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Cover photo: A mud oyster, *[illegible]*, similar to those forming the biohermal shell deposits in Port Stephens.

SCOPE OF MAJOR PROJECT A17 DISSEMINATED COPPER DEPOSITS OF THE NORTHEASTERN PART OF THE LACHLAN FOLD BELT

BY H. N. BOWMAN

Abstract

In the eastern Lachlan Fold Belt of New South Wales, disseminated copper deposits occur mainly at the northern and southern extremities of the Molong-South Coast Anticlinorial Zone and the Forbes Anticlinorial Zone. Main activity in the project will be concentrated on the northern end of the zones where three types of disseminated copper mineralization are developed — copper in andesite, copper-gold in andesite associated with small dacite to monzonite intrusives, and copper-gold-molybdenum in granodiorite.

Introduction

As a result of metallogenic mapping of the eastern Lachlan Fold Belt, certain geological problems requiring further detailed investigation were delineated. A study of the nature of disseminated copper mineralization in the northern Molong-South Coast Anticlinorial Zone and Forbes Anticlinorial Zone seemed warranted and has been designated Survey major project A17. Initial work has been done on this project by the Geochemistry Subsection in their programme of soil and rock chip sampling of the andesites of the Molong Volcanic Rise (Hobbs 1973a, b).

The disseminated copper mineralization is of economic interest as potential exists for the discovery of very large low-grade ore bodies.

Orientation Work

Detailed geological, geochemical, and geophysical work undertaken over two areas in the Goonumbla Andesite at Parkes and one area in the Yeoval Batholith at Yeoval has provided an insight into the mode of occurrence of some copper deposits in andesite and of some copper-gold deposits in granodiorite.

Geochemical results have provided information on required sample spacing, relationship of trace element content of soil and associated bedrock material, and element association as aids to delineate zones of anomalous copper content. Trace element content has shown or supported the location of faults and geological boundaries and of trends of mineralization.

Magnetics and induced polarization techniques have been used over the mineralized areas to test their efficacy in delineating mineralization.

Geological Investigations

The deposits at Parkes are developed towards the stratigraphic top of the Goonumbla Andesite, a Late Ordovician submarine andesite sheet. Mineralization consists of disseminated chalcopyrite and bornite (and/or native copper) with negligible pyrite, within felsic and augite andesites. The mineralization appears to have been associated with propylitic alteration and occurs disseminated in the host rocks at the tops of flows. Quartz veinlets, in places carrying tetrahedrite and chalcopyrite, are also developed at the tops of flows as well as within haematitic tuffs overlying them. The mineralization apparently was emplaced by late-stage hydrothermal fluids emanating from the same source as the andesite.

At Yeoval the mineralization consists of chalcopyrite-bornite-molybdenite-native gold as disseminations, veinlets, and joint plane smears within granodiorite but spatially associated with very small dacite intrusions. Little pyrite is present. Potassic alteration occurs close to the dacite and propylitic alteration further from it. The granodiorite is Late Silurian in age (Gulson and Bofinger 1972) and has not been separately shown on the Dubbo 1:250 000 Metallogenic Map (Matson in prep.); table 1 which is compiled from metallogenic map information shows the host rock as Early Devonian Yeoval Granite. Narrow belts of rhyolite occur above the granodiorite, indicating that the deposits are developed close to the roof of the batholith. The granodiorite contains hornblende, and has mafic xenoliths, high sodium, and a broad spectrum of compositions from felsic to mafic suggesting that it is an I type granite as defined by White et al. (1974). Nearby to the east of the granodiorite, andesites which stratigraphically underlie the acid volcanics are malachite stained in areas of contact metamorphism, indicating a possible source of the copper in the granodiorite.

Geophysics (T.C. Wootton)

Detailed ground magnetic surveys were conducted over two prospects, Blackridge and The Secrets, at Parkes to aid in defining zones of mineralization. Although the survey was carried out on a closely spaced grid with high precision, this technique proved to be of limited use. Two reasons can be put forward for this:

1. The proximity of the andesite flows to each other precluded definition of anomalies without interference from neighbouring flows.

2. Near-surface sources gave rise to a strong (up to 1000 gammas), usually single point response which masked any response caused by a flow or sequence.

However, there was a distinguishable magnetic response to two parallel flows at The Secrets prospect. Faults were able to be inferred from offsets in trends at the two prospects but no accurate data could be obtained on dip, depth to top, width, or depth extent of the flows.

International Nickel Australia Ltd contracted McPhar Geophysics Pty Ltd to conduct a dipole dipole survey with a 50-m dipole spacing at the two prospects (Wootton 1974). Spurious anomalies due to fences hindered the interpretation of the data in critical zones at both prospects. However, the results of the survey suggest that no large-scale sulphide sources exist at these prospects. The resistivity data did indicate a sequence of rocks alternating between higher and lower resistivity but was not sufficiently definitive to indicate the dip of the strata.

