Copper and associated polymetallic mineralization along the Camel–Tabletop Fault Zone in the Paterson Orogen, Western Australia

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Abstract

Copper and associated polymetallic mineralization has been identified in the remote eastern part of the northwestern Paterson Orogen along the Camel–Tabletop Fault Zone. The mineralization is in the Palaeoproterozoic Rudall Complex and the basal Neoproterozoic part of the Officer Basin, in diverse settings controlled by stratigraphy, unconformities, and shear structures. Copper mineralization is commonly associated with gold, silver, lead, zinc, nickel or platinum-group elements.

The Camel–Tabletop Fault Zone is the collisional boundary between the Tabletop Terrane and the western Talbot and Connaughton Terranes of the Rudall Complex. The Camel–Tabletop Fault Zone was reactivated at about 800 Ma, forming a 3–10 km-wide graben where sedimentary and rare volcanogenic rocks of the Officer Basin were deposited. The copper mineralization in both the Rudall Complex and Officer Basin is structurally controlled and unconformity associated, and may have been at least partly contemporaneous with the formation of the graben structure.

KEYWORDS: Rudall Complex, Officer Basin, Camel–Tabletop Fault Zone, greenschist facies, metamorphism, hydrothermal alteration, mineralization

Introduction

Mineral exploration by companies and mapping by the Geological Survey of Western Australia (GSWA) have identified numerous occurrences of copper and associated mineralization in the Palaeoproterozoic Rudall Complex and the Camel–Tabletop Fault Zone in the Paterson Orogen (Fig. 1).

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The Paterson Orogen (Williams and Myers, 1990) is a northwesterly trending belt of Palaeoproterozoic to Neoproterozoic rocks that, on geophysical evidence, occupies a 1200 km-long arcuate zone across the central part of Western Australia (Williams and Myers, 1990; Myers et al., 1996). The orogen is exposed along the eastern margin of the Pilbara Craton and in the Musgrave Complex (c. 1550–1150 Ma) of central Australia (Williams and Myers, 1990; Camacho and Fanning, 1995). These regions are connected by the unexposed Paterson–Musgrave structural link (Austin and Williams, 1978), indicated by a strong gravity high initially known as the Anketell Gravity Ridge (Fraser, 1976), but more recently referred to as the Warri Gravity Ridge (Iasky, 1990). Myers and Hocking (1998) showed the structural link as a series of concealed thrusts.

Economic mineralization in the northwestern Paterson Orogen is present at the Nifty copper deposit, the Kintyre uranium deposit, and the world-class Telfer gold deposits (Fig. 1). In addition, Croesus Mining NL and Gindalbie Gold NL discovered significant gold, copper, and silver mineralization in 1998 at the Magnum prospect, where further exploration is in progress. This prospect is about 100 km north of the Telfer deposit, in part of the Paterson Orogen concealed beneath the Phanerozoic Canning Basin (Fig. 1). The presence of mineral deposits and mineralized zones in the Paterson Orogen indicates that it is highly prospective for various types of mineralization. However, the mineral prospectivity of adjacent parts of the Neoproterozoic Officer Basin (Fig. 1) has been largely unrecognized until recently. The presence of economic copper, lead, and zinc mineralization at the Maroochydore deposit, near the northwestern extension of the Camel–Tabletop Fault Zone (Fig. 1), and new copper discoveries near No. 23 Well (Fig. 2) suggest that economically viable deposits may be present within the Neoproterozoic Officer Basin.

