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BASE METAL OCCURRENCE WITHIN LOWER CAMBRIAN SEDIMENTS OF THE NORTHERN FLINDERS RANGES SOUTH AUSTRALIA

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INTRODUCTION

Significant concentrations of lead and zinc with minor copper and silver have proven to be widely distributed within lower Cambrian strata in the Northern Flinders Ranges, the adjoining Torrens Sunkland and the Stuart Shelf. This report recounts the mining activity of the past, recent investigations which led to the recognition of this environment as a locus of geochemically important base metal mineralization and summarises the results of subsequent exploration activity in the years 1965/1969 by mining companies during the tenure of special mining leases in the northern Flinders Ranges. Figure 1 shows the distribution of lower Cambrian sediments, sites of previous mining operations and location of the now-surrendered special miningleases (S.M.L.)

GEOLOGICAL ENVIRONMENT

The base of the lower Cambrian throughout the Adelaide Geosyncline and adjoining Stuart Shelf is marked either by a sedimentary hiatus or local unconformity with the underlying upper Proterozoic (Marinoan) sediments.

In the northern Flinders Ranges the new cycle of sedimentation commences with the Parachilna Formation. There is an abrupt transition from the even grained resistant Pound Quartzite of the upper Proterozoic to the basal Cambrian Parachilna Formation, a weakly consolidated, easily eroded, argillaceous sandstone typified by occurrence of tubular worm borrows (Scolithus). Lenticular pebble beds, white, grey or green shales and siltstones with sandstones are common while thin algal and oolitic limestones and ferruginous or manganiferous dolomitic siltstones are present

in some sections. Theenvironment of deposition is interpreted as fluctuating between sub-littoral and shallow shelf conditions prior to a more general transgression represented by carbonate rocks. The Parachilna Formation ranges up to over 1,500ft. in thickness but is commonly seldom more than 200ft. thick. With increasing carbonate content these sediments pass upwards abruptly or through transitional passage beds into a thick sequence of dolomite and limestone, Ajax Limestone (or equivalent Wilkawillina Limestone), which covered the site of the Adelaide Geosyncline and adjoining shelf areas (Andamooka Limestone, Kulpara Limestone, etc.) as an extensive sheet outlining the shallow transgressive Cambrian sea.

The Ajax Limestone is generally dolomitic, sandy or oolitic with sedimentary breccias near the base. These are succeeded by massive Archaeocyathinae bearing limestones, commonly of high chemical purity, several thousand feet in thickness. These are in turn overlain by a barren sequence of red-brown siltstones, shales and sandstones. (Billy Creek Formation etc.).

BASE METAL MINERALIZATION

On a regional scale anomalously high lead, zinc and lesser copper contents characterise the beds near the base of the lower Cambrian in many parts of the Flinders Rangers. There is evidence that within a narrow stratigraphic interval copper mineralization is associated chiefly with sandstone and shale in the Parachilna Formation and in the overlying limestones while lead and zinc occur in an environment of sedimentary breccias, limestones and dolomites, usually in association with manganese.

Mining took place at a number of centres principally during the period 1870 to 1900. Production from near-surface secondary enrichments of oxidized copper ores was sporadic and generally not very profitable, the ore being handpicked and transported to smelters in the region. Copper mines of this

type include Red Range, Ajax, Copper King, Sliding Rock, Mount Bayley, Angepena, Balcanoona, Moro, Mount Chambers, Mount Arden and Kanyaka.

Lead sulphides carrying silver were recovered at Ediacara, Wirrealpa, Flinders, Fountain Head, Mount Lyall and Mount Chambers mines.

Only a few disjointed records of this period are available so that production from the various mines, the grade of ore mined and marketed are either unknown or far from complete. Sketchy details, mostly culled from Inspectors of Mines reports and lacking plans, have been recorded by Brown (1908). Since that time many of the mines have been reported in publications of the Geological Survey of South Australia but few underground openings are now accessible.

The Sliding Rock copper mine from which recorded ore production amounts to 1,748 tons was investigated by Dickinson (1944); this was the major copper producer in this context and the gross value of copper raised is estimated at £100,000. Next in importance with regard to copper output appear to be Mount Bayley, Kanyaka, Ajax and Copper King.

Silver-lead producers of some importance were Ediacara and the Wirrealpa mines. Slugs and boulders of galena have been found at the surface at a number of other localities but the output was generally small.

Following a detailed study of the Ediacara Basin and a programme of diamond drilling by the Department of Mines, Nixon (1963) concluded that the (principally) lead mineralization contained therein was of the Mississippi Valley type with many similarities to the southeast Missouri lead field; occurrence in dolomites; conformable attitude, with the mineralization being confined to a narrow stratigraphic thickness; association with sedimentary breccias; and absence of gangue minerals and the type of alteration commonly associated with epigenetic mineralization. Concentrations of lead, chiefly as galena, were proven to be restricted to near-basal carbonate

rocks which comprise the Ajax Limestone. He considered that the deposition of ore minerals was contemporaneous with sedimentation and that they were recrystallized and mobilized after lithification of the enclosing sediments.

Subsequently, an extended programme of sampling undertaken by Thomson (1962, 1965) disclosed that there are above-normal concentrations of base metals at this stratigraphic level elsewhere within the Adelaide Geosyncline and bordering shelves. The extensive enrichment of base metals within the lower Cambrian was attributed to either a sedimentary exhalative process contemporaneous with sedimentation or later telethermal mineralization related to an Ordovician orogeny. The importance of basement fault-shear lineaments in providing channel ways for mineralizing solutions or gases and as controls in localising base metal deposition were stressed. In figures 2 and 3 the distinct base-metal enrichment at several localities at the base of the Cambrian sequence is evident. There is also a marked association of manganese, iron, cobalt, nickel and barium at this stratigraphic level.

Exploration activity by mining companies since 1965 has further demonstrated that basemetal mineralization is widespread within lower Cambrian strata and several significant discoveries have been made. Geochemical surveys undertaken by Anaconda Australia Inc. resulted in the discovery of zinc and associated lead deposits at Puttapa which are being now developed by Electrolytic Zinc Co. of Australasia Ltd. In the Third Plain and Reaphook Hill localities Kennecott Explorations (Australia) Pty.Ltd. have outlined areas of anomalous zinc in a similar environment while the same company has investigated copper, lead and zinc occurrence in a number of other areas. Investigations at Ediacara have been extended by Conzinc Rio Australia Exploration Pty.Ltd., while similar sulphide mineralization has been recognised along the front of the Flinders Ranges between Mernmerna and Parachilna and in the Andamooka area by Mines Exploration Pty.Ltd. Following expiry of Special Mining Leases

company reports have been placed on open file but details of operations on current leases are still held as confidential.

Ediacara Mineral Field

During the period 1888 to 1913 an estimated 24,000 tons of silver-bearing high grade lead ore and a few hundred tons of secondary copper carbonate ore were mined from shallow pits and underground workings chiefly from Greenwood's and Southern workings along the western and southern margins of the Ediacara Basin. Ore from Greenwood's workings was reported to average 31.5% Pb and 8.7 ozs. Ag/ton. Zinc Corporation Ltd. carried out extensive sampling in 1938 and in 1946-7 the Department of Mines undertook a limited programme of diamond drilling based on a study of the field by Broadhurst (1947).

Interest in the locality was revived in 1961 when Nixon (1963, 1964, 1967) supervised an extended diamond drilling programme to outline limits of disseminated lead and local copper mineralization. The drilling of a further eleven diamond drill holes was undertaken by C.R.A. Exploration Pty.Ltd. during the tenure of S.M.L.77 and 144 in 1965-1966 (McQueen, 1967).

The geological structure and disposition of the various units is depicted on the plans and sections (figures 4 and 5). The Upper Proterozoic Pound Quartzite, almost 1,000ft. in thickness, that delimits the shallow closed synclinal basin is overlain by the Parachilna Formation which comprises about 50ft. of gritty sandstones, greenish shales and dolomites and includes a 10ft. thick scolithus - bearing bed. The suceeding Ajax Limestone totalling 1,000ft. in thickness has been subdivided into several units. The lowermost sandy cross-bedded dolomite ranges from 50ft. to 450ft. in thickness and comprises a well bedded unit in which breccia layers are developed, manganese is common and primary lead mineralization occurs. Laminated algal dolomite averages 120ft. in thickness and comprises buff and grey dolomites in which breccias are common, including a persistent outcropping siliceous manganiferous and iron stained breccia

near the base of the unit; manganese staining is common throughout and the unit is the host to primary lead mineralization. The uppermost unit comprises massive dolomite up to 450ft. in thickness in the centre of the basin; archaeocyathinae are common, minor breccias occur and only minor mineralization is evident.

Some difficulty was experienced in identification of some units in drill cores which had been defined from outcrop mapping, particularly with regard to cross-bedded sandy and laminated algal dolomites which have similar lithologies in part. To what extent facies changes affected identification of these stratigraphic units has not been determined.

Galena, the main "ore" mineral, occurs in individual crystals of varying size scattered throughout the dolomites, as small lenses along bedding planes, as vein fillings or as the main constituent of the matrix of sedimentary (slump) breccias. The sulphide is generally encrusted by cerussite or anglesite and in the abandoned workings the principal minerals are galena and cerussite. Copper occurs as carbonates but useful concentrations are known only in a local area in the northern section of the basin and at Black Eagle workings from whence there has been small production of ore, hand picked to 20% Cu. Patches of "gossan" located in both the southeastern and southwestern parts of the field comprise thin, conformable, iron and manganese-stained siliceous breccias which contain insignificant copper and lead contents. Several masses of psilomelane and ironstone (limonite and haematite) haematite) have been opened up by pits and shafts to provide ironstone flux for local smelting of lead ores but these deposits are superficial. Drilling down-dip from the outcrop of the gossans has revealed minor lead and copper mineralization only in D.D.10

Nxion (op.cit.) concluded that the mineralization is stratiform and confined to a relatively narrow sequence in two zones relatively richer in metals, described as being 50ft. apart and between 100ft. and 200ft. above the base of the Cambrian.