Geochemistry (J.J. Hobbs)

Geochemical samples were taken of lower clay and weathered bedrock soil horizons in the two areas in the Parkes district. In addition, rock samples were collected to give a representative selection of the andesites which crop out in the two areas. Anomalous copper zones were located within the andesite flows, and the locations of some faults were confirmed. Individual lithological units displayed individual background trace element values. Gold content of all samples was low. Total rock analyses on selected samples are to be obtained to further assist in correlation of mineralization and chemical characteristics.

The results indicated that wider sample spacing could be adopted for a regional or reconnaissance geochemical survey.

In the Yeoval district, two stages of geochemical sampling have been completed. In the first stage, involving detailed grid sampling, an area containing some copper mineralization and barren rock was sampled. Analytical results did not show high anomalous copper values, in contrast to those for samples taken near the Yeoval copper mine. However, high results (of the order of 300 ppm) were clustered and observed mineralization zones were confirmed. Again, results showed that wider spacing of samples could be used for a reconnaissance geochemical survey without the likelihood of missing anomalous zones. Analytical results have not yet been obtained for the second stage, a regional sampling programme.

Information Sources

Summaries of the geology and mineralization of the Molong-South Coast Anticlinorial Zone are to be found in Felton (1975) and Herzberger (1975). University theses on the same topics have been undertaken by Byrnes (1965), Chivas (1971), and E. Ambler (Macquarie Univ. in prep.). Much information is contained in exploration reports by companies working in recent years in the northern part of this zone, in particular in reports by Amax Exploration (Aust.) Inc. (see Shepherd 1971). Information on mineralization in the Forbes Anticlinorial Zone is contained in Bowman (1975).

In order to secure the widest range of pertinent references, several computer search runs of reports held in the Geological Survey of New South Wales were conducted. Various parameters were specified, such as copper and intrusive rocks and copper and metamorphic rocks for New South Wales and for the Bathurst 1:250 000 sheet. The results of this exercise are available at the Geological Survey although the computer search as a whole is as yet incomplete.

In order to define all areas within the eastern Lachlan Fold Belt containing deposits of the disseminated type, metallogenic maps were used to locate deposits with the following characteristics:

1. Disseminated form (plus indeterminate form on those sheets for which this form was used).

2. Containing copper or molybdenum in association with other minerals as well as independently.

These criteria were chosen because they would show all those areas in which potentially large deposits, probably of low grade, might be developed. Table 1 gives the results of this exercise.

The inclusion of indeterminate forms resulted in the selection of a few deposits which are probably outside the scope of the project, such as copper deposits at Cow Flat which probably belong to the submarine acid volcanic grouping.

Preliminary Conclusions

The vast majority of deposits meeting these criteria occur in the Molong-South Coast Anticlinorial Zone, with all large deposits occurring in the northern part. Host rocks are Late Ordovician or Devonian andesites, related sediments, or Devonian intrusives. (Later work has indicated that at least some of these Devonian intrusives are in fact Late Silurian in age.)

Three different associations seem to exist. In the first the deposits contain copper and/or gold and/or molybdenum and/or other base metals in a granite host, and occur at the northern and southern ends of the zone within two post-kinematic batholiths, the Bega and Yeoval Batholiths. They include almost all the molybdenum deposits. Preliminary investigation of the northern deposits near Yeoval suggests that they are associated with porphyry intrusives. These two batholiths are the major post-kinematic batholiths in the Lachlan Fold Belt.

Another association is that of copper without gold in andesites or related intrusives. Deposits of this type occur mainly in the northern part of the zone. Preliminary investigations at Parkes suggest that this association is localized at the top of submarine flows within carbonate-epidote alteration zones, and was probably related to hydrothermal activity associated with andesite extrusion. Native copper is a primary mineral in some deposits.

The third association is of gold-copper in altered andesite, often spatially associated with small acid to intermediate igneous intrusions commonly of quartz monzonite or dacite composition. These intrusions are often not porphyritic. However, these deposits too may fit the porphyry copper model.

Programmed Work

Geology

To make the project manageable, the investigation will be restricted initially to the northern parts of the Molong-South Coast and Forbes Anticlinorial Zones.

Further detailed investigations similar to those already undertaken will be made. From these results it should be possible to construct geological models which will be tested during regional appraisal of the areas.

Most of the important deposits appear to be related to dacite or monzonite intrusives. All the small acid intrusives in the areas will be mapped in detail and petrologically examined.