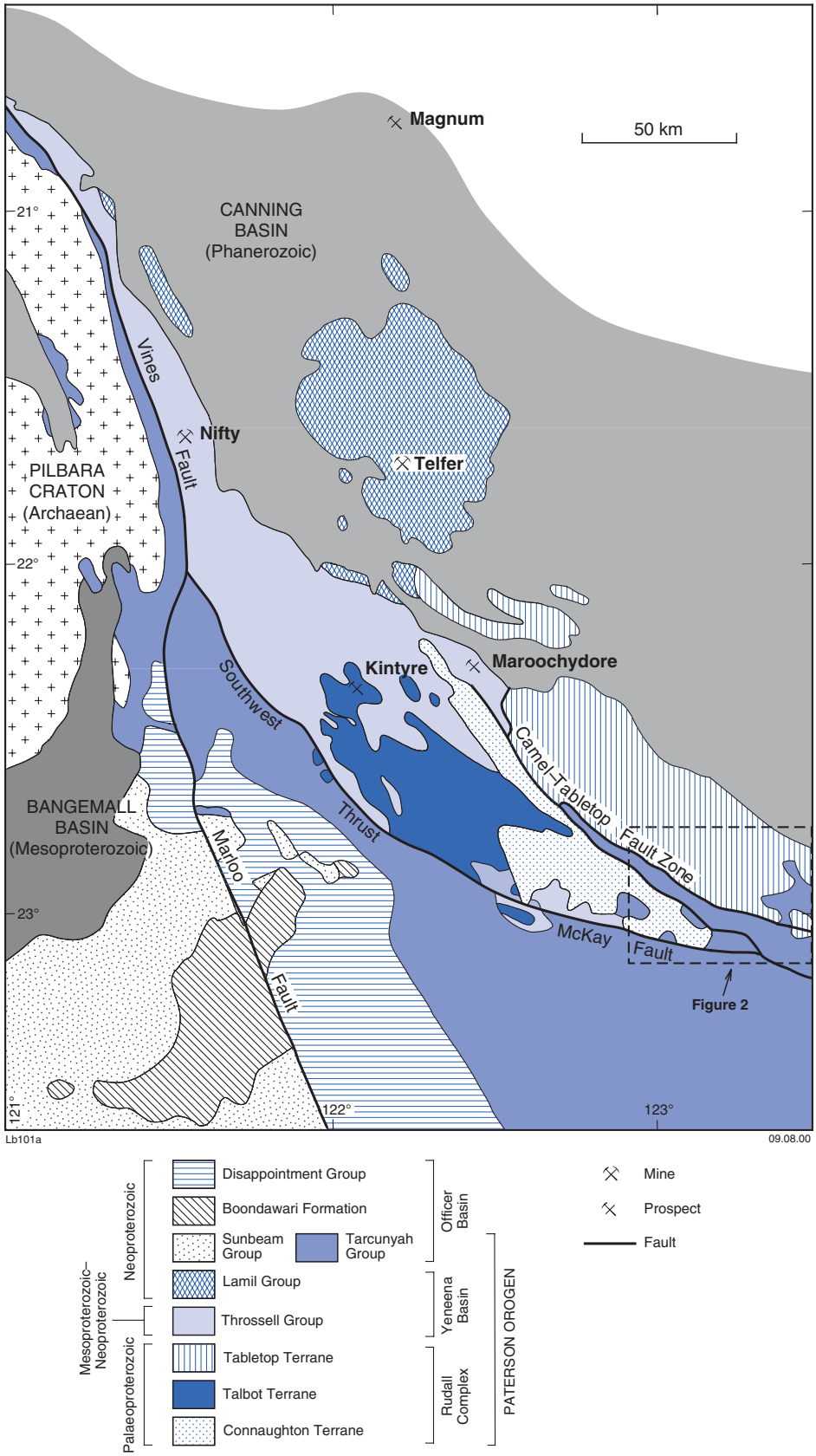

Figure 1. Regional geological setting

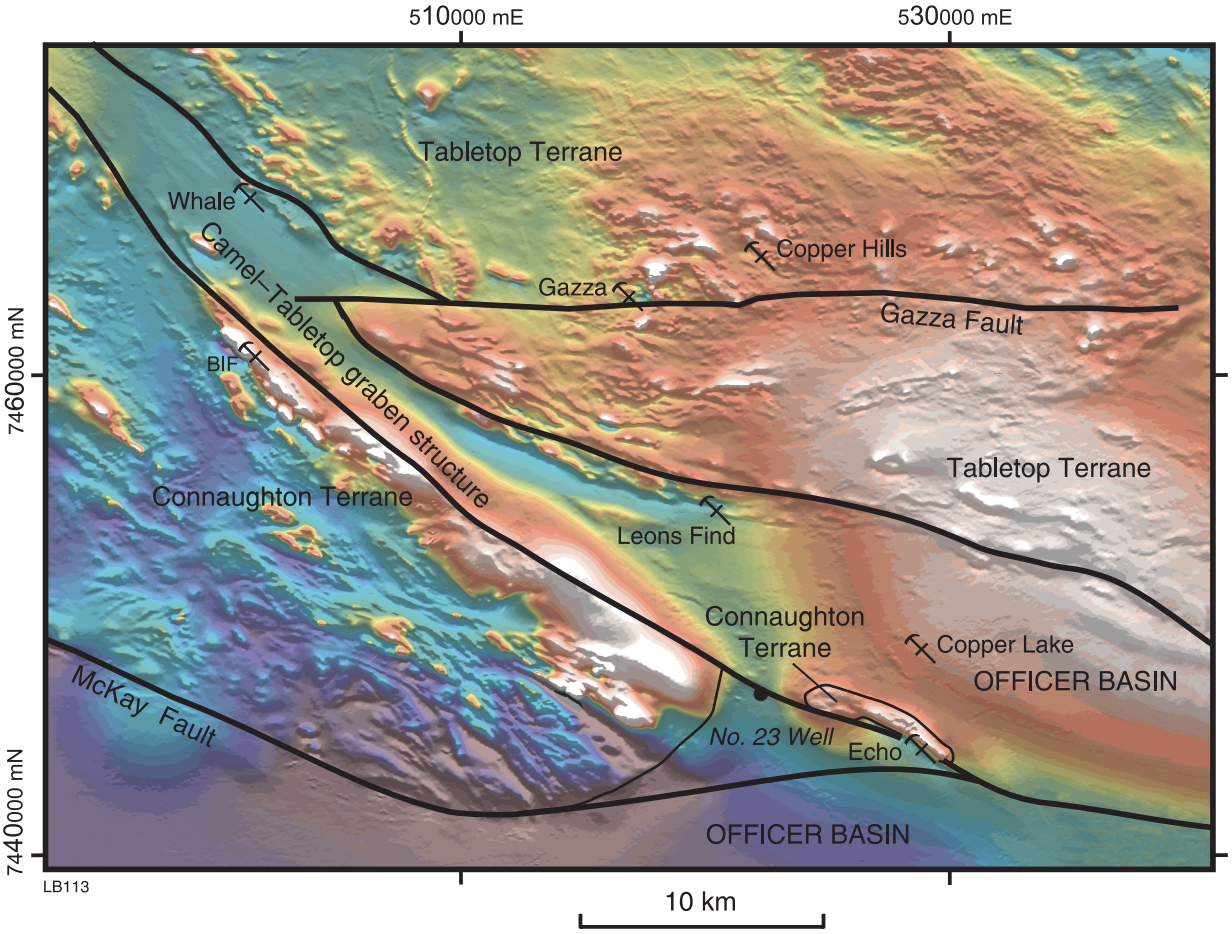

Figure 2. Magnetic image showing the location of the Camel–Tabletop graben structure and nearby copper occurrences

The Camel–Tabletop Fault Zone is in the poorly exposed eastern part of the northwestern Paterson Orogen (Bagas and Smithies, 1998), and hosts an outlier of the Neoproterozoic Officer Basin (Fig. 1). The area is geologically important because it:

- lies on or near the boundary between three terranes in the Paterson Orogen;
- contains a graben structure filled with Neoproterozoic sedimentary rocks of the Officer Basin;
- contains a diverse range of mineralization styles, including structurally controlled, unconformity-associated, and sediment-hosted stratiform mineralization, and complex associations of copper–gold and platinum-group elements (PGE).

Regional geology

The northwestern component of the Paterson Orogen includes the Palaeoproterozoic Rudall Complex, Mesoproterozoic to Neoproterozoic Throssell Group, and Neoproterozoic Lamil and Tarcunyah Groups (Bagas et al., 1999; Bagas, 2000). The Tarcunyah Group unconformably overlies the Throssell Group and is part of Supersequence 1 of the Centralian Superbasin. The Tarcunyah Group is a correlative of the Sunbeam Group in the lower part of the northwestern Officer Basin (formerly 'Savory Basin'; Bagas et al., 1999).

The outcropping Rudall Complex extends for about 120 km from near the Kintyre prospect (Fig. 1) to the Copper Hills area (Fig. 2) and can be subdivided into three distinct tectonically juxtaposed packages of rocks, referred to as the Connaughton, Talbot, and Tabletop Terranes (Fig. 1; Bagas and Smithies, 1998).

The Talbot Terrane is in the western part of the complex, and comprises banded orthogneiss and paragneiss metamorphosed to amphibolite facies at moderate pressure (Smithies and Bagas, 1997a).

