BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

Record 1981/23

Notes on the preliminary Youanmi 1:250 000 geological series map, Western Australia

A.J. Stewart (BMR), I.R. Williams (GSWA),
& M. Elias (GSWA)

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SUMMARY

The YOUANMI Sheet area (lat. 28° to 29°S, long. 118°30' to 120°E) is situated in the Yilgarn Block of Western Australia, and includes four main Archaean rock groups: gneiss terrain, greenstone belts, layered mafic-ultramafic intrusions, and granitoids. The gneiss terrain consists mainly of banded gneiss, which comprises regular foliated layers of different granitoid compositions, ranging from tonalite to granite. Other components of the gneiss terrain include: orthogneiss, which forms intrusive bodies up to 40 km long and is generally adamellite to granodioritic, with some tonalitic gneiss; quartzose paragneiss containing abundant muscovite; coarse-grained banded iron formation containing pyroxene; and ortho-amphibolite, calc-silicate gneiss, quartzite, and ultramafic schist.

Greenstone belts in YOUANMI are simple, non-repeating metamorphosed successions, and contrast markedly with the cyclic successions recognised elsewhere in the Yilgarn Block. They comprise basal mafic-ultramafic igneous rocks with rare pillow basalt and abundant banded iron formation, passing upwards into predominantly pelitic sediments and rare para-amphibolite. Felsic volcanic rocks overlie the mafic rocks in places. In the east of YOUANMI, an extensive orthoquartzite up to 1000 m thick is present at the base of the Maynard Hills greenstone belt, which suggests that a sialic terrain was being eroded during deposition of the early greenstones. Recumbently-folded banded iron formation and thin quartzite of the Cook Well greenstone belt overlie banded gneiss at several localities; the contact is poorly exposed, but appears to be an unconformity, suggesting that the banded gneiss is sialic basement to the greenstones.

Layered mafic-ultramafic rocks form three intrusions in the west of YOUANMI. The intrusions are about 4000 m thick, and comprise layers ranging in thickness from 3-30 m of gabbro, norite, melagabbro, leucogabbro, pyroxenite, anorthosite, and magnetite rock. All the rocks are partly or wholly metamorphosed, but original igneous cumulate textures are commonly preserved. Major and trace element analyses of the two larger intrusions (Windimurra and Youanmi) indicate a common origin for the two magmas.

Massive to weakly foliated voluminous granitoids intrude all of the three preceding groups, and are mostly fine to medium-grained, or medium to coarse-grained biotite adamellite; granodiorite is less abundant, and granite least. Porphyritic granite with aligned phenocrysts of microcline crops out only in the west of YOUANMI. Hornblende-bearing granodiorite, tonalite, and quartz diorite are rare. The central part of YOUANMI is a large diapiric mass of foliated granitoid containing rafts of banded gneiss and orthogneiss.

Chemical analyses of nine samples of granitoid show a calc-alkaline trend, and a higher soda content than average granitoids. The granitoids also contain above-average amounts of Rb, Ba, Pb, Th, and U, high Rb/Sr ratios, and SI indices less than 1.1, indicating an origin by anatexis of sialic igneous parent rock.

Two episodes of regional metamorphism affected the YOUANMI rocks. The first episode altered only the gneiss terrain, and formed assemblages of the lower and middle amphibolite facies. The second episode caused widespread partial retrogression of the gneiss terrain to greenschist facies, and progressive metamorphism of the greenstone sequences and layered intrusions to greenschist and lower amphibolite facies.

The structure of the Archaean rocks in YOUANMI is dominated by intrusion of the granitoids, followed by major faulting. The gneisses and greenstones form remnants separated by large expanses of granitoid. The banded gneiss terrains are characterised by steeply-dipping layering and foliation of exceptional regularity, indicating considerable flattening. The greenstones are moderately to tightly folded; early folds are cut by the granitoids, whereas some later folds can be attributed to intrusion of the granitoids. A pair of major wrench faults were formed in response to meridional compression after emplacement of the granitoids, and transcurrent displacements up to 15 km occurred, forming mylonite and orthoschist. Dolerite dykes, striking 075° and 115°, intruded the region after the wrench faulting.

Superficial Cainozoic deposits cover large parts of YOUANMI. Tertiary laterite and siliceous duricrust have been substantially eroded, and form mesas and tablelands rising above colluvial and alluvial plains, which pass down to saline playa deposits in the lowest areas. Calcrete fills the lower reaches of the larger drainage channels, adjacent to the playas.

YOUANMI produced 27 tonnes of gold between 1895 and 1947; coarse alluvial gold continues to be found in the Sandstone area using metal detectors. Ten base-metal occurrences are known, but none has yet proved economic, although zinc potential at Pincher Hill is still being assessed. The area is outside the zone of major nickel deposits of the Yilgarn Block. Uranium occurs in the channel calcretes and playas, but not in economic quantities. Vanadium is present in the magnetite of the layered mafic-ultramafic intrusions, and is currently under investigation. Total iron ore resources in the southeast of YOUANMI are estimated at 63 230 000 tonnes at 38.2% Fe.

INTRODUCTION

The YOUANMI* 1:250 000 Sheet area is situated between latitudes 28° and 29°S and longitudes 118°30' and 120°E, in southwestern Western Australia. The Sheet is named after the former gold-mining town of Youanmi, which was abandoned in 1940's (see Appendix 1 for geographic coordinates of localities). Between 1895 and about 1925, gold-mining townships also existed at Paynesville and Nungarra, and smaller mining centres were located at Hancocks, Bellchambers, Maninga Marley, and Currans. All are now abandoned, and the nearest town is Sandstone, just beyond the northern margin of YOUANMI. Most of the area is used for raising sheep and some cattle; two areas of vacant crown land are located in the southwestern part of YOUANMI, one in the Ray Rocks-Walgarry Rockhole area, the other immediately northwest of Browns Soak. With the exception of these two areas, and an undeveloped area around Horse Fall Rocks, station and mineral exploration tracks provide good access. Graded roads connect Sandstone and Youanmi with the station homesteads, and with the townships of Mount Magnet, Wiluna, Menzies, and Paynes Find. Landing grounds for light aircraft are located at Sandstone, and at Atley, Bulga Downs, Yuinmery, and Cashmere Downs homesteads.

The climate is semi-arid, with hot summers and cool winters. The mean annual rainfall is 200 to 250 mm, but its occurrence is erratic. Vegetation (Burbidge, 1942) includes: mulga (*Acacia* sp.) and small shrubs on floodplain areas (sheet wash, alluvium, and colluvium); mulga, sheoak (*Casuarina* sp.), kurrajong (*Brachychiton* sp.) and shrubs on rock outcrops and adjacent colluvium; samphire (*Arthrocnemum* sp.), saltbush (*Atriplex* sp.) and blue-bush (*Kochia* sp.) in areas marginal to salt lakes; and spinifex (*Triodia* sp.) and mallee gum (*Eucalyptus* sp.) on Quaternary sand plain. The Cainozoic yellow sand plain carries a dense growth of spinifex, mulga, and shrubs such as *Cassia*.

HISTORY OF INVESTIGATIONS

The first account of the area was by Robert Austin (1855), who visited and named Poison Rocks during an expedition from Mombekine (near Northam) to the Murchison River. John Forrest (1875) skirted the northern shore of Lake Barlee in 1969, and named Mount Alfred and Mount Holmes during a northward excursion.

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*Sheet names are shown in upper case to avoid confusion with localities of the same name.

Economic geology

The first geological accounts of the area were concerned with gold, which was discovered in the Black Range-Sandstone area in 1895. Gibson (1904, 1908) described the auriferous quartz reefs, country rock greenstones, and banded iron formations (then termed 'jasper bars' or 'hematite-quartz lodes'), and Clarke (1914) described the gold-mining area around Hancocks, southeast of Sandstone. The Youanmi gold-mining centre was described by Feldtmann (1923, 1924), who recorded the occurrence of stibnite and arsenopyrite in the Youanmi main lode, and considered the 'jasper bars' to be the surface expression of shear zones. Feldtmann & Esson (1924) described the Paynesville gold mining centre.

Reports on other minerals of economic significance include those by Connolly (1959) and Berliat (1959) on the iron ore resources of the banded iron formations; Morgan (1966) and Sanders (1969) on the water resources; Hallberg & others (1976), who prepared a map showing base and precious metal occurrences and production figures; and the compendium of uranium occurrences in calcrete by Butt & others (1977). Marston (1979) has described the major copper occurrences in the Sheet area.

Regional geology

The first regional geological study was by Talbot (1912), who visited much of YOUANMI and sketched the main geological outlines during a 'flying geological survey' of the East Murchison Goldfield. Korsch (1971) and Hockley (1971) briefly described the magnetite-bearing, layered gabbros that crop out in parts of YOUANMI, CUE, SANDSTONE, and KIRKALOCKA, and suggested that they were all members of one large intrusion. Ahmat (1971) made a detailed petrological study of a small part of one of these layered gabbros (the Windimurra Intrusion), and concluded that periodic influxes of basic magma, followed by gravitational differentation of crystals and convection currents in the cooling magma were the main mechanisms of layer formation.

Binns & others (1975) included the eastern half of YOUANMI in their broad-scale study of greenstone metamorphism in the Yilgarn Block. Hallberg (1976) included YOUANMI in his regional petrochemical study of the western Yilgarn Block, and the northeastern part of YOUANMI was included in a study of landforms, regoliths, and soils by Churchward (1977).

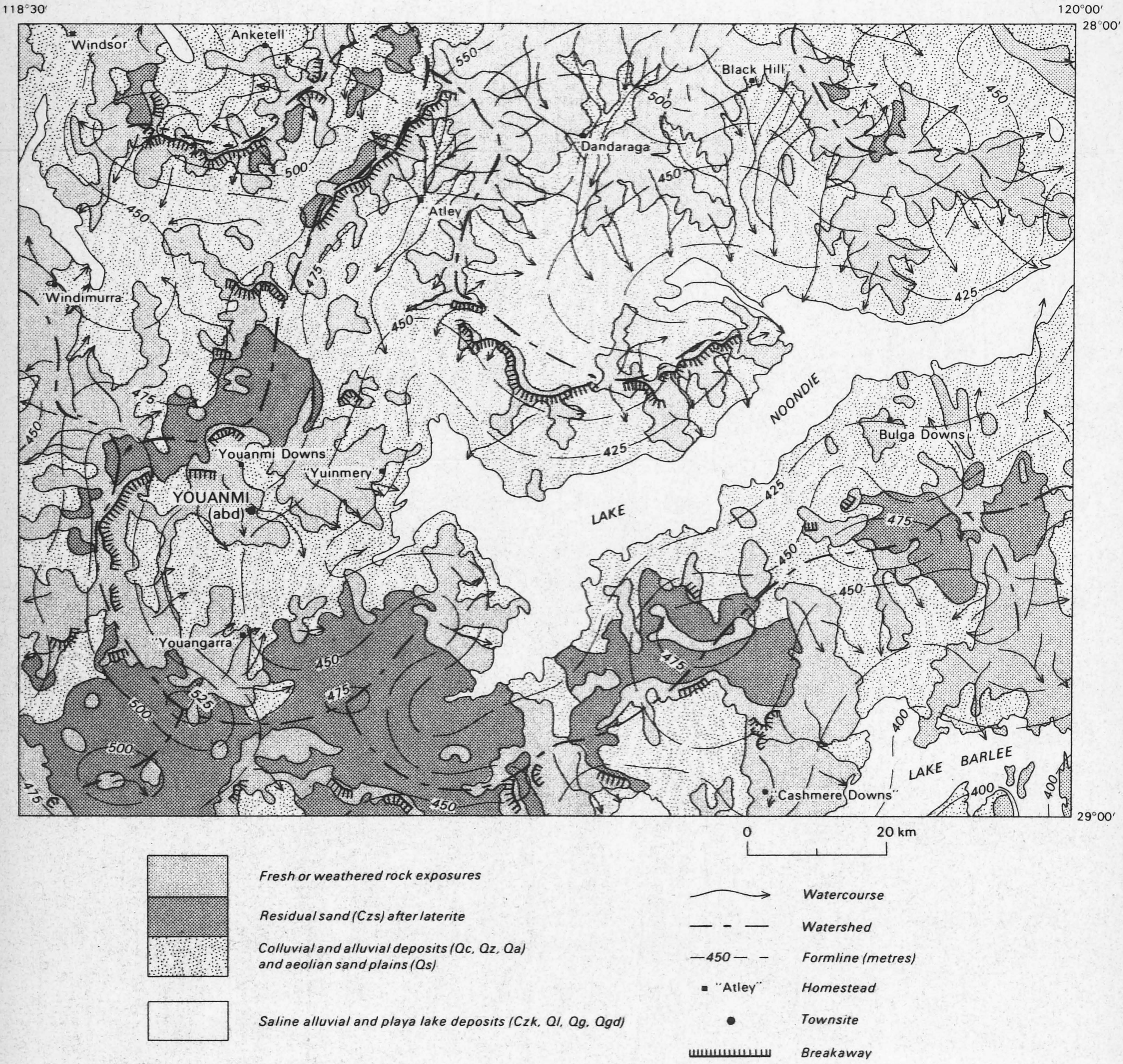

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Fig. 1 Physiographic features, Youanmi Sheet area

Geophysics

In 1968, the Bureau of Mineral Resources (BMR) carried out an airborne magnetic and radiometric survey of YOUANMI (Gerdes & others, 1970), and a map at 1:250 000 scale showing contours of total magnetic intensity and radioactivity was published by BMR in 1972. In 1974, BMR published a contoured map of Bouguer gravity anomalies of YOUANMI at 1:500 000 scale.

PHYSIOGRAPHY

The YOUANMI area (Fig. 1) is typical of the Salt Lake Division or Salinaland of Jutson (1950). The landscape is monotonous and gently undulating, and has a maximum relief of about 125 m. The area comprises two main geomorphic elements: a low depositional surface of alluvial, colluvial, aeolian, and playa deposits; and remnants of a higher, undulating surface represented by mesas and tablelands of duricrust or laterite. Topographic relief between the duricrust residuals is about 75 m. The great majority of the duricrust breakaways face south or southeast. North-south topographic profiles across YOUANMI show an overall slope to the south of about 1.6 minutes, which is very close to the southward tilt of 1.5 minutes determined by van de Graaff & others (1977) in the southeast of the Yilgarn Block. The southward tilt in YOUANMI steepened the gradient of south-flowing streams and promoted headward erosion of the duricrust and the formation of south-facing breakaways; at the same time, the gradient of north-flowing streams was reduced, hindering the formation of north-facing breakaways.

ARCHAEAN ROCKS

REGIONAL SETTING

YOUANMI is situated wholly within the Southern Cross Province (Gee & others, 1981) of the Yilgarn Block of Western Australia. The province is characterised by arcuate, generally northerly-trending greenstone belts that crop out around and between areas of granite and gneiss.

The only geochronological work that has been carried out in YOUANMI was a Rb-Sr study of the Windimurra Intrusion, that showed the intrusion to be more than 2500 m.y. old (A. Ahmat, GSWA, and J. de Laeter, Western Australian Institute of Technology, personal communication, 1980). A detailed Rb-Sr study on a wide range of granitic and gneissic rocks similar to those in YOUANMI was undertaken in BARLEE (Chapman & others, 1980). This study has shown that the granitic rocks fall mainly in the 2700-2500 m.y. range, similar to other cratonic granitoids dated in the Yilgarn Block. The gneisses in BARLEE appear to be only marginally older. Detrital zircons in banded gneisses from the Jimperding area, similar to those in YOUANMI, have yielded a U-Pb date of 3340 m.y. (Nieuwland & Compston, 1980), and gneisses from the Mount Narryer area (BYRO) have given a Rb-Sr date of 3350 m.y. (de Laeter & others, 1981).

