THE TELFER GOLD DEPOSITS, WESTERN AUSTRALIA: STRATIGRAPHY, SEDIMENTOLOGY AND GOLD MINERALISATION OF THE PROTEROZOIC YENEENA GROUP

COLIN CLIVE TURNER
B.Sc.(Hons) - Reading, U.K.
M.Sc. - McMaster, Canada

A thesis submitted for the degree of Doctor of Philosophy
of the University of New England

July, 1982

The Telfer Gold Mine, Western Australia.

Aerial view of Main Dome from the north.

August 1978.

PREFACE

The discovery of a major gold deposit in the early 1970's, in a remote area of Western Australia that was very poorly known geologically, has led to the establishment of the Telfer Gold Mine (Frontispiece) and to geological mapping and exploration in the region by the State geological survey and by mining companies. The economic importance and geological significance of the gold deposits prompted Newmont Pty. Ltd. and Dampier Mining Co. Ltd. (the developers of the mine) to instigate a Ph.D. research programme through the University of New England.

This thesis represents the first detailed account of both the gold deposits and their host Precambrian sedimentary rocks. Due to the relative lack of previous geological data, and the importance of understanding the regional geological setting of any major ore deposit, the study had two main objectives; firstly, to provide comprehensive descriptions and interpretations of the stratigraphy, sedimentology and basin development of the Precambrian sedimentary sequence; and secondly, to study and interpret the textures, mineralogy and geochemistry of the ores themselves, and relate ore genesis to the interpreted geological evolution of the region. The thesis is therefore divided into two major parts, entitled the Yeneena Group, and Mineralisation, which are preceded by a comprehensive summary.

CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

LIST OF PLATES

(At end of each chapter)

REAR POCKET

SUMMARY

The Telfer gold deposits occur within Proterozoic sedimentary rocks of the Paterson Province in north central Western Australia. In this remote arid area two major Precambrian sequences occur, the Archaean to Middle Proterozoic Rudall Metamorphic Complex, and the unconformably overlying Middle Proterozoic Yeneena Group (see Figure 1.3). The Yeneena Group consists of about 9000 m of sedimentary rocks, which have been folded about northwest-southeast trending axes, and which have suffered lowest greenschist regional metamorphism. Biotite granite plutons, dated at about 600 m.y., intrude the group in the Telfer area.

The Yeneena Group can be divided into two major units, which together comprise eight formations (see Figure 2.1). The lower part of the group outcrops in the southwest, and consists of the Coolbro Sandstone, and the Broadhurst and Choorun Formations. The upper part of the group occurs in the northeast, and includes the Isdell, Malu, Telfer and Puntapunta Formations, and the Wilki Quartzite. The upper Malu and lower Telfer Formations are the hosts of the Telfer gold deposits.

The Coolbro Sandstone and the Choorun Formation both consist dominantly of fine to coarse grained quartz-rich to subarkosic sandstones, and minor conglomerates. Cross bedding and parallel lamination are fairly common, but outcrops are more often massive or sheared. Both units are interpreted as fluvial deposits, although a marine shelf environment is possible for part of the Coolbro Sandstone. The Broadhurst Formation consists of shale, carbonaceous shale and very minor iron formation, which are interpreted as quiet marine deposits. The entire lower Yeneena Group was deposited on a tectonically stable cratonic area. To date, no economic mineralisation, and no known gold occurrences, exist in these sedimentary rocks.

The upper Yeneena Group is geographically separated from the lower part of the group, and stratigraphic relationships are therefore uncertain. However, the two units may be separated by an

unconformity, with the Isdell Formation probably overlying the Broadhurst Formation in the northeast and the Choorun Formation farther southwest.

The Isdell Formation consists of three dolomitic facies, consisting of varying proportions of dololutite, dolarenite and dolomitic mudstone. These facies are interpreted as carbonate slope and outer carbonate shelf deposits.

In contrast, the overlying Malu and Telfer Formations together form a dominantly siliclastic sequence, although the Telfer Formation also includes thick units of carbonate. Four siliclastic facies can be distinguished in these two formations, based mainly on grain size characteristics and sedimentary structures. The coarsest sediments are massive medium grained sandstones, which are interpreted as grain flow deposits. Fine to medium grained sandstones, which are commonly graded and contain abundant cross lamination and parallel lamination, are interpreted as turbidites. Very fine grained massive and cross laminated sandstones are also probably turbidites. The finest grained facies comprises interbedded claystone and siltstone, which were deposited from suspension and from very dilute turbidity currents. Coarsening upwards sequences of facies can be recognised, which are interpreted as the result of deposition on submarine fans.

