DEPARTMENT OF MINES
SOUTH AUSTRALIA

SOURCE AND DISTRIBUTION OF HEAVY METALS IN CAMBRIAN AND MARINOAN SHELF SEDIMENTS IN SOUTH AUSTRALIA

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SOURCE AND DISTRIBUTION OF HEAVY METALS IN CAMBRIAN AND MARINOAN SHELF SEDIMENTS IN SOUTH AUSTRALIA.*

ABSTRACT

The sedimentary environment of Cambrian and Marinoan shelf sediments in South Australia is outlined. Tables are presented showing the distribution of Cu and Pb in the various facies of these sediments.

Low grade copper mineralisation in some Marinoan shale and dolomite units is considered to be contemporaneous with sedimentation. The extensive enrichment of Pb in basal Cambrian sediments is attributed to either a sedimentary exhalative process contemporaneous with sedimentation or later telethermal mineralisation related to an Ordovician orogeny. Basement fault-shear lineaments and areas of Pb and Cu enrichment are inter-related.

INTRODUCTION

Since 1960 over 4,000 bulk rock samples have been collected by officers of the Geological Survey of South Australia from measured rock sections and drill holes in Cambrian and Marinoan sediments. The samples have been analysed for Pb, Zn, Cu, Ag, Cr, Co, Ni, by Australian Mineral Development Laboratories using a Baird 3 metre grating spectrograph. Where required chemical analyses for $CaCO_3$, $MgCO_3$ and P_2O_5 have also been made. The sections have all been studied as stratigraphic columns with profile plots of the elements.

For this paper the Pb and Cu results for 10 sections on the shelf and adjacent marginal geosynclinal zone are outlined in Tables 1 to 4.

The results have been arranged in stratigraphic order and grouped in the various sedimentary facies. Each rock sample analysed comprised a number of evenly spaced rock chips. The samples representing each facies are divided into two categories depending on metal content, as follows:

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(Contribution to Geological Session 1 on Structure and Geochemistry of Sedimentary Basins, Eighth Commonwealth Mining & Metallurgical Congress. Aust. & N.Z. - 1965).

	Category 1	Category 2
Pb	20 ppm or less	Greater than 20 ppm
Cu	30 ppm or less	Greater than 30 ppm

The average for each facies is obtained in each category by weighting results in proportion to the stratigraphic thickness represented by the sample. In this way an approximate value is obtained for the overall metal content of each rock unit. Weathering has affected the metal concentration of some surface samples, particularly in the basal arenites of the Cambrian. Most outcrops sampled were however relatively free from weathering alteration.

GEOLOGICAL ENVIRONMENTS

Extensive areas of flat lying Marinoan sediments occur on the Stuart Shelf. They are represented by the arenites of the Tent Hill Formation and the underlying Tregolana or Woomera Shale. These lutites are red-brown shales and siltstones with green shale laminae. Similar facies with the addition of dolomite occur in the Wilpena Group to the east in the geosyncline and marginal area. The uppermost Precambrian unit in this Group is the Pound Quartzite. The shelf and geosynclinal marginal zone is approximately defined by fault lineaments and is transitional in character. East of the shelf zone the Marinoan sequences are folded and are underlain by a thick succession of glacio-marine sediments. Farther to the southeast the Marinoan lutites become dominantly green in colour (Ulupa Siltstone). They are not represented in the tables, average metal contents are Pb 13 ppm and Cu 20 ppm.

The Marinoan sequences and lithologies on the Stuart Shelf and eastwards into the geosyncline indicate that conditions were transitional. The lutites represent shallow water muds deposited in an extensive marine gulf. Conditions changed gradually to a littoral or lagoonal environment at the close of Marinoan time with dominantly arenite sedimentation.

