	<10	2	0.67	0.20	3.35	10	0.005	0.06				
447	220.88		21.4	13.4	1.50	0.003	0.23	0.009	<10	2	0.80	0.23	3.48	10	0.0045	0.07				
448	224.13		18.7	11.9	14.8	0.004	0.195	0.008	45	8	5.50	0.96	5.73	45	0.010	0.05				
449	226.77		20.2	12.8	6.20	0.004	0.28	0.009	10	2	2.46	0.43	5.72	20	0.0075	0.07				
450	229.97		21.6	13.3	1.60	0.004	0.145	0.008	<10	3	0.56	0.20	2.80	<10	0.005	0.04				

Sample No.	Depth (m)	Hole	Ca	Mg	Insol	Sr	Fe	Mn	P	Cu	Si (Silicon)	Al	Si/Al	Ba	F	Org C	Ca/Mg	Sr/Ca	Fe/Mn	Pb/Zn
74715260	3.66	Huckitta No. 8	25.7	0.31	37.2	0.021	0.215	0.012	120	4	10.7	3.55	3.01	200	0.036	0.09				
261	6.48		25.2	0.36	35.0	0.020	0.155	0.012	135	15	10.4	3.26	3.19	150	0.034	0.10				
262	9.77		33.0	0.98	14.9	0.029	0.195	0.014	55	2	4.36	1.27	3.43	65	0.014	0.07				
263	12.65		22.4	6.30	24.7	0.010	0.40	0.030	100	8	8.00	1.82	4.40	95	0.029	0.08				
264	15.52		15.0	6.30	36.5	0.009	0.61	0.016	160	3	10.9	3.44	3.17	140	0.037	0.12				
265	18.55		13.6	3.15	50.0	0.007	0.31	0.011	300	2	18.4	3.22	5.35	190	0.026	0.10				
266	21.68		20.5	5.00	29.6	0.018	0.42	0.015	145	12	9.70	2.70	3.59	130	0.033	0.13				
267	24.67		35.1	1.33	5.05	0.061	0.125	0.011	30	2	1.56	0.44	3.55	20	0.007	0.07				
268	27.69		14.0	6.56	38.5	0.006	0.78	0.018	135	6	11.5	3.68	3.13	170	0.007	0.14				
269	30.68		21.6	9.90	11.9	0.008	0.49	0.019	70	3	3.63	0.79	4.59	50	0.033	0.05				
270	33.66		22.9	8.15	14.2	0.019	0.58	0.021	70	6	4.36	0.95	4.54	2650	0.048	0.10				
271	36.62		28.8	3.10	17.9	0.036	0.395	0.021	105	7	6.15	1.23	5.00	65		0.17				
272	39.60		19.9	4.95	29.7	0.010	0.61	0.019	190	4	9.15	2.68	3.40	130	0.054	0.17				
273	42.71		38.5	0.42	1.76	0.068	0.11	0.011	15	10	0.79	0.09	8.78	20	0.055	0.12				
274	45.70		22.0	0.52	44.0	0.022	0.155	0.011	210	3	15.4	2.60	5.92	170	0.026	0.07				
275	48.62		36.6	0.19	3.05	0.031	0.055	0.014	15	1	0.98	0.15	6.53	20	0.008	0.07				
276	54.73		37.2	0.22	6.40	0.064	0.045	0.010	20	<1	2.03	0.47	4.32	65	0.006	0.05				
277	63.98		33.8	4.75	1.58	0.021	0.21	0.021	15	<1	0.53	0.13	4.08	25	0.013	0.07				
278	66.88		17.5	2.05	49.5	0.014	0.13	0.012	95	2	22.4	0.47	47.66	75	0.009	0.05				

[illegible]