AGSO

Notes on the Geology of the Koongie Park Formation Southwest of Halls Creek, Western Australia

by

Karin Orth

Record 1997/25

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(CODES 1997)

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Summary

The Koongie Park Formation southwest of Halls Creek is made up of metamorphosed mafic volcanic dominated units (Ɛeb), felsic volcanic bearing units (Ɛeh), interbedded sedimentary rocks (Ɛe), and ironstone and chert (Ɛec). A type section for the Koongie Park Formation is proposed, and a new unit, which hosts subeconomic Zn-Cu-Pb mineralisation, is defined as the Onedin Member (Ɛeo). Metamorphism of the sequence increases towards the Loadstone Granite. Some deformation predates and some postdates granite intrusion. Brief descriptions are given of three prospects - Onedin, Gosford and Atlantis.

Introduction

Mapping of the Halls Creek and Angelo 1:100 000 has been undertaken by the Australian Geological Survey Organisation (AGSO) and the Geological Survey of Western Australia (GSWA) as part of the Kimberley-Arunta mapping accord. These map sheets straddle an area of the Koongie Park Formation of particular economic interest because of zinc-copper-lead prospects. These prospects and their host lithologies have been the focus of my PhD research at the Key Centre for Ore Deposit and Exploration Studies (CODES) at the University of Tasmania. During my investigation detailed information on the Koongie Park Formation was collected. Descriptions of the Koongie Park Formation in this area, too detailed to be included in the Halls Creek explanatory notes, are presented here. Subdivisions follow those presented on the preliminary Halls Creek geological 1:100 000 map (Blake et al., 1996).

Koongie Park Formation (Ɛe, Ɛeb, Ɛeh, Ɛec, Ɛef, Ɛeo)

The Koongie Park Formation occurs in an area southwest of Halls Creek covered by the ANGELO and HALLS CREEK 1:100 000 geological map sheets. It crops out west of the Angelo Fault, except near Angelo Mine where the formation is east of the Angelo Fault, bounded further east by a splay fault off the Angelo Fault. Outcrops in the southern area are scattered, weathered and often capped by laterite. In the Koongie Park area this formation is composed of turbiditic sandstone and shale, mafic and felsic volcanics, volcaniclastics, thin elongate layers of ironstone, chert, and minor carbonate and calc-silicate rocks.

The Koongie Park Formation is intruded by the Loadstone Granite, and the Angelo Microgranite and unconformably overlain by the Moola Bulla Formation further south (covered by ANGELO 1:100 000 map). Contacts with the Tickalara

Metamorphics are obscured by granite and gabbroic intrusions. A unit of ironstone, shale and carbonate can be traced around several fold structures and is host to mineralisation at both Onedin and Gosford Zn-Cu-Pb prospects. This unit is formalised here as the Onedin Member (informally called the Mimosa Member and Camp Shale or host horizon in company reports).

Dow & Gemuts (1969) mapped the Koongie Park Formation as Biscay and Olympio Formations. Recent dating however suggests that this unit is younger than the Olympio Formation, which is restricted to east of the Halls Creek Fault system. "Koongie Park beds" was used informally in many company reports, until the unit was named the Koongie Park Member of the Tickalara Metamorphics by Griffin & Tyler (1992) . SHRIMP dating of zircons give an age of 1843(2 Ma for lavas from this unit (Page et al., 1994; Page & Sun, 1994), making them considerably younger than the 1850 Ma Tickalara Metamorphics. The unit was subsequently raised to the Koongie Park Formation by Griffin & Tyler (1994). The radiometric dating of the Koongie Park Formation (Page et al., 1994; Page & Sun, 1994- see above) also indicates that it is significantly younger than the compositionally similar Whitewater Volcanics (1850-1865 Ma) found further west, and younger than the Biscay Formation (1875-1850 Ma) in the Little Mt Isa area which also hosts Zn-Cu-Pb prospects.

Proposed type section

The type section proposed for the Koongie Park Formation is in the Rockhole area between GR 346760 E 7974940 N and GR 346909 E 7974620 N (Fig. 1). Quartz-bearing mudstone overlies and incorporates material from laminated chert, and is overlain by the Onedin Member. Further towards Rockhole prospect it is intruded by aphyric rhyolite. Breccia, shale and minor calc-silicates occurs on the creek at GR 347565 E 7975115 N between aphyric rhyolite and the quartz bearing mudstone. The quartz-bearing mudstone decreases in clast size upwards with a maximum clast size of 0.15 m diameter near the base. The Onedin Member here includes ironstone, shale and chert. Overlying the Onedin Member are fine-grained sandstone and shale and aphyric rhyolite containing spherulites, lithophysae and perlitic texture.

The best exposures of mafic metavolcanics occur further south in the area covered by ANGELO 1:100 000 map. In the region covered by HALLS CREEK 1:100 000 map good exposures of mafic metavolcanic rocks are north of Gosford prospect at GR 345000 E 7978400 N. Here green altered fine-grained mafic metavolcanic rocks form elongate exposures with some carbonate and chlorite amygdales. Poorly sorted volcanic and sedimentary fragment rich granule conglomerate occurs among shale and sandstone.

Sedimentary rocks (Pe, Peh)

Sedimentary rocks are exposed north and south of Koongie Park homestead. Most abundant are red, yellow and brown shale; interbedded with quartz-rich turbidites, lithic rich granule conglomerate, pebbly sandstone, chert and ironstone.

Further north sedimentary rocks outcrop among mafic metavolcanic rocks and contain abundant quartz rich turbidites. In most outcrops individual beds