The Lower Cambrian marked a striking return to a marine environment following a probable hiatus or minor erosional event in the shelf area. The base of the Cambrian is represented by arenites which are very thin in the shelf area but generally thicken greatly in trough zones in the geosyncline to the east. The arenites grade upward into a very thick carbonate sequence, the lower member is dolomite but this tongues out to the east within the great Wilkalwillina and Parara Limestone succession, (Dalgarno, 1964). Later in the Cambrian, lutites and an increasing proportion of arenites were deposited. In Middle Cambrian time, marine carbonates were again deposited.

DISTRIBUTION OF LEAD (TABLES 1 & 2)

The Marinoan lutites fall within or close to the expected geochemical range of lead content expected for shales. The arenites in the Kulpara and Sellick Hill sections show local high lead contents. These are attributed to later migration or mineralisation in veins and fractures.

The Lower Cambrian sediments have striking lead concentrations in the basal clastics and dolomites within the marginal geosynclinal zone in many sections. (Thomson, 1962).

In the western shelf area, in the few sections sampled to date, no lead enrichment has been found in the basal Cambrian. This evidence, (Table 1), would appear to discount a sedimentary transfer of lead-rich sediments across the shelf from a western source area.

The Ediacara Mineral Field, (Nixon, 1963), represents the largest known lead concentration in the Lower Cambrian in South Australia. Early production was mainly from enriched patches of carbonate ore, subsequent extensive drilling by the Department of Mines to date has outlined 17 million tons of 1.13% Pb. (Nixon, 1964, unpub. Rept. R.B.58/135). Dominant mineralisation is galena.

The lead enrichment extends over a greater stratigraphic thickness of the Lower Precambrian sequence at Ediacara than in any other section yet sampled elsewhere in South Australia, (see Table 2).

DISTRIBUTION OF COPPER (TABLES 3 & 4)

The Marinoan lutites on the shelf area are generally low in copper. Copper is more abundant to the east in the marginal zone of the geosyncline, some of the concentrations appear to be related to later epigenetic mineralisation. Generally copper enrichment occurs (sometimes with visible malachite staining-, in green shale phases of the lutite, although not all green shales are cupriferous. Farther east in the geosyncline in the areas covered by the Blinman and Arrowie 1 mile sheets a striking cupriferous unit occurs. This is the Wearing Dolomite Member of the upper Marinoan lutite, the Bunyeroo Formation. The member is a persistent dolomite and shale unit several feet thick which has been mapped over a strike extent about 40 miles. Copper content is in places at least 2000 ppm. Traces of copper sulphides are present.

Further details have been published by Horwitz (1962) and the writer.*

The basal Cambrian in the eastern marginal zone shows an association with traces of stratiform copper mineralisation. Small copper ore bodies occur in cross cutting structures in the Lower Cambrian carbonates at a number of localities in the Flinders Ranges.

Copper concentrations of several hundred ppm. occur in red and green siltstones in the late Lower Cambrian Billy Creek Formation. Tuffaceous members are also associated with this Formation.

GAWLER RANGE VOLCANICS

The Cambrian and Marinoan sediments were derived from older Precambrian rocks to the west and south of the shelf zone. The Gawler Range Volcanics form extensive rock masses in this region and were very probably exposed to erosion during part of Marinoan and Cambrian time.

Reconnaissance sampling (170 samples) of the volcanics indicates that they may have an average composition of about 10 ppm. Cu and 40 ppm Pb, and consequently do not provide source material for the sediments which are exceptionally rich in heavy metals.

ORIGIN OF THE LEAD AND COPPER

The cupriferous members in the Marinoan lutites appear to be contemporaneous with sedimentation in a marine environment, apparently under reducing conditions. The Wearing Dolomite Member is followed

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*B. P. Thomson "Geology & Mineralisation in South Australia" in "Geology of Aust. Ore Deposits" 8th Comm. Min. Met. (1965) (in press).

by a dolomite sequence with abundant algal structures. It is possible that the extraction of copper from sea water was facilitated by an organic process and later the metal was fixed by absorption on clays. Large scale slumping accompanied by hinge line movement has been observed in the geosynclinal area at about this time interval of the Marinoan, (Coats, 1964). The possibility of enrighment of the bottom sediments in copper by submarine springs along hinge lines in local basins must be considered.