A minimum age of 2718 m.y. for the Kathleen Valley Gabbro, 70 km northeast of YOUANMI (Cooper & others, 1978), and a date of 2635 m.y. on the Marda felsic complex in JACKSON (Hallberg & others, 1976) are the best age constraints for the greenstone belts in YOUANMI.

Four main Archaean rock groups have been recognised in YOUANMI: (1) gneisses of igneous and sedimentary compositions, metamorphosed to middle or upper amphibolite facies; (2) greenstones, comprising a layered succession of predominantly mafic igneous rocks, subordinate felsic volcanics, and ultramafic rocks, together with banded iron formation and other sedimentary rocks, metamorphosed to greenschist or middle amphibolite facies; (3) layered mafic intrusions, which intrude the gneiss and greenstone terrains; and (4) foliated to massive granitoids, which intrude all three previous groups. Dolerite dykes of Archaean or Proterozoic age intersect the four main Archaean groups. Cainozoic sediments and duricrust cover much of the area.

GNEISSES

The plutonic igneous nomenclature used in this Record and on the accompanying geological map follows Streckeisen (1976), with the retention of the term 'adamellite' for granitoids with plagioclase forming 35-65 percent of the total feldspar.

Lithology

Gneisses occupy extensive linear zones, or occur in small enclaves entirely surrounded by granitoid (see Precambrian Geology Interpretation figure shown on the accompanying map). The gneiss zones and enclaves consist of banded gneiss (Anb) and orthogneiss (Anl), with smaller amounts of tonalitic gneiss (Ant), quartzose paragneiss (Anf), amphibolite (Ana), quartzite (Anq), ultramafic rock (Anu), and banded magnetite-quartz rock (Ani).

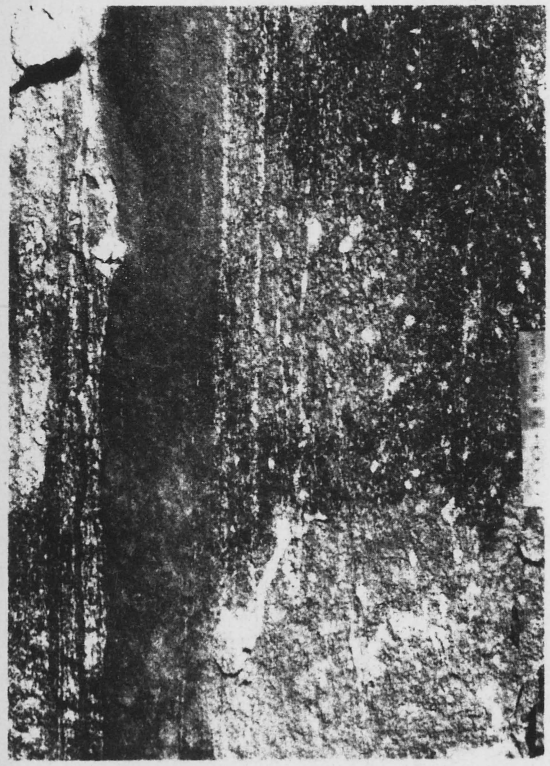

Fig. 2 — Typical banded gneiss **(Anb)** showing dark and light granitoid layers. Lat. 28°59′20″S, long. 119°12′00″E. Scale is 15 cm long.

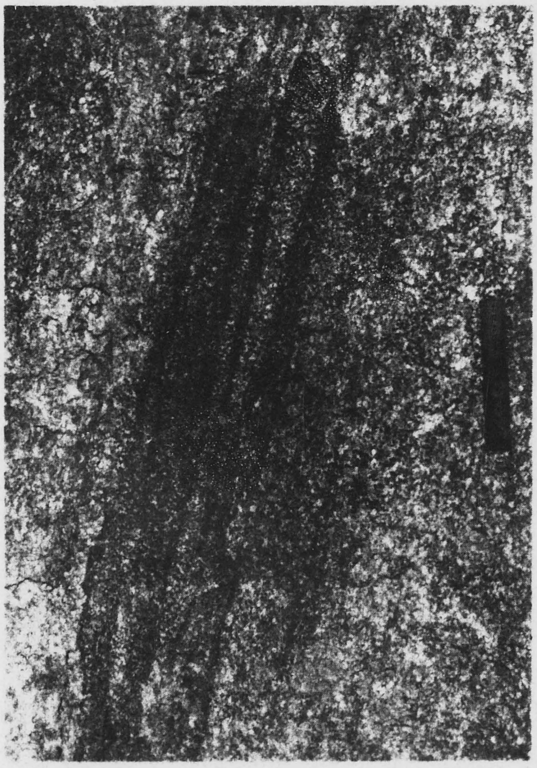

Fig. 3 — Banded gneiss **(Anb)** at Bell Rockhole, showing tapering and anastomosing dark layers or laminae. Scale is 15 cm long.

Fig. 4 — Banded gneiss **(Anb)** showing early isoclinal folds in light layers, and granitoid dyke cutting across layers. Lat. 28°58′30″S, long. 119°37′05″E. Scale is 15 cm long.

Fig. 5 — Banded gneiss **(Anb)** showing late tight chevron folds. Lat. 28°40′30″S, long. 119°32′40″E. Scale is 15 cm long.

The layers in the banded gneiss (Anb) vary in composition and grainsize, and range from a few millimetres to several metres in width. The layers are of two types: a predominant light-coloured medium to coarse-grained gneiss of granite, adamellite, or granodiorite composition; and, a subordinate dark-coloured fine to medium-grained gneiss of granodiorite or tonalite composition (Fig. 2). In some areas, concordant lenses or discordant folded dykes of granite or granodiorite are also present. Pegmatite dykes and aplite veins are common.

Overall, the compositional layers are remarkably straight and parallel even where the margins of the layers are undulating. In some areas, for example Bell Rockhole, the undulatory dark layers taper and anastomose (Fig. 3). Intrusions of one type of layer into another have been seen 8 km southeast of Little Noondie Hill, where dark granitoid forms sheets containing xenoliths of the adjoining light granitoid, and 9 km southwest of Mooloo Pool, where the light layers have partly assimilated the dark layers.

Foliation in the banded gneiss is expressed by oriented biotite flakes; where the foliation intensifies quartz and feldspar grains are flattened, and the dark layers and pegmatite masses boudinaged. Close to the greenstone belts and granitoid bodies, the texture becomes mylonitic. In general, the foliation ranges from parallel to 20° to the compositional layering. The layers are tightly to isoclinally folded, and the foliation in the layers is parallel to the axial planes of the folds (Fig. 4). At most localities, only one set of folds and one penetrative foliation appear to be present; a second set of folds (Fig. 5) was observed in the vicinity of Horse Fall Rocks. Cross-cutting aplite veins are folded, but to a lesser extent than the layers they cut, indicating that their intrusion took place during deformation.

A different type of banded gneiss occurs in the southeastern part of the Yuinmery gneiss zone, about 5 km north-northwest of Jay Bore. It consists mostly of dark grey granodioritic augen gneiss accompanied by subordinate layers of light-coloured leucogranodiorite gneiss up to 1 m thick and about 10 m apart. The augen are composed of pink microcline, and have consistently skewed tails or 'beards' of microcline which indicate an east-block-south or right-lateral sense of shear along the foliation. The augen themselves are aligned in rows which are relics of a former layering in the rock, subsequently disrupted and sheared during imposition of the foliation.

At Bell Rockhole, the coarser leucocratic layers of the banded gneiss contain tabular, subhedral megacrysts of microcline up to 6 cm long; the finer-grained melanocratic layers are very subordinate. At Horse Fall Rocks and at a locality 3 km south of Cashmere Downs homestead, banded gneiss forms disrupted xenoliths in gneissic granodiorite. The banded gneiss on the western side of the Mount Elvire (misspelt 'Alvire' on the Precambrian Geology Interpretation figure on the accompanying map) greenstone belt is cut by tightly folded granodiorite dykes.

Orthogneiss (Anl) forms a large elongate body in the Yuinmery gneiss zone, and smaller bodies of orthogneiss have been mapped at Ray Rocks, Kohler Well (Dandaraga station), Porcupine Well, Tom Well, Kevin Bore, and at locations 3 km north of Jay Bore and 4 km northwest of Jones Bore. The rock is medium to coarse-grained, and faintly banded with lighter feldspathic layers and darker, thinner, rather indistinct, and discontinuous biotitic layers or schlieren. The northern part of the large orthogneiss body, from Yuinmery homestead to Fennell Well, is generally adamellitic in composition, whereas the remainder of the body to the south, as far as Tom Well, is granodioritic. Small bodies of homogeneous leucocratic granodioritic orthogneiss intrude the weakly-banded orthogneiss in the Freshwater Well and Yuinmery areas, and in the Yuinmery area, tonalitic layers are also present. At Ray Rocks, the darker and lighter bands in the orthogneiss are composed of tonalite and granodiorite respectively, and contain ellipsoidal xenoliths of metasedimentary rock, and angular xenoliths of leucogranite.

In addition to weak layering, the orthogneiss has a northerly-striking foliation, generally defined by an entrainment of small, unoriented biotite flakes forming parallel streaky aggregates. The foliation usually parallels the layering, but cuts it at angles of up to 30° in places. Where the layers are folded, the foliation in the gneiss parallels the axial planes of the folds. The folds are cut by the intrusive bodies of gneissic granodiorite and tonalite (Ant). These intrusions are themselves cut by the gneissic foliation, and so were emplaced during shearing and folding of the orthogneiss. A later, northwesterly-striking fracture cleavage, spaced about 50 cm apart, cuts the gneissic foliation in the Yuinmery area. One and a half kilometres west of Noondie, the later cleavage is a strain slip cleavage; recrystallisation has produced a discontinuous lenticular banding.

Tonalitic gneiss (Ant) has been mapped only at the northern end of the Yuinmery gneiss zone, where it forms an elongate body about 7 km long. The rock is dark grey to greenish-grey, medium-grained, and homogeneous. It has sharp contacts which cut across the banding of the orthogneiss Anl, and it also contains xenoliths of the orthogneiss. Two foliations cut the tonalitic gneiss: the earlier is a northerly-striking, penetrative foliation of elongate quartz and feldspar grains, and aligned biotite flakes; the later is the spaced, fracture cleavage which strikes northwesterly and cuts the other gneisses, Anb and Anl, in the same area. Leucocratic veins in the tonalitic gneiss are tightly folded, and their axial planes are parallel to the penetrative foliation.

Quartzose paragneiss (Anf) crops out 15 km west-southwest of Atley homestead in the Thomson Bore gneiss zone, and 5 km northwest of Youanmi Downs homestead. In the Thomson Bore gneiss zone, the unit comprises (garnet)-biotite-muscovite-plagioclase-microcline-quartz gneiss, and abundant biotite-microcline-quartz plagioclase gneiss of the Anb type. Thin, muscovite-bearing pegmatoid and granitoid segregations parallel to compositional banding in the gneiss are believed to be products of incipient partial melting. Small concordant lenses of homogeneous granitic and adamellitic orthogneiss (Anl-type) are also present, together with dykes of muscovite-bearing adamellite (Agb). All these rock types have a strong, superimposed gneissic foliation.

A paragneiss, 5 km northwest of Youanmi Downs homestead, comprises interlayered fine-grained homogeneous quartzo-feldspathic gneiss, and lenses and pods of schistose orthoamphibolite. Pegmatite, with abundant muscovite, forms large dykes and masses, mingled with very coarse amphibolite.

Subsidiary rock types in the banded gneiss (Anb), paragneiss (Anf), and orthogneiss (Anl) terrains include banded magnetite-quartz rock after iron formation, amphibolite, calc-silicate gneiss, ultramafic rock, and quartzite. Contorted and recrystallised banded iron formation, now a hedenbergite-magnetite-quartz rock, was observed 5 km south-southwest of Yuinmery homestead in the Yuinmery gneiss zone, and 2 km southeast of Horse Fall Rocks. Banded magnetite-quartz rock containing limonite pseudomorphs after fibrous amphibole occurs 10 km east of Rainy Bore, and at Ray rocks, where lumps of surficial magnesite indicate a concealed ultramafic body. Banded magnetite-quartz rock (Ani) with abundant fibrous amphibole (?grunerite) was located at the northern end of the Thomson Bore gneiss zone, interlayered with Anf. Pods of banded magnetite-quartz rock in the ortho-gneiss (Anl) 3 km south of Freshwater Well contain quartz, magnetite, ?biotite, and a few grains of pale green amphibole.

Amphibolite pods and layers (Ana) occur throughout the banded gneiss (Anb), orthogneiss (Anl), and to a lesser extent, the quartzose paragneiss (Anf). The amphibolite that is interlayered with Anb at the northern end of the Thomson Bore gneiss zone, and in the White Cloud gneiss zone 7 km west-southwest of Daly Outcamp, is medium-grained, foliated, and consists of poikiloblastic actinolite, diopside, plagioclase (generally andesine), and sphene; quartz and opaque grains are present in some samples. Amphibolite, composed of diopside, hornblende, and andesine, forms a lens several metres wide and tens of metres long in the gneiss 10 km east of Rainy Bore. Lenses, pods, and boudins of amphibolite are present in the gneiss dome 8 km southeast of Dandaraga homestead, and consist of clinopyroxene, hornblende, and plagioclase. Most amphibolites in the banded gneiss terrain are probably metamorphosed and boudinaged relics of mafic dykes.

Calc-silicate gneiss interlayered with banded gneiss (Anb) is exposed 15 km southeast of Bulga Downs homestead, and comprises alternating laminae of amphibole-plagioclase-epidote and epidote-plagioclase.

Schistose medium-grained para-amphibolite or calc-silicate rock, containing lenticles and blebs of quartz, forms layers up to 30 m long by 3 m wide, 3 km south of Freshwater Well area in thh orthogneiss (Anl) terrain. The rock consists of hornblende, rimmed with epidote, diopside, calcic andesine, quartz, and sphene.

Ultramafic rock (Anu) has been mapped only in the southwestern part of YOUANMI, 5 km west-northwest of Rainy Bore. The rock is a pale-green, soft, flaky chlorite-tremolite schist with associated fragments of eluvial magnesite, and is surrounded by banded gneiss Anb. The schist has a steeply plunging lineation, and weathers to near-vertical ellipsoids with prominent concentric exfoliation shells. Foliated laminated amphibolite, composed of actinolite, andesine, quartz, and sphene, adjoins the schist.

An ultramafic rock associated with the amphibolite 10 km east of Rainy Bore consists of actinolite, clinopyroxene, epidote, opaque grains, sphene, and poikiloblastic quartz.

Granoblastic quartzite (Anq) forms a single outcrop in the banded gneiss (Anb) of the White Cloud gneiss zone 12 km southeast of Bulga Downs homestead.

Yuinmery gneiss zone

The Yuinmery gneiss zone is an extensive area of gneiss that extends from 10 km northwest of Yuinmery homestead to the southern boundary of YOUANMI. It averages about 7.5 km wide, and reaches a maximum width of 15 km at Freshwater Well. A lobate foliated granitic body (Agb, Agv) intrudes the southern part of the zone. The general strike of the gneiss within the zone is 320-340°; east of Kevin bore, the gneiss strikes 010°.