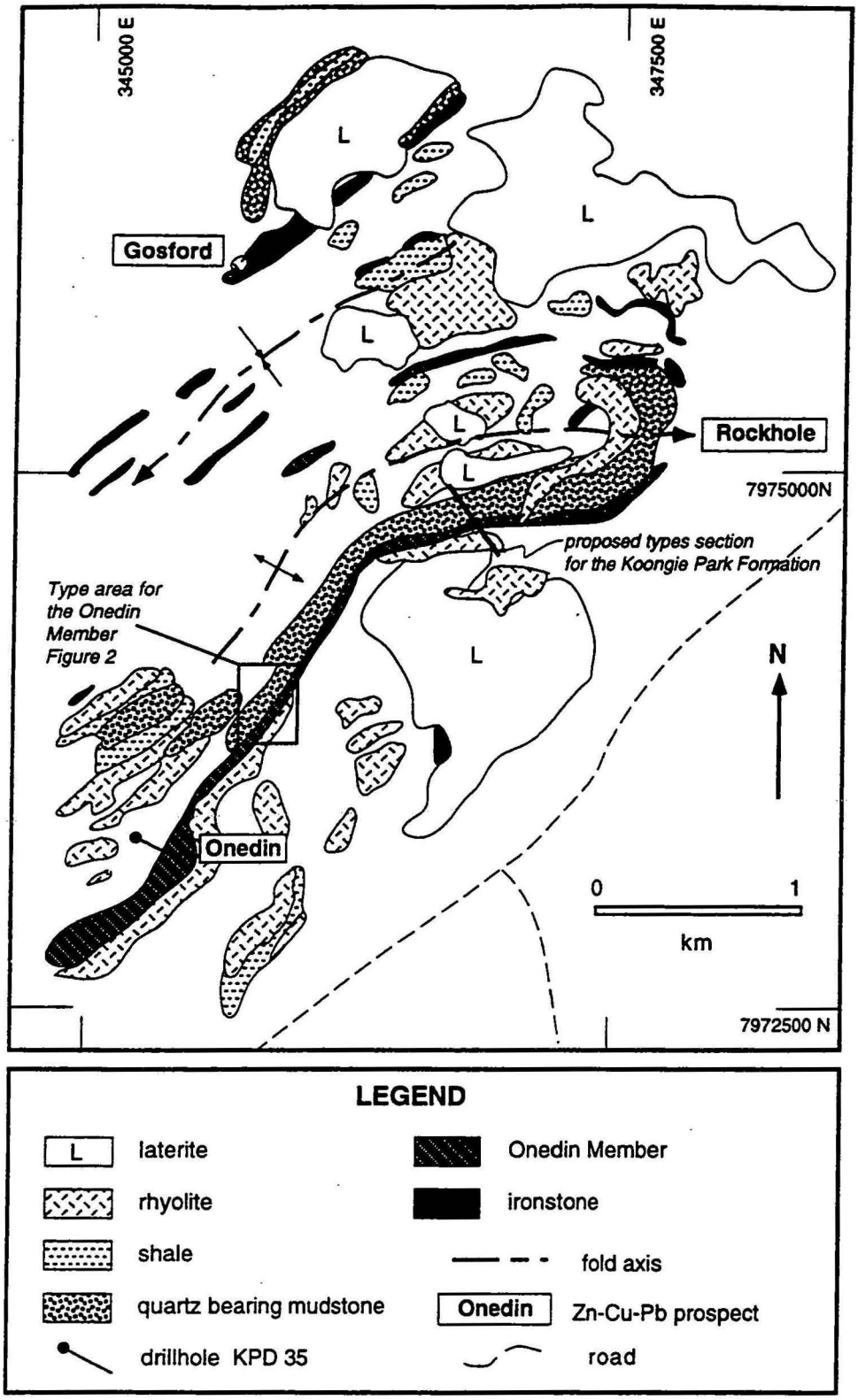


Figure 1: Detail of the Onedin-Rockhole-Gosford area showing the distribution of the Onedin Member, location of the proposed type section for the Koongie Park Formation and type area for the Onedin Member.

are between 0.03 - 0.3 m thick, with some sporadic coarse to medium-grained, graded sandstone beds and lenses 0.4-1 m thick. Sharp bases and tops are characteristic. Rare ripped-up intraclasts are incorporated into the bases of some of the thicker beds. Bouma A3, B2, C, D, E (Walker, 1984) are the most common components of the turbidites. Occasional small channel-like scours up to 2 m deep occur, filled with coarse to medium, graded sandstone.

North of Gosford prospect, among the mafic metavolcanics are dark siltstone, interbedded with poorly sorted pebbly sandstone. Abundant sedimentary and volcanic rock fragments along with quartz and feldspar grains form an open framework in a mudstone/siltstone matrix.

In the Atlantis prospect area beds of the interbedded graded sandstone and siltstone are up to 0.2 m thick. The siltstone component is higher than the medium- to fine-grained sandstone component, which often occurs as discontinuous layers with irregular bases. Beds display normally graded to massive sandstone bases (Bouma A) with overlying laminated fine-grained sandstone and siltstone (Bouma B, D). Flame structures occur at the base of some of the sandstone units. Further west from here (GR 341700 E 7967550 N) occasional 0.5-0.8 m thick coarse to medium sandstone punctuate a sequence composed dominantly of fine-grained sandstone and siltstone with beds between 0.15-0.2 m thick. Flame structures occur at the base of the thick sandstone beds.

Towards the granite intrusions an increase in the metamorphic grade is apparent and the metasedimentary rocks become schistose, spotted or gneissic with abundant biotite, retrogressed andalusite and muscovite (Peh). These rocks are well exposed on the edge of the granite north of Gosford prospect. South of Atlantis prospect biotite-quartz-sericite/muscovite schist crops out near the contact with the Loadstone Granite.

In thin section the northern turbiditic sandstone is seen to contain clasts of sub-angular to sub-rounded quartz, volcanic to subvolcanic, sedimentary and low-grade metamorphic rock fragments, kinked muscovite, opaques and tourmaline. The matrix is composed of sericite and fine-grained quartz, clay and iron oxides. In some cases these may be compacted, altered clasts rather than true matrix (pseudomatrix). Shale contains similar components with more abundant matrix and less obvious rock fragments. Foliations are defined by aligned sericite and clays. Metasediments in the Atlantis prospect area contain abundant angular to sub-angular volcanic, sub-volcanic and sedimentary rock fragments as well as volcanic quartz and euhedral feldspar. The matrix, which was possibly a pseudomatrix, is now composed of quartz, sericite, biotite and iron oxides

Mafic metavolcanic rocks (Peb)

In the Koongie Park area the mafic metavolcanic rocks form scattered weathered outcrops north and west of Gosford Zn-Cu-Pb prospect. Bodies appear tabular, between 10 m and 50 m thick and continuous over many hundreds of metres and display variable crystal size, vesicularity and alteration. They are associated with fine-grained sedimentary rocks, minor granule conglomerate and coarse sandstone which contain abundant felsic volcanic

and sedimentary clasts. Intrusive contacts are demonstrated at one locality where a coarse-grained mafic subvolcanic is chilled against and cross-cuts a sequence of turbiditic sandstone and shale (GR 342600 E 7972000 N). Elsewhere contacts are not exposed, although many of the fine-grained, amygdaloidal basalts appear concordant with the bedded sedimentary rocks surrounding them.

Highly altered cross-cutting chlorite-carbonate units found in drill core at Onedin appear to be mafic dykes.

In thin section many of the fine-grained rocks are seen to be totally metamorphosed with very little of their primary igneous mineralogy preserved. In some rocks feldspar laths are subparallel with tremolite and actinolite laths and trails of opaques, while in others the actinolite form patches of radiating crystals surrounded by albite, carbonate, chlorite and opaques. Accessory zoisite and clinozoisite are present. Amygdales of quartz, carbonate, chlorite or epidote are abundant, as are carbonate and silica veins and veinlets. In dolerite large laths of albite or oligoclase, some altered to sericite, are surrounded by and interlocking with green square and lath shaped areas (after pyroxene?) of fibrous green actinolite and/or chlorite.

Felsic volcanic, subvolcanic and associated sedimentary rocks (Pef)

Rhyolite and rhyodacite form scattered lenses and elongate irregular bodies (up to 1.2 km long and 200 m wide) among mudstone, sandstone and quartz bearing mudstone. Most bodies are aphyric, with less abundant quartz phyric and rare quartz-feldspar phyric bodies. They form small hills and often display curvilinear fracture patterns. Many bodies are composite with thin screens of sedimentary rocks, peperite (Fig. 2) and breccia between individual intrusions. Perlitic fractures mark unit margins (Fig. 3). Lithophysae and spherulites are abundant throughout some bodies, especially in the Onedin prospect area (Figs 4, 5). Amygdales of quartz and less commonly calcite are present in some elongate bodies near and southwest of Gosford.