Deposition of ore minerals was considered to be contemporaneous with sedimentation, localization being influenced by sedimentary and structural features and ore minerals being mobilized and recrystallized afterlithification of the sediments. The drilling of 35 diamond drill holes, by the Department of Mines, indicated some 17½ million tons of "ore" over a thickness of 52feet and having an average grade of 1.13% Pb. For a grade averaging 0.9% Pb with an average thickness of 58ft. the inferred reserves were estimated at 31.8 million tons (Nixon, 1967). It is apparent that mineralization is not restricted to any particular stratum and that lead and copper minerals are enclosed in various lithologies viz. a shaley facies of the Parachilna Formation and sandy cross-bedded dolomites and laminated algal dolomites of the Ajax Limestone. Drilling has intersected mineralized rock in several zones, as outlined in figures 4 and 5 in plan and in the cross-sections, marginal to the fault which defines the western limits of the basin from the surface to depths ranging to 900ft. Mineralization is richest, though of low grade, on the northwestern flank, trending to lower grade and pinching out to the south.

The drilling of eleven holes by C.R.A. Exploration Pty. Ltd. failed to extend the limits of previously indicated mineralization. A revision of indicated tonnages based on an interpretation by McQueen (1967) of distribution of mineralization in the various units is as follows:

1. body in laminated algae dolomite - 12 million tons
   average 0.84% Pb
2. body in sandy cross-bedded dolomite - 17 million tons
   average 1.23% Pb (with an enriched zone included in 2,
   of 1.2 million tons averaging 2.24% Pb.).

It was concluded that the "density of the drilling and knowledge of mineralization in the. . . . . .structure indicate that an economical deposit of base metals is unlikely to occur therein" and thelease expired on 31st March, 1967. It remains to be determined whether the down-faulted sector to

the west of the Ediacara structure is underlain by Cambrian sediments and whether or not these are mineralized.

Tabulated below are the most significant diamond drill intersections at Ediacara with their average metal contents:

Bore No.	Interval (feet)	Thickness (Feet)	% Pb	% Cu	% Zn	Ag. Ozs.	Dwts
2	105-108	3	0.97	0.02	0.01	0	8
3	6-12	6	1.43	12.4	0.28	7	7
5	115-141	26	0.91	0.01	0.005	3	19
	176-190	14	1.02	0.07	0.01	1	0
6	0-100	100	1.56	0.01	0.01	0	14
7	135-190	55	0.29	0.65	0.03	0	6
	190-290	100	1.32	0.18	0.06	0	3
10	187-247	60	0.97	0.15	0.08	0	12
13	52-100	48	0.83	0.005	0.01	0	4
14	20-115	95	1.26	0.004	0.007	0	17
15	80-180	100	1.04	n.d.	n.d.	n.d.	
17	100-100	10	1.07	n.d.	n.d.	n.d.	
	160-170	10	1.03	n.d.	n.d.	n.d.	
18	15-30	15	0.98	1.81	n.d.	n.d.	
19	21-34	13	0.20	2.78	n.d.	n.d.	
20	20-22	2	0.94	0.58	0.37	n.d.	
23	0-70	70	0.88	0.01	0.02	0	7
32	270-345	75	0.91	0.03	0.07	1	16
33A	310-380	70	1.03	0.004	0.005	0	10
34	450-510	60	0.91	0.005	0.02	0	4
	560-590	30	1.07	0.03	0.009	0	17
35	30-80	50	1.23	0.007	0.03	0	2
39	512-542	30	0.83	0.04	0.07	0	14
41	690-760	70	0.72	n.d.	n.d.	0	3
47	140-149	9	n.d.	0.38	n.d.	n.d.	

Puttapa Zinc Prospect

Special Mining Lease 113 was granted to Anaconda Australia Inc. on 16.5.66 to undertake a programme of geochemical sampling on a reconnaissance basis of selected areas that included the Ajax Limestone. Stream sediment samples taken on a density ranging from 5 to 10 per square mile were screened in the field and the minus 80-mesh fraction were submitted for determination

of Cu, Pb andZn contents after cold extraction with hydrochloric acid. These showed concentrations generally in the range 2 to 10p.p.m. Several areas showed anomalous (plus 40 p.p.m. and up to 450 p.p.m.) copper contents mostly adjacent to old copper mines - Mucatoona, Nuccaleena, Red Range, Mount Bayley, at Angepena gold field and near Patawarta Gap. Significant lead (40 p.p.m. to 400 p.p.m.) and zinc (100 p.p.m. to 1300 p.p.m.) anomalies were located in the Puttapa locality in the vicinity of the Ajax copper mine, less than two miles east of the Leigh Creek - Port Augusta railway. Follow-up rock sampling and detailed mapping outlined outcrops of willemite (Zn_2SiO_4) with associated hedyphane ($Pb\ Cl.Pb_4\ (AsO_4)$), vanadinite ($Pb\ Cl.\ Pb_4\ (VO_4)$), finnemanite ($Pb_5\ Cl(AsO_3)3$) and coronadite (lead manganate) with manganese and iron oxides. Subsequently S.M.L. 113 (expired 6.12.66) and 136 were granted to include the prospect and the area was finally surrendered on 31.3.67. This report summarises the results of work undertaken by Anaconda Australia Inc. at the Puttapa zinc deposit and is based on the report of Whitehead (1967)

At the prospect, zinc and lead minerals occur as weathered residuals and replacement deposits in a complex fault zone within an area 1,000ft. x 400 ft. of great structural complexity. Figure 6 shows the disposition of the various units of the Upper Proterozoic and the overlying lower Cambrian formations, the strata being contorted and often truncated by faults in an area marginal to the major Nor'West Fault. Locally, the Cambrian and older sediments have been intruded by masses of diapiric breccia containing blocks of finely banded shale and siltstone with halite casts, dolomite and quartzite derived from the underlying Callana Beds. The lower Cambrian succession comprises kaolinitic sandstones of the Parachilna Formation approximately 200 feet in thickness, and the overlying Ajax Limestone, 2,500ft. thick, which contains abundant well-preserved Archaeocyathinae.

Bold outcrops of white zinc silicate containing up to 52% Zn (average 40% Zn) with lead chloro-arsenates and chloro-vanadates (containing up to 46% Pb), associated with manganese and ochreous iron oxides have been mapped in detail by Whitehead

(op. cit.), figure 7, over an area 1,000ft. x 400ft., Willemite occurs in radiating, prismatic or, spherulitic aggregates, mammilated colloform bands and structureless masses. Laterally, these bodies pass abruptly into red recrystallized manganiferous dolomite which contain paper-thin mineralized films along joints and fractures, the red dolomite being a recrystallized variety of the normal grey coloured Ajax Limestone.

"No boxwork, pseudomorphous replacement or other indication of sulphides has been detected and the general appearance of the deposit strongly suggests that the zinc and lead have migrated in groundwater solutions.. ..The main concentration of zinc at the surface occurs in an extensively faulted area where massive Ajax Limestone.....is closely associated with areas of diapiric breccia, but most of the zinc-bearing outcrops are separated from diapiric material by zones of fractured.....quartzite.

"Results of geochemical stream sediment sampling in the surrounding area show lead and zinc anomalies in many creeks draining Ajax Limestone up to two miles north and one mile south of the (main) zinc mineralization. Analyses range up to 760 p.p.m. for zinc and 217 p.p.m. for lead. In contrast, the values for lead and zinc in sediments from streams draining Pound Quartzite, Wonoka shales and dolomite, and areas of diapir away from the limestone are generally low and rarely more than 7 p.p.m. " (Whitehead op.cit.)

Systematic chip sampling of the red dolomitic limestone disclosed contents of zinc up to 2,000 p.p.m. with lead generally in the range 80 to 170 p.p.m. in an area one half mile in length at the eastern margin of the deposit, to the south and at the southwestern end. Samples taken from a distance of 1/4 mile from willemite outcrops average 2,520 p.p.m. lead. The only zoning apparent is in a progressive increase in zinc and lead contents as the willemite outcrops are approached.

Arsenic content which ranges up to 180 p.p.m. in the red dolomitic limestone on the eastern side of the deposit is greatly concentrated (400 to 4,000 p.p.m.) near the willemite ourcrop; lead arsenates have since been identified.

Immediately south and west of the Ajax copper mine the Ajax Limestone is veneered by limonitic scree and several small outcrops of almost pure willemite have been located approximately one half mine east of the main zinc deposit.

Minor copper mineralization has been disclosed in the locality, at the Ajax mine (where recorded ore production amounts to 134 tons) and in shallow pits one half mile to the southwest. Sampling at the Copper King ochre deposit indicated that one near-surface section 6ft. in thickness contained 2.7% Cu while the weighted average of a number of samples was 0.70% Cu (Johns, 1956). Copper occurs principally as malachite but cuprite has also been recorded and during the period 1899 to 1908 recorded production of copper ore amounted to 122 tons with the average grade of handpicked one being 25% Cu).

The Puttapa prospect, because of the nature of the mineralization and the belief that the deposit represented but a thin residual "skin", held no further interest for the discoverers. Since title was gained by Electrolytic Zinc Co. of Australasia Ltd., drilling has been undertaken by that Company to prove over 1-million tons of 40% zinc ore with lead and plans for exploitation have been announced.

Willochra Area

Kennecott Explorations (Australia) Pty.Ltd. were granted S.M.L. 94 over an area of 135 square miles on 1.12.65 to undertake a programme of stream sediment sampling and reconnaissance rock chip sampling over the Parachilna Formation and overlying Cambrian limestones which outcrop in the Willochra locality to the north of Quorn and extending towards Hawker. Three areas were outlined which were considered (McNeil 1966(a)) to warrant further exploration viz.

(1) Mt. Arden - Comstock area where sampling showed that there are anomalous zinc, lead and copper contents within lower Cambrian strata over a strike length of 17 miles.

(2) Radford Creek area where anomalous lead and zinc contents were disclosed at the same stratigraphic level.

(3) Adjacent to the Kanyaka copper mine.

S.M.L. 94 was surrendered on 31.5.66 and three new leases within the limits of S.M.L. 94 were sought and granted to the company to further explore the area defined - these are discussed separately below.

Mount Arden - Comstock Area

Minor copper (Mount Arden mine) and ironstone (Donnelly's or Comstock deposits) located within the Parachilna Formation 15 miles north of Quorn were exploited during the period 1880 to 1900 (Brown 1908; Jack 1922; Armstrong 1937; Kingsbury 1955).

At Mount Arden mine numerous shallow shafts and pits have exposed small discontinuous thin veinlets, stains, irregular patches and bunches of malachite and azurite over an area of 1,500 ft. x 300ft. There is no defined lode and the copper carbonates occur patchily along the bedding and in fractures within kaolinitic siltstone, ferruginous jasperoidal shale and limonitic breccia. Selective mining resulted in the production of little more than 20 tons of hand picked ore containing 14% to 20% Cu.

