CENTENAIRE DE LA SOCIÉTÉ GÉOLOGIQUE DE BELGIQUE,
GISEMENTS STRATIFORMES ET PROVINCES CUPRIFÈRES, LIÈGE, 1974, 419-427

THE GITOLOGY OF SOME ADELAIDEAN STRATIFORM COPPER OCCURRENCES

N. J. ROWLANDS (*)

ABSTRACT

The gitology of some Adelaidean stratiform copper occurrences is discussed and compared with the bedded copper ores of Shaba Province, Zaire Republic. Both the Katanga and Adelaidean System are of Upper Proterozoic Age.

Sedimentation in South Australia during the late Proterozoic (Adelaidean) was cyclic; four major cycles are recognized. Conformable copper mineralization occurs at more than one stratigraphic level in the Adelaidean System.

These congruent copper occurrences are in shallow marine sediments, deposited under an arid climate in a lagoonal or marginal marine environment. The host sediments formed in sinuous palaeolittoral zones and contain evidence of biological activity and associated reducing conditions. The host rocks are quartz-feldspar clastic assemblages which are variably dolomitic, argillaceous and carbonaceous.

Generally the copper mineralization occurs in transgressive marine sediments close to underlying unconformities. The key to the understanding of these occurrences appears to lie in a knowledge of the palaeogeography under which the host sediments were deposited.

The sulphides are a pyrite-chalcopyrite-chalcocite assemblage. Vertical sulphide mineral zoning is very minor; lateral sulphide zoning is more common, and appears related to lithofacies. Sulphides are finely disseminated, and intimately related to primary depositional features.

The metamorphic grade at most of the occurrences is very low. However, at one, the host rocks are now high grade metamorphics and here the metamorphism has produced a coarsely crystalline sulphide assemblage.

Post depositional structures are not a major mineralization control. Syndepositional structures are closely associated with the bedded copper mineralization.

With the exception of thin volcaniclastics and lamprophyric dykes at one occurrence, and minor alkali metasomatism at another; no known igneous activity is associated with these occurrences.

Although many of these occurrences were the site of small gouging operations in high grade secondary mineralization at the turn of the century, none supports a significant mining operation.

INTRODUCTION

This paper describes the environmental setting of some stratiform copper occurrences within the Adelaidean System (see fig. 1).

(*) Utah Development Company, Exploration Department, 167 Eagle Street, Brisbane, 4000, Australia.