Red, yellow and brown shale occur between the rhyolite and rhyodacite bodies. Shale interbedded with occasional sandstone and granule conglomerate (Figs 6, 7). Ironstone is sporadic, but when present can be traced within a sequence over several kilometres of strike length and may be associated with chert and shales with cherty nodules. One ironstone (GR 347400 E 7975100 N) can be traced over 30 m before grading laterally into chert. Fragments of chert are incorporated into the base of a distinctive coarse quartz bearing mudstone east and north of Onedin, north of Gosford and north of Atlantis. It varies in thickness and quartz content along its length. Quartz form 10-15% of the rock in two main populations: bipyramidal or rounded and embayed crystals up to 4 mm across; and irregular shaped crystals less than 1 mm across.

Also present are monomictic and polymictic breccia lenses north and northeast of Onedin, siliceous mudstone at Gosford and north east of Onedin, and minor cross-bedded red siltstone which is interbedded with 0.2 - 0.3 m thick sandstone near Rockhole.

In thin section rhyolite and rhyodacite display embayed quartz and euhedral feldspar phenocrysts (if present) set in a fine-grained quartz-albite-(sericite)-(chlorite) matrix.

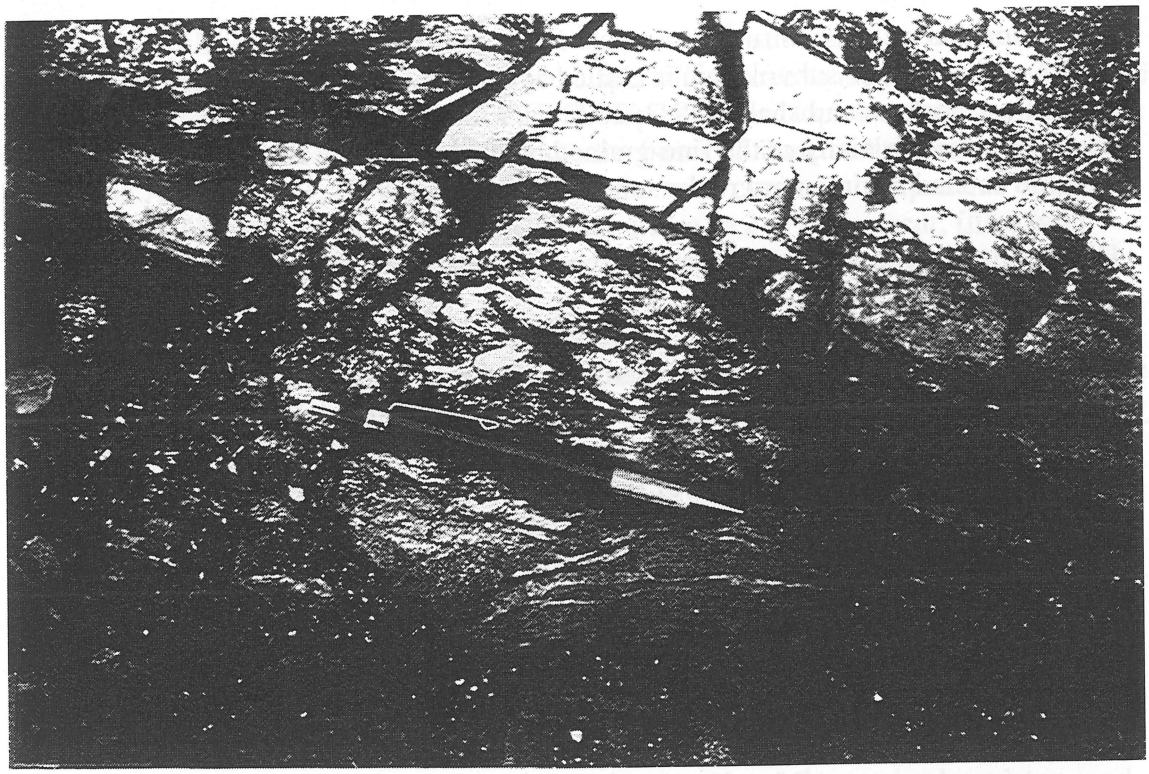


Fig.2. Quartz-feldspar phyric rhyolite (coarser material) intruding fine-grained siliceous sandstone and siltstone. Patches of mixed material are peperitic (above pencil) indicating that the sediments were not lithified when the intrusion occurred GR 347930 E 7976045 N. Felsic subvolcanic, Koongie Park Formation (Pef).

Fig. 3. Photomicrograph of perlitic aphyric rhyolite near the contact with Onedin Member. Chlorite is invading along perlitic fractures. Onedin prospect, KPD 32, 251 m; ppl. x 25 - width of field of view is 6 mm across. Unit Pef, Koongie Park Formation.

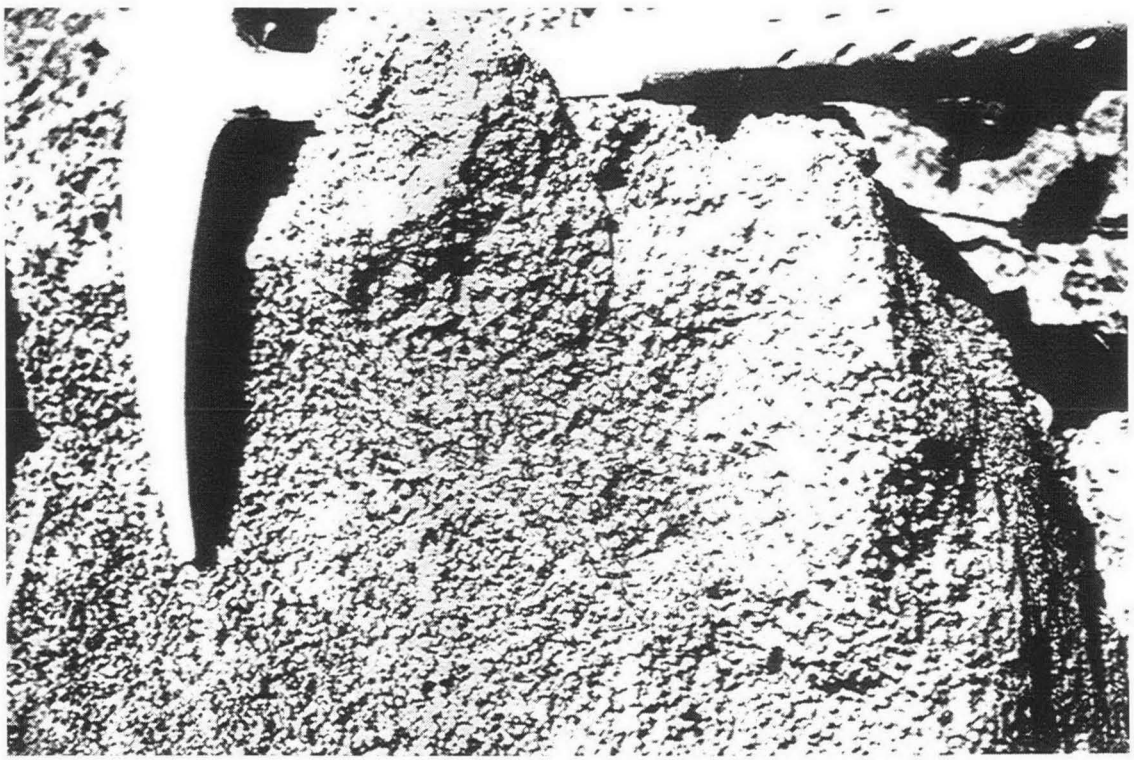


Fig.4. Surface outcrop of weathered spherulitic aphyric rhyolite within 1 m of the contact with interbedded sandstone and shale. GR 345492 E 7973770 N. Unit Pef, Koongie Park Formation.