About two miles to the south, a number of discontinuous ironstone pods outcrop in a zone traceable over a strike length of three miles in the Comstock locality round the keel of a tight synclinal structure. The ore comprises massive limonite with a little haematite, manganiferous in part, which results from surface enrichment of two beds of iron - and manganese-impregnated siltstones less than 250 ft. in width that are interbedded with sandy shales, siltstones and sandstones. Exploratory adits driven below the main ore bodies prove that

they do not persist im depth and that they are superficial secondary deposits. There are four main groups of workings from which 17,500 tons of ironstone were mined and shipped to Port Pirie for smelter flux during the 1890's. The north-eastern workings 30ft. x 70ft. and 30ft. deep are based on a limonite mass 700ft. long and average 40ft. wide; reserves of 140,000 tons of 48.4% Fe ore remain (Whitten, 1963). The main or southeastern outcrop has been exposed in a quarry to a depth of 40ft.; reserves of 51.7% Fe ore approximate 100,000 tons. The northwestern ore body outcrops over a length of 400ft. and averages 16ft. in width; reserves are estimated at 16,000 tons. A number of pods of manganiferous limonite have been tested by an adit and pits in the southwestern sector of the area where reserves aggregate 63,000 tons. Total reserves of ironstone aggregate 350,000 tons with iron contents ranging from 48 to 58% Fe and insolubles contents ranging to 16%; selected pyrolusite samples contained up to 35% Mn but these and the ironstone deposits are generally too small and of too low grade to be marketable.

Following discovery of significant concentrations of lead and zinc within the boundaries of S.M.L. 94 by Kennecott Explorations (Australia) Pty.Ltd. (McNeil, 1966 (a)) that company sought and was granted S.M.L. 108 covering 18 square miles in the Mount Arden - Comstock locality on 1.6.66 to undertake further exploration; the results of geophysical and geochemical surveys, trenching and drilling undertaken to 31.8.67 when the lease expired have been detailed by McNeil (1966(b), 1967 (a)) and are summarised hereunder.

The area studied is depicted in figure 8 which shows the lower Cambrian and older sedimentary units disposed in two tight adjacent synclines. The Parachilna Formation, comprising 200ft. to 500ft. of thin-bedded argillaceous sandstone, siltstone, massive dolomite and dolomitic shale, forms dubdued outcrops and is often mantled by scree derived from the underlying Pound Quartzite. The Wilkawillina Limestone is about 1,400ft.

in thickness and includes well-bedded sandy, partly oolitic, pale grey limestone with interbedded siltstone at the base and passing to massive blue-grey limestone in the upper parts of the formation.

Stream sediment samples taken on a density of generally more than 8 per square mile indicated that the lower Cambrian formations were anomalous with respect to copper, lead and zinc contents over a strike length of about 17 miles. These showed zinc contents generally ranging from 20 to 60 p.p.m. and exceeding 150 p.p.m. in the Comstock area with more significant and more continuous concentrations in the eastern syncline along the flanks of Ragless Range over the Parachilna Formation and the Wilkawillina Limestone. Zinc contents of up to 1,740 p.p.m. were reported from the eastern syncline while in the Comstock area anomalous base metal contents included zinc up to 1,000 p.p.m., lead to 410 p.p.m. and copper (which is more or less confined to the Mount Arden mine area) to 100p.p.m. Follow-up rock chip sampling indicated that zinc mineralization ranging between 0.2% and 1.0% Zn occurred over stratigraphic widths of 20ft. to 50ft. within the basal beds of the Wilkawillina Limestone and in the central part of the Parachilna Formation.

Self potential (9 lines over a length of 5.5 line miles) and induced polarisation (3 lines over 1.1. line miles) traverses were metered but geophysics proved to be of little assistance as no large or high intensity anomalies were defined.

To evaluate zinc mineralization associated with goethite and manganese wad along the western flank of Ragless Range nine trenches were excavated using a bulldozer and these were channel sampled; a summary of results is tabled below:

Trench No.	Sample interval (ft.)	p.p.m.					
		Zn	Pb	Cu	Co	Ni	Mn
1	10	125	110	1550	140	50	10,000
2	120	3600	120	65	117	106	10,000
3	40	6775	135	42	170	160	10,000
4	90	2480	710	80	45	88	720
5	60	4250	340	90	50	115	2,425
6	100	6410	165	23	204	150	10,000
7	70	11730	135	120	167	248	10,000
8	40	3750	77	60	140	203	3,360
9 failed to penetrate overburden 13ft. thick - not sampled							

One sample 10ft. in width from trench 7 contained 3.55% Zn

The area in which the highest surface zinc values occur (see figures 9 and 10) was tested by four non-core drill holes (aggregate 1485ft.) with the best intersections being as follows

Hole No.	Interval (feet)	P.p.m.		
		Zn	Pb	Cu
1	260-270	3650	-	-
2	0-200	2260	-	-
3	100-130	3800	-	-
4	137½-150	10050	150	50

The zinc mineral proved to be chalcophanite (Mn, Zn) $0.2MnO_2.2H_2O$) which is invariably associated with goethite and manganiferous wad. No sulphide mineralization was detected. It was condluded that stratiform zinc mineralization as chalcophanite without significant copper or lead, is present in the lower Cambrian sediments along a strike len gth of 7 miles in the eastern syncline in association with manganese in the basal part of the Wilkawillina Limestone and the central part of the Parachilna Formation. Mineralization was proven to extend down dip with relatively higher grades (up to 3.5% Zn) at surface resulting from surface enrichment of primary grades of between 0.2 - 1.0% Zn. Copper occurs in the Parachilna Formation

separately from, and to the west of, the zinc mineralization; it is less extensive are rarely exceeds 0.2% Cu. It was concluded that though the lease had not been exhaustively tested "all the evidence is against the occurrence of mineable grade zinc mineralization".

Radford Creek Area

Three exploratory shafts were sunk 10ft. to 20ft. in depth, at the turn of the Century, to expose copper carbonates in a formation 2 to 3ft. wide adjacent to a shear zone separating lower Cambrian limestones from shales of the Wonoka Formation near Radford Creek. A sample taken contained 4½% Cu (Brown, 1908 p.66) Several pits have also been sunk approximately one mile to the south in a pod of manganese adjacent to a fault zone.

Special Mining Lease 109, six square miles in area, within the limits of the former S.M.L. 94 was granted to Kennecott Explorations (Australia) Pty.Ltd. on 1.6.66 to undertake an extended programme of exploration which included rock chip and soil sampling, geophysical surveys, trenching and drilling to investigate further the lead - zinc - copper mineralisation which was located in this locality during the course of a stream sediment geochemical programme (McNeil, 1966 (a), 1966 (c), 1967 (b)).

The lower Cambrian sequence within S.M.L. 109 includes 200ft. of thinly bedded argillaceous sandstones and siltstones with massive dolomite and dolomitic shale of the Parachilna Formation ahd these are overlain by the Wilkawillina Limestone about 1400ft. in thickness (figure 11) These comprise a block having a strike length of less than two miles and margined on all but the western side by Upper Proterozoic sediments faulted into juxtaposition. The Parachilna Formation is largely obscured by scree derived from the underlying quartzites.

Stream sediment samples taken by McNeil (1966 (a)) showed contents of up to 1000 p.p.m. Pb, 700 p.p.m. Zn and 70 p.p.m. Cu. Follow-up soil and rock chip sampling disclosed

high coincident anomalies with respect to those metals in association with iron and manganese oxides within the Parachilna Formation and at the base of the Wilkawillina Limestone traceable over a strike of almost one mile. Geophysical surveys yielded inconclusive results; several small self-potential anomalies were detected over 8 lines comprising 2.5 line miles; induced polarization measurements taken along a line 0.3 mile in length showed small anomalies not coincident with known mineralization. Five trenches were cut using a bulldozer in the area of greatest metal concentration where soil samples contained up to 4,800 p.p.m. Pb, 2,650p.p.m. Zn and 390 p.p.m. Cu and rock chip samples showed up to 3.8%Pb, 1.15% Zn and 0.13% Cu (figures 12, 13 and 14). Analyses of samples cut from the floors of the trenches are tabled below:

Trench No.	Sample Interval (feet)	P.p.m.					
		Zn	Pb	Cu	Co	Ni	Mn
1	33	1410	135	70	102	78	10,000
2	88	1820	97	40	140	104	10,000
3	144	6210	800	90	220	130	10,000
4	120	3380	4630	745	60	64	10,000
5	200	330	760	140	16	15	55

Two non-core rotary drill holes were sited to probe the deposits at depth (figures 15 and 16). Hole 1, inclined 59° was drilled to a depth of 315ft. and intersectedlow grade mineralization that averaged 0.12% Pb, 0.11% Zn over the interval 185 to 315 feet.; surface grades up-dip from the drill intersection were approximately 1% Pb, 1% Zn. Hole 2, drilled vertical to 525 ft. intersected, within the Parachilna Formation, ochreous limestone with minor sandstone and shale containing up to 0.34% Zn and 0.30% Pb over a stratigraphic width of about 20ft. downdip from the main area of surface mineralization.

The zinc mineral was determined by AMDEL as chalcophanite while cerussite was detected in the drill cuttings.

The westerly extension of the mineralized lower

Cambrian strata between the Radford Creek locality and Simmonston are obscured by Quaternary outward gravels. The lease was surrendered on 31.8.67.

Kanyaka Area

When inspected by Austin in 1863 (Brown, 1908, p.65) several shafts had been sunk at the Kanyaka copper mine, the deepest being 90ft. and connected by drives extending for about 240ft., on a well defined lode dipping at a low angle in apparent conformity with the enclosing Parachilna Formation sediments. Blue and green copper carbonates occupied a lode 2ft. to 2½ft. in thickness within slates and sandstone which strike northwest-southeast. After a period of inactivity mining was resumed about 1899 when 200 tons of 10% copper ore were recovered from workings which now included shafts and pits extending along strike a distance of over 1,000ft. and an open cut 50ft. x 12ft. x 25ft. deep. Subsequent recorded production (Rev. of Min. Op. 3 (1905), 4(1905), 5(1906), 6(1907) and 23(1961) totalled 165 tons with grades ranging from 7½% to 16% Cu.

The mine area is covered by 2ft. to 12ft. of quartzite scree and all shafts except one at the western end have since collapsed and filled. Several shallow pits have also been sunk on a copper prospect several miles to the north of the Kanyaka mine.