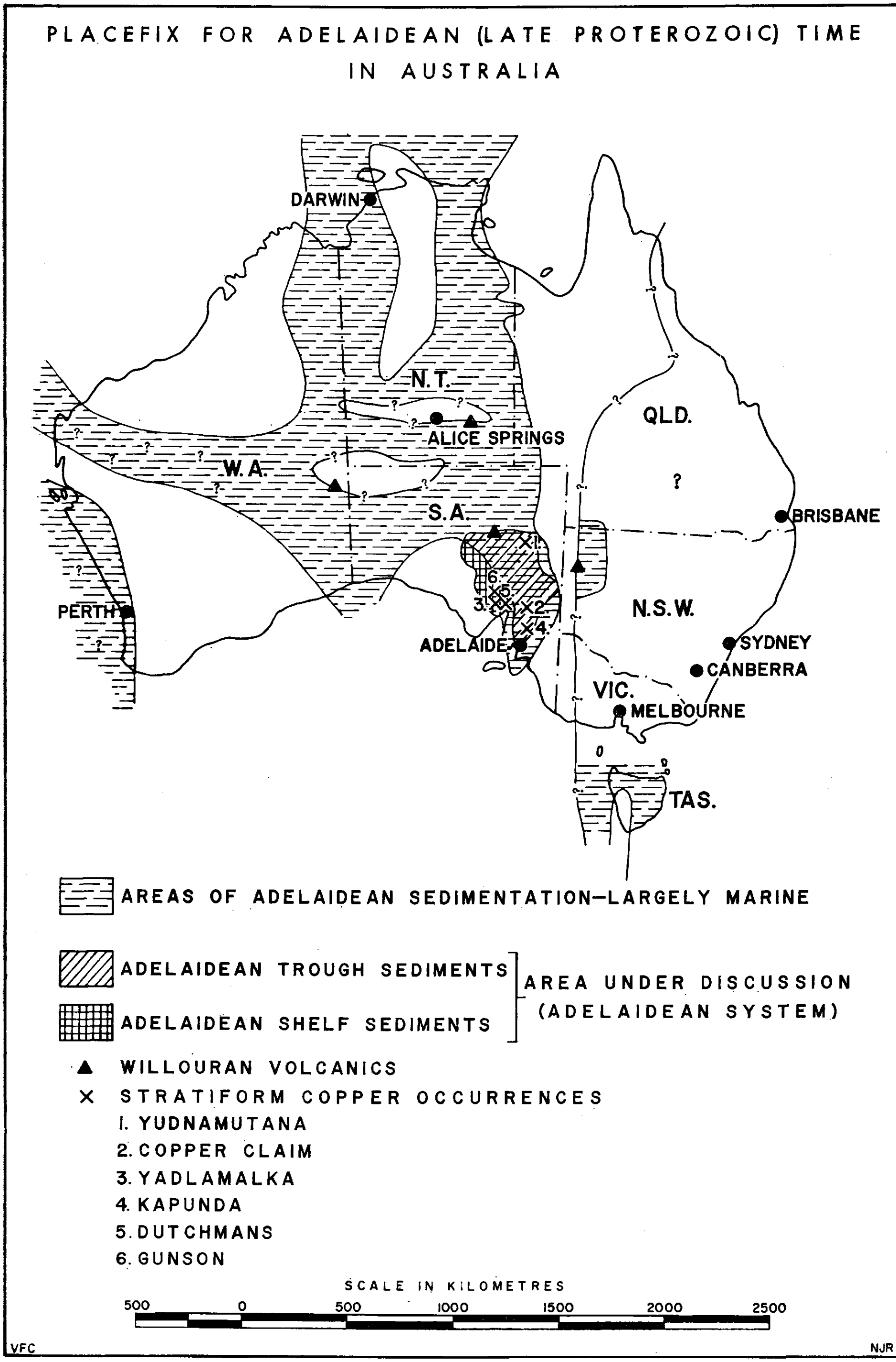
PLACEFIX FOR ADELAIDEAN (LATE PROTEROZOIC) TIME IN AUSTRALIA
DARWIN
N.T.
ALICE SPRINGS
W.A.
S.A.
QLD.
BRISBANE
N.S.W.
SYDNEY
CANBERRA
ADELAIDE
VIC.
MELBOURNE
TAS.
PERTH
AREAS OF ADELAIDEAN SEDIMENTATION—LARGELY MARINE
ADELAIDEAN TROUGH SEDIMENTS
ADELAIDEAN SHELF SEDIMENTS
AREA UNDER DISCUSSION (ADELAIDEAN SYSTEM)
WILLOURAN VOLCANICS
STRATIFORM COPPER OCCURRENCES
1. YUDNAMUTANA
2. COPPER CLAIM
3. YADLAMALKA
4. KAPUNDA
5. DUTCHMANS
6. GUNSON
SCALE IN KILOMETRES
500
0
500
1000
1500
2000
2500
VFC
NJR

FIG. 1

"Adelaidean" is a time term used in Australia to cover the approximate range 1.4 to 0.6 b.y. B.P. The term is derived from the Adelaidean System (a pile of marine sediments deposited in this interval) although Adelaidean aged rocks are widespread in Australia (fig. 1).

Rocks of the Adelaidean sedimentary stack were deposited in a bathymetrically shallow, intracratonic epeiric basin. These sediments were deposited by four major cycles of sedimentation. They are now preserved in a north-south trending orogenic belt (fig. 1).

Absence of turbidites, very subordinate vulcanism, and two distinct ice ages, characterize the deposition of the Adelaidean System.

Widespread copper anomalism (in both vertical and lateral sense) is a feature of the sediments in the Adelaidean palaeobasin.

Six specific examples of congruent cupriferous occurrences are used in this paper to illustrate the spectrum of environments for bedded copper in Adelaidean Strata.

The geographic and stratigraphic localities of these six examples are shown in figures 1 and 2 respectively.

Although this paper only cites evidence from these six occurrences, the general environmental setting which emerges, applies to a host of other minor Adelaidean stratiform copper occurrences. Where a gitological parameter is specific to an occurrence, the name of that occurrence is shown in parenthesis.