A sedimentary-exhalative origin for the lead in the basal Cambrian has been suggested by the writer, Thomson (1962). Contemporaneous enrichment of the sediments from below was attributed to solutions or gases emanating along basement fault lineaments. Cambrian volcanic activity was in progress at this time in other parts of Australia.

Continued regional mapping has given support to the importance of lineaments in mineralisation control and the distribution of geochemically high areas. Regional mapping evidence now shows that the Ediacara mineral field is located on the eastern side of a major north-south fault or shear zone.

Any theory of ore genesis must take these structural features into account. An alternative to the sedimentary-exhalative hypothesis is to relate the basal Cambrian lead mineralisation to the widespread Ordovician orogeny in South Australia which is becoming apparent from Rb/Sr age determinations (W. Compston, pers. comm.). This alternative hypothesis would suggest that telethermal solutions rose along lineaments and deposited most of the lead in the covering blanket of Cambrian carbonate. Some solutions escaped to higher levels in piercement structures or along active fault structures such as those known in Kangaroo Island and in Fleurieu Peninsula to the south of Adelaide.

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TABLE 1 LEAD DISTRIBUTION IN SHELF SEDIMENTS

AGE	FACIES	WOOMERA D.D.H. NO. 1.				GOURLAY LAGOON				TEA TREE CREEK				YARRAWURTA CREEK				MINLATON NO.1 BORE				
		t	n	r	a	t	n	r	a	t	n	r	a	t	n	r	a	t	n	r	a	C
MIDDLE CAMBRIAN	Limestone																	62	2	4-10	8	1
																		65	1	25	25	2
LOWER CAMBRIAN	arenite																	313	10	1-10	3	1
																		*61	2	20-30	21	2
	lutite													622	8	10-12	11	60	2	1-2	2	1
																						2
	limestone													1091	3	5-20	14	941	7	108	5	1
														12	3	20-50	36					2
	dolomite																	1003	9	1-15	7	1
	arenite					22	3	5-8	6	22	2	2-15	13					140	7	1-14	2	1
MARINOAN	arenite	250	11	12-20	15	5	1	5	10													1
																						2
	lutite	471	10	15-20	16					22	2	20	20									
		50	1	11	30																	
	arenite													565	3	10-15	11					1
																						2

t = stratigraphic thickness sampled, in feet
n = number of bulked samples analysed
r = range of Pb content in parts per million
a = weighted average of Pb content in parts per million

C1 = samples containing less than 20 ppm Pb
C2 = sample containing more than 20 ppm Pb
* = evaporites
x = single rock samples

TABLE 3. COPPER DISTRIBUTION IN SHELF SEDIMENTS

AGE	FACIES	WOOMERA D.D.H. No. 1				GOURLAY LAGOON				TEA TREE CREEK				YARRAWURTA CREEK				MINLATION NO. 1 BORE				
		t	n	r	a	t	n	r	a	t	n	r	a	t	n	r	a	t	n	r	a	C
MIDDLE CAMBRIAN	limestone																	127	3	3-6	15	1
																						2
LOWER CAMBRIAN	arenite													622	8	10-21	15	374	12	2-8	4	1
																						2
	lutite																	60	2	8-10	9	1
																						2
	limestone													743	21	5-40	30	760	6	2-8	7	1
														361	4	50-80	54	181	1	40	40	2
	dolomite																	1003	9	2-10	15	1
																						2
	arenite					22	3	4-5	4	22	2	7-8	7					140	7	3-10	5	1
																						2
MARINOAN	arenite	250	11	1-25	5	5	1	6	6													1
																						2
	lutite	47	10	3-12	5					22	2	5	5	565	3	15-30	25					1
		50	1	75	75																	2
	arenite																					1
																						2