The Yuinmery gneiss zone consists mainly of banded gneiss (Anb), showing incipient migmatisation, and orthogneiss (Anl), which forms a large elongate body in the centre of the gneiss zone and several smaller bodies at Ray Rocks, Kevin Bore, and locations near Tom Well and 3 km north of Jay Bore. Leucocratic veins and small conformable bodies of strongly gneissic granitoid (Anl-type) are interpreted as migmatitic neosomes. Minor rock types include gneissic tonalite (Ant), and small amounts (not mapped) of amphibolite and banded iron formation. A well exposed rock dome 8 km northwest of Yuinmery homestead shows banded gneiss (Anb) intruded by apophyses of homogeneous gneissic tonalite (Ant); both are enclosed in, and intruded by, adamellite orthogneiss (Anl). The compositional banding in the gneiss (Anb) is obliquely transected by the margin of the adamellite orthogneiss. All three units are cut by foliated biotite adamellite (Agb) farther to the north.

Abundant orthogneiss is a distinctive feature of the Yuinmery gneiss zone. The large central body of orthogneiss at the northern end of the zone has intrusive contacts against the adjoining banded gneiss, and appears to be a syntectonic batholith. The smaller bodies of orthogneiss are also intrusive. The small pods and lenses of amphibolite and banded iron formation 3 km south of Freshwater Well are probably xenoliths. Orthogneiss 3 km north of Jay Bore is irregularly and weakly banded, and contains abundant pegmatite swirls, discontinuous schlieren, and xenoliths of the nearby banded gneiss (Anb).

The eastern margin of the Yuinmery gneiss zone is irregular, because of the emplacement of later granitoids (Age, Agb, Agm). The western margin is a well defined mylonite zone, the Yuinmery Fault, that separates the Yuinmery gneiss zone from the Youanmi greenstone belt in the north, and from poorly-exposed granitoid in the south. The fault truncates major structures in the greenstone belt; it is well exposed 4 km west of Yuinmery homestead, where it is marked by mylonite consisting of fine porphyroclasts of quartz and feldspar in a very fine-grained granular quartzo-feldspathic matrix. The fault is also well exposed 5 km south-southwest of Yuinmery homestead, where banded muscovite-biotite-plagioclase-microcline-quartz gneiss and biotite-microcline-quartz-plagioclase gneiss (Anb) are faulted against tremolite-chlorite schist (Aur), amphibolite (Aba), and banded iron formation (Aiw). The muscovite content of the gneiss increases towards the fault, and the gneiss adjacent to the fault shows much postcrystallisation deformation, including elongation of quartz to ribbons, kinking and folding of muscovite, and fracturing of plagioclase. Folds in the banded gneiss include an early isoclinal set of folds with axial planes parallel to the gneissic foliation, and a later gently north-plunging open set of folds with Z-vergence. The later set folds the compositional banding and the gneissic foliation, and possibly formed during movement of the gneiss adjacent to the mylonite zone. Within the greenstone belt, foliation in amphibolite is crenulated adjacent to the mylonite zone, and most of the lineations (mineral elongations) plunge north. Banded iron formation in the greenstone belt strikes obliquely into the mylonite zone and is weakly recrystallised. It consists of grunerite, magnetite, and quartz, and contrasts markedly with a thin, contorted, faintly banded hedenbergite-magnetite-quartz rock in the adjacent gneiss. The iron formation in the gneiss has a strongly-recrystallised metamorphic texture, and a mineral assemblage which indicates middle amphibolite facies or higher.

The original relationship between the Youanmi greenstone belt and the Yuinmery gneiss zone is not known. The greater intensity and complexity of deformation in the gneiss zone suggest a more complicated, and therefore longer, geological history than that of the greenstone belt.

White Cloud Gneiss Zone

The White Cloud gneiss zone is the most extensive and, in places, the best exposed gneiss zone in YOUANMI. It extends from 3 km northwest of Mount Alfred north-northwesterly to the northern boundary of YOUANMI just north of Black Hill homestead, a distance of 105 km. The gneiss zone continues a further 25 km north into SANDSTONE. The maximum width of the zone is 12 km, and its average width is about 5 km. The gneiss within the zone strikes between 320° and 360°, and dips from vertical to steeply east or west.

The distinctive feature of the White Cloud gneiss zone is its proximity to two narrow, dynamically-metamorphosed greenstone belts, (the Maynard Hills and Cook Well greenstone belts). The Maynard Hills greenstone belt is in tectonic (fault or shear zone) contact with the eastern margin of the gneiss zone from Denham Bore in the south northward to Middle Well. Farther to the north, the eastern margin of the gneiss zone is intruded by an elongate lobe of foliated adamellite (Agb). The Cook Well greenstone belt adjoins the western margin of the gneiss zone between Kurrajong Bore and Mistletoe Well; north and south from there, however, the greenstone belt strikes into, and is bordered on both sides by the gneiss zone. Northwards from Maninga Marley, the western margin of the gneiss zone is in tectonic contact with the Sandstone greenstone belt; southwards from Kurrajong Bore, it is irregularly intruded by massive or foliated coarse granitoid (Agb).

The Edale Fault is a large, quartz-filled, arcuate, northerly-trending fault that cuts obliquely through the northern and southern parts of the White Cloud gneiss zone. South of Kurrajong Bore, lineations on the west side of the fault plunge 30-40° to the north, whereas lineations on the eastern side plunge 5-20° to the south. The Edale Fault also forms the western margin of the Cook Well greenstone belt, and truncates later granitic rocks (Agb).

The White Cloud gneiss zone consists entirely of compositionally banded gneiss, and is well exposed 1 km southeast of Visitors Bore and 6 km southeast of White Cloud Bore. At the White Cloud Bore locality, the banding ranges from 1 cm to 3 m wide and is paralleled in places by thin leucocratic pegmatoid and granitoid veins, which indicate incipient migmatisation. Acutely-angled discontinuities in the banding are interpreted as faults, or as very tight folds that have been faulted. The near-parallelism of these structures with the banding suggests a high degree of elongation.

The compositional banding is overprinted by a strong coplanar or slightly oblique gneissic foliation which becomes more intense marginal to the greenstone belts. Adjacent to the Cook Well belt, it is balstomylonitic, and enhances the banding. Away from the greenstone belts, the texture in the gneiss is granoblastic-elongate.

The structural relationship between the White Cloud gneiss zone and the Cook Well and Maynard Hills greenstone belts is obscure. Six kilometres southeast of White Cloud Bore, a ridge about 2 m high of metamorphosed banded iron formation of the Cook Well belt forms an outlier overlying vertically dipping mylonised banded gneiss, although the contact is concealed by colluvial scree. The banded iron formation has a thin quartzitic rock, which may be a basal quartzite, on its western side, and is tightly and recumbently folded. The recumbent folds are folded by later upright open folds, and by a still later crenulation. The mylonitic fabric in the gneiss is absent from both the banded iron formation and the quartzite. The contact of the banded iron formation and the gneiss could be either an unconformity or a low-angle fault. The second interpretation, however, requires extrapolation of the fault below other greenstone outliers to the north and south; the simpler unconformable interpretation is therefore preferred. A similar exposure occurs 3 km northwest of Elspon Well, where a thin quartzitic rock with intrafolial folds separates banded iron formation on the east from banded gneiss to the west. A third exposure, 6.5 km southeast of White Cloud Bore, shows a steeply northerly-plunging synformal keel of banded iron formation in close proximity to vertically-dipping banded gneiss.

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Lineations in the gneiss plunge gently to the south. The evidence at all three localities is consistent with the interpretation that the Cook Well greenstone belt rests unconformably on the White Cloud gneiss zone.

A fault forms the eastern contact between the White Cloud gneiss zone and the Maynard Hills greenstone belt. At a locality 2.6 km northeast of Denham Bore, westerly-facing vertically-dipping mafic rocks (mainly amphibolite) are in abrupt contact with steep, easterly-dipping mylonised banded gneiss. Thin slivers of gneiss a few metres wide occur within the amphibolite, and are interpreted as being tectonically emplaced within the amphibolite. Dykes of foliated Agb intrude both gneiss and amphibolite. Seven kilometres west of Daly Outcamp, a similar abrupt tectonic contact between mylonised gneiss and foliated amphibolite is exposed; thin slices of gneiss occur within the amphibolite. Later lit-par-lit intrusions of foliated Age and Agb occur at this contact.

Thomson Bore Gneiss Zone

The Thomson Bore gneiss zone is located 9 km west of Atley homestead; it is about 18 km long, and has a maximum width of 3 km. The gneiss strikes about 030°, and has steeply westerly to vertical dips. It is intruded on its eastern side by a layered mafic-ultramafic body, the Atley intrusion (Adj). The western margin is intruded, in places in lit-par-lit fashion, by foliated porphyritic adamellite (Agl) and medium-grained biotite adamellite (Agb). Dykes of both these granitoids are found within the gneiss zone. The zone consists of muscovite-bearing quartz-rich gneiss (Anf) and banded gneiss (Anb) interlayered with calc-silicate gneiss and para-amphibolite. Muscovite-bearing pegmatoid and granitoid segregations parallel the banding. The abundance of muscovite, quartz-rich gneiss, and calc-silicate rock distinguishes the Thomson Bore gneiss zone from all other gneiss zones in YOUANMI, with the exception of the western margin of the Yuinmery gneiss zone, where muscovite appears to be related to faulting.

The rocks in the Thomson Bore gneiss zone were metamorphosed to middle and upper amphibolite facies, and subsequently underwent retrogressive greenschist metamorphism, forming secondary albite, chlorite, epidote, and actinolite.

Unnamed areas of Gneiss

One kilometre east of Unaly Hill, an area 10 km by 2 km of poorly exposed banded gneiss (Anb) and orthogneiss (Anl) may be an enclave or continuation of the Yuinmery gneiss zone. The area is enclosed in foliated adamellite (Agb). The western margin of the gneiss is a faulted contact with a narrow greenstone belt sandwiched between the gneiss and Unaly Hill itself, which is a large quartz blow in the Youanmi Fault.

Eight small outcrops of banded gneiss and orthogneiss occur in a meridional zone in the centre of the composite granitoid body (Agb, Age, Agv), which occupies the central part of YOUANMI. The northernmost outcrop, 5 km southeast of Dandaranga homestead, is a northeasterly-plunging banded gneiss dome with a core of foliated granitoid. Banding and foliation in the gneiss are not axial planar to the dome, but curve around it, and show small-scale minor folding in the axial-planar region. The structure of the dome is congruent with structures in the adjacent Sandstone greenstone belt. The major structure is a mineral-elongation lineation plunging northeasterly at 35°-45°, parallel to the axes of the folds in the gneiss and greenstones. The contact with the greenstones appears to be predominantly tectonic, although locally intrusive relationships are apparent. The contact is accompanied by a steep metamorphic gradient in the greenstones. The gneiss dome may be a diapir of cold, remobilised basement which rose in to the greenstones and deformed them.

A grey medium-grained biotite-adamellite orthogneiss (Anl) 5 km southwest of White Well contains large rafts of migmatised banded gneiss (Anb). The banded gneiss is cut by foliated dark-grey gneissic granodiorite or tonalite, which also has a later strain-slip cleavage similar to that described from 1.5 km west of Noondie in the Yuinmery gneiss zone. All the gneisses show retrograde metamorphism.

At Porcupine Well, on the northern margin of Lake Noondie, nebulitically banded and lineated adamellite orthogneiss with a granoblastic-elongate texture resembles the weakly banded orthogneiss (Anl) of the Yuinmery gneiss zone.

In several exposures 3 km north of Horse Fall Rocks, medium-grained gneissic granodiorite, containing prominent grains of allanite, disrupts lenticular, undulatory bands of darker fine-grained granodiorite gneiss (Anb). The gneiss has been folded twice: firstly, by very narrow isoclinal folds (fig. 4) parallel to banding and commonly accompanied by small isoclinal intrafolial folds, and secondly, by tight chevron folds (fig. 5) which fold the banding and the isoclinal folds. Recrystallised and deformed banded iron formation is associated with the gneiss, 2 km southeast of Horse Fall Rocks.

At Bell Rockhole, banded gneiss comprises an anastomosing network of subordinate thin dark biotitic laminae in a matrix of coarser light granitic gneiss.

The banded gneiss on the western side of the Mount Elvire greenstone belt is very well exposed, and shows three interlayered types of gneiss: (1) dark-grey fine-grained homogeneous biotitic gneiss; (2) white coarse-grained layers and diffuse blebs of pegmatitic quartzo-feldspathic gneiss; and (3) a streaky mixture of thin folded laminae and films of biotite in abundant quartzo-feldspathic pegmatoid. The layers and laminae are tightly to isoclinally folded, and are cut by dykes of granodiorite and aplite which are themselves tightly folded.

In the northwestern part of YOUANMI, exposures of banded gneiss between Webster Well (Anketell) and Seventy One Mile Bore consist of fine-grained tonalitic gneiss, medium-grained granitic gneiss, and fine to medium-grained siliceous leucocratic gneiss. The body of granitic orthogneiss 4 km north-northwest of Jones Bore is irregularly and weakly banded, and contains abundant pegmatite and schlieren. The gneiss is cut by dykes of the surrounding Agb granitoid.

The area of banded gneiss between the Youanmi and Yuinmery Faults, along the southern margin of YOUANMI, is poorly exposed; where observed, it comprises the typical interlayered assemblage of grainitoid gneisses, amphibolite, and banded iron formation. This banded gneiss terrain contains the only known occurrences of ultramafic rocks (Anu) in YOUANMI; these are at localities 5 km west-northwest and 10 km east of Rainy Bore.

Discussion

The origin of the gneiss terrain in the Yilgarn Block is much debated, and involves two main theories: one, that the gneiss terrain is part of the sialic basement upon which the greenstones were deposited (Archibald & Bettenay, 1977; Archibald & others, 1978; Gee, 1979; Gee & others, 1981); the other, that the gneiss terrain is the early kinematic parts of granitoids that formed by partial melting of the greenstones (Glikson, 1972, 1978, 1979). In YOUANMI, the probable unconformity between banded iron formation and gneiss 6 km south-east of White Cloud Bore, and the polymetamorphic character of the gneisses, in contrast to the single metamorphism observed in the greenstone, support the theory that the gneisses are remnants of a pre-greenstone sialic basement.

THE LAYERED SUCCESSION

In this section, the various greenstone rock types are described, and are followed by a description of the individual greenstone belts. All the rock-types are metamorphosed, but the original rock-type can often be determined because the metamorphic grade is generally low.

Ultramafic rocks

Ultramafic rocks in the succession include peridotite (Aup), serpentinised peridotite (Aus), pyroxenite (Aux), komatiitic (high-Mg) basalt (Aur, Abu), talcose rocks (Aue), and serpentinised dunite (Aud). The ultramafic rocks are commonly altered to surficial variegated pale-brown siliceous rock, or to greenish-yellow translucent chalcedony.

Peridotite (Aup) containing a primary igneous texture occurs 5 km east of Dandaraga homestead, in the Sandstone greenstone belt. Small elongate bodies of serpentinised peridotite (Aus) crop out at several places in The Stock Well-Edale Bore area in the southern part of the Cook Well belt, on the eastern side of the Mount Elvire belt, and at Curran Well in the Youanmi belt. Other bodies, too small to map, occur in the southern part of the Mount Elvire belt, in map-unit Aue. The rocks are finely mottled black and yellowish-green, and consist of fine serpentine (antigorite), chlorite, tremolite, and opaque grains.

Metamorphosed pyroxenite (Aux) is present 2 km west and 10 km north of The Stock Well; 10 km northwest of Daly Outcamp and 3 km northeast of Mount Forrest in the Maynard Hills greenstone belt; and at numerous places in the layered Windimurra and Youanmi Intrusions, and in the layered intrusion southwest of Atley homestead. The pyroxenites not associated with the layered gabbro intrusions are tabular bodies up to a few hundred metres long, and are composed of fine tremolite, chlorite, and opaque grains. The pyroxenites forming part of the layered intrusions are described in the section on Layered Mafic-ultramafic Intrusions.