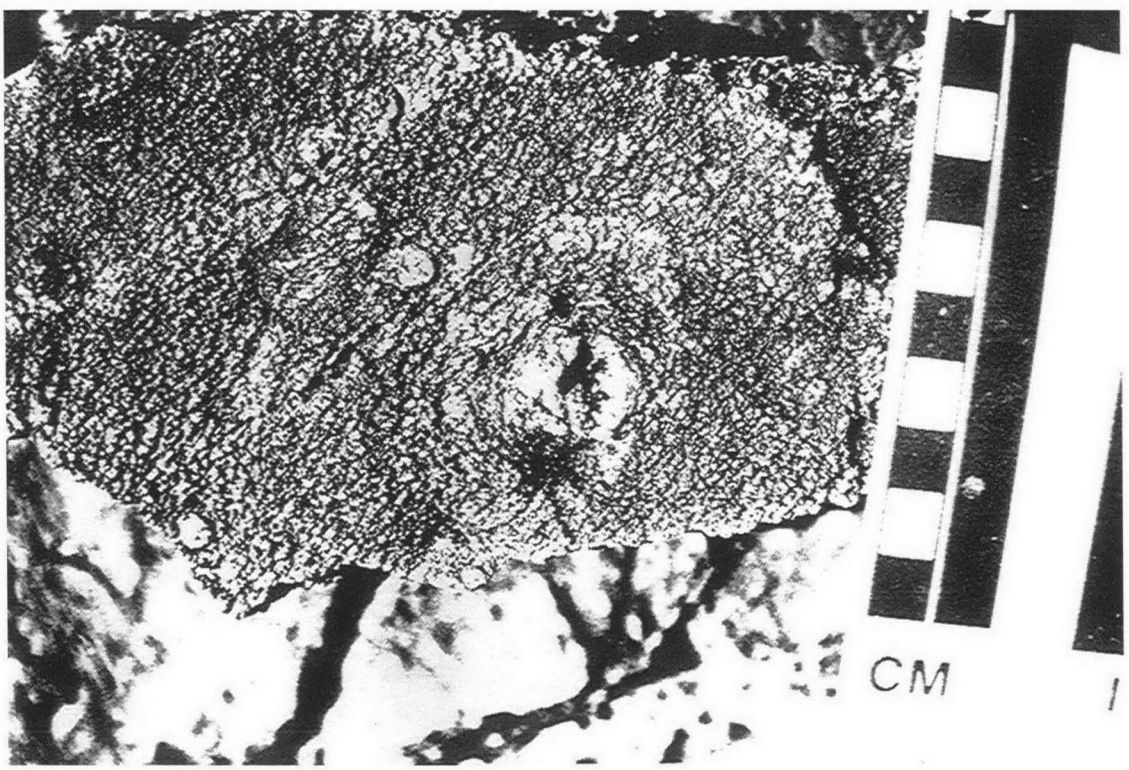


Fig. 5. Weathered outcrop of aphyric rhyolite with lithophysae at GR 346048 E 7973830 N. Unit Pef, Koongie Park Formation.

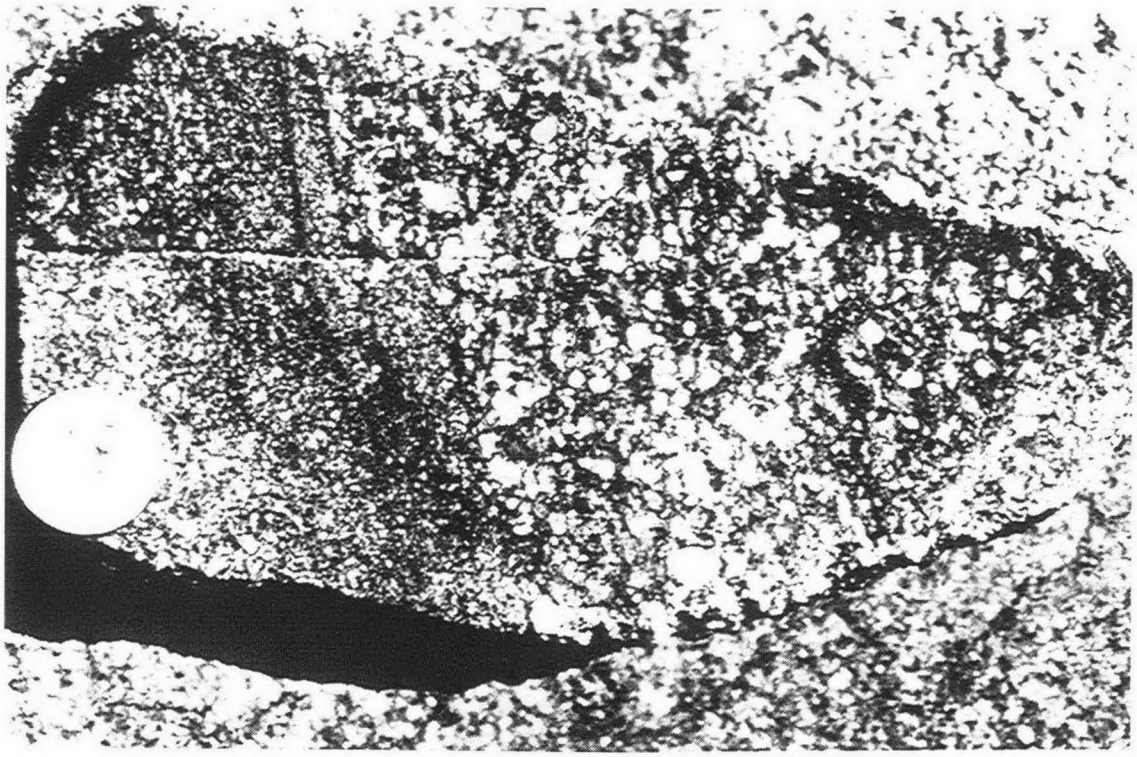


Fig. 6. Normally graded coarse to medium sandstone and granule conglomerate with blue quartz and feldspar crystals as well as abundant rock fragments. GR 344165 E 7974195 N. Unit Pef, Koongie Park Formation.