Table 1
DISSEMINATED Cu, Cu-Au, AND Mo-W DEPOSITS IN THE EASTERN LACHLAN FOLD BELT

1:250 000 sheet Grid ref.	Deposit	Commod.*	Host rock	Host rock age	Size†
SYDNEY					
30998427	Marsden Swamp Creek	Mo, Cu	Orthoclase granite, pegmatite veins, monzonite	Carb.	4
303825	Bells Creek	Cu	Rhyolite	Dev.	4
304822	–	Cu	Rhyolite	Dev.	4
312828	Little River	Cu	Gabbro, diorite(?)	Carb.	4
ULLADULLA					
331668	Boolijah Creek	Cu/Pb	Metabasalt	Late Dev.	4
BEGA					
29714328	Quandalo	Cu	Sandstone	Late Dev.	4
27194317	Egan Peaks	Mo	Aplitic segregation in Bega muscovite granite	Dev.	4
27204294	Stoney Creek	Mo	As above	Dev.	4
27264293	Sawyers	Mo	Metasediments	Ord.	4
24674290	Wog Wog Mtn	Mo	Aplite segregation in Bega biotite granite	Dev.	3
28884662	Black Range	Mo	Granite	Dev.	4
27854480	–	Mo	–	–	4
26104365	Copper Hill	Cu/Ag,Pb	Sheared biotite granite	Dev.	4
268449	Myrtle Creek prospect	Cu	Granite	Dev.	4
25524466	McDonalds	Mo	Aplite dyke in hornblende granite	Dev.	4
25434527	Fultons	Mo	Siliceous granite	–	4
25464586	Knoxs	Mo	Biotite adamellite	Dev.	4
24924605	Hammond and Standons	W/Mo	Aplite dyke in gneissic granite	Dev.	4
26544636	Tantawanglo	Pb,Cu/Zn, Au,Ag	Granite	Dev.	4
26874647	Solomons	Au,Cu/Pb, Zn,Ag	Biotite-chlorite schist	Ord.	4
25934874	J.K.	Cu,Pb, Zn/Ag,Sb	Biotite granite	Dev.	4
26104849	Fultons	Pb,Au/Cu	Granite	Dev.	4
23785084 23805084	Kydra	Au,Ag/Pb, Cu	Aplite and biotite granite	Dev.	4
20405076	Monaro	Cu/Ag	Quartzite and slate	Ord.	4
18575083	Wolfram Hill	W/Cu	Greisenized granite	Dev.	4
CANBERRA					
29776160	Monga (Budawang)	Cu	Chloritized and epidotized amygdaloidal basalt	Dev.	4
26355765	Krawaree	Mo	Granite	Dev.	4
27906055	Araluen	Mo/Cu	Porphyritic leucogranite	Dev.	4
BATHURST					
182912	Copper Hill	Cu,Au	Dacite porphyry, andesite	Ord.	3
163913	Delayneys Dyke	Au/Cu	Altered basic sediments, hornfels,	Sil.	3
149883	Bumberry	Cu,Au	Quartz porphyry, skarn, slate	Sil., Dev.	3
171895	–	Cu	Andesite, limestone	Sil.	4
181896	Peabody	Cu	Andesite	?	4
188894	Mt Keenan	Cu	Andesite	Ord.	4
180881	–	Cu,Au	Andesite	Ord.	4
176866	Dalcoath	Au/Cu	Diorite	Dev.(?)	3
222876	Carangera	Cu/Au,Ag	Andesite, siltstone	Ord., Sil.	3
201855	Infirtaris	Cu	Andesite	Ord.	4
183833	Burly Jack	Cu	Andesite	Ord.	3
184832	–	Cu	Andesite	Ord.	4
182829	Belmore	Cu	Andesite	Ord.	3
182822	Wangoola	Cu	Andesite	Ord.(?)	3

Table 1 *(cont.)*

1:250 000 sheet Grid ref.	Deposit	Commod.*	Host rock	Host rock age	Size†
BATHURST					
210845	–	Cu	Diorite	?	4
210843	Coombing copper	Cu	Andesite	Ord.	?
199845	–	Cu	Andesite, basic hornfels	Ord.	4
249846	Sugarloaf and Mountain Run	Cu,Au	Schist	Sil.	3
260839	–	Cu	Chlorite-carbonate-talc hornfels	Ord.(?)	4
276859	Acme	Cu	Granite, acid volcanics	?	4
279860	Mt Tennyson molybdenum prospect	Mo	Skarn (Mo), amphibolite (Au and Cu)	Sil.-Dev.	3
282858	Gemalla molybdenum prospect	Mo	Skarn (garnet-calc-silicate)	Dev.	4
169804	Pope of Rome	Cu	Schist	Sil.(?)	4
277848	Diamond Hill molybdenite deposits	Mo	Skarn	Sil.	4
DUBBO					
20390066	–	Cu/Au	Andesite, schist	Sil.	4
19229970	Comobella	Cu,Au	Andesite	Ord	4
17289794	Ponto	Cu	Porphyry	Sil.	4
17589771	–	Cu	Andesite	Sil.	4
15859514	Yeoval and Lady Lizzie	Cu	Granodiorite	Dev.	4
14689437	Vaughans Ridge	Cu,Au	?	Sil.-Dev.	4
15229456	Goodrich	Cu,Au,Ag	Granodiorite	Dev.	3
15419424	Jakes	Cu	Granodiorite	Dev.	4
18789607	Camelford Park	Cu	Andesite, basalt	Ord.	4
18899571	Bells	Cu	Acid volcanics	Ord.	4
19059669	Apsley	Cu	Basalt, andesite	Ord.	4
19009397	–	Cu	Andesite(?), acid volcanics	Ord.	4
19049453	–	Cu	Andesite	Ord.	4
19209326	–	Cu,Au	Andesite	Ord.	4
18029430	Blatherys Gap	Cu,Ag	Andesite	Dev.	4
FORBES					
60889161	Copper Ridge west	Cu	Andesite	Late Ord.	4
60999161	Copper Ridge east	Cu	Andesite	Late Ord.	4
61799103	The Secrets	Cu	Andesite	Late Ord.	4
61929120	Black Ridge	Cu	Andesite	Late Ord.	3
61889119	–	Cu	Andesite	Late Ord.	4
57838461	–	Cu	Granodiorite porphyry	Early Dev.	4
NARROMINE					
62519528	Peak Hill	Au/Cu	Quartz-illite schist	Ord.	2
62539522	Bobby Burns	Au/Cu	Quartz-illite schist	Ord.	3
62559530	Wythes and Mooney	Au/Cu	Quartz-illite schist	Ord.	3
62579526	Great Eastern	Au/Cu	Quartz-illite schist	Ord.	3
52589523	Crown of Peak Hill	Au/Cu	Quartz-illite schist	Ord.	3