Talc rock (Aue), with or without magnesite, crops out extensively in the Mount Elvire greenstone belt, and in the Sandstone greenstone belt west and north of Dandaraga homestead. The unit as mapped also includes some metadolerite, basalt (metamorphosed to chlorite schist), banded iron formation, and serpentinite pods. The talc rocks are probably altered peridotite.

Serpentinised dunite (Aud) crops out only in the southern part of the Youanmi greenstone belt. The rocks are generally deeply weathered, but fresh serpentinite is exposed 2 km southeast of Curran Well, where dark-grey pieces of felted antigorite are set in a medium-grained matrix of talc, chlorite, and opaque grains. Serpentinised dunite is also exposed at Curran Well, in association with serpentinised peridotite.

Komatiitic (high-Mg) basalts are the most abundant ultramafic rock type. They occur in the Mount Elvire, Youanmi, Sandstone, and Cook Well greenstone belts, and to a lesser extent in the Maynard Hills greenstone belt. The basalts are interlayered with banded iron formation, tholeiitic basalt, dolerite, and peridotite. In map unit Aur, the rocks are massive to schistose, greenish-black to silvery-grey, fine-grained chlorite-tremolite-actinolite assemblages with various amounts of talc, serpentine, epidote, and quartz. Many of these rocks are dynamically-metamorphosed equivalents of massive komatiitic basalt (Abu). Some of the Abu bodies resemble tholeiitic basalt (Ab, Abb) in the field, but can be distinguished in thin section by their plumose or dendritic texture.

Altered komatiitic basalt in the Sandstone greenstone belt consist of fine-grained plumose amphibole, minor stilpnomelane, quartz, and opaque grains. Amygdales contain quartz and epidote. An unaltered komatiitic basalt 2 km north-northeast of Iron Knob Bore consists of plumose clinopyroxene needles in a fine-grained matrix (devitrified glass?).

In the Cook Well greenstone belt, a large elongate body of komatiitic basalt up to 1 km wide is exposed immediately east of The Stock Well. The northern part of the body consists of weakly-schistose fine-grained chlorite-tremolite rock. The southern part contains amygdales and flow-top breccias, and consists of skeletal clinopyroxene largely replaced by talc, and small amounts of epidote, clinozoisite, calcite, quartz, and ferroan zoisite.

Mafic extrusive rocks

Metamorphosed basalt (Ab) is exposed mainly in the Sandstone and Cook Well greenstone belts; smaller amounts are present in the Maynard Hills, Cook Well, Mount Elvire, and Youanmi greenstone belts. The basalt is generally tholeiitic (Hallberg, 1976), but as mapped in the Sandstone greenstone belt includes some komatiite, because the two were found to be indistinguishable in

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the field. The basalts are massive, and have been statically metamorphosed to assemblages of sodic plagioclase and actinolitic amphibole. Relict plagioclase is present as labradorite. Pillows and amygdales are present in places.

Massive amygdaloidal basalt (Aby) crops out in the Youanmi and Cook Well greenstone belts, and at Unaly Hill, 20 km southwest of Atley homestead. The amygdales consist of quartz and epidote or clinozoisite. Three kilometres east of Fitz Bore in the Youanmi belt, several successive basalt layers 1-3 m thick contain numerous amygdales; the amygdales increase in abundance and size westward, eventually coalescing and forming a breccia composed of chunks of metabasalt a few centimetres across enclosed in an irregular vuggy matrix of siliceous epidosite. The breccias represent former highly vesicular flow-tops. The metabasalt fragments are composed of tremolite, epidote, and calcite. The basalt in the southern part of the Cook Well greenstone belt contains amygdales in some layers, and also a layer of very tough autobreccia, some tens of metres thick, comprising angular fragments of metabasalt (clinozoisite-actinolite-albite) in a subordinate matrix of coarser actinolite, quartz, and clinozoisite.

Fine-grained tholeiitic metabasalt (Abb) is characteristically pale greenish-grey on fresh surfaces, and crops out mainly in the Sandstone greenstone belt; a small body has also been mapped in the Mount Elvire belt. The metabasalt unit in the Sandstone belt includes some komatiitic basalt, as the two rock types are indistinguishable in the field. The metabasalt is massive, and metamorphosed to an actinolite-clinozoisite (or epidote)-quartz-chlorite-albite assemblage, whereas the komatiitic basalt consists almost entirely of plumose amphibole with minor plagioclase and epidote.

Carbonated metabasalt (Abk) is exposed 3 km north of Pincher Well in the Youanmi greenstone belt, and shows the characteristic karren of solution weathering. The rock is composed of calcite, chlorite, quartz, sericite, and opaque grains.

Fine-grained foliated and lineated amphibolite (Aba), formed by dynamic metamorphism of basalt (Binns & others, 1975), is exposed at localities on the eastern and western flanks of the Sandstone greenstone belt, at the northern end of the Cook Well belt, throughout most of the Maynard Hills belt, in the southern half of the Mount Elvire belt, and 5 km west of Atley homestead. The rocks are dark greenish-black, and consist largely of oriented actinolite, retrograded plagioclase commonly as clinozoisite-albite aggregates, and fine quartz. The amphibolite 2.5 km west-northwest of Forty Five Bore in the Mount Elvire belt contains abundant tourmaline.

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Mafic intrusive rocks

Massive gabbro and dolerite (Ado) crop out in the Black Range-Sandstone-Raffertys Patch area in the north; in the Youanmi Downs-Southern Cross Well area in the southwest; in the Mount Elvire greenstone belt northeast of Cashmere Downs; and in The Stock Well-Brooking Hills area in the southeast of YOUANMI. The rocks generally form concordant layers or lenses in sequences of mafic volcanic or sedimentary rock. In the Black Range-Sandstone-Raffertys Patch area, dolerite (with uralitised mafic minerals) forms sills surrounded by basalts and banded iron formation. Two kilometres west of Youanmi Downs, uralitised dolerite is intruded by pyritic tonalite aplite dykes 50 cm wide; hematitic rutilated quartzite ('freddite'; see section on banded iron formation and related rocks) forms pods along the dolerite/aplite contact. At Southern Cross Well, 7 km east-southeast of Youanmi Downs homestead, tough massive fine-grained norite is intruded by vein quartz and aplite, and is only slightly metamorphosed; hypersthene and calcic labradorite are fresh, whereas clinopyroxene is partly altered to actinolite, and chlorite forms a few cross-cutting veinlets. In the Mount Elvire greenstone belt, massive dolerite, grading from medium to fine-grained crops out just north of Forty Five Bore, and at the northern end of the greenstone belt. The dolerite is concordant with the surrounding metasediments and basalts. In The Stock Well-Brooking Hills area, gabbro grading to dolerite contains prominent prisms of actinolite, and shows a faint westerly-dipping foliation (dimensional grain orientation).

Coarse-grained amphibolite (Ada) crops out in four areas: between Four Corners Well and Hell Gates Well in the northeastern part of YOUANMI, where lenses of foliated amphibolitised dolerite form part of the Maynard Hills greenstone belt; 6 km east of Youanmi, where tough metadolerite containing abundant xenoblasts of strained quartz is intruded by numerous veins of foliated microtonalite; in the Mount Elvire greenstone belt at the southern margin of YOUANMI; and 1 km north of The Stock Well.

Dolerite and gabbro (Adj) are described separately, in the section on 'Layered mafic-ultramafic intrusions'.

Felsic extrusive and fragmental rocks

Felsic volcanic rocks occur mainly in the west of YOUANMI, where they are intruded by the Windimurra Intrusion and occupy much of the Youanmi greenstone belt. The Mount Elvire greenstone belt also contains a small amount of felsic volcanic rock. In the Youanmi, Freddie Well, and Curran Well areas, and in the Mount Elvire greenstone belt, the rocks are deeply weathered, making precise identification impossible. Hence, many are mapped as unassigned felsic volcanics (Af). The rocks consist of massive fine-grained kaolinised muscovite-quartz-feldspar rock or sericite-quartz schist. At the abandoned Youanmi mine, interbedded kaolinised fragmental rhyolite and massive porphyritic rhyolite are interlayered with banded iron formation, fuchsite schist, and white-to-purple laminated tuff. Felsic volcanics 3 km west of Freddies Well and 3 km west of Curran Well include deeply weathered sericite schist, chlorite-sericite schist, and massive sericite-quartz rock with pyrite voids. These volcanics are interbedded with banded iron formation, and an unusual porous mineralised quartzite termed 'freddite' (described later, in the section on 'Banded iron formation and related rocks').

Dacite (Afl) crops out on the eastern side of Pincher Hill in the Youanmi greenstone belt, and is metamorphosed to fine-grained grey-green schistose hematite-chlorite-quartz rock. It is underlain by fragmental rocks (Aft) of which the most abundant is green tuffaceous metadacite, which is strongly cleaved and lineated, and composed of recrystallised quartz, chlorite, sericite, bleached biotite, and leucoxene. The tuffaceous metadacite is characterised by pale diffuse ovoids a few millimetres long that contain more quartz and less chlorite than the surrounding rock, and may originally have been lapilli. The tuffaceous dacite is interbedded with porphyritic rhyolite containing phenocrysts of quartz and topaz, blue and white banded chert, banded iron formation, and agglomerate. The agglomerate is composed of angular fragments of recrystallised chert and volcanic rock (now altered to chlorite, and tiny opaque rods) in a groundmass of microcrystalline quartz, chlorite, and more opaque material. A pipe or pod about 3 m across of silicified and sericitised dacite occurs 200 m east of the summit of Pincher Hill and is bleached white; it is penetrated by quartz veinlets, and may originally have been a fumarole. At the northern end of Pincher Hill, tuffaceous metarhyolite and dacite contain abundant limonite cubes after pyrite, and are interbedded with green pyritic-chloritic chert, banded iron formation, and pyritic quartzite ('freddite').

Deeply weathered tuff (Aft) 5 km east of Youanmi Downs homestead is completely weathered to brightly coloured variegated clay, but clearly retains its pyroclastic texture. Weathered vitric lithic tuff containing pumice fragments is exposed 12 km east-northeast of the homestead, and cleaved lapilli tuff is exposed 8 km east of the homestead. At Paynesville, in the extreme

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northwestern corner of YOUANMI, coarse-grained greenish-grey tuff consists of bipyramidal quartz crystals up to 3 mm across in a very fine-grained chlorite-sericite-quartz matrix, commonly with a spherulitic texture. Frosty quartz overgrowths are present on many of the quartz phenocrysts.

Coarser fragmental volcanics (Afx) are found in YOUANMI only at Paynesville, and are mostly greenish-grey cleaved agglomerate containing elongate angular clasts up to 10 cm long composed of chlorite-sericite-quartz in a similar matrix. Beds of tuff up to 20 m thick occur with the agglomerate.

Clastic metasedimentary and associated rocks

Argillite and shale (Ass) crop out in the cores of synclines in the Mount Elvire greenstone belt, and in the southern part of the Maynard Hills greenstone belt. In the Mount Elvire belt, the sediments are poorly exposed, and include grey shale (composed of quartz, muscovite, and abundant detrital zircon), cleaved siltstone (composed of recrystallised quartz and limonite), and laminae of grey chert. Three kilometres north of Mount Alfred in the Maynard Hills belt, the sediments include argillite, black shale, and siliceous shale, and are host to the Mount Alfred copper prospect.

Orthoquartzite, muscovite quartzite, and muscovite quartz schist (Asq) form a prominent horizon along much of the eastern margin of the Maynard Hills greenstone belt, and can be traced discontinuously for about 85 km in YOUAMNI, and for a similar distance farther south in the adjoining MENZIES area, where conglomerate is also present (Kriewaldt, 1970). The quartzite was previously recorded by Talbot (1912) and Connolly (1959). The quartzite-schist association forms the lowermost unit of the greenstone sequence, but its contact with the underlying (or adjoining) granite or gneiss is everywhere concealed by scree. The maximum thickness of the unit is about 1000 m in the Maynard Hills. The quartzite is generally white, laminated to medium-bedded, platy to flaggy, and fine-grained; it is composed of deformed and recrystallised quartz, oriented muscovite, and accessary tourmaline and rutile. In places the mica is fuchsite, which imparts a green colour to the rock.

Pelitic metasediments (Alp) are exposed in the northern part of the Maynard Hills greenstone belt, and form a thin persistent layer extending for some 25 km along the axis of the belt. The unit is quartz-muscovite schist with minor micaceous quartzite, garnet-biotite-quartz schist, and garnetiferous quartzite. Other rock-types include andalusite-muscovite-quartz schist, garnet-tourmaline-biotite-feldspar-quartz schist, garnet-biotite-cordierite-andalusite-quartz schist, and tourmaline-muscovite-quartz-sericite (after cordierite?)-andalusite schist.

Magnetite-chlorite schist (Alc) has been mapped at Mount Alfred and 16 km north of Bulga Downs homestead in the Maynard Hills greenstone belt, and 6 km north of Bulga Downs homestead, in the Cook Well greenstone belt. The rock is fine-grained, and consists essentially of small magnetite euhedra in a matrix of strongly oriented chlorite. The schist 16 km north of Bulga Downs homestead also contains actinolite, epidote, albite, and tremolite.

Para-amphibolite (Aap) crops out extensively in the northern part of the Maynard Hills greenstone belt, and has a fine-scale banding or lamination which is probably after bedding. The rock is fine to (rarely) medium-grained, and consists of various amounts of diopside, hornblende, plagioclase, quartz, and sphene. Calc-silicate rock composed of diopside, epidote, calcite, garnet, opaque grains, and sericite-like cryptocrystalline material, occurs 2 km southwest of Red Knob; another calc-silicate rock 7 km south of Red Knob has alternating laminae of quartz and diopside. The rocks may be derived from mixtures of mafic tuff, sand, and carbonate.

Banded iron formation and related rocks

This group includes banded iron formation of low (Aiw) and medium (Aim) metamorphic grades, banded or mottled chert (Aic), and a mineralised quartzite called 'freddite' (Aiq). The iron formation and chert form resistant beds up to 10 m thick, and are flanked by soft hematitic slate or deeply weathered mafic or ultramafic igneous rock. In the Mount Elvire greenstone belt, and in the southern part of the Maynard Hills greenstone belt, banded iron formation forms the most prominent hills in YOUANMI. Medium-scale folds are present in the banded iron formation at many localities. The folds show great variation in orientation and vergence, and may include soft-sediment slump folds as well as folds of tectonic origin.

Banded iron formation of low metamorphic grade (Aiw) is the most abundant unit in the group, and is present in all greenstone belts. It consists of alternating laminae of black or grey hematite (generally weathered to limonite or goethite) and brown, yellow, red, or white chert which is brightly coloured by a small amount of weathered iron minerals. Pyrite occurs in the banded iron formation at Youangarra homestead.

Banded iron formation of moderate metamorphic grade (Aim) contains fibres of ferruginous amphibole such as cummingtonite and grunerite in or adjoining the siliceous layers. The amphibole is replaced by limonite in the weathered rock, but the characteristic felted amphibole texture is retained. The ferruginous layers are coarsened and altered to magnetite, and the silica is recrystallised to a fine-grained polygonal mosaic. A green and brown iron formation, 5 km south-southeast of Forty Five Bore in the Mount Elvire greenstone belt, consists of alternating laminae of grunerite and quartz, together with a few grains of green hornblende and rare euhedra of magnetite.