t = stratigraphic thickness sampled, in feet

C1 = samples containing less than 30 ppm Cu

C2 = samples containing more than 30 ppm Cu

TABLE 2. LEAD DISTRIBUTION IN MARGINAL GEOSYNCLINE SEDIMENTS

AGE	FACIES	KULPARA				SELLICK HILL				WILKATANA D.D.1				EDIACARA D.D. E24/61				MT. SCOTT				
		t	n	r	a	t	n	r	a	t	n	r	a	t	n	r	a	t	n	r	a	C
MIDDLE CAMBRIAN	Limestone																	55	2	1-5	3	1
																		140	2	50-150	96	2
LOWER CAMBRIAN	arenite																	75	2	12-15	14	1
																		90	2	25	25	2
	lutite					315	9	10-20	16									330	7	15-20	17	1
						505	11	30-50	38									50	1	25	25	2
	limestone					290	4	1-10	2									394	14	1-20	9	1
																		50	1	30	30	2
	dolomite	185	4	5-10	6	910	17	1-15	6	517	10	4-20	8	20		17	17	365	8	8-20	12	1
		132	2	25-40	34	160	2	25-30	27					960		50-1000+	650+	185	5	25-70	47	2
	arenite	55	5	4-18	14	530	19	4-20	8	44	4	4-15	10					24	1	2	-	1
		69	5	25-150	52	360	34	25-800	86	13	1	27	27	50		70	70	28	4	30-300	118	2
MARINOAN	arenite	272	11	3-20	12	860	17	1-20	15					6	1	1	18	53	1	3	3	1
		140	5	20-25	22	175	3	50-100	58													2
	lutite	1128	23	10-20	17					493	8	1-10	8									1
		355	5	20-40	25																	2
	arenite	998	10	10-20	15																	1
		500	5	20-100	52																	2

[illegible] thickness sampled in feet a = weighted average of Pb content parts per million

TABLE 4 COPPER DISTRIBUTION IN MARGINAL GEOSYNCLINE SEDIMENTS

AGE	FACIES	KULPARA				SELLICK HILL				WILKATANA D.D.H.No.1				EDIACARA D.D.H. E 24/61				MT. SCOTT				
		t	n	r	a	t	n	r	a	t	n	r	a	t	n	r	a	t	n	r	a	C
MIDDLE CAMBRIAN	limestone																	185	4	2-14	9	1
																						2
LOWER CAMBRIAN	arenite																	145	3	3-15	11	1
																		20	1	4000	4000	2
	lutite					85	6	30	30									280	8	10-18	12	1
						435	14	40-60	47													2
	limestone					290	4	8-15	12									444	15	6-20	11	1
																						2
	dolomite	317	6	15-25	18	910	19	5-20	13	517	10	4-15	9	806	-	-	15	598	13	8-30	13	1
														90	-	60-1200	400					2
	arenite	109	8	-	30	890	55	8-20	14	26	3	3-20	7					40	3	12-25	17	1
		15	2	4-150	90					31	3	40-50	44	50	-	10-400	180	12	2	40-50	43	2
MARINOAN	arenite	395	14	15-30	27	765	19	3-30	13					6	1	10	10	53	1	8	8	1
		17	2	40-50	46	270	6	40-100	55													2
	lutite	1287	27	6-25	12					493	8	3-10	8									1
		196	2	60-100	80																	2
	arenite	1408	14	6-15	10																	1
																						2

t = stratigraphic thickness sampled, in feet
n = number of bulked samples analysed
r = range of Pb content in parts per million
a = weighted average of Pb content

C1 = samples containing less than 30 ppm Cu
C2 = samples containing more than 30 ppm Ci