Comparisons between the Katangian and Adelaidean Systems in relation to stratiform copper are made.

SYNDEPOSITIONAL GITOLOGY

Cycle of sedimentation of host rocks. — Yudnamutana occurs in first cycle sediments derived from pre-Adelaidean basement. Copper Claim and Gunson are located near the unconformity separating first/second cycle Adelaidean strata. Dutchmans, Yadlamalka, and Kapunda are well into second cycle sediments (fig. 2).

Sedimentological analysis has shown that the copper mineralization is invariably associated with a positively oscillating (transgressive) phase overlying a stillstand (I-sequence). Generally, footwall strata are coarser clastics than the host rocks. Hangingwall rocks encompass a wide textural and compositional range.

Palaeogeographic setting. — The host rocks for the six examples cited were deposited in either the littoral zone, lagoons or deltas. The coarse clastics, detrital felspars, development of pronounced lenticular interfingered facies patterns point to water that was shallow, and fluctuating in level.

The biogenic features in the host rocks include stromatolites, framboidal pyrite and generally high carbon content. Stromatolites are known from the Gunson and Copper Claim sequences. Dutchmans mineralization occurs in a highly stromatolitic stratigraphic unit. I regard the dolomitic rocks associated with the mineralization as lithified organic-rich carbonate muds. Framboidal pyrite occurs in the cupriferous rocks at Copper Claim (Pontifex, 1972), and carbonaceous material forms up to 20 % of some of the host rocks at Copper Claim (Gransbury, 1973).

Sedimentary structures in the cupriferous horizons and associated rocks all point to shallow water deposition. Common structures (except at the highly meta-

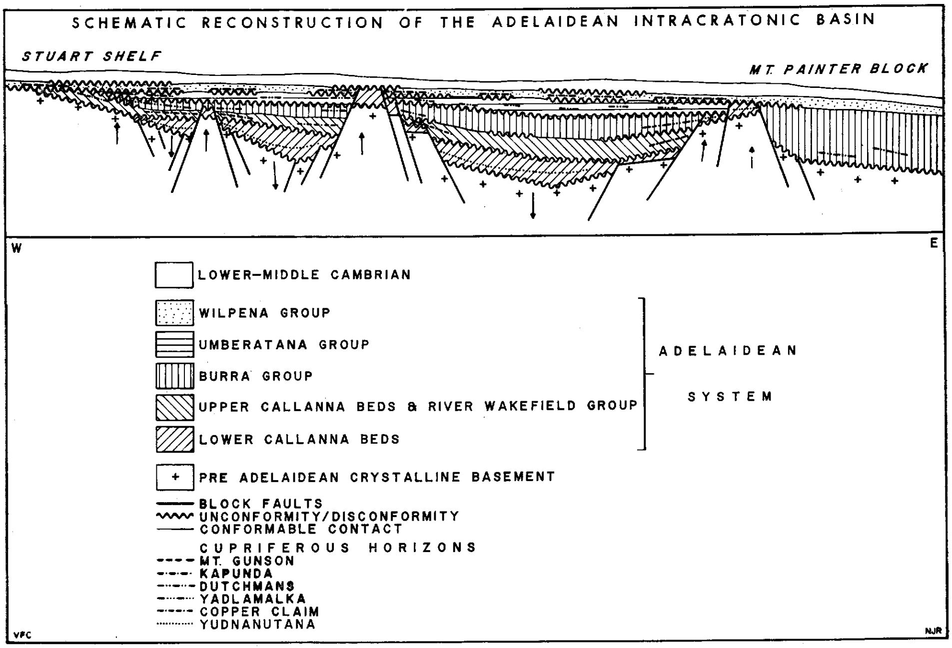

FIG. 2

morphosed Yudnamutana occurrence) are ripple marks, mud-cracks, cross-beds, graded beds and algal evidence. Additionally a possible palaeochannel (± 1 km across) occurs at Yadlamalka.

Syndepositional tectonics such as slump breccias and clastic dykes (Copper Claim) point to mild tectonic instability or deposition at a prograding delta front.