In the Kanyaka syncline (figure 17) the Parachilna Formation varies from 200ft. to 400ft. in thickness and consists of thinly bedded white clayey sandstone, with worm burrows and interbedded white siltstone and limestone in the upper parts; the formation is limited in outcrop, being mostly veneered by quartzite scree derived from the underlying Pound Quartzite. The Wilkawillina Limestone, about 1600ft. in thickness, is a massive blue-grey limestone containing occasional Archaeocyathinae and chert pods; it is sandy, oolitic and buff-coloured near the base. The top of the unit is mottled and of dark colour

and passes into the Parara Limestone which includes flaggy grey limestones with grey and olive-green siltstones. The uppermost Cambrian formation is the Oraparinna Shale (Milnes and Preiss, 1967).

Within S.M.L. 94 stream sediment samples and rock chip samples taken from a number of traverses showed several areas of anomalous base metal content. Isolated anomalous copper values occur but they are not related to any known or obvious mineralization; a stream sediment sample taken from immediately below the Kanyaka mine contained only 52 p.p.m. Cu (McNeil, 1966a) suggesting that mineral dispersion trains are short.

In Special Mining Lease 110, granted on 1.6.66 over an area of 15 square miles to Kennecott Explorations (Australia) Pty.Ltd., efforts were directed towards assessing the Kanyaka copper mine area - an area lacking manganese in surface outcrop in contrast to the Comstock and Radford Creek localities (McNeil, 1966(d), 1967(c)).

Self-potential geophysical traverses were metered (5 lines, 2 line miles) which showed several small anomalies not correlated with known mineralization while induced polarization of a single traverse 0.3 mile in length gave inconclusive results.

From the mine dumps (figure 18) 57 samples representing about 500 tons of mineralized rock rejected during mining operations, were taken for analysis and contained an average 1.43% Cu, 0.076% Pb and 0.56% Zn. Five dump samples were scanned spectrographically (contents p.p.m. tabled below) and it is noteworthy that in addition to copper, lead and zinc there are significant concentrations of nickel, cobalt and the rare earths, scandium, lanthanon and yttrium.

TABLE 1

Sample No.	16360	19370	16380	16390	16400
Cu	3000	10000	10000	10000	10000
Pb	1000	800	1500	1500	500
Zn	600	10000	10000	500	500
Co	60	2000	2000	15	80
Ni	150	1200	1200	25	250
Sn	2	2	2	2	1
Bi	3	3	3	3	3
Cd	3	3	3	8	3
Ag	2.5	3.0	15.0	5.0	1.0
V	200	200	200	200	15
B	100	200	200	150	20
As	70	70	50	70	70
Cr	200	200	250	200	120
Mo	4	4	2	1	1
Be	5	3	1	8	40
Ga	20	15	8	30	3
Ge	1	1	1	1	1
Mn	15	70	5	15	200
Li	250	200	100	200	50
Rb	100	80	80	100	30
P	800	600	1000	1000	1000
Ba	300	300	400	500	250
Sr	500	150	150	150	120
Sc	80	300	1	80	30
La	500	700	100	100	100
Y	500	800	100	600	500

Ta, Nb, Os, Rh, Ir, Te, Tl, Sb, Au, W, Pd, In, Cs, Zr, Ce not detected.

Five trenches, cut by a bulldozer to depths of 4ft. to 10ft. within the mine area (figures 18 and 19) to expose bedrock under cover of quartzite scree, revealed traces of malachite and azurite in sandstones of the Parachilna Formation over a width of almost 180 ft. and along strike for a distance of at least 1,000ft. Results of sampling are tabled below (average of samples cut from both walls and floor).

Pit No.	Sample Interval (feet)	average p.p.m.						
		Cu	Pb	Zn	Co	Ni	Ag	Mn
1	29	113	163	42	7	14	0.5	-
2	52	114	837	56	5	-	-	-
3	35	125	64	243	48	-	-	-
4	100	1255	820	970	59	52	-	23
5	80	2768	800	337	21	31	-	154

The drilling of eleven non-core rotary holes aggregating 3,112ft. (see figure 19 for location, figures 20 and 21 for results) outlined a zone of low grade zinc/copper mineralization in this same area. "The holes were closely spaced to allow correlations between hole sections and thus prove whether or not the mineralized zone is conformable with the sediments.....and there is no doubt that the mineralized zone, as exposed on the surface and intersected in the boreholes, has a stratiform nature" (McNeil, 1967(c)). Copper contents ranged up to 0.5% but generally there is only a trace of copper (less than 100p.p.m.) Dolomitic limestones in the upper part of the Parachilna Formation contain up to 2.75% Zn over a stratigraphic interval of about 10ft. Though the water table is at a depth of 100ft. to 120ft. oxidation effects persist to a depth in excess of 300ft. From the surface to about 100ft. no zinc minerals were detected in the cores while copper occurs as azurite and malachite; in the interval 100ft. to 200ft. zinc occurs as chalcophanite while some secondary copper sulphides are present. Mineralogical examination by AMDEL of samples taken from Hole 1 disclosed that primary sulphides occur below

a depth of 375ft. and sphalerite, galena and pyrite were recognised in the interval 375ft. to 387ft. 6 ins.

In an attempt to establish continuity of mineralization at the surface, seven trenches (T6 to T12) were cut having a total effective length of 2,880ft. to a depth of up to 10ft. within the Parachilna Formation for about four miles north along strike from the Kanyaka Mine. Tabled below are results of trench sampling; base metal contents are low throughout; manganese content exceeded 100p.p.m. only in T8.

Trench No.	Sample Interval (feet)	p.p.m.		
		Cu	Pb	Zn
T.6	150	20	20	20
T.7	300	20	20	20
T.8	90	140	80	250
T.9	110	125	400	600
T.10	210	125	880	250
T.11	150	60	900	125
T.12	10	100	120	1100
	250	25	350	125

As it was "evident that the copper mineralization at Kanyaka represents a small, localised deposit" S.M.L.110 was allowed to lapse on 31.10.67.

Reaphook Hill Zinc Prospect

Reconnaissance rock chip sampling by the Department of Mines near Reaphook Hill in 1963 had shown 350p.p.m. Cu and over 1% Zn over an interval of 65ft. within the Wilkawillina Limestone and though prospectors had previously gouged several small shallow pits in outcrops of manganiferous limonite in the locality the significance of the prospect remained undetermined umtil Kennecott Explorations (Australia) Pty.Ltd. acquired S.M.L.95 over an area of 57 square miles on 1.12.65 (McNeil, 1966(e), 1966(f). On expiration of that lease two further leases, S.M.L.137 (Emu Bore area of 9 square miles) and S.M.L.138 (Reaphook Hill area of 57 square miles), were granted on 1.12.66.

Stream sediment sampling undertaken by that company and analysis of the minus 20 mesh fraction indicated that copper contents were generally in the range 20 to 25 p.p.m. with several samples containing in excess of 45 p.p.m.; lead contents were generally less than 30 p.p.m. but samples taken from channels draining the lower Cambrian rocks were anomalous and in excess of 100p.p.m.; coincident with the lead anomalies, zinc values from the basal Cambrian sediments ranged up to 1170 p.p.m. (McNeil, 1966 (e). Two areas were thus outlined, Emu Bore area where follow-up surface sampling and traversing discounted useful enrichment of zinc and the Reaphook Hill prospect where subsequent activity was concentrated (McNeil, 1968).

The stratigraphy and structure of the area depicted in figure 22 were detailed by Loos, Milnes and Preiss (1967). The Parachilna Formation which ranges up to almost 100ft. in thickness is here characterised by gritty, poorly sorted argillaceous sandstone and conglomerate lenses with well-rounded quartz pebbles up to 1 inch in diameter dispersed in a matrix of weakly consolidated sand and grit. The outcrop is poor and the formation is almost completely obscured by derived gravels. The basal beds of the Wilkawillina Limestone comprise brown to buff coloured, manganese-stained, sandy dolomites which are succeeded by massive brown, buff or blue-grey dolomitic limestone totalling 1400ft. in thickness. The physiography of the area is dominated by ridges of white Pound Quartzite of which Reaphook Hill is the highest and rising to 1271 ft. above sea level. Over its outcrop length the Cambrian limestones tend to show an accordance of summit levels at about 300ft. above the surrounding plains, remnants of a now-dissected erosion surface.

The Cambrian and underlying strata are disposed in broad scale open folds but repetition of the stratigraphic units by faulting complicate the structure.

Zinc mineralization is associated with ferruginized and manganiferous limestone as chalcophanite, scholzite ($Ca, Zn_2(PO_4)_2 \ 2H_2O$), and manganese wad in massive to irregularly

banded goethitic and manganese-rich masses and as disseminations. Chip sampling revealed substantial zinc content within the basal 600ft. of the Wilkawillina Limestone over an area approximately 4000ft. x 2000ft. in the area (see figure 22). Chip samples showed isolated zinc contents of up to 20% Zn while the best traverses were 60ft. at 4.09% Zn and 80ft. at 3.56% Zn over two different stratigraphic horizons. The zinc content is low in the Parachilna Formation except for the scholzite occurrence wherein white prismatic needles of this mineral comprise three discrete masses directly overlying sandstones and loosely consolidated gravels less than 60ft. stratigraphically above the top of the Pound Quartzite. These outcrops have a high iron and manganese content and contain 20% Zn and 30% P_2O_5.

Lead, copper and silver are present in trace amounts; cobalt and nickel are present in anomalous concentrations while manganese content is high throughout the Wilkawillina Limestone. Galena occurs in calcite veins within the underlying Wonoka Formation and accounts for the high lead and zinc stream values in the Emu Bore locality. Selected minor metals content of selected samples are as under:

	Zn%	p.p.m.					Mn %
		Cu	Pb	Ni	Co	Ag	
Goethitic and zinciferous wad	4.9	10	26	448	1070	0.5	37.5
Scholzite	20.7	35	83	39	125	1.5	1.8

Three lines of self-potential survey over 1.1 line miles and 0.8 line miles of induced polarization were metered and the several small weak anomalies defined by these methods were attributed to pyrolusite.

Two non-core rotary holes (total 737ft.) and 5 diamond drill holes (aggregate 2,054ft.) were drilled without disclosing sulphides or mineralization below the base of oxidation; poor core recoveries were achieved.

Drilling disclosed low grade zinc contents within the basal 600ft. of the Wilkawillina Limestone (average 0.2% Zn)

with a zone up to 20ft. in width near the centre of the Parachilna Formation containing from 0.3% to 2.0% Zn. The fault-bound block of limestone which contained the best surface grades and showing 2% to 5% Zn, proved to be a "crust" ranging from 10 to 20ft. in thickness and underlain by yellow-brown clays. The zinc and manganese have apparently been concentrated at the surface within the basal units of the Cambrian strata by weathering and erosional processes. The scholzite occurrence in the Parachilna Formation results from the surface enrichment of zinc and phosphorus derived from originally low grade mineralization within the Parachilna Formation (McNeil, 1968).