REGIONAL GEOCHEMICAL SAMPLING IN THE CAMBRIAN AND UPPER PROTEROZOIC ROCKS OF SOUTH AUSTRALIA

ABSTRACT

by

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Systematic rock sampling of the Cambrian stratigraphic units was commenced by the Geological Survey in 1960. To date over 4,000 bulked rock samples have been collected from measured rock sections, and all have been analysed spectrographically for Pb, Zn, Cu, Ag, Cr, V, Co, Ni, at the Australian Mineral Development Laboratories. Many of the samples were also analysed for Fe, Mn, Ba, and a special group was tested for Au, Bi, Cd, Ge, Hg, Mo, Sb, Sn. Analyses for $MgCo_3$, $CaCO_3$, and P were made where considered necessary.

Cambrian sediments in South Australia occur in two distinct environments.

1. The Kanmantoo Trough Zone

This zone extends for over 200 miles through Kangaroo Island and along the eastern flank of the Mt. Lofty Ranges. It probably extends farther NE under the Tertiary Murray Basin. The sediments are geosynclinal greywackes and arkoses with interbedded black pryitic shales and rare limestones. They include the Nairne Pyrite member in the Brukunga Formation (Barker, 1:250,000 sheet). The rocks are strongly folded, faulted, regionally metamorphosed and, in places, granitised and intruded by granite plutons, basic dykes and plugs. Cu, Pb, Ag, Au, As, Zn, mineralisation is known in the trough.

2. The Adelaide Miogeosyncline and Western Shelf Zone.

Areas of fossiliferous Lower to Middle Cambrian sediments occur in a broad zone 350 miles long, extending N from Kangaroo Island and the western Mt. Lofty Ranges. Commencing with a well defined basal clastic sequence, the sedimentary facies is dominantly carbonate passing upwards into green shale, red siltstones and finally red clastics with minor carbonates. The rocks are not metamorphosed. Dolerites of probable Cambrian age intrude

the underlying Adelaide System sediments. Mineralisation is Pb, Ag, Cu, associated with Ba, Mn, and Fe. It is both stratiform and cross cutting.

3. Sampling Results from Kanmantoo Trough Zone

(i) Nairne Pyrite Member etc. Sample traverses were made at 1 mile intervals and closer across the Nairne Pyrite member and a higher pyritic member. Cu and Pb contents exceeding 1000 ppm occur within the main and upper pyritic member at several points between 5 miles S, and 6 miles N, of Brukunga. A Pb anomaly area was located in the upper horizon near Harrogate, and Pb CO_3 mineralisation was subsequently found in this locality. Farther S and N, Cu and Pb results did not exceed several hundred ppm. A sample traverse of 8 miles length along the Mt. Barker Creek, south of the Callington-Kanmantoo Cu mining area, showed a marked rise in heavy metal content in the Cambrian sediments at the Nairne Pyrite member, and the higher values continued in the overlying sediments.

Over 100 line-miles of regional sample traverses have now been completed across the exposed Kanmantoo Group sediments on the mainland. Preliminary study shows that a relatively high heavy metal background is present within the metasediments in an area between Strathalbyn, Brukunga and Callington. This area includes the most important Cu bodies in the region. The same sediments, although including pyritic black shales equivalent to the Nairne Pyrite horizon, are low in heavy metals between Strathalbyn and the South Coast.

The Brukunga formation, including carbonaceous black shales, is also developed in a basin E and NE of Truro. The formation in this area is not associated with abnormal heavy metal concentrations.

(ii) Palmer Fault Zone. Cu, Pb and Zn anomalies were obtained in a zone 20 miles long, adjacent to the Palmer fault scarp which forms the NE limit of the Mt. Lofty Ranges. Small Pb Zn bodies occur in Lower Cambrian Limestone in this zone. Cu is associated with black shale (schist), quartz veins and basic rocks including amygdaloidal andesites.

(iii) Granites: A zone of granite intrusives and granitised sediments extends from Murray Bridge to Angaston. The rocks in this zone are generally low in heavy metals.