Chert (Aic) is found in the eastern part of the Sandstone greenstone belt, the northeastern part of the Mount Elvire belt, and the southern part of the Cook Well belt. One or two beds of chert (too thin to show on the map) form a persistent marker horizon interbedded in the banded iron formation of the northern half of the Mount Elvire belt, and can be recognised on the limbs of all the major folds in that area (Fig. 10). The chert is generally white or yellow, with blue or reddish-brown ferruginous mottling; it is almost everywhere recrystallised to quartzite, which is irregularly grained from fine to coarse. The constituent quartz grains are polygonal and equant, and some are thinly coated with hematite. In some samples, hematite forms small irregular lumps or spongy masses. In one sample, 5 km southwest of Matris Bore, the iron mineral is grunerite.

Unrecrystallised chert is exposed at the western margin of the chert outcrop in the south of the Cook Well belt. It is white and chalcedonic, and is underlain to the east by white and grey shale which is itself underlain by recrystallised chert.

Chert-pebble conglomerate forms a distinctive horizon several metres thick on the western limb of the major syncline forming the northern half of the Mount Elvire greenstone belt. It is located a few tens of metres above the chert horizon described above. The conglomerate consists of flat angular chips of recrystallised chert in a poorly-sorted matrix of angular quartz, opaque grains, and limonite. The chert chips are subparallel to the bedding. The upper part of the conglomerate contains numerous poorly-rounded pebbles of vein quartz.

'Freddite' (Aiq) crops out only in the southwestern part of the Youanmi greenstone belt, where it is interbedded with the felsic volcanics of the Pincher Hill, Freddie Well, and Curran Well areas. Other exposures (too small to map) are known, approximately 5 km south-southwest of Youanmi (Edwards, 1977). In the Pincher Hill-Curran Well area, the rock is a white, yellow, or

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blue coarse-grained porous quartzite with a thin indistinct convoluted bedding defined by changes in the abundance of pores. The pores are lined with limonite, and some also contain amorphous silica. In places, the holes are larger and connected, resulting in an irregular gossanous mass of cellular blue quartz and brown limonite. At one locality, 3.5 km northwest of Curran Well, porous quartzite passes along strike into quartz-hematite banded iron formation. At the northwestern end of Pincher Hill, the freddite is a coarse-grained colourless quartzite composed of large irregular grains of quartz with serrated boundaries, limonite cubes after pyrite, and biotite. It is interbedded with banded iron formation and thin-bedded green chloritic-pyritic chert.

Three kilometres west of Freddie Well, the freddite is a medium to coarse-grained bluish-purple porous quartzite which is discontinuously laminated to thin-bedded, and tightly folded. In places, it passes along strike into massive limonitic cellular quartz. The freddite contains small specks of fresh pyrite, voids after larger pyrite grains, and malachite stains. The quartz grains are recrystallised to mosaics of fine polygonal grains, and enclose abundant needles of rutile. Some freddite contains chloritised biotite and iron-amphibole.

Thin discontinuous freddite crops out along one side of a dyke of tonalite aplite which intrudes medium to fine-grained metadolerite 2 km west-northwest of Youanmi Downs homestead. The quartz occurs as round grains packed with very thin needles of rutile; some of the grains have partly concave surfaces, and many are coalesced. The cusps between the grains are filled with fine-grained hematite, and some also contain chalcedony.

Unweathered freddite in drill core in the Freddie Well area is composed of round blue rutilated quartz grains in a matrix of sulphide (sphalerite, chalcopyrite, pyrrhotite, and pyrite); in places, sulphide constitutes almost the entire rock (C.K. O'Connor, 1971). O'Connor suggested that the quartz originated as a colloidal precipitate; the coalesced bleb-like shapes of the quartz grains tend to support this. The close association of freddite with felsic volcanic rocks suggests a volcanic exhalative origin for the silica and base-metal sulphides (CRA Exploration, 1976; Sargeant, 1978). The discontinuous pods of freddite along the margin of the tonalite aplite dyke near Youanmi Downs homestead may have precipitated the wall of a volcanic conduit which was subsequently filled by the aplite.

STRATIGRAPHY OF THE GREENSTONE BELTS

Five greenstone belts have been named in YOUANMI - Sandstone, Maynard Hills, Cook Well, Mount Elvire, and Youanmi - and these are outlined in the Precambrian Geology Interpretation figure on the accompanying map. Two smaller greenstone remnants at Unaly Hill and Paynesville are unnamed. The three layered gabbroic intrusions at Windimurra, Youanmi, and Atley are not restricted to the volcanic successions of the greenstone belts, and so are not regarded as parts of them. Rough stratigraphic sequences for the five named belts are shown in Figure 6. The sequences in the Maynard Hills and neighbouring Cook Well belts are similar; to a lesser extent, the Sandstone and Mount Elvire sequences also resemble each other. The Youanmi sequence includes abundant pyroclastic felsic volcanics; similar volcanics crop out at Paynesville in YOUANMI, and at localities in KIRKALOCKA, where they are called the 'Kantie Murdanna Volcanics' (Baxter & others, 1980).

Sandstone greenstone belt

The Sandstone greenstone belt consists of tholeiitic basalt (Ab, Aba, Abb), with smaller amounts of dolerite (Ado, Ada), banded iron formation (Aiw), ultramafic komatiitic basalt (Aur), ultramafic intrusions (Aup), and clastic sedimentary rocks (Ass; these do not occur in YOUANMI, but do occur in SANDSTONE to the north. The northerly plunge of metamorphic mineral-elongation lineations in metabasalt near the western margin of the belt, the predominantly northerly plunge of minor folds in the banded iron formation, and the northerly dip of easterly-striking banded iron formation in the centre indicate that the greenstone belt as a whole is a northerly-plunging antiform. Bands of iron formation in the limbs and northern part of the belt are reasonably concordant with the antiform, but in the centre of the belt, in the Nungarra-Dandaraga-Maninga Marley area they are disharmonic. The disharmonic folding is probably superposed folding that accompanied emplacement of the gneiss dome 5 km southeast of Dandaraga. The structure of the southeastern area of the belt is also complex, with large-scale parasitic isoclinal folds in the Mount Dwyer area.

Northerly facings in pillow lavas 5 km northwest of Nungarra and 3 km west-northwest of Maninga Marley, indicate that the antiform is an anticline. Hence, the oldest rocks in the belt are komatiitic basalts around the northern margin of the banded gneiss dome 5 km southeast of Dandaraga homestead. These are overlain to the north, east, and west by massive tholeiitic basalt (mostly Abb but with intercalations of Ab basalt), beds of banded iron formation and chert, and sills of dolerite; a lens of komatiitic basalt occurs near the top of the sequence on the western side of the anticline. The basalt along the eastern and western margins of the belt near the Edale and Youanmi Faults has been dynamically metamorphosed to fine-grained amphibolite (Aba).

Maynard Hills greenstone belt

The Maynard Hills greenstone belt extends from Kayline Bore in the north to the southern boundary of YOUANMI, a distance of 113 km; the belt continues a further 90 km south across BARLEE and MENZIES. In YOUANMI, the belt averages 2-3 km wide; south of Mount Forrest steeply-plunging folds increase the width to 6 km. To the west, the belt is in contact with banded gneiss of the White Cloud gneiss zone, or with foliated syntectonic granitoid. To the east, the belt is intruded by massive or weakly-foliated, post-tectonic granitoid. The belt itself is pervasively injected by granitoid and abundant pegmatite, particularly north of Volprecht Well, where 50 percent or more of any section taken across the belt is granitoid. Metasedimentary rocks make up more than half of the belt itself.

The stratigraphic sequence dips and faces west. The lowermost rocks, on the eastern side of the belt, are quartzite, fuchsite quartzite, and interlayered quartz-muscovite schist. These are overlain by banded iron formation interlayered with ?tuffaceous pelitic rock, metabasalt, and tremolite-chlorite rock (ultramafic komatiitic basalt). The banded iron formation is thickest around Mount Forrest and Mount Richardson. It is generally overlain by up to 1500 m of metabasalt south of the Maynard Hills. Three kilometres north of Mount Alfred, the iron formation is overlain by argillite, cupriferous slate, and amphibolite.

There appears to be a facies change north of the Maynard Hills. The quartzite thins markedly, banded iron formation and metabasalt become minor components of the sequence, and para-amphibolite and pelitic schist make up most of the sequence. Metamorphic grade in the Maynard Hills greenstone belt increases northward, from upper greenschist facies around Mount Forrest to middle amphibolite facies (cordierite-andalusite in pelitic schist) west of Daly Outcamp. The increase in metamorphic grade may have been caused by the abundant granite intruded into that part of the belt. The increase is in contrast to the

the situation in the adjoining White Cloud gneiss zone, where the rocks are at the same metamorphic grade throughout the entire length of the zone, except for the metamorphic grade of retrogressive mylonites adjacent to the greenstone belt.

The major structure in the Maynard Hills belt is a second-generation antiform-synform couple at and east of Mount Forrest. The fold axes plunge steeply to the north. Earlier folds are isoclines and intrafolial folds within the banded iron formation. The antiform-synform pair is S-verging, suggesting sinistral shear along the margins of the greenstone belt. Several sinuous first-generation fold axes lie oblique to the main trend of the belt 3 km west of Kohler Well (Bulga Downs). The flexuring of the fold axes also indicates sinistral movement along the margins of the greenstone belt.

Cook Well greenstone belt

The Cook Well greenstone belt crops out for 120 km across the eastern part of YOUANMI, from Black Hill homestead to Lake Barlee, and extends into SANDSTONE to the north and BARLEE to the south. It averages less than 1 km wide except at Lake Barlee, where it widens to 10 km. From 4 km east-southeast to 17 km south-southeast of White Cloud Bore, the belt consists of a series of synformal keels of banded iron formation entirely surrounded by banded gneiss (Anb). The belt is poorly exposed; from Black Hill homestead to Cabaret Bore it consists of isolated exposures, mostly of foliated metabasalt (Aba) and banded iron formation (Aiw) with a thin quartzite at the base. Solitary outcrops of ultramafic volcanics (Aur) and chlorite schist (Alc) are present near Lake Noondie. South of Cabaret Bore, where the belt reaches 10 km wide, there is a thick mafic and ultramafic sequence of metamorphosed and amygdaloidal basalt (Aba, Aby), komatiitic basalt (Abu), gabbro (Ado), ultramafic intrusions (Aux, Aus, Aup), banded iron formation (Aiw), and chert (Aic).

Dips in the belt are generally steep. North of Black Hill homestead, the dips outline part of a southerly-plunging synform, and 6 km southeast of White Cloud Bore, the banded iron formation is recumbently folded. Another kilometre to the southeast again, tight to isoclinal folds with steep plunges are the only recognisable large folds. Metamorphic grade is upper greenschist facies in the southern part of the belt, and increases northwards to middle amphibolite facies near Black Hill homestead.

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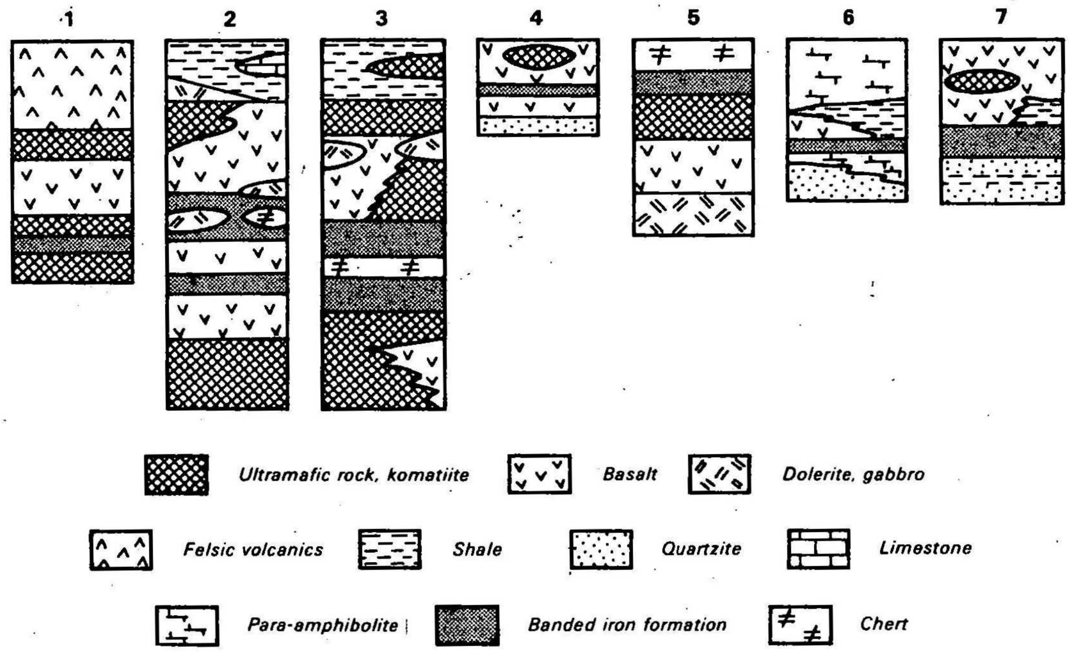

1 **Youanmi greenstone belt**, east of Youanmi Fault. Approximate thickness 2.7 km

2 **Sandstone greenstone belt.** Shale and limestone at top occur only in SANDSTONE. Approximate thickness 5 km

3 **Mount Elvire greenstone belt.** Approximate thickness 1.6 km

4 **Cook Well greenstone belt**, northern part. Approximate thickness 0.6 km

5 **Cook Well greenstone belt**, southern part. Approximate thickness 3 km

6 **Maynard Hills greenstone belt**, northern part. Approximate thickness 1.5 km

7 **Maynard Hills greenstone belt**, southern part. Approximate thickness 3 km

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Fig. 6 Generalised stratigraphic successions through greenstone belts, YOUANMI

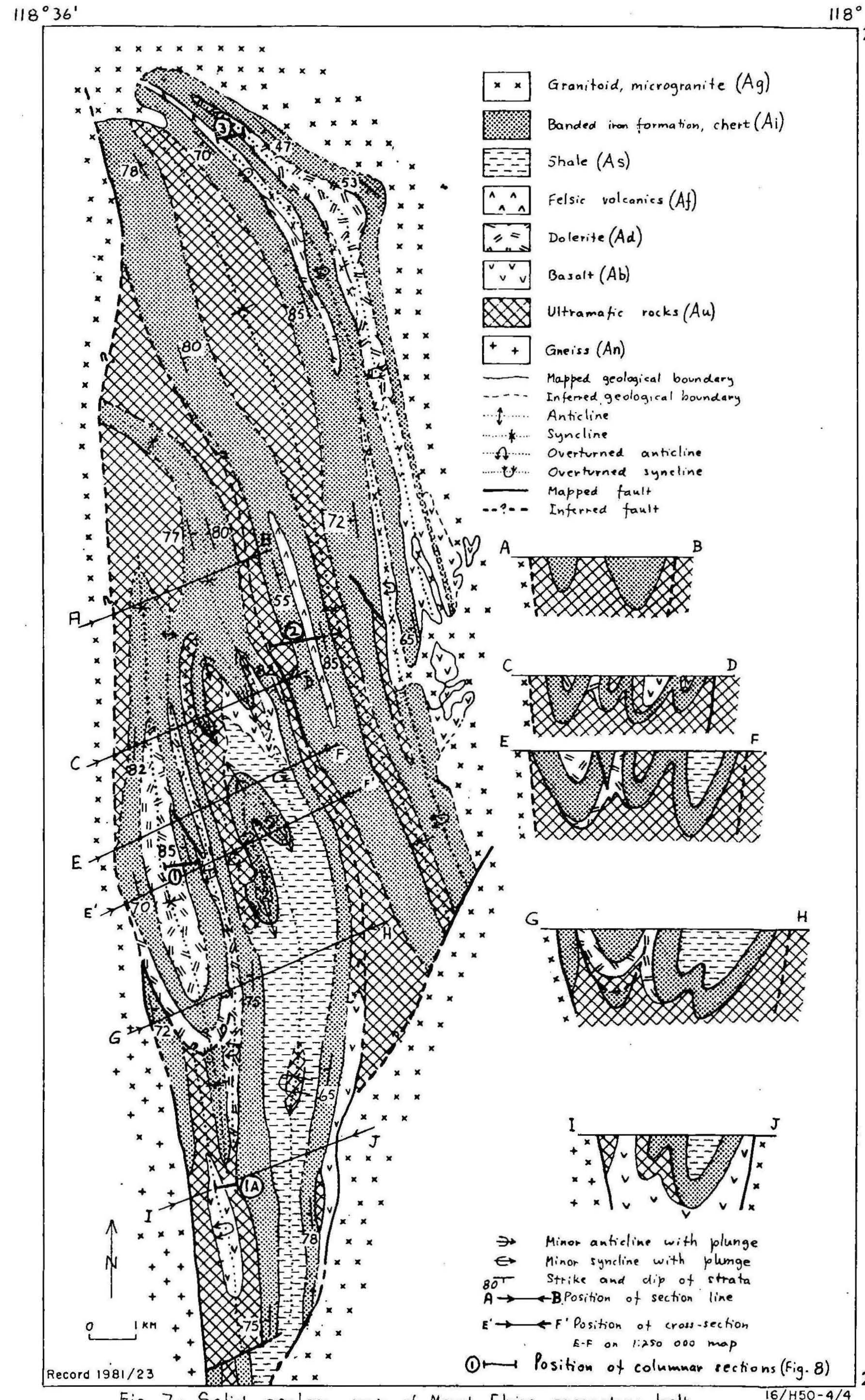

Fig. 7: Solid geology map of Mount Elvire greenstone belt.