The Connaughton Terrane, in the central part of the complex, consists of a succession of mafic gneiss and schist, orthogneiss, and paragneiss. These rocks are metamorphosed to the amphibolite–granulite transitional facies at high pressures (Smithies and Bagas, 1997b).

The Tabletop Terrane is poorly exposed and forms the eastern portion of the Rudall Complex. The terrane comprises a sequence of mafic schist, amphibolite, and metasedimentary rocks that resemble the sequence in the Connaughton Terrane. However, there is no evidence that the peak metamorphic grade exceeded upper greenschist facies or that it was accompanied by high pressure. The Tabletop Terrane is also characterized by the presence of weakly

foliated tonalite and leucogranite (Smithies and Bagas, 1997a), which are dated at 1490 and 1300 Ma respectively (Bagas and Smithies, 1998). As there are no known granitic intrusions of that age range in the terranes to the west, the Tabletop Terrane may have been geographically separate until at least 1300 Ma. The Tabletop Terrane probably collided with the Connaughton and Talbot Terranes before the Mesoproterozoic to Neoproterozoic Miles Orogeny that culminated before deposition of the c. 800 Ma Tarcunyah Group (Bagas and Smithies, 1998).

The intensity of the foliation developed in the Tabletop Terrane increases closer to the Camel–Tabletop Fault Zone, which marks its boundary with the Connaughton Terrane (Bagas and Smithies, 1997). The fault also corresponds to the southwestern margin of the regional Warri Gravity Ridge (Iasky, 1990). Bagas and Smithies (1998) interpreted the fault zone as a collisional zone, which, during subsequent extension, formed a graben between 3 and 10 km wide containing the Karara Formation of the Tarcunyah Group in the study area.

Mineralization

Recent mapping (Bagas, 1999) and exploration by Australian Platinum Mines NL since the mid-1990s has identified widely spaced copper mineralization in the northern part of the northwestern Officer Basin, an area not previously regarded as prospective by companies involved in uranium and base metal exploration in the Rudall Complex. Mineral occurrences in the region are polymetallic and include copper associated with various concentrations of silver, gold, lead, zinc, cobalt, nickel, PGE, and rare earth elements. Details of prospects in the area are presented in Table 1, and their locations shown in Figure 2.

Copper mineralization from these prospects can be classified into three major styles. The classification adopted is not genetic, but is based on the association of mineralization with specific geological features.

Table 1. Significant copper and associated mineralization along the Camel–Tabletop graben structure

Prospect	*Significant assays*	*Metal association*	*Host rocks*	*Geological unit*	*Mineralization style*
BIF	0.76% Cu[a] 0.4% Cu[b] 0.5% Zn[b] 0.2 ppm Au[b]	Ag–As–Au–Cu–Mo–Pd–Pt–Zn	Felsic gneiss–schist at the contact with BIF	Rudall Complex	Shear zone hosted
Whale	1.3% Cu[a] 1 m at 0.22% Cu[b]	Au–Cu	Mafic gneiss, sandstone	Karara Formation and Rudall Complex	Unconformity associated
Gazza	1.4% Cu[a] 170 ppm Ag[a] 0.32 ppm Au[a] 713 ppm Co[a] 0.4% Ni[a] 9.3% Pb[a] 2.6% Zn[a]	Ag–As–Au–Co–Cu–Ni–Pb–Pd–Pt–Th–Zn	Gossanous quartz–carbonate veins hosted by chlorite schist after amphibolite	Rudall Complex	Fault hosted
Copper Hills	11% Cu[a] 3.5% Ag[a] 0.23% Au[a] 0.49% Pd[a] 0.34% Pt[a] 0.2% Ag[b] 0.2% As[b] 31% Cu[b] 531 ppm Ce[b] 0.5% Pb[b] 1.3% Zn[b]	Ag–As–Au–Bi–Co–Cu–Mo–Ni–Pb–Pd–Pt–Se–Th–V–Zn	Graphite–chlorite schist, carbonate rocks, and quartz veins hosted by sheared amphibolite	Rudall Complex	Shear zone hosted with marked mineralization
Leons Find	15% Cu[a] 5.18 ppm Au[a]	Au–Cu	Sheared mafic rock (basalt or high-level sill)	Karara Formation	Shear zone hosted
Copper Lake	0.2% Cu[a] 6000 ppm Cu[b]	Cu	Mudstone, and tuffaceous sandstone and siltstone	Karara Formation	Sediment-hosted stratiform
Echo	10 ppm Au[a] 0.2% Cu[a] 0.15% Co[a]	Au–As–Co–Cu	Quartz vein hosted in sandstone and schist	Throssell Group and Rudall Complex	Unconformity associated