*x,y equal   †1 large
x/y major/minor   4 small

Geophysics (T.C. Wootton)

The aeromagnetic method is useful in delineating gross structure and location of the andesite belts. Data from the Bureau of Mineral Resources, Geology and Geophysics, can be used for this purpose, and the detailed surveys flown for exploration companies can be utilized for more accurate definition and, in well-defined cases, can lead to quantitative estimations of geometry (e.g., Emerson et al. 1972).

Ground magnetic surveys as applied in the Parkes area have been shown to be of little advantage since most of the information could be obtained directly by geological mapping. This does not preclude the possibility of helpful information being obtained by this inexpensive method in other areas where the flows are not so closely spaced.

The induced polarization method would directly detect and delineate disseminated mineralization in this environment and can be used to assess the potential of an area, as has been shown in the Parkes area.

It is unlikely that gravity methods would be successful in locating monzonite intrusions in andesites.

No other geophysical technique could reasonably be expected to yield useful or diagnostic information on disseminated mineralization in this environment.

The effectiveness of geophysical techniques within the other associations of mineralization has yet to be tested.

Geochemistry (J.J. Hobbs)

Initially, available geochemical data on the areas to be investigated are to be compiled. Geochemical surveys will probably be undertaken in conjunction with geological mapping.

If an area has previously been sampled, additional sampling will be carried out to correlate results and to obtain samples of rocks and soil for the determination of a wider range of elements. Samples are to be analysed for the common base metals and for certain volatile elements associated with andesites and likely to be affected by alteration or hydrothermal fluids.

In areas of known mineralization, where drill core is available, analyses of described core sections are to be obtained for determination of zones of alteration and primary/secondary disperson.

Whole rock analyses will be carried out as an aid in classification and comparison of intrusives and extrusives. If possible, age and isotope work will also be undertaken.

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SHELL DEPOSITS, PORT STEPHENS

BY C. PEAT AND P. S. ROY

Abstract

Very large deposits of dead molluscan shells, considered to be biohermal reefs, have been delineated in Port Stephens. It has been concluded that the reefs built up during the latter part of the Holocene Transgression, using the submerging Pleistocene clay as a substrate. The reefs now occur as topographic highs on the bed of the estuary.

Introduction

Extensive field investigations carried out in 1930-1931, 1936, and 1950 by The Broken Hill Proprietary Co. Ltd (B.H.P.) and the Sulphide Corporation Pty Ltd delineated large shell deposits in Port Stephens. Additional information on these and other shell deposits in the estuary was acquired during 1970 and 1973 by the Geological Survey of New South Wales from surface sampling, drilling, seismic surveys, and underwater observations (see figure 1).