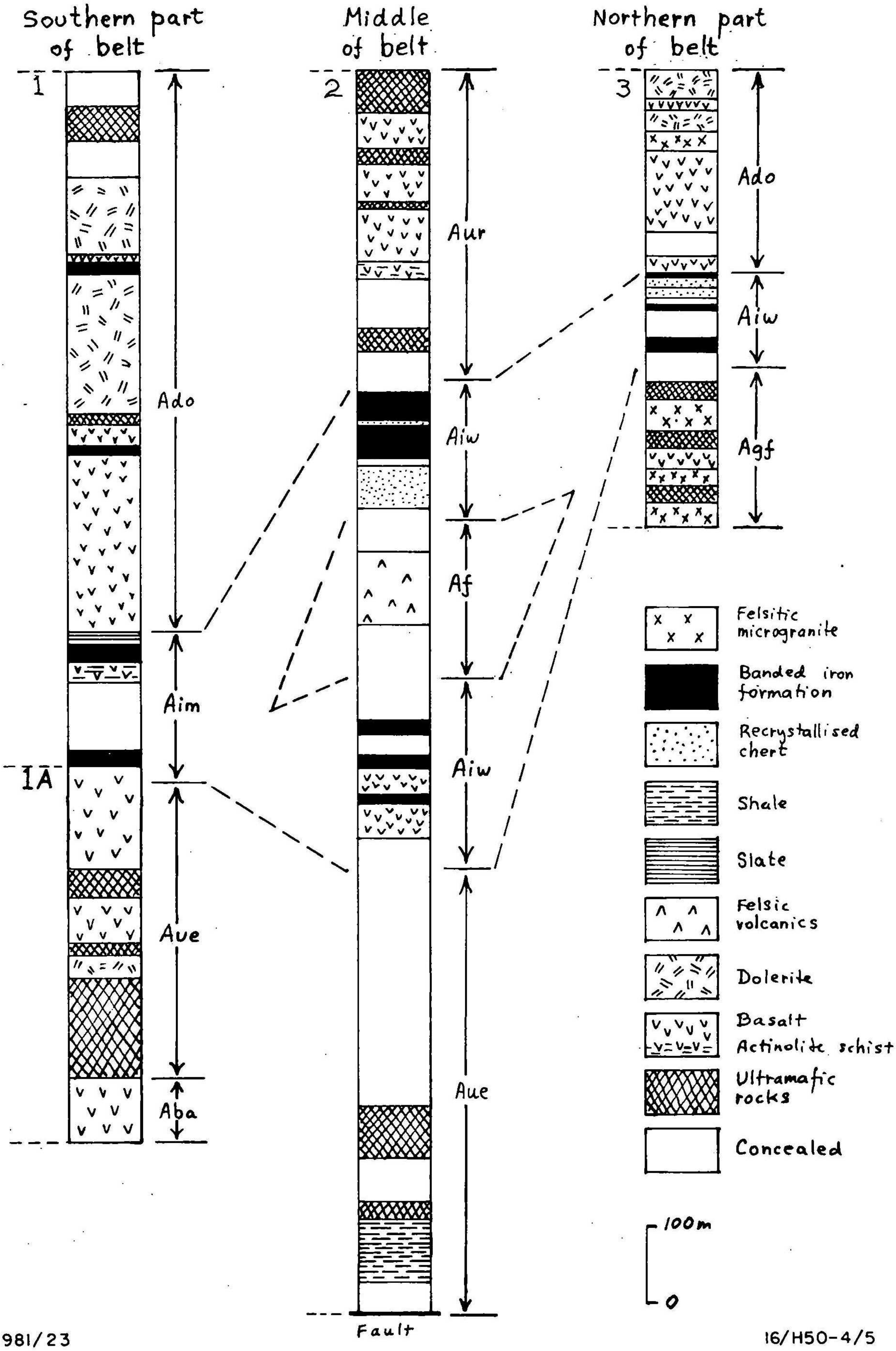

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Fig. 8 : Diagrammatic columnar sections through sequence in Mount Elvire greenstone belt. Thicknesses of individual layers not to scale. Positions of columns shown in Fig. 7.

The proximity of the Cook Well and Maynard Hills greenstone belts, and their similarity of metamorphic grade and lithologic sequence - quartzite at the base followed by banded iron formation, ultramafic, and mafic rocks - indicate that they probably belonged to the one belt, but are now separated by erosion.

Mount Elvire greenstone belt

The Mount Elvire greenstone belt crops out in the southeastern part of YOUANMI, and extends south into BARLEE. It is well exposed, and a solid geology map of the Mount Elvie greenstone belt is presented in Figure 7. The belt comprises two groups of synforms and antiforms, separated by a fault and bounded by faults or intrusive granitoid. The complete greenstone sequence is nowhere preserved. Four diagrammatic sections through the belt are shown in Figure 8. The best exposed, and most complete sequence is near the middle of the belt, and is about 1700 m thick (column 2 in Fig. 8).

The greenstone sequences in the two faulted parts of the belt are similar, though not identical. Both contain only one major group of banded iron formations. In the northern part, the group includes a lens of deeply-weathered quartz-clay rock mapped as a felsic volcanic, and a marker horizon of recrystallised chert which crops out on all of the fold limbs. The chert is absent from the southern part of the belt. Below the banded iron formation group, the sequence in both parts of the belt is mostly ultramafic, generally talc-carbonate assemblages with some serpentinite. In the northern area this interval is extensively intruded by felsite sills. In both parts of the belt, the ultramafic rock is underlain by metabasalt. The sequence above the banded iron formation group includes tholeiitic basalt, komatiitic basalt, and shale with lenses of talc-carbonate rock.

Metamorphic facies is generally greenschist, but assemblages of the low amphibolite facies occur across the central part of the belt, where the two synforms adjoin. Dips are steep to overturned, except at fold hinges. No sedimentary facings were observed, but the sequence is assumed to be upright in the absence of evidence to the contrary. Two phases of folding have taken place. The first formed the major synforms and antiforms with gently plunging axes, and the second formed smaller kink-like folds with vertical axes superimposed on the limbs of the first folds, e.g., 3 km north of Forty Five Bore. The variations in plunge of the axes of the first folds, and the gentle curves in the axial planes of these folds at the northern ends of both major synforms probably formed as a result of a meridional stress component during the first phase of folding.

Youanmi greenstone belt

Eastern portion. The poorly-exposed Youanmi greenstone belt is cut by the Youanmi Fault. The eastern portion is triangular; it is approximately 17 km across in the south and approximately 17 km from south to north. It is bordered by the Yuinmery Fault to the east, and intruded by biotite adamellite (Agb) to the south. The sequence in the eastern part of the belt comprises thick ultramafic rocks (komatiitic basalt, serpentinised peridotite, and serpentine-talc-chlorite-tremolite assemblages) interlayered with thin banded iron formation. It is overlain to the west by amygdaloidal basalt containing well-preserved flow-top breccias, dipping and facing west. Mafic fragmental (pyroclastic) rocks are interlayered with the basalts. Layered gabbro with cumulate textures (part of the Youanmi Intrusion) intrudes this horizon around Fitz Bore and Southern Cross Well.

Overlying the amygdaloidal basalt are tremolite-chlorite rocks, followed by a poorly-exposed, deeply-weathered sequence of felsic pyroclastic rocks, including lithic, vitric, crystal, and lapilli tuffs. The composition of these pyroclastic rocks is difficult to determine because of the deep weathering; originally, they may have been dacitic in composition. Traces of copper have been reported west of Smith Well (Yuinmery copper prospect).

Generally, the metamorphic grade is low (low greenschist facies), and primary textures are preserved, particularly in the felsic volcanics. Higher-grade (low amphibolite) dynamic metamorphism occurred along the eastern margin of the belt next to the Yuinmery Fault.

The regional structure of the eastern part of the Youanmi belt is dominated by a large northerly-plunging synform (syncline) containing the felsic volcanic rocks in the core. A possible northerly-plunging antiform passes through Nine Mile Bore. Both structures are truncated by the Yuinmery and Youanmi Faults.

Western portion. The western portion of the Youanmi greenstone belt comprises two parts separated by the Youanmi Intrusion. The northern part consists of felsic volcanics retrogressively metamorphosed to sericite-quartz schist, banded iron formation, and massive dolerite. The rocks form a gently northerly-plunging antiform, and appear to be truncated by the Youanmi Intrusion to the south. A small body of paragneiss (Anf) crops out at the northern margin, but its contact with the greenstone belt is obscured.

The southern part consists mainly of deeply weathered ultramafic intrusives and felsic volcanics. Gold was obtained from both rock types in the past, and traces of nickel and copper are known also (Youangarra prospect). Unweathered dacitic volcanics and pyroclastics are well exposed at Pincher Hill, and are associated with pyritic chert and freddite (Aiq). The freddite extends west to Freddie Well, and contains zinc sulphide in high concentration but small tonnage (Freddie Well prospect).

Lineations and fold axes at Pincher Hill indicate a doubly-plunging north-south antiform which may have joined the antiform in the north, before being separated by the Youanmi Intrusion. The antiforms complement the synform in the eastern part of the belt.

Unnamed greenstone belts

Two small unnamed greenstone belts occur in the western part of YOUANMI. One greenstone belt, at Paynesville, consists of felsic tuff (Aft) and agglomerate (Afx) that have been intruded by, and occur as roof pendants in the Windimurra Intrusion. They are part of the Kantie Murdanna Volcanics (Baxter & others, 1980). Both the felsic tuff and intrusive gabbro have yielded gold, and also contains copper.

Another small greenstone belt about 1 km wide and 4 km long is situated immediately east of Unaly Hill, 22 km north-northeast of Yuinmery homestead in the western part of YOUANMI. The eastern margin of the belt is a fault contact with banded gneiss. The belt consists of banded iron formation, amygdaloidal basalt, and dolerite, dynamically metamorphosed to medium grade. Many tight Z-verging folds are present in the mafic rocks, and resemble those in the banded gneiss and greenstone 5 km south-southwest of Yuinmery homestead. Hence, the tectonised eastern contact between gneiss and greenstone may be the northern extension of the Yuinmery Fault.

Discussion

The greenstone succession in several parts of the Yilgarn Block has been subdivided into regional stratigraphic units; charts of these schemes are set out in Williams (1975), Hallberg (1976), and Baxter & others (1980). In general, at least four subdivisions are recognised, comprising (from bottom to top) lower mafic, lower sedimentary, upper mafic, and upper sedimentary successions. In contrast to these repetitious successions, however, the YOUANMI greenstone belts appear to be simple, non-repeating successions. They are generally characterised by basal mafic-ultramafic igneous rocks with rare pillow basalt and abundant intercalated banded iron formation, passing upwards into predominantly pelitic sedimentary sequences. Restricted felsic volcanic piles overlie the mafic rocks in places. The YOUANMI greenstone sequences possibly correlate with the lower mafic and sedimentary successions described elsewhere in the Yilgarn Block. The extensive orthoquartzite unit at the base of the mafic succession in the Maynard Hills and Cook Well greenstone belts is the most prominent unit of this lithology found in a lower mafic succession. It suggests that a sialic terrain was exposed for erosion during the deposition of this greenstone belt.

LAYERED MAFIC-ULTRAMAFIC INTRUSIONS

Layered mafic to ultramafic intrusive rocks crop out only in the western part of YOUANMI, and form three large intrusions: (1) the Windimurra Intrusion (Adjw), a large layered body which also crops out in KIRKALOCKA, CUE, and SANDSTONE; (2) a somewhat smaller layered body (Adj) immediately southwest of Youanmi townsite; and (3) a still smaller layered gabbro (Adj) 10 km southwest of Atley homestead.

The Windimurra Intrusion (Adjw) (Ahmat, 1971; de la Hunty, 1973) is about 4000 m thick, and has a total outcrop area of 2120 km^2, of which about 530 km^2 is in YOUANMI (these figures do not include 200 km^2 of overlying felsic volcanics). A formal stratigraphic definition of the Windimurra Intrusion is set out in Appendix 2. The intrusion comprises hundreds of layers, several metres to several tens of metres thick, of gabbro, dolerite, norite, olivine norite, clinopyroxene norite, leucogabbro, leuconorite, olivine leuconorite, melagabbro, hypersthene melagabbro, anorthosite, uralitised pyroxenite, and magnetite rock. Small amounts of gabbro pegmatite, and veins of microdolerite and microdiorite are also regarded as part of the intrusion. Original igneous cumulate textures and minerals are commonly preserved. In some samples, however, the original mafic minerals are partly or completely altered: clinopyroxene has gone to uralitic actinolite; orthopyroxene to tremolite; olivine to a mixture of talc, magnetite, and serpentine; and plagioclase to sericite or clinozoisite. The composition of the unaltered plagioclase (optically estimated from albite twinning) in all the rock-types except microdiorite, falls in the range An_{51} to An_{77} (labradorite to bytownite), and 20 out of the 23 determinations fall between An_{64} and An_{77}. Magnetite

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is a major component of some of the gabbro or dolerite layers, and in places layers up to 3 m thick are composed of 95 percent magnetite. Several such layers, each separated by several metres of gabbro, have been distinguished as subunit $\underline{Adjw}_1$ on the map, and other magnetite layers are exposed 2 km west of Deep Bore and 1.5 km north of Webster Well (Windimurra) where they lie within and just above subunit $\underline{Adjw}_3$. The magnetite contains titanium and vanadium. In a similar magnetite deposit at Barrambie, in SANDSTONE, the titanium occurs as exsolution lamellae and graphic intergrowths of ilmenite in the magnetite, and the vanadium is combined in solid solution in the magnetite and to a lesser extent in the ilmenite (Ward, 1975); the same presumably holds for the Windimurra magnetite.

The Windimurra Intrusion is cut in places by sills and dykes of microdolerite; the dykes generally strike at about 345°. Apart from their grainsize, they are similar to the host gabbro in mineralogical and chemical composition and in metamorphic grade.