Faulting appears to have exerted some control on mineralization and localization of the manganese which has an affinity for zinc.

Representative surface chip samples and cores from D.D.4 were scanned spectrographically for a number of elements which indicated that Zn, Co, Ni, Cd and Mn have been enriched within the topmost 5 to 30ft. of the limestone. In bore 4 between 268 feet and 273 ft. the samples contained 500 p.p.m. Y, 500 p.p.m. La and 1000 p.p.m. Ce. The down-dip projection of the scholzite zone between 273 ft. and 280 ft. contained 0.25% Zn The locations of drill holes and results of drilling are depicte in figures 22 and 23.

It was concluded that small tonnages of 2% to 4% secondary zinc mineralization occur at or near the surface of a faulted block of Wilkawillina Limestone with manganese in wad or as chalcophanite but incapable of sustaining a mining operation and the leases were surrendered on 18.4.68.

Third Plain Zinc Prospect and ajoining areas

Small outcrops of high grade zinc mineralization (willemite) were located during the course of a regional stream sediment sampling programme by Kennecott Explorations (Australia) Pty.Ltd. in the Third Plain Creek locality and Special Mining Lease 143 was acquired by that company on 1.1.67 over an area

of 30 square miles to evaluate the prospect (Besley, 1967(a)).

In this region, lower Cambrian sedimentation was influenced bytectonic activity adjacent to the Oraparinna and Wirrealpa Diapirs which resulted in reduced thickness or absence of the Parachilna and other Formations whilst immediately to the south a much greater thickness of lower Cambrian sediments accumulated in a graben in the Wilkawillina Gorge area as a consequence of contemporaneous subsidence related to development of the Oraparinna Diapir. The easterly dipping strata have been subsequently dislocated by a number of sub-parallel transverse faults oriented northeast- southwest and with lateral displacemen generally less than 100ft.

Regional reconnaissance sampling of stream sediments of the Cambrian tract along the eastern margin of the Flinders Ranges disclosed anomalous zinc contents in excess of 400 p.p.m. about onemile south of Balcoracana Creek whereas elsewhere in this region these were generally in the range30 to 50 p.p.m. Follow-up sampling disclosed a train of anomalous values in the creeks drainingnorth from the Third Plain area and this led to the discovery of willemite in outcrop at the base of the massive grey to buff dolomitic limestone. The Parachilna Formation comprises kaolinitic sandy shale lenticles only a few feet in thickness or is locally absent.

The several lenticular outcrops of willemite are up to 40ft. wide and 150ft. in length and are separated and surrounded by an area 1000ft. x 400ft. of reddened haematitic dolomite containing from 0.1% to 1.0% Zn (See figure 24). The mineralization and environment is analogous to that pertaining at Puttapa Willemite containing up to 55% Zn is mainly in the form of white radiating spherulitic aggregates or colloform bands, massive or as spherules in dolomite. Manganese oxides are intimately associated, lead is a minor constituent but one example contained 3.5% Pb, while arsenic content is high and exceeds 1% in some samples.

Chip samples were taken along lines to define the surface grades and extent of mineralization. Spectrographic

analysis of selected samples are tabled below:

	Sample No.						
	1	2	3	4	5	6	7
Zn (%)	0.9	55.5	2.3	41.5	0.2	16.0	52.5
Pb (%)	3.5	0.3	0.05	0.55	0.05	0.1	0.2
Mn (p.p.m.)	10,000	250	10,000	5000	25	3000	50
As "	6000	5000	120	10000	50	150	200
Co "	60	1	12	10	1	4	1
Ni "	80	1	7	100	1	2	1
Cd "	5	3	10	3	3	3	3
Cr "	15	12	4	100	400	4	4
V "	20	20	2	50	12	10	3
Mo "	50	2	1	6	1	1	1
Ga "	5	1	1	7	1	1	1
Ge "	5	150	1	200	1	3	70
Ba "	250	80	40	100	5	150	10
Sn "	5	1	50	150	1	20	1
B "	8	300	1	7	3	4	300
P "	400	500	100	250	120	100	150
Sc "	1	1	1	12	1	1	1

Besley (op.cit) noted that "the relationship between this supergene surface outcrop of zinc mineralization and the primary mineralization is obscure" and concluded that, in this arid environment, open circulation of silica-laden groundwaters through fault zones and fractures would facilitate the enrichment of zinc silicate possibly derived in turn from carbonate (smithsonite) and primary low grade sulphide (sphalerite).

No sub-surface exploration was undertaken, hence a reliable assessment of reserves is not currently available. The lease expired on 30.9.67 and a mineral claim has subsequently been pegged.

An area of 200 square miles was granted to Kennecott Exploration (Australia) Pty. Ltd. on 1.9.66 as Special Mining

Lease 124 to undertake a programme of stream sediment sampling westerly from the Reaphook Hill locality and adjoining the Third Plain area to the south. The Cambrian strata are concealed along the northern and eastern flanks of the ridge which culminates in Mount Mantell and comprises Pound Quartzite. Lower Cambrian outcrops are restricted to the Wilkawillina Gorge area. Some 500 stream sediment samples were taken utilizing a a helicopter but no anomalous base-metal contents were disclosed (Clema 1966 (a), 1967 (a)) copper values were generally in the range 10 to 20 p.p.m., lead 10 to 20 p.p.m. and zinc 40 to 50 p.p.m. and S.M.L. 125 was relinquished on 1.3.67.

Kennecott (Australia) Pty.Ltd. were granted S.M.L.123 over an area of 600 square miles on 1.9.66 in the Wirrealpa - Mount Frome locality which included the Wirrealpa lead mine (Ridgway, 1949; Mansfield, 1953) and the Mt. Chambers lead and copper mine. Stream sediment sampling was expedited by use of a helicopter; some 3000 samples were taken and the minus 80 mesh fraction was analysed for copper, lead and zinc. Three anomalous areas were outlined, designated Wirrealpa, Mt. Lyall and Mt. Chambers, over which the regional stream sediment sampling revealed abnormal lead and zinc contents in streams draining lower Cambrian Wilkawillina Limestone (Besley, 1967(b)).

In the Wirrealpa - Mt. Lyall locality the Parachilna Formation and succeeding limestones are disposed in open fold structures which have been disrupted by normal faulting and associated diapiric intrusion. Galena and barytes occur in small veins at the Wirrealpa lead mine within the Wilkawillina Limestone and these have been mined to a depth of 195 ft. from several shafts and underground workings and at the surface for a length of 280ft.; recorded production exceeds 1000 tons of ore. Numerous limonitic-manganese oxide pods which are concentrated near the base of the carbonate sequence proved to have low base-metal contents. The highest values recorded in sediments from streams draining the Wilkawillina Limestone ranged up to 300 p.p.m. zinc and 160 p.p.m. lead. Follow-up rock chip sampling

failed to reveal any significant mineralization.

In the Mount Chambers area shallow workings expose malachite-stained siltstones and minor blebs of galena in limestone have been recorded. Chip sampling was undertaken to define a stratigraphic thickness of almost 3,000ft. where regional stream sediment sampling had revealed abnormal lead and zinc concentrations (Besley, 1967 (b)). The highest metal contents proved to be 200 p.p.m. Pb and 1,000 p.p.m. Zn over a length of 100ft. A number of small manganese-iron oxide cappings scattered throughout this area also have low base-metal contents with one isolated high of 200 p.p.m. Pb and 2,500 p.p.m. Zn being located.

As it was considered that there was little likelihood of the occurrence of economic deposits of lead, zinc or copper in the region, the lease was relinquished on 31.5.67

Moro Area

Copper was discovered 9 miles west-southwest of Wertaloona H.S., in the Moro locality, in 1857. Numerous shallow pits comprising the Moro (Moorod, Moorowie, Balcanoona mines and the Moro Central prospect were worked during the period 1861 to 1865 with desultory mining activity to 1908 for recovery of copper carbonates but recorded production amounts to only 25 tons. The richest patches or ore were mined principally from deposits within the Parachilna Formation, where stratigraphic control on mineralization is evident (figure 25) and hand picked to about 20% grade as was then the practice. Malachite staining is prominent in the Pound Quartzite and in fault breccia adjacent to the boundary fault near the Moro ruins and one mile to the west and southwest where copper mineralization is localized at the crest of a north pitching anticline and around the flanks of this structure within the Parachilna Formation. The core of the anticline is occupied by massive dolomitic limestones, sandy limestones and dolomitic shales of the Wonoka Formation (Leeson, 1967). The overlying

Pound Quartzite comprises massive white sandstone (over 1,000ft. in thickness) which forms high hills flanked by valleys marking Parachilna Formation outcrop. The Parachilna Formation which outcrops poorly consists of about 100ft. of buff to white thinly-bedded silty sandstones with dolomite lenses. Contacts with the succeeding chocolate to buff coloured massive Wilkawillina Limestone are generally obscured by masses of manganiferous ironstone and scree, particularly along the eastern limb of the anticline. The Cambrian limestone outcrops in low plateaux. The structure is dislocated by numerous cross-faults along that limb and by several near-strike faults with which manganiferous ironstone "gossans" are associated.

During the tenure of Special Mining Lease No.54 over an area of 2½ square miles by C.R.A. Exploration Pty.Ltd. in 1963 chip sampling undertaken by MacKenzie and Macnamara (1963) near the Balcanoona Mine outlined an area of low grade copper mineralization, the principal mineral being malachite with some azurite and minor chalcocite. Extensive copper staining and veining in joints, fractures and narrow breccia zones within the Pound Quartzite showed up to 2.25% Cu in several chip sampled traverses over lengths of up to 15ft. The mineralization which spans a stratigraphic interval of about 600ft. within the uppermost units of the formation is sporadically developed over an area measuring 2,400ft. in length by 400ft. average width. Patches of better grade ore, having an aggregate surface area of only 12,000 sq. ft. and averaging 0.54% Cu, are separated by large areas of near-barren quartzite. Thin malachite stainings often with limonite and manganese oxides occur on the undersides of crags but seldom on the upper exposed surfaces. The outer detectable limits of this mineralization is indicated in figure 25

It was considered that copper was derived from the overlying beds of the Parachilna Formation and accumulated in closely jointed and broken quartzite at the anticlinal crest under the control of a pre-existing water table whereas the tighter formations on the limbs were not mineralized. As the indicated tonnage of

890 tons per vertical foot of 0.54% Cu "ore" was too small to support a mining operation the lease was abandoned in December, 1963.