The otherwise flat floor of the depository was interrupted by some pronounced submarine highs, thought to be due to block faulting of the pre-Adelaidean basement. Such palaeohighs are interpreted at Copper Claim, Gunson, Yudnamutana. At the time of the first major marine incursion the Adelaidean palaeobasin was divided into several discrete depositories by these highs. At the time of deposition of the cupriferous sediments some of these highs formed palaeoislands (fig. 2).

An arid palaeoclimate probably prevailed during formation of most of the occurrences. This is suggested by halite and anhydrite casts, mud cracks, minor aeolianites (at Yadlamalka), and red-bed strata (at Dutchmans).

Primary rock colours (except Dutchmans) are grey, black or green, suggesting foul bottom euxinic conditions. Dutchmans occurs in a red-bed environment and is possibly non-marine.

There is almost no evidence of igneous activity associated with mineralization. For Copper Claim, possible palaeorifting and associated block faulting, together with thin (20 cm) felsic pyroclastics points to a waning volcanic stage. Post-Adelaidean alkalic ultrabasic dykes (Pontifex, 1973) intrude the host stratigraphy at Copper Claim. At Yudnamutana post-Adelaidean potash metasomatism affects some of the host stratigraphy, but appears unrelated to the copper mineralization (Pontifex, 1973; Chuck, 1973; Kitch, 1973).

Host lithology. — Host rocks are amphibolitic marbles and arenites (Yudnamutana); lithic arkoses (Gunson); carbonaceous arkosic siltstones (Kapunda); carbonaceous dolo-siltites, carbonaceous dolo-arenites and volcaniclastic arenites (Copper Claim); arkosic arenites (Yadlamalka); and lenticular arenaceous siltstones locally known as "grey beds" (Dutchmans). Calcareous cement is a common lithologic feature.

The amphibolitic Yudnamutana host rock is regarded as the metamorphic product of an original dolo-argillite.

Dolomitic host rocks are never pure dolomites. They are usually dark coloured, relatively massive and fine grained, with bedding laminae from 0.2 mm to 3 cm thick.

Argillaceous-siltstone host rocks constitute one of the better mineralized lithofacies. They are generally carbonaceous (Copper Claim and Kapunda) and vary from dolo-siltites to argillaceous siltites. Highly fissile black graphitic shales (Copper Claim) rich in sericite, form a local minor constituent of some mineralized strata. The siltites and dolomites interfinger with each other. Both have suffered soft-sediment deformation.

The arenaceous host rocks carry the best grades of copper; the texture varies from fine grained (Kapunda, Dutchmans and Yadlamalka) to conglomeratic (Gunson, Copper Claim). Some have a pyroclastic component (Copper Claim) others contain lithic fragments (Gunson and Dutchmans).

The most favourable host lithology appears to be a fine grained carbonaceous dolo-arenite.

All host rocks are generally sericitic and chloritic.

Mineralogy-zonation. — From the bottom to the top of the Adelaidean sedimentary stack there is a zonation from copper to lead-zinc mineralization. This culminates in the widespread lead-zinc mineralization associated with the basal Palaeozoic marine transgression that overlies Adelaidean strata (fig. 2).

Base metals and gold are concentrated in the central and eastern portions of the palaeotrough. This clustering is thought to reflect proximity to source areas.

Gunson shows a vertical and lateral zoning from copper to lead-zinc mineralization. Copper mineralization generally gives way vertically to pyrite. Lateral mineral zoning (controlled by lithofacies changes) from pyrite through chalcopyrite to chalcocite is shown at all the occurrences under discussion. Chalcopyrite is the most common copper sulphide species.

Primary mineralization. — In the hypogene zone mineralization consists of pyrite-chalcopyrite-chalcocite.

Pyrite is the most common sulphide species. It has the following modes of occurrence: As blebs in carbonate concretions within the carbonaceous shales. As detrital disseminations in silty beds at the base of graded silty-shaley beds. As coarse (up to 2 cm across) pyritohedrons in discordant and congruent (diagenetic?) quartz-calcite veins. As minute disseminations in black graphitic-argillites, dolo-argillites, and carbonaceous silty dolo-arenites. Pyrite mineralization occurs in disseminations in association with chalcopyrite. Thin section work has recognized framboidal pyrite in some of the more finely disseminated mineralization.