Gabbro pegmatite forms pods and layers several metres long, particularly at localities 6 km north and 3 km east-southeast of Deep Bore. The pegmatites contain labradorite, large prismatic single crystals up to 30 cm long of pale green hornblende, and smaller prismatic crystals up to 10 cm long of grey clinopyroxene which is partly replaced by tremolite and brown amphibole.

Microdiorite dykes a metre or so thick also cut the Windimurra Intrusion, and commonly strike parallel to the microdolerite dykes, about 345°. The microdiorites consist almost entirely of andesine or oligoclase (saussuritised), accompanied by accessory chlorite and opaque grains.

Epidosite forms dykes, sills, and pods in many parts of the Intrusion, and is a product of the greenschist retrogressive metamorphism, particularly of plagioclase.

In the Paynesville-Windsor area, coarse-grained layered gabbro of the Windimurra Intrusion intrudes felsic volcanic rocks of the Kantie Murdanna Volcanics (Baxter & others, 1980). Five kilometres southwest of Windimurra homestead, the Intrusion is cut by a granitoid dyke with chilled margins of porphyritic microtonalite; it is also cut in several places by dykes of granite pegmatite, which carry abundant lepidolite, and 1 km southeast of Windimurra homestead, by a dyke of porphyritic microtonalite. The porphyritic dykes have given Rb-Sr whole-rock isotopic dates in excess of 2500 m.y., thus making the Intrusion Archaean in age (A. Ahmat, GSWA, and J. de Laeter, Western Australian Institute of Technology, personal communication, 1980).

The layered intrusion (Adj) southwest of Youanmi townsite is very similar to the Windimurra Intrusion; it has been formally named the Youanmi Intrusion subsequent to the printing of the accompanying map (a formal definition of the Youanmi Intrusion is included in Appendix 2). Rock-types of the Youanmi Intrusion include gabbro, leucogabbro, melagabbro, pyroxenite, and anorthosite. In general, the mafic minerals are completely pseudomorphed by actinolite. Plagioclase compositions range from An_{54} to An_{77}. Unlike the Windimurra Intrusion, olivine is not known in the Youanmi intrusion. Very fine-grained hypersthene microgabbro 1.5 km northwest of Ram Bore, has undergone only slight greenschist metamorphism, which formed intersecting veinlets of actinolite a few millimetres thick. The unaltered microgabbro exhibits a xenomorphic or xenoblastic texture; the grains are equant, have slightly curved boundaries which are commonly concave, and many boundaries meet at 120° triple points.

The Atley intrusion (informal name; Adj), southwest of Atley homestead, is similar to the Windimurra and Youanmi Intrusions described above, and shows rhythmic layering and cumulate texture. The body has a maximum thickness of 4.5 km, and is exposed over a distance of 17 km, a further 13 km of unexposed gabbro to the south is indicated by aeromagnetic data. The compositional layers recognised are gabbro, olivine gabbro, leucogabbro, pyroxenite (completely altered to talc-chlorite-tremolite), anorthosite, and magnetite rock. All the rocks have undergone greenschist facies static metamorphism, but primary igneous textures have generally been preserved.

Chemical analyses for major and trace elements of the Windimurra and Youanmi layered intrusions are set out in Tables 1 and 2 in order of increasing Differentiation Index (normative quartz + orthoclase + albite + nepheline + leucite in weight percent; Thornton & Tuttle, 1960). Variation diagrams of various oxides and trace elements plotted against Differentiation Index (Fig. 9) show considerable scatter, probably arising from the metamorphosed state of the rocks. Nevertheless, the points representing samples from the two intrusions (Windimurra - squares; Youanmi - stars) plot together, consistent with a common origin for the two magmas.

GRANITOID ROCKS

Lithology

Granitoid rocks occupy most of YOUANMI, and are mapped as fine to medium-grained (Age), medium to coarse-grained (Agb), porphyritic (Agl), seriate-textured (Agv), felsitic microgranite (Agf), and mixtures of different

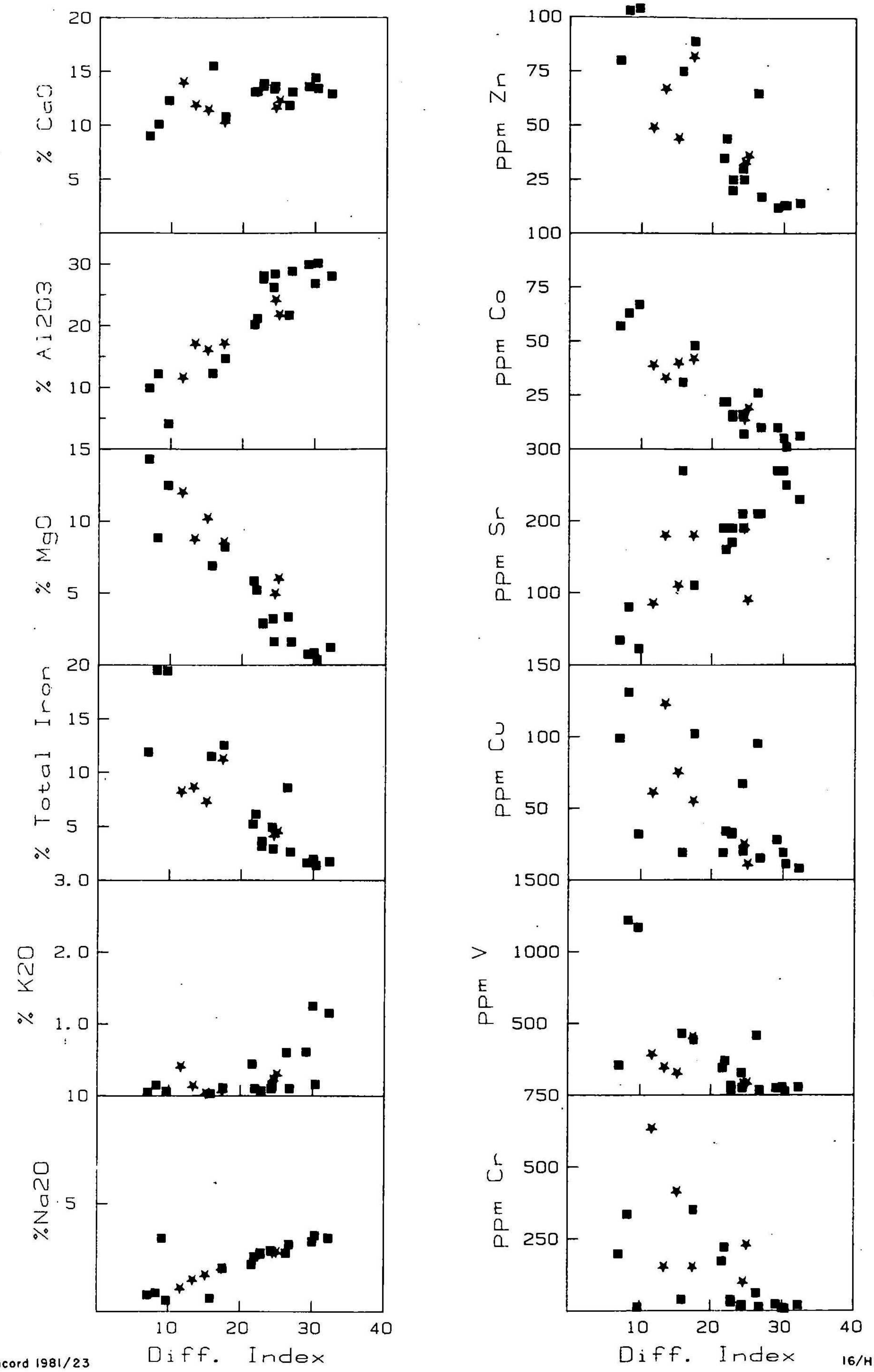

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Fig. 9 Variation diagrams of major oxides (left) and trace elements (right) plotted against Differentiation Index in Windimurra Intrusion (squares) and Youanmi Intrusion (stars)

Table 1: Chemical analyses of Youanmi Intrusion

BMR No.	79110015B	79110022A	79110015D	79110022D	79110016D	70110015F
Diff. index	11.65	13.35	15.13	17.42	24.54	25.04
SiO_2 %	48.7	47.3	49.7	46.6	49.0	50.2
TiO_2	0.57	0.88	0.38	1.69	0.21	0.23
Al_2O_3	11.6	17.1	16.1	17.2	24.2	21.8
Fe_2O_3	2.74	1.80	1.60	2.63	1.20	1.32
FeO	5.75	7.01	5.85	8.86	3.13	3.31
MnO	0.16	0.13	0.13	0.15	0.05	0.08
MgO	12.00	8.75	10.21	8.54	4.95	6.00
CaO	14.00	11.90	11.43	10.35	11.65	12.27
Na_2O	1.09	1.48	1.70	2.01	2.74	2.75
K_2O	0.41	0.14	0.04	0.07	0.23	0.30
P_2O_5	0.02	0.13	0.02	0.09	0.02	0.02
H_2O^+	2.44	2.39	2.18	0.89	1.56	1.59
H_2O^-	0.23	0.24	0.15	0.03	0.42	0.15
CO_2	0.08	0.04	0.07	0.13	0.13	0.08
SO_3	0.03	0.20	0.03	0.05	0.04	0.04
Total	99.8	99.5	99.6	99.3	99.5	100.1
V ppm	285	195	155	405	80	85
Cr	635	153	414	152	100	229
Co	39	33	40	42	14	19
Cu	61	123	75	55	25	11
Zn	49	67	44	82	33	36
Rb	130	11	18	4	75	290
Sr	85	180	110	180	190	90
Y	10	12	6	10	6	36
Zr	8	60	10	75	6	170
Nb	<4	<4	<4	<4	<4	24
Ba	10	130	25	40	30	580
La	20	<20	<20	30	<20	40
Ce	<20	30	<20	30	<20	110
Pb	<2	220	55	8	75	55
Th	10	4	8	4	<4	38
U	<4	<4	<4	<4	<4	6

Analyst: Amdel, Report AC4461/80

Methods: Major elements by X-ray fluorescence and chemical methods. V, Cr, Co, Cu, Zn by atomic absorption spectrophotometry: Rb, Sr, Y, Zr, Nb, Ba, La, Ce, Pb, Th, U by X-ray fluorescence.

		Lat.	Long.
79110015B	Melagabbro	28° 40' 50"	118° 39' 30"
79110022A	Orthopyroxene microgabbro	28° 38' 30"	118° 43' 00"
79110015D	Gabbro	28° 40' 50"	118° 39' 30"
79110022D	Orthopyroxene microgabbro	28° 38' 30"	118° 43' 00"
79110016D	Leucogabbro	28° 43' 00"	118° 39' 30"
79110015F	Leucogabbro	28° 40' 50"	118° 39' 30"

Table 2: Chemical analyses of Windimurra Intrusion

BMR No.	79110073B	79110092A	79110067	79110087	79110061C	79110101
Diff. index	7.04	8.25	9.69	15.80	17.57	21.63
SiO_2 %	48.6	40.9	44.5	49.6	48.3	49.5
TiO_2	0.34	2.40	2.67	0.96	0.96	0.48
Al_2O_3	9.90	12.2	4.10	12.3	14.7	20.2
Fe_2O_3	1.55	8.25	10.14	5.98	3.09	1.40
FeO	10.48	12.06	10.32	6.09	9.75	3.96
MnO	0.03	0.11	0.10	0.11	0.06	0.10
MgO	14.30	8.83	12.48	6.88	8.20	5.83
CaO	9.00	10.10	12.30	15.50	10.8	13.10
Na_2O	0.78	0.87	0.52	0.61	2.00	2.18
K_2O	0.05	0.15	0.06	0.03	0.11	0.44
P_2O_5	0.01	0.02	0.02	0.05	0.04	0.04
H_2O^+	4.31	3.24	2.02	1.91	1.30	2.26
H_2O^-	0.03	0.29	0.13	0.19	0.05	0.29
CO_2	0.13	0.03	0.08	0.05	0.08	<0.02
SO_3	0.03	0.04	0.03	0.02	0.05	0.05
Total	99.5	99.5	99.5	100.3	99.5	99.9
V ppm	210	1220	1170	430	385	190
Cr	198	335	13	39	350	172
Co	57	63	67	31	48	22
Cu	99	131	32	19	102	19
Zn	80	103	104	75	89	35
Rb	2	4	4	7	3	170
Sr	34	80	22	270	110	190
Y	4	8	12	12	12	14
Zr	6	18	22	36	22	32
Nb	<4	<4	<4	<4	<4	<4
Ba	<10	35	<10	<10	35	65
La	20	<20	<20	<20	<20	<20
Ce	<20	<20	<20	<20	<20	<20
Pb	2	36	<2	<2	<2	2
Th	6	<4	<4	<4	4	<4
U	<4	4	<4	<4	<4	<4

Analyst: Amdel, Report AC4461/80. Methods: as for Table 1.

	Lat.	Long.
79110073B Pyroxenite	28°26'05"	118°30'50"
79110092A Pyroxenite	28°30'45"	118°30'50"
79110067 Pyroxenite	28°24'00"	118°33'20"
79110087 Melagabbro	28°31'00"	118°31'45"
79110061C Pyroxenite	28°18'15"	118°30'35"
79110101 Leucogabbro	28°32'30"	118°34'15"

Table 2 continued

BMR No.	79110079C	79110073D	79110058G	79110079B	79110057C	79110061A
Diff. Index	22.00	22.84	22.87	24.29	24.43	26.39
SiO_2 %	48.5	48.2	47.7	47.6	48.5	46.4
TiO_2	0.89	0.16	0.16	0.53	0.24	1.29
Al_2O_3	21.2	27.6	28.1	26.2	28.4	21.7
Fe_2O_3	1.54	1.06	0.85	1.27	0.97	3.03
FeO	4.75	2.20	2.87	3.78	2.04	5.85
MuO	0.09	0.04	0.04	0.05	0.03	0.12
MgO	5.19	2.91	2.86	3.20	1.61	3.33
CaO	13.14	13.64	13.89	13.36	13.60	11.82
Na_2O	2.53	2.65	2.71	2.82	2.79	2.70
K_2O	0.10	0.07	0.06	0.10	0.13	0.60
P_2O_5	0.03	0.02	0.02	0.06	0.04	0.04
H_2O^+	1.31	1.38	0.65	0.87	0.80	2.04
H_2O^-	0.16	0.07	<0.01	0.14	0.11	0.07
CO_2	<0.02	0.13	0.10	0.10	0.21	0.17
SO_3	0.06	0.04	0.04	0.05	0.04	0.10
Total	99.5	100.2	100.0	100.1	99.5	99.3
V ppm	155	65	40	155	50	415
Cr	220	38	30	14	20	61
Co	22	15	16	16	7	26
Cu	34	32	33	67	20	95
Zn	44	20	25	30	25	65
Rb	4	2	<2	14	5	18
Sr	160	170	190	210	190	210
Y	8	<4	6	6	4	8
Zr	26	<4	6	20	14	24
Nb	<4	<4	<4	<4	<4	<4
Ba	40	10	<10	25	30	120
La	20	<20	<20	<20	20	<20
Ce	<20	<20	<20	<20	<20	<20
Pb	<2	<2	<2	<2	2	<2
Th	<4	<4	<4	<4	4	<4
U	<4	<4	<4	<4	<4	<4

	Lat.	Long.
79110079C Gabbro	28°28'00"	118°35'15"
79110073D Gabbro	28°26'05"	118°30'50"
79110058G Gabbro	28°17'40"	118°33'25"
79110079B Gabbro	28°28'00"	118°35'15"
79110057C Leucogabbro	28°17'10"	118°32'50"
79110061A Gabbro	28°18'15"	118°30'35"