An area of four square miles in this same locality was granted on 1.8.65 to F.R. Hawkins (Copper)Pty. Ltd. as S.M.L. 89 but after drilling four shallow percussion drill holes with discouraging results this lease and a surrounding area of 110 square miles (S.M.L. 91) were acquired on 1.9.65 by Kennecott Explorations (Australia) Pty.Ltd. to further explore the occurrence of base-metal mineralization of an apparent stratiform nature (Brooks, 1966(a); Clema, 1966(b); Lennon, (1966)). On expiry of those areas two further leases were granted to the same company on 1.9.66, both 45 square miles in area, S.M.L. 127 encompassing the Balcanoona Mine Locality (Brooks, 1966(b); Lennon, 1967 (a), 1967 (b)) and S.M.L. 128 (Ironstone Bore area) immediately adjoining to the south (Clema, 1966(c), 1957 (b), Brooks, 1967). Kennecott Explorations (Australia) Pty. Ltd. carried out a programme of stream sediment, rock chip and pit dump sampling, geological survey and diamond drilling, the results of which, until surrender of S.M.L. 128 on 9.5.67 and of S.M.L.127 on 31.10.67, are detailed below.

Stream sediment sampling (500 samples) rock chip sampling (120 samples) and testing of old pit dumps in the vicinity of the Moro Central prospect showed copper contents ranging up to several per cent, several tenths of one percent zinc, trace lead and cobalt in lower Cambrian strata and resulted in the discovery of cinnabar (containing up to 5% Hg), associated with malachite, in a pit located 100 yards northerly from Moro ruins adjacent to the major fault bounding the Lake Frome plains.

The Moro Central prospect is located within the Parachilna Formation wherein sedimentary control to copper mineralization is apparent over a stratigraphic width of up to 50ft. about the nose and both flanks of the anticline intermittently over a strike length of at least $2\frac{1}{2}$ miles. Sampling has shown that the overlying limestones are anomalously rich in lead

and zinc and, to a lesser extent, copper, particularly in gossanous areas and adjacent to faults while sampling undertaken by MacKenzie and MacNamara (Op.cit.) outlined limits of copper mineralization in the vicinity of the Balcanoona Mine within the Pound Quartzite. Mineralization within the Parachilna Formation comprises irregular patches, veinlets andimpregnations along joints of malachite, azurite and minor chalcocite; samples taken from the dumps of the numerous shallow pits contained up to 4%Cu. The less-broken siltstones and the dolomitic sequences within this formation contain only a few hundred parts per million copper at most while along the outcrop of the Parachilna Formation, in the complementary limb of the syncline to the northeast, there is no visible copper mineralization. An adit was chip sampled at 10ft. intervals over its length of 120ft.; from the portal to 70ft. the weathered rock averaged 0.76% Cu, 135p.p.m. Pb, 926p.p.m. Zn and 290 p.p.m. Co while less weathered rock from 70ft. to 120ft. contained 320 p.p.m. Cu, 40 p.p.m. Pb, 88 p.p.m. Zn, and 22 p.p.m. Co

Manganese ores are associated with, and form part of a secondary manganiferous ironstone formation which caps a mineralized zone along the faulted contact between Pound Quartzite and Wilkawillina Limestone on the eastern limb of the anticline. The gossan-type manganiferous ironstones are secondary deposits resulting from concentration and replacement of the underlying belts similar in nature and form, and in a similar structural environment, as occur elsewhere in the Flinders Ranges at the same stratigraphic level vix. at Mt. Arden (Comstock), Radford Creek, Reaphook Hill, Bunyeroo, Parachilna, Ediacara, Eregunda, Bungoola, Narina, Copper King etc. They are concentrated on areas of the Wilkawillina Limestone penetrated by faults and to some adjacent parts of the Parachilna Formation and the Pound Quartzite which have been affected by faulting. The surface cappings are locally up to 8ft. in thickness and comprise massive colloform, banded or brecciated ironstone (limonite and haematite) with earthy goethite and manganese oxide (psilomelane and wad).

The manganese content shows a considerable range from 0.2% to 44.5% with iron content in these extremes being 51.5% and 4.9% respectively (Fairburn, 1967). The underlying limestones have proved to be favourable host rocks for cavity and joint filling and for replacement deposits; relict bands of unreplaced massive limestone are discernible within some manganiferous ironstone masses. Malachite, azurite and coblat wad are sometimes associated with the gossanous rock; analyses of several grab samples are tabled below

Sample No.	Mn(%)	Cu (%)	Co(%)
1	23.4	3.2	0.11
2	20.4	0.03	0.12
3	21.4	6.3	0.98
4	34.4	0.07	0.29
5	7.8	6,5	0.50

Geophysics was undertaken, including self-potential profiles over twelvelines aggregating 16,750ft. and induced polarization across the basal Cambrian section in the area of visible mineralization; several small, rather ill-defined anomalies were defined.

Diamond drilling was undertaken (see figures 25 and 26) to test for presence of stratiform base-metal deposits as follows:

....B1 to test for continuity of grade and possible secondary copper enrichment in the zone of copper carbonate occurrence within the Pound Quartzite. Drilling to 647ft. penetrated purple sandstone under white quartzite with sporadic grains of pyrite. Almost full core recovery was achieved but no copper minerals were detected.

....B2 where the target zone comprised the down-dip extension of the lower part of the Wilkawillina Limestone, which commonly contains 0.1 to 0.4% zinc and 0.1% lead at the surface, and the Parachilna Formation just west of the

zone where pit dump samples contain up to 2% Cu and 400ppm Yttrium. The hole, 529ft. in length penetrated Pound Quartzite and disclosed minor pyrite. The core was weathered throughout; poor core recovery was achieved in the zone of interest.

.....B3 designed to intersect the same zone as in B2 well below the zone of weathering, was drilled to 1121feet. Core recovery was poor and sludge samples from the Parachilna Formation showed copper contents generally in the range 12 to 25p.p.m., lead 40 to 150p.p.m. and zinc 30 to 50p.p.m.

.....B4 drilled to 500ft. in Pound Quartzite in the western limb of the anticline revealed only traces of pyrite on bedding planes and joints without disclosing base metal mineralization.

.....B5 to identify the source of an I.P. anomaly below manganiferous ironstone cappings with anomalous copper on the eastern limb of the anticline in an area of faulting. The hole was abandoned due to caving at 504ft. after penetrating dolomite (0 - 250ft.), goethitic siltstones (250-314ft.) and brown clays with goethite and manganese oxides (314 to 504ft.) Over the interval 308ft. 6 ins. to 383ft. average copper content was 0.13% in what core was recovered and between 445ft.6 ins. and 504ft. average copper content was 0.28%. At 472 to 504ft. zinc content was 710p.p.m. while lead was 140p.p.m.

.....B6 drilled vertical to 531ft. 6 ins. to further test the same zone as B5, penetrated Pound Quartzite after intersecting goethitic silts and clays of weathered Parachilna Formation between 190ft. and 483ft. and proved 32ft. of 0.50% Cu, 50 to 80p.p.m. lead and 300 to 600p.p.m. zinc in the core recovered in the interval 416ft. to 448ft. Recovery of core was extremely poor. Occasional flecks of malachite were detected in the Pound Quartzite between 522ft. and 527ft.

Further chip sampling was undertaken on the western limb of the anticline where the Parachilna Formation showed 1500

p.p.m. zinc over a width of 30ft. but failure of the drilling to disclose other than minor concentrations of base-metals in SML127 and the lack of anomalies in SML128 led Kennecott Explorations (Australia) Pty.Ltd., to surrender these leases.

Thermercury mineralization of the Moro area suggests "introduction or mobilization of mineralization along some of the major faults of the area" but its economic significance has not been determined.

LAKE TORRENS AREA

An area of 14,540 square miles embracing the western flanks of the Flinders Ranges, the Lake Torrens Sunkland and adjoining Stuart Shelf was granted to Mines Exploration Pty.Ltd., (M.E.P.L.) on 15.6.66 as S.M.L. 115 for a period of three months to delineate, if possible, mineralized lower Cambrian Limestones in outcrop or under shallow cover, preferably where these are flat lying.

Tc the east of the lake theWilkawillina Limestone is exposed adjacent to Mount Scott Range, in the foothills of the Flinders Ranges between Nilpena and Edeowie Gorge and the Cotabena Syncline (Dalgarno 1966). The equivalent Andamooka Limestone is exposed at the northern extremity of Lake Torrens and as a thin flat-lying veneer on the Stuart Shelf (Johns 1966, 1968). In the Sunklands, Quaternary and Tertiary sedimentary cover precludes direct exploration in Cambrian rocks but, in the Wilkatana area, oil exploration drilling has revealed a completely covered basin of Cambrian carbonate rocks.

A broad regional reconnaissance geochemical programme was undertaken by M.E.P.L. initially by stream sediment sampling with A.A.S. determination of copper, lead and zinc of the minus 80-mesh fraction after leaching by hot 25% nitric acid followed up by rock chip sampling to assist in evaluation of those results to check base metal contents of exposed basal Cambrian carbonate rocks and ditinctive, iron stained or gossanous rocks (Roberts 1966).

Rock chip sampling of a distinctive iron-stained basal Cambrian dolomite bed 20ft. in width in Parachilna Gorge revealed contents of 310ppm, copper, 8500 ppm lead and 19500 ppm zinc, over its full width. However, stream sediment results were considered to be more meaningful, particularly with regard to lead and using a high threshhold value of 100ppm for lead there proved to be a zone extending along the front of the Flinders Ranges between Brachina Gorge and Parachilna Gorge and beyond over a strike length of more than 15 miles with anomalous values.

To the west of Lake Torrens stream sediment sampling proved unsatisfactory because drainage channels are broad, ill-defined and contain considerable wind blown sand. Rock chip sampling revealed an area of interest northeast of Andamooka Opalfield on the shore of Lake Torrens where a distinctive leached and iron stained limestone bed showed 630ppm copper, 115ppm lead and 270ppm zinc.

Core from Santos Wilkatana No.1 bore was analysed to provide data as to background metal values in apparently un-mineralized rocks from the same stratigraphic horizon. In addition to traces of chalcopyrite the presence of galena just above the base of the Cambrian at this site, supports the view that base metal mineralization occurs in areas not formerly suspected. Tabled below are results obtained in the Cambrian carbonate rocks of Wilkatana No.1 bore.