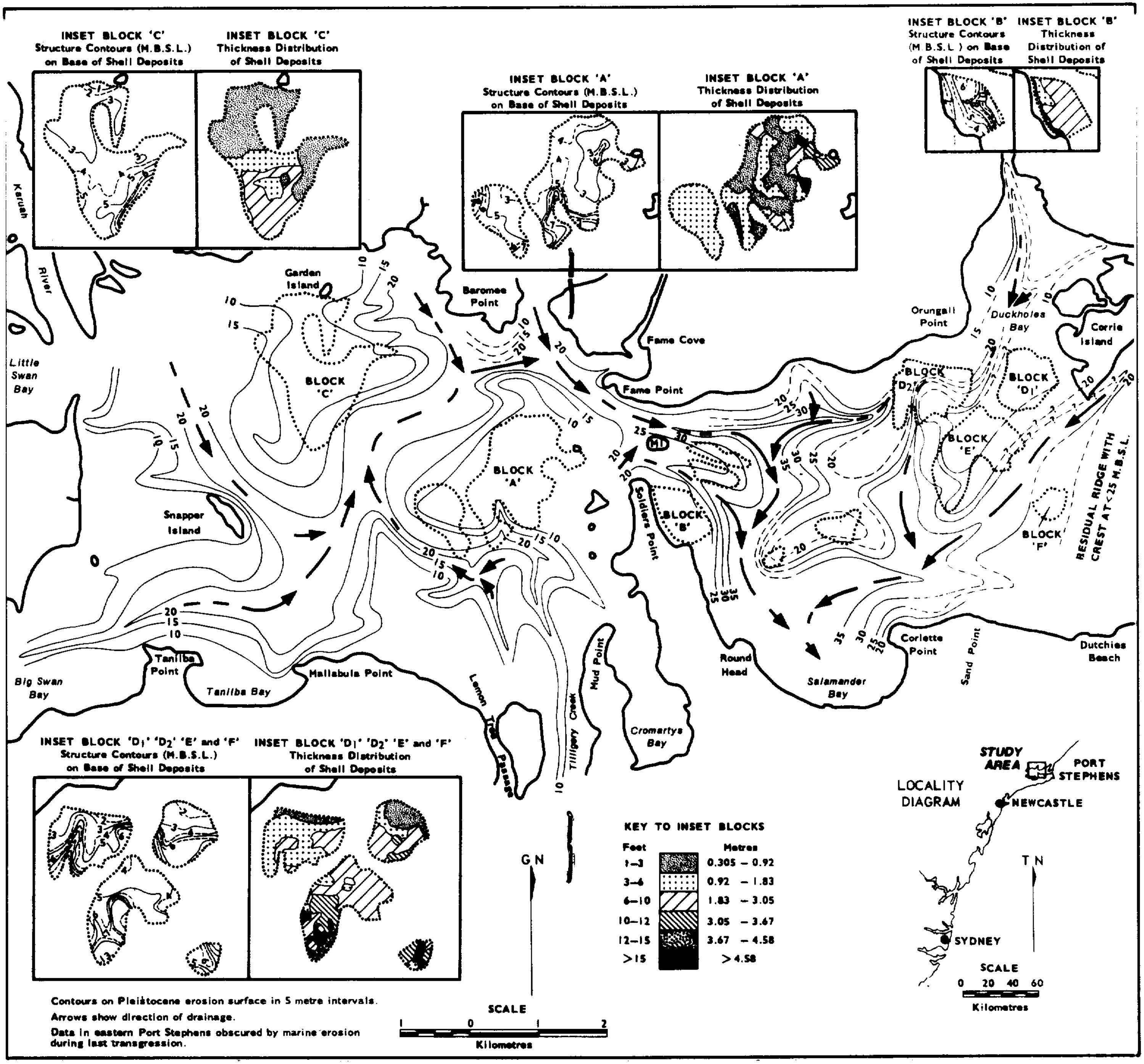

FIGURE 1. LATE PLEISTOCENE EROSION SURFACE AND SHELL BIOHERMS, PORT STEPHENS.

Field Investigations

The shell deposits in Port Stephens were investigated by B.H.P. with a view to their use as blast furnace flux. A preliminary survey by K.C. Church in 1930 proved the existence of large reserves of shell by means of 462 spear-point probes. In 1931 a final survey was completed involving sixty-five samples (Pearson 1931). These samples, taken as an average of the whole shell interval intersected in each post-hole bore, were washed through a 0.833-mm screen and their carbonate content calculated per unit volume. Absolute shell thickness was gained from post-hole bores but was determined only approximately by the proving spears. The deposits have been described as "clean deposits of shell, more or less admixed with sand" composed of "large sized shells varying from 3" or 4" up to 6" and 7" in size" (Pearson 1931). Other areas also investigated were Fullerton Cove, Broken Bay, and possibly Lake Illawarra.

The Sulphide Corporation conducted surveys in Port Stephens in 1936 (E.D. Coulter) and in 1950 (A.C. Wellham) to determine the quantity and quality of the shell for cement manufacture. The 1950 survey made use of all pre-existing work, together with an additional 109 spear points and 85 post-hole samples obtained by means of a 0.2-m clamshell type post-hole digger (Wellham 1950).

Average samples of shell were washed through a 3.17-mm sieve to remove the mud/sand matrix. Seven major shell deposits were delineated in this manner and are shown as Blocks A to F in figure 1. There appears to be a random pattern in the distribution of shell thickness values; in most places the shell beds are less than 2 m thick but thicken to at least 8.3 m. (Although not stated in the reports, it is assumed that the shell thicknesses were measured from the water bottom.) Other minor deposits, not shown in figure 1, were reported at Lemon Tree Passage (up to 1.5 m thick and silt covered) and in the channel north of Tea Gardens (up to 1 m thick). The proportion of shell to clastic material was determined for the seven major deposits and was found to be 49.5 per cent at Blocks D_1, D_2, E, and F, 49 per cent at Block B, between 41.0 and 47.9 per cent at Block A, and 40 per cent at Block C — giving an average of 45.5 per cent for all shell deposits tested in Port Stephens. This figure compares favourably with an average figure of 46 per cent shell content for dredge samples collected from the bed of Port Stephens at Blocks A to F during the Geological Survey's bottom sediment survey in 1973. In conclusion, Wellham (1950) stated that "the sizing analyses of the shell from the deposits show a fair percentage of large oyster shells (1½") with the ½" to 1/8" sizing showing the greatest percentage. It is evident from the physical condition of the shell that the beds are of extremely great age. The large oyster shells are pitted with numerous small holes; sand fills these holes ..."