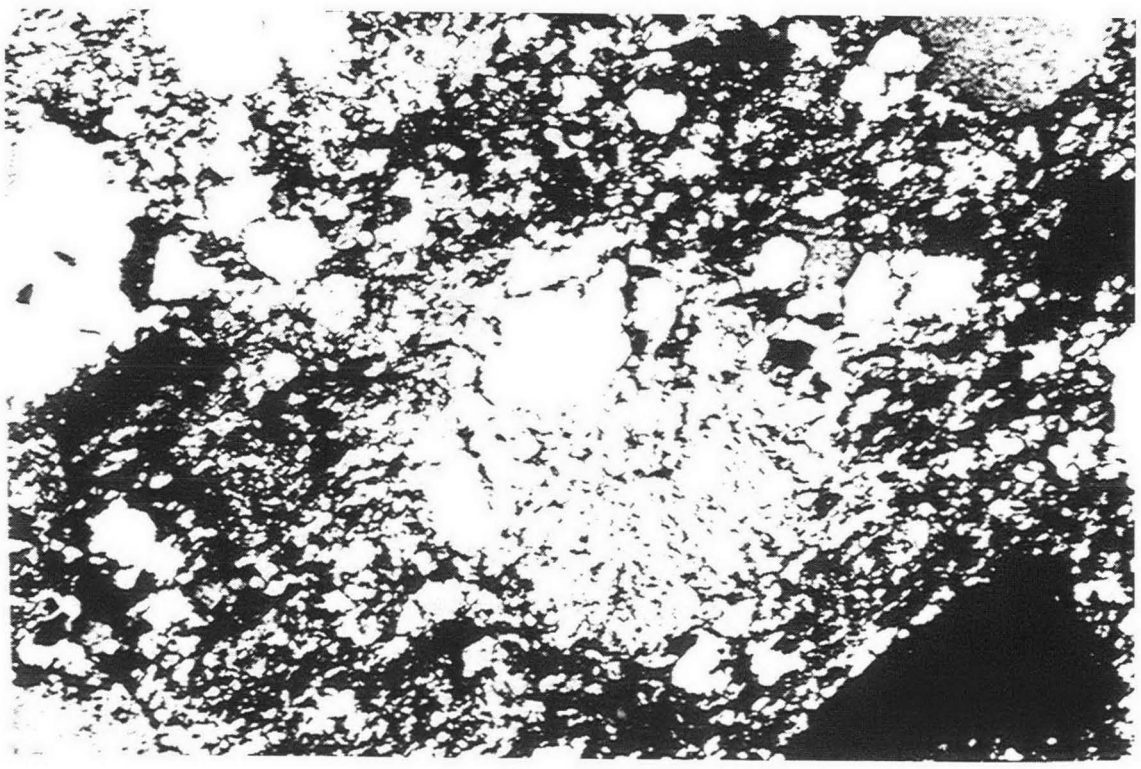


Fig. 7. Photomicrograph of felsic volcanic fragments and quartz in coarse sandstone Koongie Park Formation (=060(L.P)ef). Crossed nicols, x 25; field of view is 6 mm across. Sample from GR 344165 E 7974195 N

Accessory minerals include opaques, zircon and apatite. Matrix quartz and albite form spherulites, micropoikolitic patches (snow-flake texture) and infill vesicles. Sandstone and granule conglomerate contain angular to subrounded felsic and minor mafic volcanic clasts, sedimentary rock fragments, large quartz grains, euhedral feldspar, and subvolcanic clasts composed of coarse interlocking quartz and feldspar (Fig. 7). Sedimentary fragments predominate.

Ironstone, calcareous and calc-silicate rocks (Eec)

Ironstone forms prominent ridges and subdued hills at and north of Onedin prospect and south of Atlantis prospect; and also forms subdued outcrops north and west of Atlantis prospect. It is associated with red shale, carbonate, calc-silicate and chert and occurs at three or more stratigraphic levels including the Onedin Member at Onedin prospect.

In the hills north of Onedin prospect the upper unit is composed of laminae of chert, haematite and magnetite with elongate chert nodules and lenses (Fig. 8). Thick ironstone units, several metres wide compose these hills. Most individual beds are less than 0.3 m thick, but are abundant over a stratigraphic interval of tens of metres with intervening shale, chert, chert nodules and occasional carbonate. Carbonate is commonly silicified at the surface and similar in appearance to chert. It may be marked by large, often quartz-filled vughs. These intervals can be followed over many kilometres along strike.

Chert can be white or black at the surface. It is up to 0.5 m thick, lensoidal and commonly contorted into rounded folds. It is occasionally laminated, with alternating coloured laminae, but generally massive, especially when overprinted with superficial silicification. It can be spongy and gossanous with casts where sulphides have weathered out.

In thin section chert laminae with minor magnetite are sandwiched between magnetite laminae. Magnetite crystals are euhedral to subhedral with irregular margins. In drill core, some ironstone is green due to iron rich chlorite and grunerite. Lath-like, subaligned stilpnomelane is also common in the silicate portions. Later higher sulphidation pyrite and pyrrhotite cross-cut the magnetite rich laminae. Quartz forming chert is fine to coarsely crystalline (0.025 mm - 0.07 mm diameter) with straight crystal edges and many 120 degree triple junctions, indicative of metamorphic recrystallisation.

Onedin Member (Eeo)

Mineralisation is hosted in the Onedin Member at Onedin prospect. It encompasses the informal Mimosa and Camp Shale Members or "host horizon" used in company report on the Onedin prospect (Arsarco, 1983 to Sewell, in press). Thickness of this unit varies from at least 150 m at Onedin prospect to only 50 m thick some 500 m northeast . The Onedin Member is continuous for at least 3.5 km northeast of Onedin prospect. It is folded and reappears at Gosford prospect and the ridge extending northeast (Fig. 1).

At Onedin prospect and east of Gosford prospect the Onedin Member is faulted against and appears to overlie a distinctive blue-quartz bearing rhyolite and

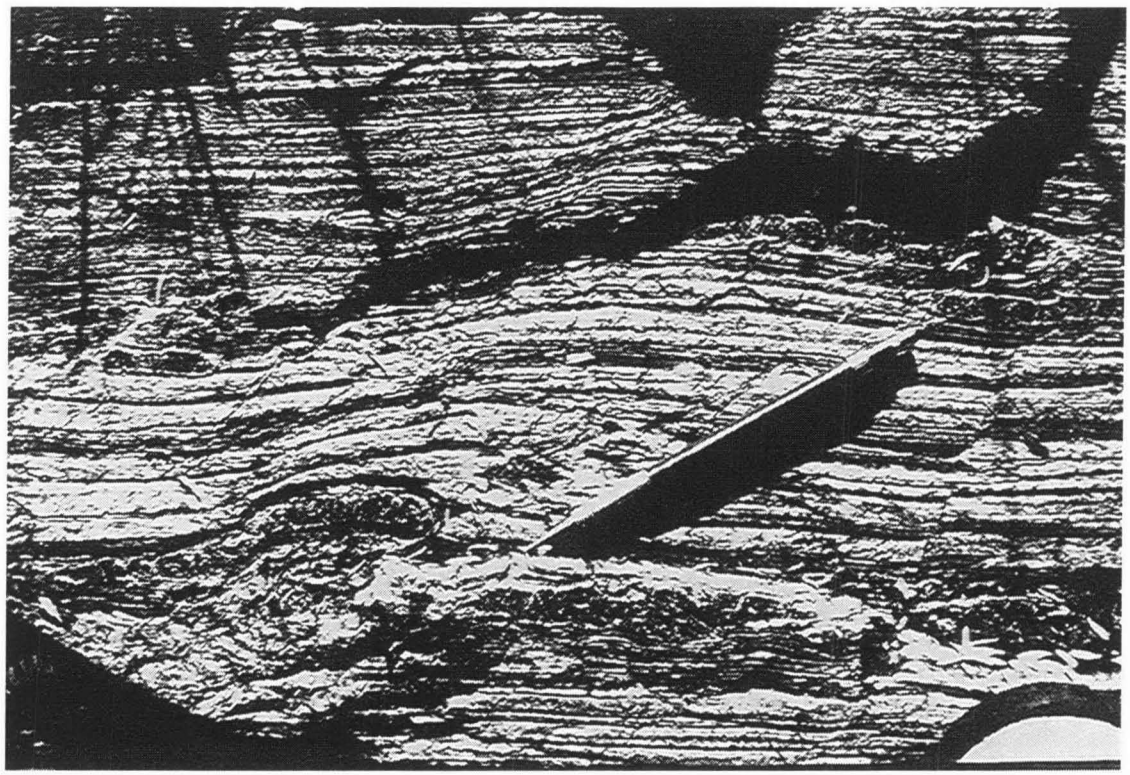


Fig 8. Laminated chert and ironstone. Laminae display contortions and are cut by small faults. Some dark cherty nodules. GR 345200 E 7975225 N, Koongie Park Formation (unit Pec).