Interval ( )	p.p.m.			Remarks
	Cu	Pb	Zn	
463-486	10	35	194	
-504	10	25	177	
-549	10	35	162	
723-728	10	35	370	
-733	10	25	570	
-738	10	15	340	
-743	10	25	260	
-748	10	25	193	
-753	15	35	340	
-758	10	15	193	
-763	20	25	200	
-768	10	15	114	

Interval ( )	p.p.m. Cu	Pb	Zn	Remarks
-774	10	15	1050	
-800	85	90	290	
-870	95	60	445	
-840	205	60	131	
-860	40	50	97	
-880	15	25	148	
-900	400	35	77	
-920	50	50	315	
-940	80	50	200	
-960	70	35	270	
-980	15	25	148	
-980	15	25	148	
-1000	40	35	155	
-1050	510	60	325	
-1040	1200	60	2400	
-1060	150	50	200	
-1080	480	50	120	
-1100	370	35	50	
-1120	125	35	89	
-1140	15	25	120	
-1160	620	35	81	Traces of chalcopyrite
-1180	25	35	177	
-1200	35	35	93	
-1220	20	35	77	
-1240	25	50	185	
-1260	35	50	114	
-1280	15	35	50	
-1300	10	25	24	
-1320	65	700	58	Traces of galena
-1337	25	50	107	

Cores from Wilkatana bores Nos. 2 and 3 showed low and constant copper and lead values with zinc variable and generally in the range 150 to 300 p.p.m. In the available core from bore 4 a sample taken from 936ft. 6ins. contained 5200 ppm copper, 2000 ppm lead and 1480 ppm zinc.

The results obtained thus far were so encouraging that further leases were sought over the areas of interest, the prime target being occurrence of lead.

ROXBY DOWNS AREA

In the Roxby Downs area S.M.L. 129 was granted over an area of 950 square miles on 14.9.66 and was subsequently surrendered on 14.8.67 after follow-up rock chip sampling (total 275 samples) revelaed no outstanding metal values though limestones contained up to 80ppm.lead in the vicinity of Purple Downs H.S. (Roberts 1967d).

ANDAMOOKA AREA

An area of 800 square miles was granted to M.E.P.L. as S.M.L. 130 in the Andamooka locality on 14.9.66. At the expiration of S.M.L. 130 on 14.11.67 another lease, S.M.L. 130A of 171 square miles, was applied for and obtained within the original area.

Analysis of some 500 predominantly rock chip samples, taken throughout the area of S.M.L. 115, established that a distinctive leached, manganese and iron stained basal Opalfield Andamooka Limestone bed occurring north-east of Andamooka/and on the edge of Lake Torrens gave geochemical assays up to 1700ppm copper, up to 410 ppm lead and up to 650 ppm zinc while background values had been established in the range 5 to 25ppm copper, 10 - 35 ppm lead and 10 to 80 ppm zinc (Roberts 1967 (a), (b), (c)). Two samples taken from the western shore of Lake Arthur contained 430 ppm and 180 ppm lead respectively. A total of 281 rock chip samples were collected within the area of S.M.L. 130 to define the principal area of interest.

To check the possibility that the aacmalous geochemical results north-east of Andamooka were indicative of sulphide mineralization below the level of oxidation induced polarisation surveys (3=.8 line miles) were undertaken, including follow-up work (Roberts, 1967 (e), 1968 (a) (d)). Shorter electrode spread follow-up surveys revealed zones of possibly anomalous I.P. effects which were tested by diamond drilling (Roberts, 1968 (e), (g) (i)) - see Figure 27:

--- LTA1 (total depth 303ft.) penetrated partly leached (with coatings of iron and manganese oxides in vughs) massive off-white to grey-blue Andamooka Limestone to 112ft. 6ins. Sandy sections and intraformational conglomerates were reported. Fine pyrite mineralization was intersected from 49ft. to 111ft. 6ins. as aggregates and single crystals in vughs, on fractures and in dark chloritic aggregates. Purple, green and grey Yarloo Shale was penetrated at 112ft. 6ins. to 303ft.

--- LTA2 (194ft.) in Andamooka Limestone to 121ft. disclosed numerous vughs lined with iron and manganese oxides to 54ft. and fine pyrite in chloritic aggregates and in fractures between 58ft. and 98ft. Yarloo Shale was intersected from 121ft. to 194ft. when drilling was terminated.

--- LTA3 (145ft.) disclosed Andamooka Limestone to 134ft. with pyrite between 58ft. and 98ft. in fractures, as fracture coatings, in dark irregular inclusions and vughs. A transition zone comprising silts, shale, limestone and calcarenite 1 foot in thickness separated the carbonate sequence from Yarloo Shale below.

No base metal mineralization was revealed and finely disseminated pyrite in the Andamooka Limestone proved to be the source of the geophysical I.P. anomaly being tested. The lease expired on 14.1.1969.

PARACHILNA AREA

Special Mining Lease 131, granted to M.E.P.L. on 14.9.66, comprised two separate areas; the Parachilna - Mernmerna area of 672 square miles where definite anomalies for lead, zinc and copper had previously been established and the Wilkatana area of 73 square miles. The latter area was surrendered on 14.11.67 without further investigation whereas the area embraced by S.M.L. 131 was expanded to cover an area of 984 square miles on 15.11.67 as S.M.L. 131A and it was in this tract that effort was directed until surrender on .....

The extent of the lower Cambrian carbonate rocks in this region are depicted on the Parachilna geological map (Dalgarno and Johnson, 1966); see Figure 28. Sampling of regular traverses (Johns 1967, Olliver and Cramsie, 1967 (a) (b)) and diamond drilling (Cramsie, 1967) has demonstrated that the lower part of the carbonate sequence is dolomitic and includes beds of relatively pure dolomite while the upper part comprises high grade limestone. The occurrence of coarse grained galena on the flank of the ranges five miles north of Brachina Gorge on which limited earlier mining activity has been conducted marked the only known base-metal mineralization in this zone until investigations by M.E.P.L. disclosed widespread anomalous lead occurrence in stream sediments between Brachina Gorge and Parachilna Gorge and beyond. Regional geochemical surveys were used as the initial exploration method; subsequently detailed geochemical surveys, geological mapping, geophysical surveys and diamond drilling were undertaken.

Over a length of 20 miles extending from 8 miles north of Parachilna Gorge to Edeowie Gorge stream sediment samples taken from the majority of creeks draining the lower Cambrian carbonate rocks have disclosed anomalous lead contents, and with insignificant copper (See Figure 28). Over 3300 stream sediment samples were taken to reveal very strong, persistent, anomalous dispersion trains with lead contents as high as 1480 ppm. in stream silt (Roberts 1967, (a) (b), (c), (f)). To the north of Parachilna Gorge lead and zinc contents of gully sediments were lower than those between Parachilna Gorge and Edeowie Gorge. In detail, stream sediment geochemistry has variously revealed zones of anomalous lead-zinc dispersion trains, areas of anomalous lead dispersion trains and areas of anomalous zinc dispersion trains.

Minor copper carbonate mineralization has been discovered, generally in association with galena-bearing horizons, about 6 miles north of Brachina Gorge.

One of the more interesting zones where there are consistently anomalous lead and zinc contents is centred in

geophysical line 1 (approximately 6 miles north of Brachina Gorge and termed the "Galena Creek area"); this zone extends for a distance of almost five miles along strike in a drag folded sector disrupted by minor faulting. The most extensive outcroping of galena has been discovered in this area and rock analyses indicate significant contents of zinc probably occurring as zinc silicate (Roberts, 1968 (b)). Concentrations of lead and zinc are also apparent adjacent to the fault at Brachina Gorge.

In grid "A" area adjacent to a major fault south of Brachina Gorge there is a zone of anomalous zinc values with minor lead, in turn followed southerly by a zone of increasing lead values which is markedly concentrated in the Bunyeroo Gorge area and extending for some 2 miles north and 3 miles south of Bunyeroo Gorge. Minor galena mineralization has been located in outcrop in the gorge within the lower Cambrian carbonate rocks. Southwards to Edeowie Gorge the stream sediments show high zinc contents.

Some anomalous lead and zinc values were indicated in the Cotabena Syncline area, particularly in the southeastern sector where a gossan-like horizon in the basal Cambrian has been located. Of some 260 samples taken in the Cotabena area the highest base metal contents recorded were 700ppm lead and 2700 ppm zinc.

The geochemical investigations and follow-up mapping led to the discovery of lead sulphide mineralization of two broad types (Roberts 1968 (b), (c) (f), (h)):-

(1) Generally conformable galena occurrences form two distinctive horizons generally varying from 5 to 10ft. but up to 70ft., in width and traceable in outcrop up to 1,000ft. along strike at various locations in the same general stratigraphic position, particularly within the lower, blue, dolomitic member of the lower Cambrian Wilkawillina Limestone and extending dis-

continuously from two miles south of Bunyeroo Gorge to 7 miles north of Brachina Gorge.

Galena occurs as disseminations, as isolated small cubes and in fine fracture fillings, films and veinlets commonly less than ½ inch in width; zinc is considered to be present as zinc silicate. Several bulked composite samples taken from outcrop 6 miles north of Brachina Gorge assayed as follows:

	Lead (%)	Zinc (%)	Silver (ozs/ton)
Sample 1	5.4	1.4	0.20
Sample 2	9.8	8.0	1.20

Also at this general stratigraphic level more extensive iron and manganese-stained and, in part, gossan-like developments have anomalous lead and zinc contents.

(2) Less extensive galena mineralization in the upper limestone member in association with breccia zones and with calcite veining. An attempt has been formerly made to mine lead ore in this environment five miles north of Brachina Gorge, near the flanks of the range. Galena occurs sporadically as fine to medium-grained disseminations and veinlets and in occasional masses up to 12" x 8" x 4".

Widely spaced orientation lines were surveyed, designed to check the nature of I.P. response over mapped galena-bearing horizons, to check this horizon where sulphide mineralization had not been sighted and to establish whether it was possible to penetrate the Quaternary and Tertiary cover at lease immediately west of the ranges where the Lower Cambrian carbonate rocks dip beneath the plain. All lines exhibited a sharp drop in apparent resistivities west of the ranges indicating that the younger cover was not being penetrated on the relatively short electrode spread lengths used (200ft.) On line 1 possibly anomalous effects were disclosed in the vicinity of the lowest galena-bearing horizons with definite anomalies over the upper wider galena-bearing horizons to the west. On line 2 possibly

anomalous effects were recorded over the stratigraphy of interest. Like results were achieved in the vicinity of known narrow galena-bearing beds on line 4.