In 1970 a marine seismic reflection and drilling programme by the Geological Survey of New South Wales delineated the erosional upper surface of the Pleistocene sediments (mainly clays) beneath Port Stephens. This surface coincides with the base of the overlying Holocene muds in western and central Port Stephens. It was formed primarily by fluvial erosion during the last glacial low sea level stand, although to the east of Corrie Island it was modified later by marine erosion during the Holocene Transgression. The erosion surface is contoured in figure 1 and comprises broad, level plateau-like highs which rise to above 10 m bsl and are dissected by steep-sided channels between 20 and 35 m deep. These channels represent drainage systems contiguous with the Karuah River which coalesced with tributary channels in

central Port Stephens and drained southwards beneath Salamander Bay at a depth of more than 35 m bsl. Further to the east a northeast-trending basement ridge between 20 and 25 m bsl extends from Corlette Point across the estuary. This ridge acted as a barrier that deflected river drainage toward the south.

Unfortunately the drilling programme provided no additional data on the shell deposits. The narrow diameter (13 mm) of the drill pipe prevented representative sampling of the coarse shell deposits. Also, because of the sample treatment procedure, the shell content of only the sand-sized fraction, and not of the total sample, was determined.

During a bottom sediment survey of Port Stephens by the Marine Subsection of the Geological Survey of New South Wales in 1973, twenty-nine samples dredged from the bottom were found to contain an average of 46 per cent coarse-grained shell material per unit volume. Of these, twenty-two were located within Blocks A to F delineated as shell deposits by B.H.P. and the Sulphide Corporation. The remaining seven samples were situated on large banks on the present day bed of the estuary. Three of these banks, West, Ballast, and Channel Banks, were investigated using SCUBA apparatus.

West Bank is steep sided, with a maximum gradient of 1 to 12.5 on its eastern face, and flat topped. Its top is composed of medium to fine-grained, muddy, calcareous sand containing up to 20 per cent quartz and a few dead shells. On the upper part of the sides of the bank the sand is overgrown with weed and eventually gives way to shells and mud at about -5 m. From -5m to about -20 m there is a hard-packed layer of dead molluscs (mainly mud oysters, *Ostrea angasi*) covered with a veneer of mud. These shells are often encrusted with barnacles and are riddled with holes bored by sponges and algae. (Similar findings were reported in the B.H.P. - Sulphide Corporation investigations in 1930 and 1950). Below -19 to -20 m the bottom flattens and comprises soft mud with occasional clumps of shell near the base of the bank.

Ballast Bank is a small steep-sided feature in Salamander Bay. Its narrow top consists of very fine-grained quartz-lithic sandy and shelly mud above -9 m. Its western face is very steep (1:12.5) and a small V-shaped depression occurs at the base between -13 and -14 m. The eastern face slopes steeply down to -12 m, at which point the gradient flattens out. The sides of the bank are composed of gritty mud with frequent clumps of dead molluscs above -12 m.

Channel Banks lie off the eastern end of Middle Island; they are elongated in an east - west direction and coincide with a high in the Pleistocene substrate. Their crests rise to within about -7 m and are separated by a depression less than 13 m deep. The northern face of these banks drops precipitously with a gradient of 1:5 to a depth of -36 m in the main channel between Middle Island and the northern shore of the estuary. Their southern face slopes less steeply to a channel about 20 m deep that runs between Soldiers Point and Middle Island. The northernmost of these twin banks was examined by diving methods and was found to be densely populated in places by living bryozoans, sponges, and ascidians interspersed with soft mud. Although relatively few shells were found on the surface of the banks, it is likely that biohermal reefs occur beneath a veneer of mud.

In February 1974 the Marine Subsection again investigated West, Ballast, and Channel Banks and Block E using SCUBA apparatus. Bulk samples collected on West and Ballast Banks and Block E comprise dead representatives of the species and genera shown in table 1 in decreasing order of abundance. At Block E and Channel Banks, bryozoans and sponges were also occasionally found. A small excavation to a depth of 0.65 m was made at a water depth of 15.5 m in the steep (1:10) northeastern side of Block E in an effort to determine the internal composition of the deposit. A similar fauna to that shown in table 1 was found in the top 0.15 m but below this large, densely packed mud oysters (*Ostrea angasi*) up to 180 mm long occurred exclusively. A sample from the base of the excavation was radiocarbon dated (Sydney University Radiocarbon Laboratory) at 2070 ± 100 yr BP (SUA-366).

Summary of Results

Seven features characterize the shell bioherms in Port Stephens:

1. Shell thicknesses vary at random from 0.3 m to 8.3 m (B.H.P. and Sulphide Corporation data), but may exceed 20 m in the West Bank.