NOTES: [a] surface rock chips: all copper assays are averages, whereas other elements are highest values
[b] drill intersections, showing highest values

SOURCE: Assay data provided by Australian Platinum Mines NL

The three styles are:
- structurally controlled mineralization;
- unconformity-associated mineralization;
- sediment-hosted stratiform mineralization.

All these deposits show varying degrees of hydrothermal alteration. Alteration in mafic rocks in the Rudall Complex is characterized by plagioclase altered to sericite and epidote (clinozoisite), amphibole (actinolite) locally altered to iron–magnesium chlorite, and clinopyroxene altered to actinolite. Fine granular epidote also fills fractures and locally replaces the matrix.

Carbonate and chlorite alteration has commonly destroyed the primary textures of calc-silicate rocks in the area. The carbonate matrix, which also contains apatite, locally replaced tremolite, and chalcedony replaced part of the matrix. The hydrothermal alteration is indicated by the assemblage tremolite–carbonate–chlorite–apatite.

Dolerite dykes contain platy actinolite aggregates, which have replaced medium-grained clinopyroxene interlocked with microphenocrysts of plagioclase. Plagioclase is pervasively altered to sericite–epidote (hydrothermal alteration) or to microcline with granophyric textures (potassic metasomatism due to the action of residual fluids from cotectic crystallization of the dolerite). Amphibole is altered to chlorite and biotite. The matrix contains accessory amounts of fine anhedral and secondary apatite, and is cut by thin veins of plagioclase. Other accessory phases are opaque minerals (?magnetite) rimmed by titanite. These mineral associations are interpreted as hydrothermal alteration related to the emplacement of the dolerite dykes and is best developed around dyke swarms (e.g. near the Gazza prospect, Fig. 2). At least some of these dykes intruded the Karara Formation as sills and dykes (Bagas, 1999).

Hydrothermal mineralization of possible similar age has also been reported 200 km south of the Paterson Orogen near Quadrio Lake (Hocking et al., 2000). The mineralization consists of barite–hematite stockworks with anomalous quantities of gold, arsenic, and antimony, hosted by a shale-dominated unit of probable Mesoproterozoic age in the Oldham Inlier surrounded by the Officer Basin.

Structurally controlled mineralization

Mineralization in most prospects is hosted in easterly trending faults or shear zones. The host structures are mostly dilational openings associated with the southeasterly trending Camel–Tabletop Fault Zone, which is a persistent structure that has been active at least during the Mesoproterozoic to Neoproterozoic Miles Orogeny and late Neoproterozoic Paterson Orogeny, and probably earlier (Bagas and Smithies, 1998).

At the Copper Hills polymetallic prospect (Fig. 2), structurally controlled copper mineralization is developed along a southeasterly trending curvilinear and vertical shear zone, about 2 km in length, in dolomitic carbonate and graphite–chlorite schist within amphibolite. Copper mineralization at the prospect consists of lenticular and vertical veins rich in malachite, chrysocolla, and azurite. The veins are up to 5 m thick and contain a coarse zonation, from zinc–lead–silver-rich mineralization towards the edge to silver–gold–platinum–palladium-rich mineralization in the centre. The richest mineralized zones are in dilational jogs along the shear zone, with samples assaying up to 11% Cu, 3.5% Ag, 2.3 kg/t Au, 4.9 kg/t Pd, and 3.4 kg/t Pt (Table 1). A mineral resource estimate, in accordance with the JORC (1999) code, is not yet available. However, we estimate that there may be 0.7 Mt at 1.05% Cu and 2.05 Mt at 0.37% Zn, using a cut-off grade of 0.2% for both copper and zinc. These estimates are considered uneconomic.