The chalcopyrite mineralization has two modes of occurrence. Firstly, as fine disseminations, which are difficult to see with the naked eye unless the core or hand specimen is wet, or has been cut and polished. These disseminations are in contrast to pyrite, in that they have irregular grain boundaries. The pyrite usually shows moderate to good euhedral form. Chalcopyrite disseminations are most commonly associated with dolo-arenites and dolo-siltites. Fine disseminations are the most common mode of chalcopyrite occurrence.

Secondly, chalcopyrite occurs as coarsely recrystallized (up to 2 cm) grains in congruent and discordant quartz-carbonate veins. These recrystallized grains are highly irregular in shape, which is in marked contrast to the pyritohedral pyrite in these veins. At the highly metamorphosed Yudnamutana occurrence, sulphide grains are up to 5 cm across (Chuck, 1973).

Secondary mineralization. — Sulphides almost never occur in outcrop. Supergene mineralogy consists of pyrite, limonite pseudomorphs after pyrite, malachite, azurite, cuprite and native copper. At Kapunda the bedded zone contains abundant chalcocite (after pyrite and subordinate chalcopyrite). At Yudnamutana supergene chalcocite after chalcopyrite is known. Gossans on these occurrences are rare.

A gossan (Yudnamutana) that I have studied could be described as follows. Original sulphides are extensively replaced by limonite. Pseudomorphous replicas of pyrite are common. Chalcopyrite occurs as anhedral grains in limonitized fractures. Chalcopyrite in limonite is invariably altered and largely replaced by digenite and covellite. Rarely, chalcopyrite grains may have a core of pyrrhotite indicating replacement of pyrrhotite by chalcopyrite.

Drilling has indicated weathering depths in excess of 200 metres. Electron probe analyses on rocks from this weathered zone have shown copper contained in the chlorite lattice (Cooper *et al.*, 1973).

Controls of sulphide distribution. — The following are some of the controls of sulphide distribution that I have recorded in the mineralized strata.

Both detrital pyrite and chalcopyrite occur along foreset laminae of cross-bedded arenites. The grain size of the chalcopyrite is extremely fine, but tends to be coarser in coarser grained host rocks. Chalcopyrite is more abundant in the coarser, basal portions of graded beds.

Soft sediment deformation (such as clastic dyking) has redistributed chalcopyrite, indicating that the chalcopyrite predates this pre-lithification deformation.

Syn-sedimentary structures such as scours and cut-and-fill structures have sulphides in the fill material.

Bedding exercises a striking and precise control on sulphide distribution.

Congruent and discordant quartz-carbonate veins are a feature of some mineralized horizons. Some of these veins contain coarsely crystalline sulphides, whereas others, although penetrating mineralized laminae, are quite barren.

Postdepositional gitology. — The Adelaidean System is a miogeoclinal sedimentary prism deposited peripheral to cratonic elements. Rifting of the palaeocratons probably initiated sedimentation.

Two phases of mild tectonism (Musgravian and Sturtian) deformed the sedimentary pile while it was being deposited. Lower Palaeozoic orogenesis folded Adelaidean strata to produce the Flinders, Mt. Lofty and Willouran Ranges.

No major structural controls have been observed for the copper mineralization, although faulting (Kapunda) obviously displaces cupriferous stratigraphy. Tectonism must increase the inherent porosity of host rocks and may have provided extra "plumbing" for relocation of mineralization by groundwater.

Gunson is not folded. Copper Claim has a conical style of folding (Kitch, 1973). The other occurrences have a cylindrical similar style of folding, with a sub-diapiric disharmonic style at Yudnamutana.

At Yudnamutana host rocks have reached the amphibolite facies of metamorphism. The other examples are either unmetamorphosed (Gunson) or may just have reached the lower greenschist facies.

Diagenesis probably concentrated mineralization in minor lateral secretion carbonate veins. Diagenesis also resulted in upgrading of montmorillinite to chlorite-illite with concomitant expulsions of complexed copper from the montmorillinite lattice.

ADELAIDEAN/KATANGIAN COMPARISONS

Figure 3 shows one interpretation of the Late Proterozoic palaeogeography of Gondwanaland; the relative positions of the Adelaidean and Katangian Systems are indicated.

I have used the two Late Precambrian ice ages to make the time equivalance statement of figure 4.