2. The bioherms form banks on the bed of the present estuary.

3. Bioherms occur wholly within the Holocene sediment sequence and do not extend below the Pleistocene erosion surface.

4. The bioherms are massive, as opposed to layered, and comprise over 50 per cent by volume of shell material, predominantly *Ostrea angasi*.

5. All shell deposits coincide with the position of topographic highs on the Pleistocene erosion surface. (This relationship is not established for Block F which was not intersected by a seismic traverse.)

6. The base of the bioherms closely follows the irregularities in the underlying Pleistocene surface. Insets in figure 1 show the contoured base of shell deposits A to F to be of the same order and display a similar pattern to the contoured Pleistocene substrate. This is especially evident on the southern side of Blocks A and D_2 where small channels cut into the Pleistocene clay are reflected in the contoured base of the shell deposits.

7. The shell deposits are mostly confined to the plateau-like tops of the Pleistocene highs which generally lie between 5 and 10 m bsl. In western Port Stephens the shells extend down the Pleistocene valley sides to 10 m bsl but in central Port Stephens they extend to at least 20 m bsl (Block B and West Bank).

TABLE 1

VARIETIES OF SPECIES POPULATING THE SURFACE OF THE SHELL DEPOSITS IN PORT STEPHENS

MOST COMMON VARIETIES

Molluscs -

Ostrea angasi Linne
Proxichione chemnitzi Hanley
Acritopaphia transfusa Iredale
Crassostrea commercialis Iredale and Roughley
Chlamys asperrimus Lamarck
Trichomya hirsuta Lamarck
Pecten bendedictus fumatus Reeve

RARER VARIETIES

Bryozoans -

Cellepora sp.
Retepora sp.

Sponges -

Halme sp.
Polymastia sp.

Molluscs -

Bedeva hanleyi Angas
Septa (Monoplex) parthenopea
Lopha cf. *cristigalli* Linn.
Cardium tenuicostatum
Fallartemis sculpta Hamey
Notospisula parva (Petit)
Anadara trapezia (Deshayes)
Circe sugillata Reeve
Placamen placidum Philipps
Tapes turgida Lamarck
Tugali parmaphoidea Quoy and Gaimard
Malleus novelesianus Iredale
Pinna menkei Reeve
Natica sp.
Nassarius sp.
Turrid
Acteon sp.
Pitar sp.
Pyrene sp.
Crepidula aculeata (Gmelin)

Annelid -

Galeolaria sp.

Molluscs were identified by P. Coleman (Australian Museum) and the authors.

Bryozoans and sponges were identified by F. Rowe (Australian Museum).

Proposed Historical Development

Five stages in the development of shell bioherms during the progressive inundation of Port Stephens are shown diagrammatically in figure 2.

The lowest levels of the pre-transgression drainage system occur in central Port Stephens between Corlette Point and Soldiers Point and were the first to be submerged to form the proto-estuary. At this time western Port Stephens was still above sea level and subject to fluvial processes (see figure 2A) Muds, supplied by the rivers and creeks flowing mainly through western Port Stephens, were deposited in the small proto-estuary. Drill holes in central Port Stephens encountered mud with minor amounts of shell down to -33 m. There is however no evidence of dense shell accumulations at this depth. River flow probably dominates the tidal influence at this time with the result that conditions were too brackish to support vigorous shell growth.

When rising sea level reached about -20 m the ridge extending northeast from Corlette Point was breached and an active tidal entrance channel was opened to the east (see figure 2B). At this stage molluscs began to colonize the stiff Pleistocene clay substrate in eastern Port Stephens. Increasing salinity associated with more efficient tidal flushing through the new entrance channel is thought to be the causal factor.

Between -20 and -15 m (figure 2C) the tidal regime became well established in central Port Stephens and shells continued to proliferate, building upwards on older deposits to keep pace with rising sea level. On West and Ballast Banks the upward growth of the reefs outstripped the contemporaneous accumulation of mud on the adjacent bed of the estuary with the result that isolated mounds began to form. Elsewhere the shells colonizing the sides of the drowned valley continued to grow vertically on older shell deposits and to spread laterally over new areas of the clay substrate as it was progressively submerged. At this stage the river channels in western Port Stephens were submerging but conditions were presumably too brackish for massive colonization by molluscs.

Between -15 m and -10 m (figure 2D) continued submergence in western Port Stephens increased salinity and tidal flushing, and molluscs began colonizing the shallow peripheries of the Pleistocene "highs". The reefs in central Port Stephens continued to grow as the substrate progressively submerged. However, farther to the east, tidal deltaic marine sands, washed into the estuary over the bedrock ridge, began to mantle the shell deposits.