The mineral association at the Copper Hills prospect shows strong similarity to the assemblage at the nearby Gazza prospect, and both prospects are hosted by hydrothermally altered and sheared amphibolite in the Tabletop Terrane of the Rudall Complex (Table 1). The Gazza prospect is within the easterly trending Gazza Fault (Fig. 2), where a 5 km-long zone contains patchy mineralization. This mineralized zone has not been tested by drilling.

At the BIF prospect (Fig. 2), copper mineralization is in shear zones that cut through banded iron-formation (metamorphosed to amphibolite facies). The prospect is on the western edge of the Camel–Tabletop Fault Zone, at the contact between metamorphosed banded iron-formation and quartz–K-feldspar–biotite schist in the Connaughton Terrane.

Unconformity-associated mineralization

The unconformable contact between the Rudall Complex and overlying rocks of the Throssell and Tarcunyah Groups is mineralized at the Echo and Whale prospects (Table 1, Fig. 2).

The Echo gold–copper–cobalt prospect has a stockwork of quartz veins containing chalcopyrite and pyrite along the contact between quartzite and conglomerate of the Throssell Group and chlorite and sericite schist in metamorphosed banded iron-formation of the Rudall Complex, which together form an inlier in the Karara Formation (Bagas, 1999).

The Whale copper prospect is on the northeastern edge of the Camel–Tabletop Fault Zone, in an alteration zone developed along the sheared unconformable contact between sandstone of the Karara Formation and tremolite gneiss of the Rudall Complex. The alteration zone is characterized by malachite staining, epidote, quartz, sericite, and chlorite, and is similar in style to the Copper Hills prospect.

Sediment-hosted stratiform mineralization

The Copper Lake copper prospect is about 7 km east of No. 23 Well, close to the northeastern edge of the Camel–Tabletop Fault Zone (Fig. 2). Disseminated chalcopyrite appears to be stratabound and in shale, mudstone, and tuffaceous siltstone and sandstone towards the lower part of the basal (predominantly conglomeratic) unit in the Karara Formation (Bagas, 1999). The mineralized sequence contains

malachite (after disseminated chalcopyrite) and can be traced for about 600 m, with rock-chip samples containing up to 6000 ppm Cu (Table 1). This mineralization could be syndepositional and could represent the only sediment-hosted stratiform mineralization in the area.

The Karara Formation in the Copper Lake area has been subdivided into a lower conglomeratic unit and an upper sandstone unit (Bagas, 1999). The conglomeratic unit is mineralized, with chalcopyrite altered to malachite, and consists of polymictic conglomerate interbedded with sandstone, siltstone, and shale. A 10–20 m-thick sheared mafic bed, with abundant malachite and azurite staining, has also been recognized towards the base of the formation in the area. This unit may be interpreted as either an altered basalt or a high-level sill. The upper nonmineralized sandstone unit consists of quartz sandstone, quartz–feldspar wacke, and minor interbeds of shale and conglomerate.

A significant characteristic of the basal conglomeratic unit of the Karara Formation is the potassic alteration represented by K-feldspar in mineralized zones, giving the rock a reddish colour, such as at the Copper Lake prospect. The zone of alteration is highlighted by high counts on the potassium channel of airborne radiometric surveys in the area. This association between mineralization and potassic alteration may be used as a tool for mineral exploration. In addition, sericitization, chloritization, and ferruginization are typically associated with fractures.

Discussion and conclusion

The northwestern Paterson Orogen has proven potential for gold (Telfer, Magnum), copper–lead–zinc (Nifty, Maroochydore), and uranium (Kintyre) mineralization. In addition, mapping by GSWA and mineral exploration companies has indicated significant prospectivity for polymetallic mineralization throughout the Paterson Orogen (Bagas et al., 1995; Bagas et al., 1999) and the northwestern Officer Basin region, including the Oldham Inlier (Hocking et al., 2000).

Most of the mineralization identified in the eastern part of the northwestern Paterson Orogen is associated with hydrothermal alteration along fractures, shear zones, and faults formed during or after the Miles Orogeny.

The recent discovery of the sediment-hosted copper mineralization in the northern part of the northwestern Officer Basin (see above) has also significantly highlighted the prospectivity of the basal part of the Tarcunyah Group, particularly in the Camel–Tabletop Fault Zone. It is probable that this style of mineralization is related to extensional movement along the Camel–Tabletop Fault Zone during the early stages in the deposition of the c. 800 Ma Tarcunyah Group in the basal part of the northwestern Officer Basin.

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