(iv) Basic Igneous Rock: Extensive sampling of basic igneous rocks away from Palmer fault area, and scapolitised microdiorite dykes NW of Brukunga, did not show abnormal heavy metal contents.

Recently, pyrite-magnetite mineralisation was noted (J.O. Olliver pers. comm.) is association with scapolitised microdiorite during diamond drilling at Angaston; maximum Cu values were 300 p.p.m.

(vi) Dawesley Aeromagnetic Anomaly Area: A gossan outcrop in the vicinity of an aeromagnetic anomaly near Dawesley showed a Cu anomaly, and one Mines Department drill intersection in primary sulphides assayed over 1% Cu. This mineralisation is associated with pyrite and magnetite and is located on a regional fracture system.

(vii) Sulphophile elements: Recently drill core from Brukunga and surface samples across the Nairne Pyrite member at the Mt. Barker Creek were analysed spectrographically for the sulphophile elements Bi, Cd, Ga, Ge, Hg, In, Mo, Sb, Sn, as well as Au. Results were as follows:- Au, Cd, Ge, In were less than 2 p.p.m. Sn was generally less than 2 and rarely 10 p.p.m., Bi generally 5 p.p.m. or less. Mo reaches a maximum of 80 p.p.m. in the drill section and 250 p.p.m. in the creek section. Mo is associated with Hg (up to 1.2 p.p.m.)

Conclusion: Geochemical results and their relationship to regional geology have so far not proved any extensive stratiform mineralisation approaching ore grade. Further prospecting is recommended along, and adjacent to, major fracture systems on the margins of the high temperature zones of regional metamorphism.

4. Sampling Results of the Adelaide Miogeosyncline and Western Shelf Zone

Over 2,100 surface and drill hole bulk rock samples of Cambrain stratigraphic units have been collected and analysed from about 50 measured sections or drill holes. Six of these sections extend from basal to Middle Cambrian. The remainder are generally restricted to the basal Cambrian.

Cu-Zn anomalies were obtained in ferruginous and manganiferous outcrops of the basal Cambrian at Kulpara, Yorke Peninsula. One hole was drilled in 1960 revealed a weak lead anomaly at the base of the Cambrian.

Renewal of interest in 1961 in the Ediacara Pb-Ag field, which occurs at the base of the Cambrian, led to the subsequent widespread geochemical investigation of this stratigraphic position. The deposits are of the Mississippi Valley Type (Nixon, 1963). The investigation showed that large areas of the basal Cambrian in the Adelaide miogeosyncline have a geochemically high Pb, Zn and Cu content; generally several hundred p.p.m. Pb and occasionally more. Areas also exist with less than 30 p.p.m Pb. At Sellicks Hill near Adelaide anomalies of up to 5000 ppm. Pb were obtained. The lead anomalies occur in calcareous and dolomitic siltstones above the basal clastic unit and below the thick carbonate sequence which is frequently oolitic in its lower members. The writer (Thomson, 1962) has attributed the high Pb content to contemporaneous enrichment of the Cambrian sediments by exhalative solutions or gases which were introduced along lineaments or their intersections in diapiric areas.

Cu anomalies occur in the green facies of the shale overlying the Lower Cambrian carbonate sequence ? Similar weak Cu anomalies are associated with green shale and dolomite interbeds in the Balcoracana Formation in the Middle Cambrian. Traces of $CuCo_3$ and galena are present.

Stratiform Cu association with a thin green shale unit and dolomite in a barren red siltstone sequence is widespread (Horwitz 1962) in the Central Flinders Ranges in the Upper Proterozoic (Wilpena Group) sequence. Cu content of the green shale is frequently 2000 p.p.m. and of the red siltstone, 10 p.p.m. Traces of chalcopyrite and chalcocite are present in the dolomite. The great lateral extent of the mineralisation indicates that it was penecontemporaneous with sedimentation.

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