volcaniclastic unit. At Gosford prospect it is associated with blue-quartz bearing, flow banded rhyolite and amygdaloidal rhyolite. Relationships between these units have not been constrained. It is intruded and overlain by spherulitic rhyolite at and east of Onedin prospect. East of Gosford it is overlain by turbiditic sandstone and shale which become more shale rich and ironstone bearing upsequence. The type section for the Onedin Member is designated up across the unit from the base at GR 345965 E 7973590 N, 500 m northeast of Onedin (Fig. 9). This section however, does not display all the features of the member and should be supplemented by viewing drill hole KPD 35 from Onedin prospect between 193 m and 398 m (Figs 10, 11).

Surface exposures of the Onedin Member are composed of ironstone interbedded with red shale, chert, nodular chert minor carbonate and gossanous layers. In drill core at Onedin prospect lithologies include chloritic, talc rich and black shale interbedded with lenses of carbonate and calc-silicates, including tremolite-talc bearing schist and iron-rich dolomite.

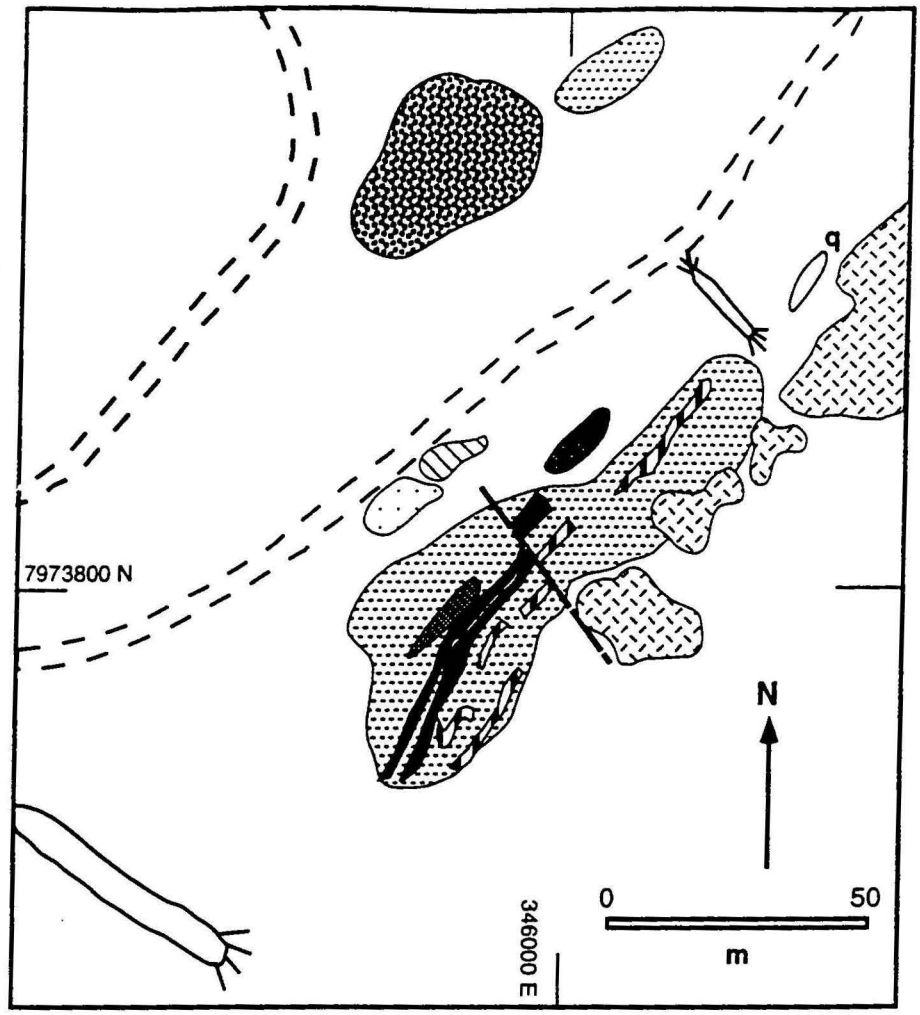
Metamorphism

Metamorphic grade of many of the metasediments and the mafic metavolcanic rocks increase towards the contact with the granite intrusion. Most metasedimentary rocks are composed of quartz-sericite-albite-chlorite±biotite with intervening basalts composed of actinolite-epidote-carbonate-albite±hornblende±quartz-sphene. These assemblages are consistent with lower to moderate greenschist facies metamorphism. Towards the contact large muscovite and biotite crystals are observed and within 50 - 75 m of the contact spotting and andalusite laths are common. Mafic volcanic units become amphibolites within this zone. Retrogression has overprinted some of these higher grade areas with andalusite pseudomorphed by sericite/muscovite and quartz.

Deformation

Six deformation events are imprinted on the Koongie Park Formation. Metasedimentary rocks of the Koongie Park Formation often display two strong cleavages which produce abundant pencil shales. The main strong deformation predates granite intrusion. It formed tight to isoclinal upright folds with wavelengths of 200 - 500 m. These folds are re-folded by NNE-oriented tight to open folds which are present in both the Koongie Park Formation and the overlying Moola Bulla Formation. Sinistral shearing can be associated with this second deformation. Locally cleavage produced by the second deformation is dominant with crenulations only visible at thin-section scale. This probably post-dates the granite intrusion. A third generation of folding produced tight to open NE trending folds. These produce pencil shales in conjunction with the first or second generation foliations. A fourth deformation produced NW oriented, open fold with broad-spaced crenulations in hinge zones.

Broad subhorizontal folds, kinks and fractures postdate these earlier structures. The latest events are represented by silicified faults displaying both dextral and sinistral movements and include the Highway and the Angelo Faults.