Manganese-rich gossan-like developments were located in a number of areas during the survey, several of the largest and most accessible of which (north of Parachilna Gorge and north of Bunyeroo Gorge) have been formerly tested by shallow pits and obviously small production derived. Some 642 soil and rock samples were taken from the various gossans which showed high lead and, particularly, zinc contents. It was recognised that manganese-and-iron-rich "gossans" are not uncommon in limestones - the alkali pH conditions associated with outcropping limestone could cause precipitation of manganese and iron from percolating groundwaters and form gossanous cappings not directly related to deeper metallic mineralization and scavenge anomalous amounts of base metals from solutions which might originate from know lead and zinc-bearing lower Cambrian carbonate rocks. Two such zones were located north of Parachilna Gorge (grid "B"). The westernmost outcrops intermittently over a strike length of about three miles as pod-like manganese-rich gossan developments of variable length and width on the flank of the ranges on limestone stratigraphically higher than the lead-zinc-bearing dolomites. Limited prospecting for manganese was carried out in this zone some 30 years ago. Rock chip samples did not reveal any high lead values and only two samples contained more than 1000 ppm zinc. Situated immediately to the north and east is a rather different distinctive iron-and manganese-stained, partly gossanous horizon, at the base of the Cambrian carbonate sequence, close to or at the same stratigraphic horizon as that which contains lead-zinc mineralization further to the south. Rock chip analyses revealed up to 590 ppm copper, 1100 ppm lead and 8700 ppm zinc. Soil geochemistry was undertaken at 50ft. intervals on grid "B" and 13.0 line miles of Geophysical I.P. survey were undertaken to indicate possible I.P. effects on a number of lines. No magnetic anomalies were detected in ground magnetometer survey of the gridded area.

Samples taken from gossanous pods up to 200ft. x 100ft. which occur on limestone one mile south of Parachilna Gorge (grid "E") contained up to 760 ppm copper, 1200 ppm lead and 560 ppm zinc.

A small gossan-like mass located 4000ft. north of geophysical line 1 in the lower Cambrian carbonate member proved to have the following metal contents - 30 ppm copper, 1300 ppm lead and 900 ppm zinc.

A narrow but persistent gossan-like horizon at least 5000ft. in length, located in the Bunyeroo Gorge area and situated at the base of the lower Cambrian carbonate sequence showed the following contents on analysis:- 190 ppm copper, 2100 ppm lead and 8000 ppm zinc. A manganese-stained bed, 3ft. in width near the base of the sequence and located 3000ft. north of Bunyeroo Gorge contained 1275 ppm lead and 750 ppm zinc while an iron-stained band, 6ft. wide, at the base and located 1000ft. south of Bunyeroo Gorge showed 2450 ppm. lead, and 1850 ppm zinc. In the extreme southwest of the area at grid area "C" a heavily iron-stained and gritty Cambrian bed showed on analysis 3950 ppm lead and 1050 ppm zinc; an I.P. survey in this area proved abortive.

In grid "A" area detailed geochemical and geophysical work was undertaken along a major fault zone separating Pound Quartzite and Wilkawillina Limestone on an extensive gossan development almost 4000ft. long and up to 100ft. wide, located two miles north of Bunyeroo Gorge where bulk samples taken from six groups of old shallow workings had zinc contents of almost 1% (see table below):-

Sample No.	%Zinc	% lead	ozs. silver/ton
1	0.73	0.08	0.20
2	0.95	0.15	0.25
3	0.95	0.15	0.30
4	0.95	0.07	0.25
5	0.95	0.07	0.38
6	0.80	0.05	0.25

Though a survey with magnetometer disclosed no

magnetic response definite I.P. anomalies were indicated in the gossan zone. To determine whether the gossan was related to deeper metallic mineralization diamond drilling was undertaken as below (see Figure 29):

--- LT1, depressed 55°E, abandoned at 444ft.

0-370ft. Pound Quartzite, partially weathered and fractured.

-444 No core.

--- LT2, depressed 60°W, abandoned at 395ft.

0-395ft. Wilkawillina Limestone, fractured, iron-and manganese-stained oolitic limestone with narrow manganese-rich bands.

Selected sections assayed as follows:

Ft.	% Zn	Ozs. Ag/ton
100-127	0.60	0.40
127-140	0.60	0.60
140-142	0.60	0.40

--- LT3, depressed 60° bearing 310°, designed to complete the test planned for LT2.

0-583ft. Wilkawillina Limestone, manganese-and iron-stained fractured and brecciated limestone with short sections of massive manganese and iron oxides.

Selected sections assayed as follows:

Ft.	% Zn
493 - 497'6"	1.05
503'10"-510'6"	1.32

-601ft. Pound Quartzite.

--- LT4, depressed 50°, bearing 310°,

0-355ft. Wilkawillina Limestone, manganese-and iron-stained fractured and brecciated limestone with short sections of massive manganese and iron oxides.

-384ft. Pound Quartzite.

It was considered (Roberts 1968 (h)) that this is a "false" gossan, comprising transported manganese and iron oxides which includes appreciable zinc by ionic substitution but "the

outcome of this drilling in no way detracts from the exploration potential of the known galena-bearing dolomite horizons".

To test an I.P. anomaly assocated with the base of the lower Cambrian sequence where there are anomalous contents of lead (8500 ppm) and zinc (19,500 ppm) in a 20ft. wide dolomitic bed one diamond drillhole (LT5) was collared close to the Parachilna - Blinman road in Parachilna Gorge on a bearing 87½, depressed 50°. Insignificant mineralization was detected.

The investigations of M.E.P.L. have revealed concentrations of lead and zinc over some 60 strike miles of similar stratigraphy. "The exposed lower Cambrian carbonate rocks represent only a small proportion of the potential Cambrian limestones and work has been concentrated in the eastern limb of a large regional anticline, which is generally covered by Quaternary and Tertiary sediments west of the Flinders Ranges. Reasonably good prospects also exist for the presence of other Cambrian basins in the belt between the ranges and Lake Torrens" (Roberts, 1968 (h)).

SUMMARY

Investigations relating to the occurrence of basemetal minerals in lower Cambrian sediments in the Flinders Ranges which were initiated by the Geological Survey and subsequently followed up by exploration companies has disclosed widespread lead, zinc and minor copper mineralization within narrow stratigraphic confines.

Geochemical prospecting which has included stream sediment sampling, followed up by rock sampling and drilling has resulted in the delineation of a number of areas over which there are, previously unsuspected, significant concentrations of lead and zinc, in particular, and has located high grade deposits at Puttapa.

Lead sulphide is discernible in outcrop in many localities as disseminations and in minor massive concentrations but small scale mining operations have formerly been limited to

a few localities.

Oxidised near-surface secondary concentrations typify the previously exploited copper deposits and several newly discovered willemite occurrences. Structural control in their localization is apparent. Accumulations of manganese and iron oxides in these situations constitute "false gossans". Manganese is a notorious scavenger of zinc and appreciable amounts of zinc and minor lead, cobalt, nickel and arsenic have accumulated with manganese wad and goethite by adsorption or ionic substitution through the circulation of groundwaters adjacent to fault zones.

Lead, zinc and copper sulphides in lower Cambrian carbonate sequences are known also from Yorke Peninsula and on Fleurieu Peninsula and within the Kanmantoo Group in the eastern Mount Lofty Ranges and on Kangaroo Island. The search for those metals throughout the Adelaide Geosyncline and adjoining shelf is being intensified while the Torrens "hinge zone" constitutes an almost wholly concealed tract wherein the possibility exists of concentrations of metals in flat lying or only gently deformed strata and investigations are continuing.

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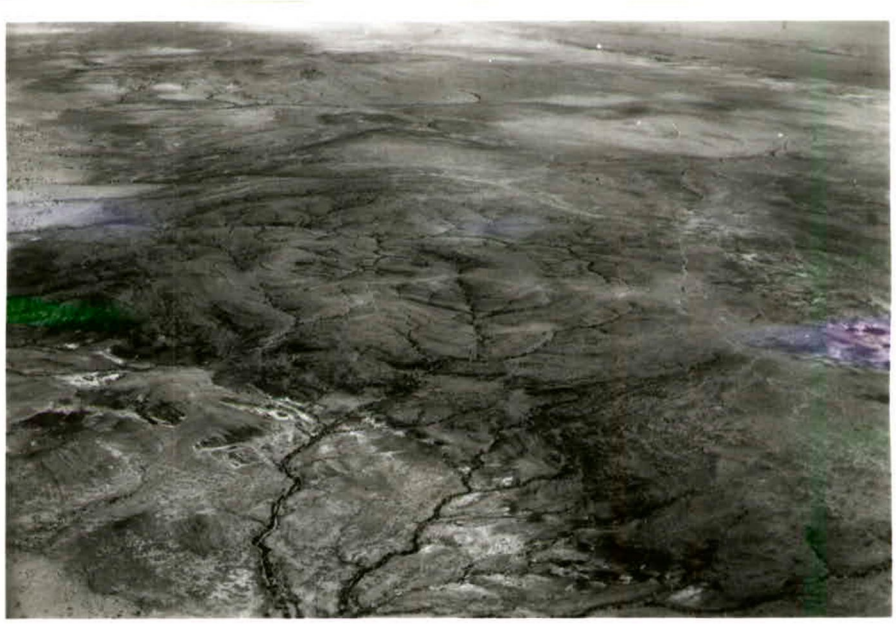
J5 1845

Plate I Sliding Rock copper mine, view northerly across sliding Rock Creek to bluff of Pound Quartzite.



J5 12944

Plate II Ediacara Mineral field, aerial view looking north across gently folded Ajax Limestone

J 5 18756

Plate III Willemite outcrop, Puttapa zind prospect. Mineralized Ajax Limestone in foreground; Mount Bayley Range in right background

K 5 18757

Plate IV Reaphook Hill zinc prospect. Exploratory trench exposes scholzite deposit in Parachilna Fm. in foreground; mineralized Wilkawillina Limestone outcrops at extreme right. Reaphook Hill in background.

K5 18758

Plate V Aerial view looking westerly to Reaphook Hill; zinc-bearing Wilkawillina Limestone (dark outcrops) in foreground. Scholzite exposed in flooded trench (left foreground)

Hd. Bunyeroo 18759

Plate VI Old workings in zinciferous manganese "gossan" concentrated on fault separating Pound Quartzite and Wilkawillina Limestone, south of Drachina Gorge, Grid area "A".