The Puntapunta Formation, which conformably overlies the Telfer Formation, consists mainly of arenaceous dolomite and lesser amounts of carbonate-rich sandstone. Both lithologies are probably carbonate shelf deposits. The Wilki Quartzite is a thick sandstone sequence, much of which has been metamorphosed by intruding granites. The unit is tentatively interpreted as siliclastic shelf deposits.

Palaeocurrent measurements suggest that the dominant palaeoslope during deposition of the upper Yeneena Group was to the north or northeast. Although no volcanic rocks occur in the group, high feldspar contents of some of the sandstones (particularly in the Isdell Formation) suggest tuffaceous sources for parts of the sequence. The entire Yeneena Group may have been deposited either at a continental margin or within a failed rift type of intracratonic basin.

The Telfer ores are stratiform bodies, generally less than 1 m thick, which occur around the gently to moderately dipping flanks of two en echelon doubly plunging anticlines (Main Dome and West Dome), which are themselves part of a larger domal structure (the Telfer Dome). The major ore body (the Middle Vale Reef, or MVR) occurs in a claystone and siltstone unit in the upper Malu Formation, and two widespread and two less widespread ore bodies (the E Reefs) occur in similar host rocks in the lower Telfer Formation. The maximum areal extent of any single ore body is about 1.5 - 2 sq. km.

The ores are oxidised to depths of about 95 m, and are mined by an open cut method. Above this depth the ores consist of auriferous iron oxides and less auriferous quartz, and below this depth they comprise auriferous pyrite and quartz set in kaolinitic siltstone and claystone.

The MVR has been the most extensively studied of the ores. Logging of drill core has proved that this ore body is stratiform and occurs in the lowest 2 m of the Middle Vale Siltstone Member, which conformably overlies the Footwall Sandstone Member. The top of the ore is a sharply defined bedding plane, directly above which there is virtually no mineralisation. The base of the MVR varies from being sharp to diffuse, and below the ore, mineralised veins are common in the upper few metres of the Footwall Sandstone, being of ore grade themselves in places. The gross features of the E Reefs are similar to those of the MVR, but there is less closely associated veining.

In the few drill cores of pyritic MVR that exist, four textural types of mineralisation can be distinguished (their oxidised equivalents can also be recognised in pit exposures). These are, massive to crudely laminated granular pyrite with minor quartz, laminated granular pyrite within kaolinitic siltstone, massive coarse grained quartz with minor pyrite, and disseminated and vein mineralisation in the footwall. Gold occurs dominantly within pyrite, as small inclusions and perhaps also in solid solution. Chalcopyrite inclusions also occur in the pyrite, and supergene chalocite is abundant in some core intersections. The ores average about 10 ppm

Au, but individual assays of over 100 ppm are not uncommon; copper values of over 2% are also fairly common in the supergene enriched ore.

Lateral, down-dip stratigraphic equivalents of the ores are thin limestone and minor dolomite units, and in two core intersections "chert" layers occur together with the carbonate. It is uncertain how laterally extensive are these carbonate beds, but there is some evidence that they are localised phenomena.

The pyritic ores are enriched mainly in Fe and S, and in some samples also by SiO_2. These elements probably represent a straightforward addition to the normal siliclastic sediment. Several trace elements are also concentrated in the ores, being mainly associated with pyrite; Au and Cu are greatly enriched; Ag, As, Co and Mo are moderately enriched; and Zn, Cd, Hg, Tl, Sn, Pb, Zr, P, Bi, Mn, W, U and Ni show slight enrichment in some samples. Co : Ni ratios of pyrite are high, commonly exceeding 10. $\delta^{34}S$ values of pyrite from the MVR at Main Dome range from +3.8 to +4.6‰, and values from pyrite in the same horizon at West Dome range +1.45 to +2.05‰. Veins in the footwall sediments at Main Dome have similar sulphur isotope ratios to those of the MVR.