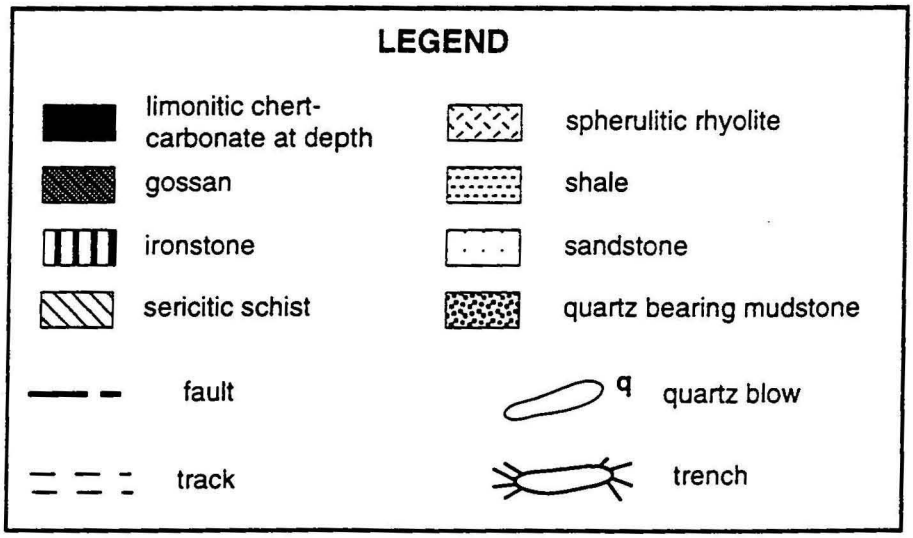


Fig.9. Map of type area for the Onedin Member

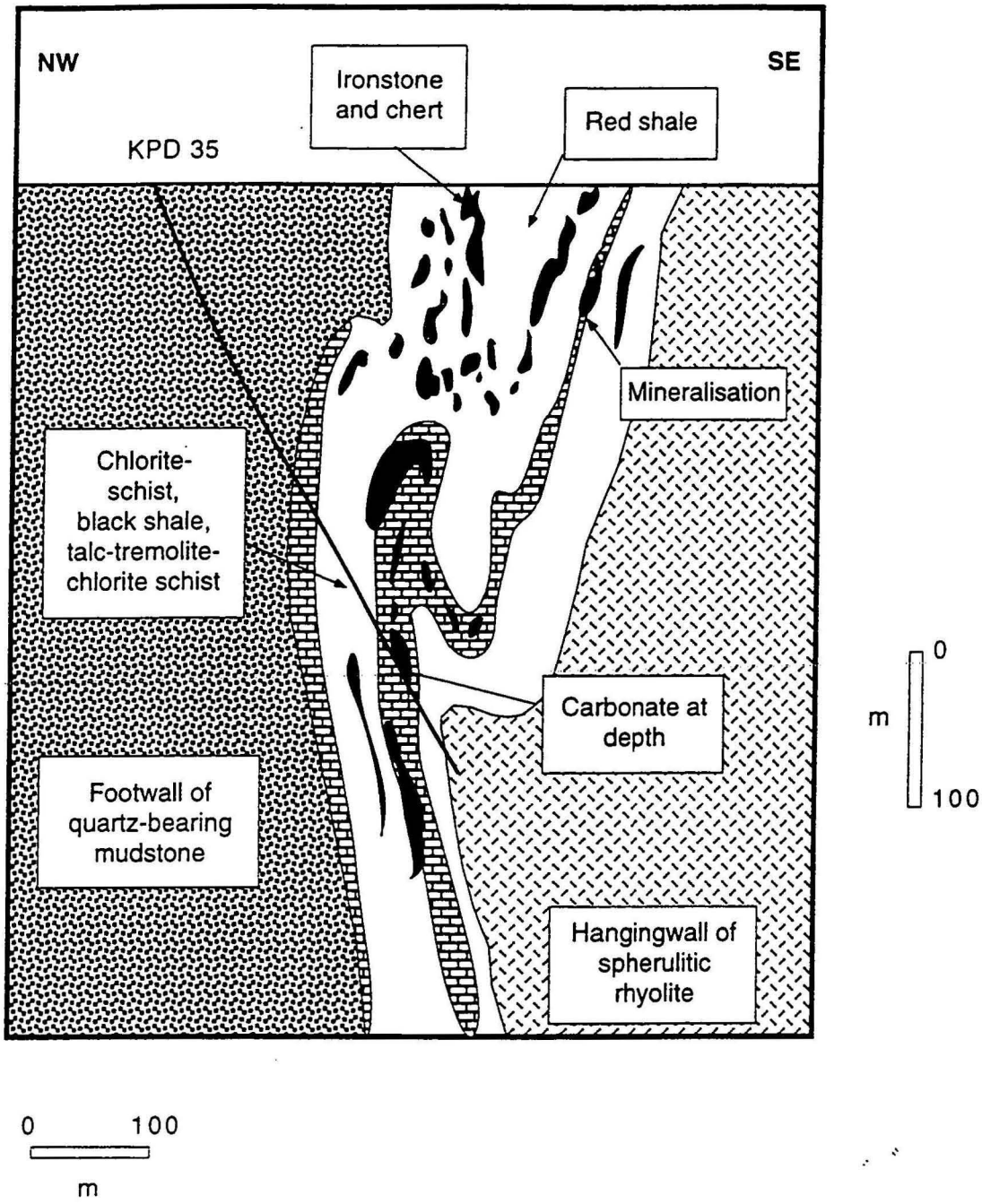


Figure 10. Schematic cross-section of the Onedin Member at Onedin prospect showing the relationship of the unit to KPD 35 (after Sewell *in press*)