There is probably no other time in geological history for which evidence of almost world-wide glaciation is so strong. Harland (1959) ascribes this widespread occurrence of drift tillites in the Upper Proterozoic to a unique configuration of the continents that allowed drift ice to reach equatorial regions; however, it still seems simpler to suppose that the climate change recorded by the tillites was intense and worldwide in its effects.

Attempts to dress the history of Late Precambrian depositories in suits of modern plate tectonic clothes seem to result in some unhappy fits and some stretching at the seams. I suggest that even in the Late Precambrian crust and mantle were not differentiated sufficiently to produce "thick" rigid plates requiring subduction at one locality to compensate for rifting at another. Rather the dominant style of Precambrian tectonism was universally rifting (Hutchinson, R. W., pers. com., 1973).

Both the Adelaidean and Katangian sedimentary prisms are the product of intracratonic depositories. There is evidence for the development, globally, of conditions that allowed the accumulation of very large quantities of copper in sediments (fig. 4). I suggest it is likely this coincides with changes that are part of a general pattern in atmospheric, biogenic and crustal evolution.

What exactly those changes were I do not claim to understand, but they led to the deposition, in quiescent, marginal marine, reduzate stable-shelf environments peripheral to cratonic nuclei, of cupriferous sediments. The climate was arid and the deposition followed a prolonged period of weathering. Generally speaking (and particularly in the Katangian and Adelaidean Systems) there was a lack of volcanic activity, and subsequent levels of metamorphism developed were only very low (i.e. the deposition zone did not subsequently as part of its development, become a subduction zone). Diapirism is a feature of both Supergroups.

The Eh-pH physico-chemical barrier where continental waters meet marine waters in the palaeolittoral zone, coupled with facies changes appears to be the most consistent environmental "thread" linking the cupriferous horizons in both Supergroups, as well as those in Russia, Northwestern America, Rhodesia, Zambia and Southwestern Africa (fig. 4).