Several features of the ores suggest that the stratiform mineralised layers either pre-date folding or were formed early in the deformation. For example, faults which were contemporaneous with the folding displace the ores; pyrite and quartz are sheared in places, which probably occurred during folding; and pressure fringes occurring around pyrite grains are thought to have formed during cleavage development.

Certain features of the ores are considered to be of sedimentary origin. These include; the sharp conformable tops of the ores; the delicate layering of granular pyrite, which in one case is cross laminated; and rare compactional features such as flame structures and drapes over nodular quartz.

The ores have been previously described as saddle reefs, but they are deduced not to have formed in structural dislocations during folding, partly for the above reasons, and also because folding is much more open than in areas where such gold deposits occur. The granite bodies in the Telfer area are considered to have intruded the folded sedimentary sequence at a much later date than the deformation, and are therefore unconnected with the ore formation. Replacement of limestone beds prior to or during early folding cannot be entirely discounted as a possible origin of the ores, but the favoured origin is syngenetic precipitation of auriferous pyrite from submarine hydrothermal springs. Quartz probably represents a slightly later addition to the ores. The "chert" and limestone beds may also have formed as a consequence of hot spring exhalations. Despite their occurrence in a thick sedimentary sequence, apparently devoid of volcanics, the stratiform ores show similarities of form and chemistry with the volcanogenic Kuroko-type deposits.

The source of metals is speculated to have been deep-seated mafic igneous bodies. This would be consistent with the pronounced gravity high which occurs over the Yeneena Group fold belt. However, the sulphur isotope data suggest that extensive mixing of any magmatic fluids with connate water occurred in the sedimentary pile. Faulting at depth, contemporaneous with sedimentation, probably controlled sediment thickness variations over the Telfer area, and may have provided channelways for ascending hydrothermal waters. These thickness variations may have indirectly controlled the sites of fold axes during later deformation. Other, structurally controlled, quartz-rich gold deposits in the area (which are at present un-economic) may have formed by the mobilisation of gold during deformation.

The upper Yeneena Group is a gold-rich metallogenic province, in which further economic gold deposits may well be discovered. Thin syngenetic gold deposits may also occur in other sedimentary sequences deposited at tectonically active (rifted?) continental margins.

ACKNOWLEDGEMENTS

Numerous people have contributed in a variety of ways to the production of this thesis, and it is a pleasure to acknowledge here all of these individuals. Professor R.L. Stanton is particularly thanked for his initial, and quite unexpected, suggestion of the thesis topic, which had come to his attention from Mr. R.T. Russell, then Vice President (Exploration) of Newmont Pty. Ltd. Special thanks are due to Dr. Barrie McKelvey for his supervision and friendship during my three years residence in Australia, and for almost two years of subsequent helpful correspondence.

The following Newmont geologists are thanked for their willing assistence at Telfer, particularly in the early stages of the project - R.T. Russell, D.S. Tyrwhitt, M.F. Lenard, Q. Amos, J. Kalnejais, S. Turner and N. Norris. At the University of New England, the following are thanked for advice on chemical and mineralogical analyses - J.D. Kleeman, G.I.Z. Kalocsai, A.J. Stolz and B.H. Flinter. The technical assistance of D. Cameron, J. Cook, D. Morgan and N. Petrasz is also gratefully acknowledged. Dr. J. Wilmshurst of CSIRO in North Ryde is thanked for his advise on general analytical aspects of the Telfer ores, and assistance with certain analytical procedures; Dr. S.S. Sun, also of CSIRO, is similarly thanked for performing the sulphur isotope analyses.

I am very grateful to the following colleagues and friends for various assistance and encouragement - Quentin and Pat Amos, Heather Auld, Ken Cross, Bob Haydon, Martin and Jenny Lenard, Ray Roberts and Joe Stolz.

Most of the thesis plates were printed by T. Bain; figures in Chapter 1, and also Figure 2.1 were drafted by C.McCraw; Figures 3.1 and 3.2 were drafted by F. MacLachlan; and Figure 6.4 was drawn by E. Long. The expert typing of the bulk of the thesis by Betty Scott was much appreciated, and J. Nyberg assisted with the final stages of typing.

The study would have been impractical without logistical support and travelling expenses provided by Newmont Pty. Ltd. and Dampier Mining Co. Ltd. I am also grateful to both the University of New England for the award of a Research Scholarship, and to the Institute of Geological Sciences for allowing three years leave of absence to carry out the study.