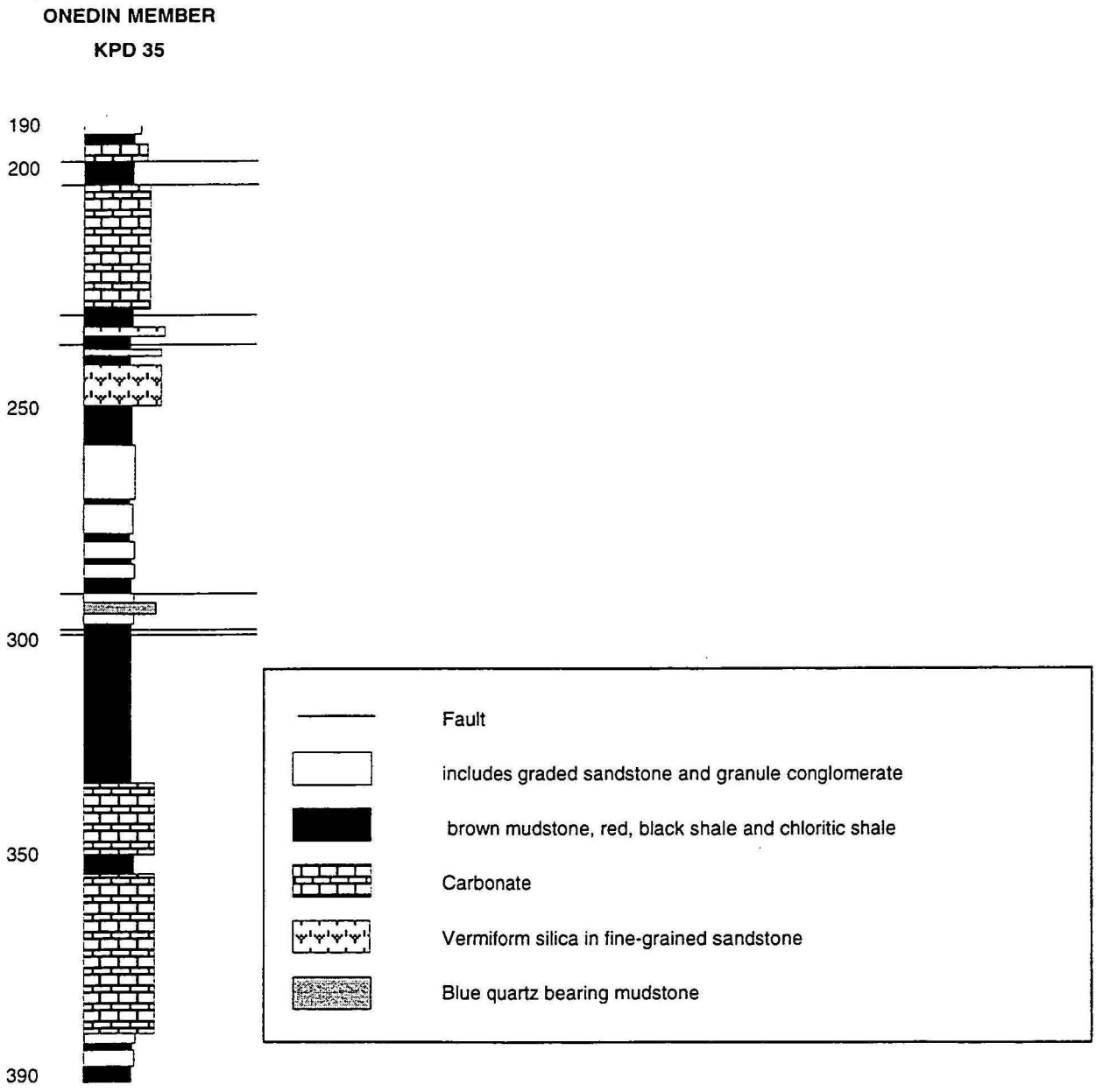


Figure 11. Log of drill core KPD 35, through the Onedin Member at Onedin prospect.

Mineralisation

Onedin prospect

The Onedin prospect lies on the southern side of a faulted antiform which plunges both northeast and southwest. Mineralisation is hosted by the Onedin Member and is marked on the surface by a subdued gossan. It is underlain and faulted against blue quartz bearing chloritic schist (informally known as the "Coolibah Member"). The footwall also contains volcaniclastic sandstone, conglomerate and breccia and rhyolitic sills. Overlying the mineralisation are rhyolitic to rhyodacitic sills (generally known as the "Weldons Creek or Weldons Member"-see Fig. 10). These are cross-cut by later altered mafic dykes.

The Onedin Member at this point thickens to at least 150 m thick compared to 50 m at the surface 300 m northeast. It forms a south plunging, northwest dipping synform-antiform couplet which is overturned (Sewell, in press). Basal shale and ironstone are overlain by chloritic schists, grey siltstone, black shale and carbonate. The carbonate, composed of iron-rich dolomite and dolomite, and tremolite-talc-quartz-chlorite±magnetite±sericite schist, host sphalerite-pyrrhotite-pyrite-galena mineralisation. The sphalerite is red and iron rich. Minor tetrahedrite, tennantite and bismuthanite occur in association with galena. Carbonate displays a spectrum of textures: small nodules and coalesced nodules in a talc-chlorite matrix; dolomitic rhombs; dolomite and calcite veins and veinlets; and massive recrystallised dolomite (Hill & Orth, 1994). Mineralisation in the carbonate host is generally massive and forms the richest intersections while in the host schists it is in thin layers parallel to bedding or forms stringers and veins.

The mineralisation is metamorphosed and deformed. No original textures are obvious as most minerals are coarsely recrystallised, and some have been mobilised into cross-cutting veins.

Magnesium-rich minerals form an alteration halo which extends through the footwall and also affects portions of the hanging wall spherulitic rhyolite. Albite is present in the hanging wall, but absent in the footwall. Pyrrhotite forms a halo to the main sulphide lenses, providing downhole and strong surface EM responses (Sewell, in press).

Estimates of mineralisation at Onedin prospect are up to 1 Mt at 11% Zn, 1% Pb, 1% Cu (Sewell, in press).

Gosford prospect

Gosford prospect is 2.8 km north of Onedin prospect (Fig. 1). Mineralisation at Gosford prospect is hosted by chert, ironstone and shale. These outcrop on a ridge which contains a small gossan. It is probably part of the Onedin Member.

Tight northeast trending folds characterise the ironstone, shale and chert unit. Folds plunge steeply to the WSW and west, and their limbs dip northwest. Surface, mapping indicates that to the north, and possibly underlying the host unit, is a blue-quartz bearing, partially flow banded rhyolite. South of the ridge containing the gossan there is another amygdaloidal rhyolite.

A drill hole by Kennecott intersected mineralisation, composed of stringersand semi-massive sphalerite, pyrite, pyrrhotite and chalcopyrite with ahalo of disseminated pyrite and pyrrhotite. Estimated grade of mineralisation over the massive sulphide intersection is 6.3 m @ 0.31% Cu, 2.45% Pb, and 11.2 % Zn (Sewell, in press). The main host is silicified, brecciated chert. Only minor carbonate and tremolite/actinolite-talc schist occur at this prospect.

Atlantis prospect

Atlantis - Pus-eye prospect occurs south of Onedin prospect at GR 344800 E 7968600 N. RAB and percussion drilling in the Atlantis-Pus-eye area define a southerly plunging open anticline (Sewell, in press). A small pod, roughly 8 m wide of mineralisation lies on the western limb. Later folding of the anticline has occurred around a NE axis.

Mineralisation is marked at the surface by a magnetic gossan which produces a strong magnetic anomaly in this area. Down dip to the west this becomes more cherty and grades into chlorite-magnetite schist which hosts the mineralisation. The footwall is composed of chlorite-tremolite schist and the hanging wall is an albitised rhyolite. The rhyolite may be either extrusive or intrusive. Contact relationships are enigmatic in the creek exposure to the north and have not been resolved by RAB or percussion drilling.

Sewell (in press) estimates the grades in the small mineralised pod to total 0.1 Mt with an average grade of 14% Zn, 0.3% Pb and 0.2% Cu.

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Captions for photographs

Fig.2. Quartz-feldspar phyric rhyolite (coarser material) intruding fine-grained siliceous sandstone and siltstone. Patches of mixed material are peperitic (above pencil) indicating that the sediments were not lithified when the intrusion occurred GR 347930 E 7976045 N. Felsic subvolcanic, Koongie Park Formation (Pef).

Fig. 3. Photomicrograph of perlitic aphyric rhyolite near the contact with Onedin Member. Chlorite is invading along perlitic fractures. Onedin prospect, KPD 32, 251 m; ppl, x 25 - width of field of view is 6 mm across. Unit Pef, Koongie Park Formation.

Fig.4. Surface outcrop of weathered spherulitic aphyric rhyolite within 1 m of the contact with interbedded sandstone and shale. GR 345492 E 7973770 N. Unit Pef, Koongie Park Formation.

Fig. 5. Weathered outcrop of aphyric rhyolite with lithophysae at GR 346048 E 7973830 N. Unit Pef, Koongie Park Formation.

Fig. 6. Normally graded coarse to medium sandstone and granule conglomerate with blue quartz and feldspar crystals as well as abundant rock fragments. GR 344165 E 7974195 N. Unit Pef, Koongie Park Formation.

Fig. 7. Photomicrograph of felsic volcanic fragments and quartz in coarse sandstone Koongie Park Formation (unit Pef). Crossed nicols, x 25; field of view is 6 mm across. Sample from GR 344165 E 7974195 N

Fig 8. Laminated chert and ironstone. Laminae display contortions and are cut by small faults. Some dark cherty nodules. GR 345200 E 7975225 N, Koongie Park Formation (unit Pec).