As sea level rose above -10 m (figure 2E) the broad, plateau-like tops of the Pleistocene "highs" in both eastern and western Port Stephens were submerged and the reefs, which had originated on the Pleistocene valley sides, spread laterally and colonized their entire surfaces. Marine sands, which were building up and mantling some deposits in the east, also provided a suitably solid substrate for colonization. Development continued up to at least 2000 years B.P. with the reefs rising to within 2 m of present sea level. Subsequently however, the mud oyster population declined dramatically and was replaced by the less prolific shell population shown in table 1. Reef growth virtually ceased at this time.

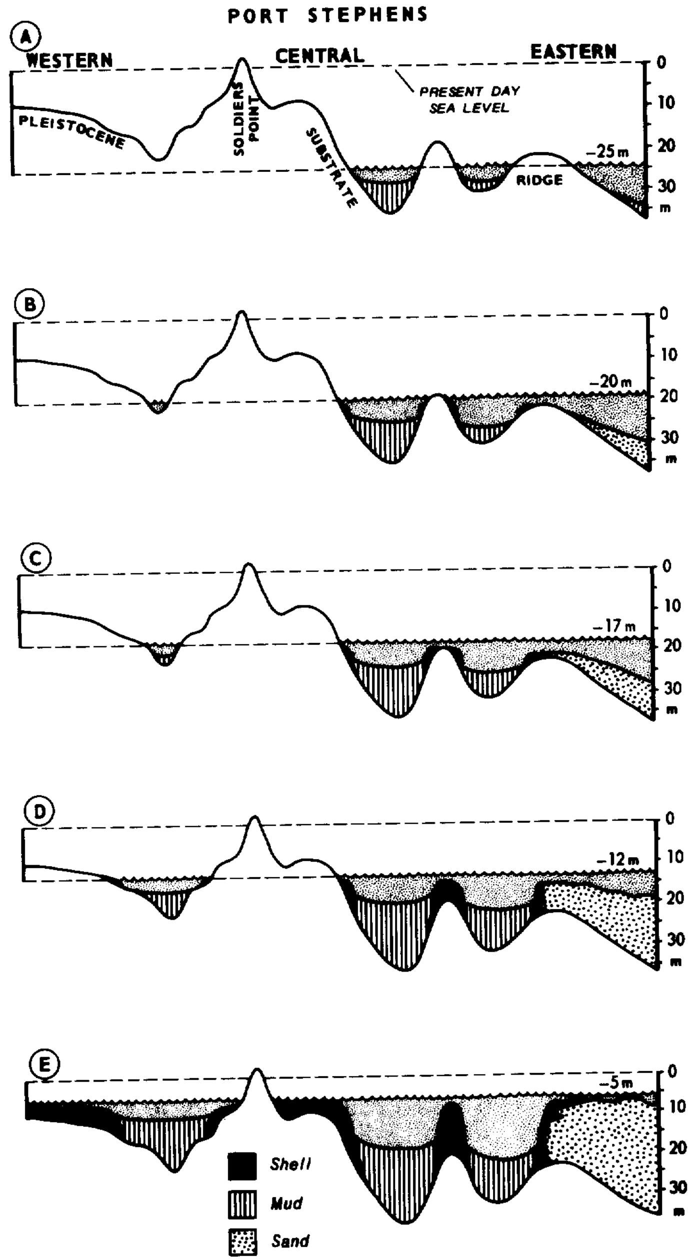

FIGURE 2. STAGES IN THE PROPOSED HISTORICAL DEVELOPMENT OF SHELL BIOHERMS

The reason for the cessation of growth of the shell deposits is not clear. It seems possible that the prolific growth rate was geared to a sea level rising at the rate of about 1 m per 100 years. As this rate declined toward zero approximately 5000 to 6000 years ago, reef growth diminished. Possibly the process of self-silting by the oysters (Lund 1957), which probably enhanced the vertical growth of the shell deposits during the transgression, became detrimental to the colonies when sea level stabilized.

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CORRIGENDUM

Since publication of Quarterly Notes 18, two errors have been found in table 2 on page 4. At the bottom of the left hand column headed DM Wanaaring DDH 1, the figure should be 288, not 228. At the top of the right hand column, (mm/1000 yr) was omitted below the heading "Depositional rate". The corrected table is given below.

TABLE 2

SAMPLE CORRELATION DETERMINED PRIOR TO RADIOMETRIC DATING, WITH AGES AND DEPOSITIONAL RATES

(Dated intervals are bracketed)

DM Wanaaring DDH 1	DM Yantabulla DDH 1	DM Weilmoringle DDH 1	K-Ar age (±2.5m.y.)	Depositional rate (mm/1000 yr)
(116-120 m)	53-55 m	131 m	96.6	
(150-154 m)	76-84 m	180-183 m	96.6	80-100
229-235 m	161-184 m	(269-274 m)	97.9	4-21
(253-257 m)	192-201 m	283-290 m	99.8	16-26
288 m	224-228 m	318 m	101.2	

EDITORIAL NOTE

Quarterly Notes of the Geological Survey of New South Wales enable rapid publication of short notes and progress reports. They are issued on the first day of January, April, July, and October each year and distributed widely throughout Australia. The Quarterly Notes constitute a publication for the establishment of priority for stratigraphic and fossil names.

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