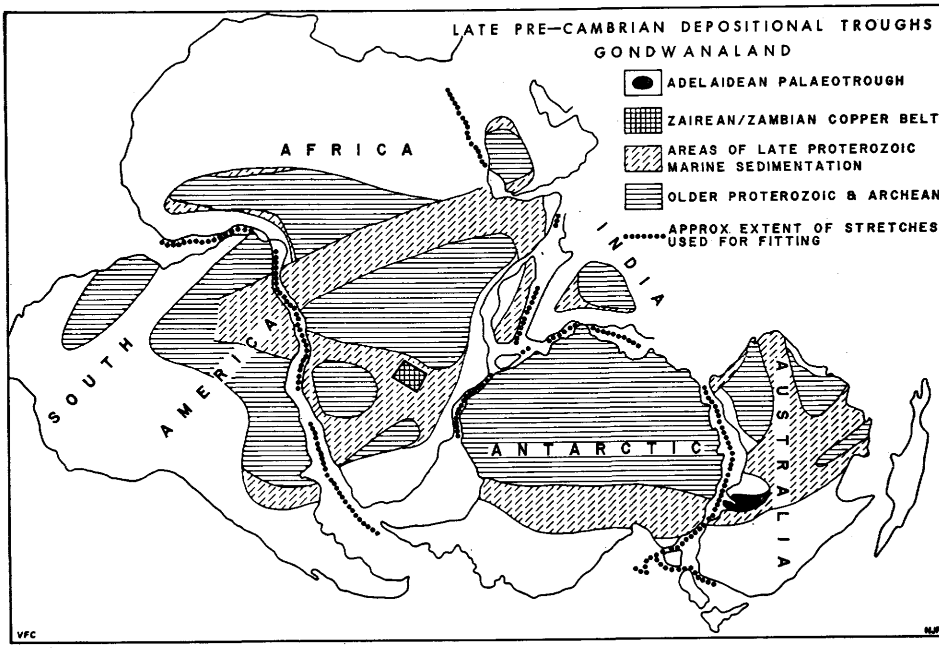

FIG. 3

CORRELATION OF SOME LATE PROTEROZOIC EVENTS AROUND THE WORLD

NORTH-WEST AMERICA	ZAMBIA	ZAIRE	RHODESIA	SOUTH-WEST AFRICA	SOUTH AUSTRALIA
WINDERMERE SYSTEM HORSETHIEF FORMATION	UPPER KUNDELUNGU / MIDDLE KUNDELUNGU (TILLITIC)	KUNDELUNGU SUPERIEUR / KUNDELUNGU (MOYEN) PETIT CONGLOMERATE	SIJIRIRA SANDSTONE	NAMA SYSTEM / SCHWARZ RAND TILLITES	WILPENA GROUP / MARINOAN TILLITES
TOBY CONGLOMERATE	LOWER KUNDELUNGU (TILLITIC)	KUNDELUNGU INFERIEUR GRAND CONGLOMERATE	PIRIWIRI SERIES (TILLITIC)	MULDEN SERIES / OTAVI SERIES: TSUMEB STAGE, OTAVI TILLITE	UMBERATANA GROUP / STURTIAN TILLITES
UPPER MISSOULA GROUP / LOWER MISSOULA GROUP	MWASHIA GROUP	MWASHIA PLUS MOFYA & DIPETA	MOUNTAIN SANDSTONE SERIES	OTAVI SERIES: ABENAB STAGE	BURRA GROUP
MIDDLE BELT	UPPER ROAN GROUP	SERIES DES MINES	ARGILLACEOUS SERIES	NOSIB FORMATION	CALLANNA BEDS
RAVALLI GROUP / LOWER BELT	LOWER ROAN GROUP	R.A.T.	"MINERALISATION" / ARENACEOUS SERIES		
BASEMENT (±1·5 b.y. B.P.)					

VFC NJR

FIG. 4

To date the only major difference between Adelaidean and Katangian rocks is the presence, in the second, of major stratiform copper orebodies; I predict that in time this difference will also be removed.

ACKNOWLEDGEMENTS

I thank Utah Development Company for allowing me the permission, time and opportunity to both prepare and present this paper.

Thanks are due to my colleagues Bob Kitch, Graeme Chuck, Andrew Drummond, Neil Stuart and Alan Hitchcox whose work has contributed to my understanding of these copper occurrences. Vic Chamagne drafted the figures and prepared the slides.

Special thanks are due to Oliver Warin, who checked the manuscript, and who conceived the Utah stratiform copper search.

References

CHUCK, R. G. (1973). — U.D.C. Special Report No. 214. Unpublished Company Exploration Progress Report.

COOPER, R. S. and HENLEY, K. J. (1973). — Amdel Mineralogical Report No. MP 3602/73. Unpublished U.D.C. Report.

FERREIRA, E D. (1972). *Carta Tectonica do Brasil.* Nota Explicativa Republica Federativa do Brasil. Bol. No. 1.

GRANSBURY, R. J. (1973). Unpublished Geophysics Hons. Thesis. University of Adelaide.

HARLAND, W. B. and BIDGOOD, D. E. T. (1959). — Palaeomagnetism in some Norwegian Sparagmites and the Late Precambrian Ice Age. *Nature,* Vol. 184, Suppl. 24, No. 4702, p. 1215-1240.

KITCH, R. B. (1972-1973). — U.D.C. Special Report Nos. 199 and 212. Unpublished Company Exploration Progress Reports.

KRASON, J. (1967). — *Perm Synkliny Boleslawieckiej (Dolny Slask) Prace Wroclawskiego Towarzystwa Naukowego.* Serial B, No. 137, 151 p.

MARTIN, H. (1965). — *The Precambrian Geology of S.W.A. and Namaqualand P.R.U.* University of Capetown, 159 p.

PONTIFEX, I. R. (1972). — McPhar Mineralogical Reports Nos. 806, 819, 992, 1058, 1322, 1043, 1262, 938, 968, 1052, 1090, 1322, 1114, 1093. Unpublished U.D.C. Reports.

ROWLANDS, N. J. (1972-1973). — U.D.C. Special Reports Nos. 181, 183, 184, 185, 207, 213. Unpublished Company Exploration Progress Reports.

ROWLANDS, N. J. (1973). — The Adelaidean System of South Australia: A Review of its Sedimentation Tectonics and Copper Occurrences. *Idaho Bureau of Mines and Geology: Belt Symposium.* Vol. 1, p. 80-108.

ROWLANDS, N. J. (1964). — The Geology of the Area West of Meyers Pool, Rhodesia. Unpublished U.C.R.N. Honours Thesis.

Imprimé en Belgique