Table 2 continued

BMR No.	79110073C	79110079A	79110091A	79110062A	79110085C
Diff. Index	26.82	29.10	30.02	30.41	32.29
SiO_2	48.2	48.0	47.2	49.4	48.7
TiO_2	0.10	0.37	0.18	0.12	0.20
Al_2O_3	28.8	29.9	26.8	30.1	28.0
Fe_2O_3	1.42	0.90	1.54	0.92	0.63
FeO	1.35	0.82	0.59	0.55	1.16
MnO	0.03	0.02	0.04	0.01	0.02
MgO	1.59	0.74	0.85	0.36	1.20
CaO	13.07	13.57	14.40	13.40	12.90
Na_2O	3.10	3.40	3.23	3.52	3.40
K_2O	0.10	0.61	1.25	0.16	1.15
P_2O_5	0.02	0.06	0.02	0.04	0.03
H_2O^+	1.66	1.57	3.38	0.70	1.98
H_2O^-	0.15	0.30	0.21	<0.01	0.06
CO_2	0.20	0.03	0.15	0.09	0.14
SO_3	0.05	0.02	0.03	0.02	0.04
Total	99.8	100.3	99.9	99.4	99.6
V ppm	35	50	55	25	55
Cr	13	23	10	7	20
Co	10	10	5	1	6
Cu	15	28	19	11	8
Zn	17	12	13	13	14
Rb	2	210	400	<2	520
Sr	210	270	270	250	230
Y	<4	<4	<4	4	4
Zr	<4	26	6	18	4
Nb	<4	<4	<4	<4	<4
Ba	30	140	190	20	200
Lu	<20	<20	<20	<20	30
Ce	<20	<20	<20	<20	<20
Pb	<2	<2	9	<2	<2
Th	4	<4	<4	<4	4
U	<4	<4	<4	<4	<4

	Lat.	Long.
79110073C Leucogabbro	28°26'05"	118°30'50"
79110079A Anorthosite	28°28'00"	118°35'15"
79110091A Anorthosite	28°30'55"	118°31'15"
79110062A Anorthosite	28°20'25"	118°31'30"
79110085C Anorthosite	28°31'30"	118°32'45"

granites (Agm). Deeply weathered granitoid which cannot be assigned to any of these categories is denoted by Ag. The contacts between different granitoids indicate that their order of emplacement differed from place to place. The granitoids range from massive to foliated; the foliation arises from alignment of biotite flakes, and from flattening of quartz and feldspar grains to ovoids or lenticles. The areas of strongly foliated granitoid are denoted by a wavy screen on the accompanying map.

All the granitoids are composed of microcline, plagioclase (commonly zoned), quartz (usually partly or wholly recrystallised), and biotite or chlorite. Muscovite, zircon, apatite, sphene, allanite, epidote and opaque grains are common accessories; hornblende was noted in only three samples. Rare veinlets of quartz and epidote, ranging in strike from 040° to 070°, cut all the granitoids, and are flanked by zones of reddened granitoid several centimetres wide.

The most abundant granitoid in YOUANMI is the medium to coarse-grained Agb. Its composition ranges from granite to granodiorite (all biotite-bearing), with adamellite the most abundant and granite the least. The grainsize differs from place to place, and seriate-textured patches a few metres in extent are common. Phenocrysts of microcline are uncommon, and mantled feldspars rare. Pegmatite and aplite veins, and masses are numerous; greisen, however, was observed at only a few localities in the western part of YOUANMI. The Agb granitoids are almost everywhere deformed and foliated to some extent, and slightly retrogressively metamorphosed; plagioclase is sericitised, biotite partly or completely chloritised, and quartz recrystallised to a fine-grained polygonal mosaic. Epidote and prehnite are present in some samples. Lineated hornblende-biotite granodiorite forms a large body between Atley homestead and Jew Well, and massive hornblende granodiorite and tonalite grading westward to quartz diorite form a small body 13 km west of Yuinmery homestead.

Fine to medium-grained biotite granodiorite (Age), forms discrete plutons up to 25 km across, and contains coarse sphene as an abundant accessory. The large pluton between Yuinmery homestead and Eighteen Mile Bore is intruded by coarse-grained Agb at Noondie, but the smaller Age plutons at Cashmere Downs homestead and 4 km southwest of Mitchell Well, intrude Agb and Agl (Fig. 10).

Seriate-textured biotite adamellite (Agv) consists of a mixture of fine to coarse-crystals, and is a textural variant of Agb; it forms several bodies up to 20 km across, and many small occurrences a few metres across. It is generally weakly foliated, and contains abundant pegmatite.

Porphyritic granite (Agl) is characterised by tabular euhedral phenocrysts of microcline up to 6 cm long (Fig. 10). Pegmatite dykes are numerous in this unit.

Sheets of grey felsitic microgranite (Agf) crop out on the eastern side of the Mount Elvire greenstone belt. The rock is generally very fine-grained to aphanitic, massive to weakly foliated, and is composed of microcline, quartz, muscovite, and biotite. In places it coarsens aplite or pegmatite. The microgranite generally forms sills up to 5 km long in the greenstone sequence, but 3.5 km southwest of Matris Bore one sheet cuts the greenstone sequence at a slight angle.

Mixed granitoids (Agm) have been observed at Noondie, Horse Fall Rocks, and at localities northeast of Daly Outcamp. Three granitoids are present at Noondie: dark fine-grained granodiorite Age, which forms large xenoliths in medium-grained foliated granodiorite Agb; and dykes of seriate-textured medium to coarse-grained Agv granitoid, which cut both Age and Agb. Large xenoliths of granodiorite orthogneiss (Anl) are also present in the Agb component at Noondie, and show the older foliation and younger fracture or strain-slip cleavage typical of the Yuinmery gneiss zone. The host Agb shows only a weak foliation. At Horse Fall Rocks, medium to coarse foliated granodiorite (Agb) with augen texture encloses large xenoliths of banded gneiss (Anb); numerous veins and masses of pegmatite and aplite are also present. Ten kilometres northeast of Daly Outcamp, several small but prominent hills are composed of coarse seriate granitoid and are cut by veins of muscovite-biotite microgranodiorite ranging from 10 cm to 20 m wide.

The distribution of the granitoids in YOUANMI can be summarised in terms of three zones -

Western zone (west of the Youanmi Fault)

The Western Zone contains all the major varieties of granitoid observed in YOUANMI, including the only exposures of the porphyritic adamellite (Agl). The medium to coarse-grained Agb is generally massive in the north, but foliated along the margins of the greenstone belts and in the southern part of the zone. A very coarse-grained, stongly-foliated body extends from Yagar to Jones Bore, in the centre of the zone. This body commonly shows a moderately-strong augen texture, with ovoid feldspars wrapped by films of oriented biotite. Aplite veins, schlieren, and lenticular biotitic xenoliths are obliquely cut by the foliation in the host granitoid. Four kilometres southeast of Palagea Rock-

50

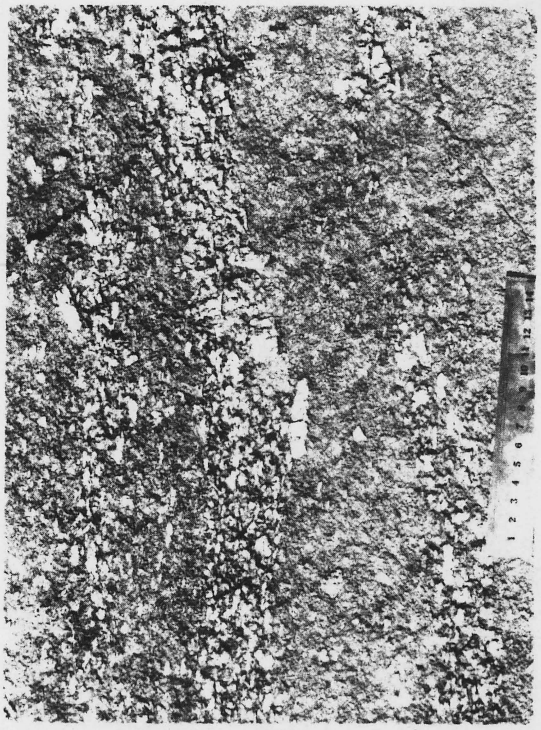

Fig. 10 — Fine-grained granodiorite **(Age)** intruding and disrupting porphyritic granite **(Agl)**. Lat. 28°34′15″S, long. 118°40′35″E. Scale is 15 cm long.

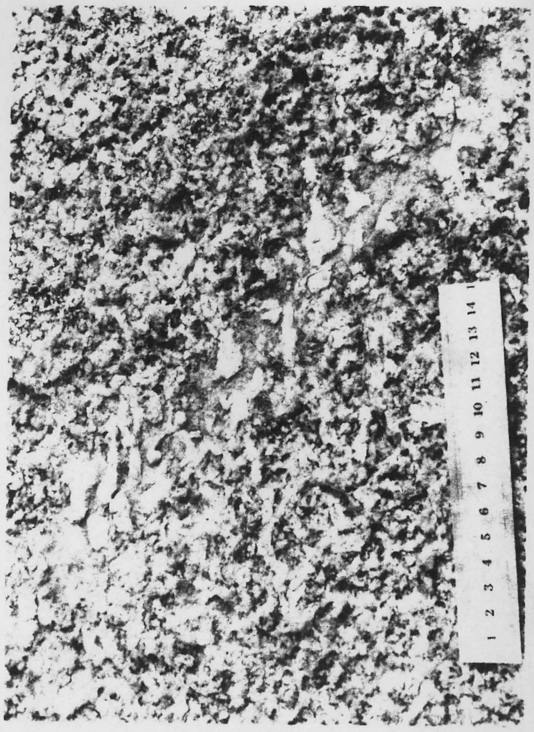

Fig. 11 — Foliated porphyritic granite **(Agl)** obliquely cut by aplite vein containing megacrysts of microcline arranged epitaxially on phenocrysts in host granite. Lat. 28°37′25″S, long. 118°38′25″E. Scale is 15 cm long.

Fig. 12 — Porphyritic adamellite **(Agl)** containing orientated microcline phenocrysts and a lenticular xenolith (top left), cut by pegmatite vein in which the microcline grains are orientated subparallel to the foliation. Lat. 28°25′00″S, long. 118°41′40″E. Scale is 15 cm long.

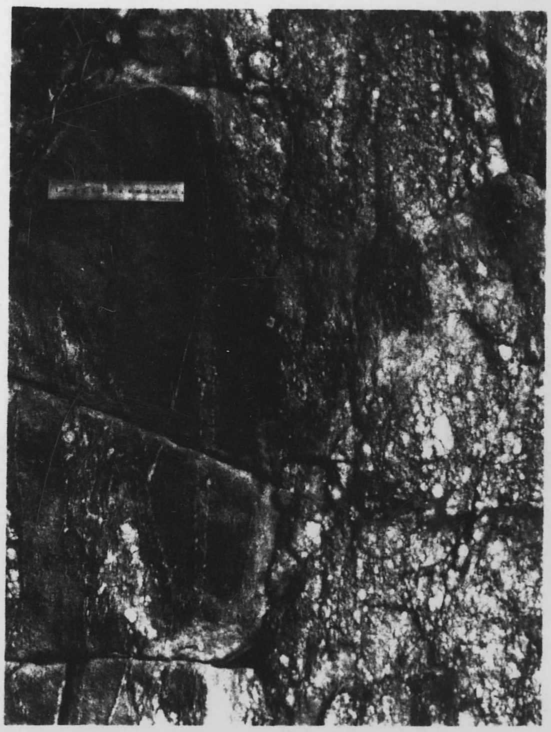

Fig. 13 — Fine-grained granodiorite **(Age)** intruded by pegmatite, the two then folded and foliated together. Lat. 28°58′30″S, long. 119°36′20″E. Scale is 15 cm long.

holes, the foliated granitoid is cut by a fracture cleavage of strongly oriented biotite which strikes 345°, oblique to the long axes of the feldspar augen.

Porphyritic adamellite (Agl) forms four discrete plutons in the western zone. The microcline phenocrysts of the porphyritic adamellite show parallel alignment, which in the southernmost pluton (see the Precambrian Geology Interpretation figure on the accompanying map) appears to be a magmatic platy flow structure (the phenocrysts are aligned, whereas the coarse groundmass is massive). The next pluton to the north, around Bungarrow Bore, has a weak foliation defined by the aligned phenocrysts and the parallel alignment of biotite flakes in the groundmass. This foliation cuts through numerous biotite schlieren, some of which are marginal to or completely surround the lenticular masses of granite pegmatite. At one locality, an aplite vein oblique to the platy parallelism of the microcline phenocrysts shows epitaxial outgrowths of microcline; these outgrowths grew on the surfaces of those microcline phenocrysts cut by the walls of the vein (Fig. 11). The small pluton 1 km west of Yalinga Bore contains lenticular biotitic xenoliths, some of which are oblique to the platy parallelism of the surrounding porphyritic adamellite. However, these xenoliths contain biotite flakes and small subhedral porphyroblasts of feldspar which are themselves aligned with the platy parallelism of the surrounding adamellite. Moreover, microcline crystals in a cross-cutting pegmatite vein are also oriented parallel to the biotite and feldspar alignment in the adamellite, and oblique to the walls of the vein (fig. 12). Hence, in these areas at least, the platy parallelism of the microcline tablets in the adamellite appears to be tectonic in origin. The northernmost body of porphyritic adamellite, 3 km west of Thomson Bore, is also tectonically foliated.

Fine to medium-grained massive granodiorite (Age) forms several plutons in the western zone; several well exposed contacts show that they intrude Agl and Agb, and were the last granitoids emplaced in this area.

Central zone (between the Youanmi Fault and the Edale Fault)

The Central zone is the largest of the three zones, and consists chiefly of coarse-grained sparsely-porphyritic foliated adamellite and granodiorite (Agb). Blue-grey lineated hornblende-biotite granodiorite forms a distinctive body between Atley homestead and Jew Well. A separate lobate pluton of Agb intrudes the southern part of the Yuinmery gneiss zone. Some contacts, for example those along the southern margin of the Sandstone greenstone belt, are intrusive and unsheared. Rafts of greenstone occur within the granite, e.g. northeast of Hayes Well, and a stockwork of metabasalt rafts separated by granite dykes occurs along the eastern margin of the Mount Elvire greenstone belt. Other contacts are strongly sheared, with coplanar fabrics in the granitic rock and the adjacent gneiss or greenstone. Lenticular xenoliths are abundant, and include biotite-rich schist and schlieren, banded gneiss derived from the Anb terrain, rare amphibolite, and microgranodiorite (Age). Biotite in the xenoliths is oriented parallel to biotite in the surrounding granitoid; pegmatite veins have a coarse fracture cleavage that also parallels the biotite orientation. The foliation is clearly tectonic; it is particularly strong in a central and steeply dipping meridional zone about 20 km wide that extends from Cashmere Downs to the Sandstone greenstone belt. This zone of strong foliation includes seven enclaves of banded gneiss Anb and orthogneiss Anl. The foliation dips less-steeply to the east and west away from the meridional zone, suggesting a northerly-plunging domal structure.

Massive unrecrystallised adamellite of the coarse even-grained (Agb) and seriate varieties (Agv) occurs in the eastern part of the Central Zone; it intrudes the foliated granodiorite, and was magmatically emplaced after the foliated granitoids forming the bulk of the Zone.

The Central Zone includes several plutons of fine to medium-grained biotite granodiorite (Age). The largest of these plutons crop out between Yuinmery homestead and Eighteen Mile Bore, and contains indistinct ovoid feldspar poikiloblasts and abundant accessory sphene. Quartz is recrystallised, but the rock is not strongly deformed. Pegmatite dykes and biotitic schlieren are common. The southern margin of this pluton is intruded by coarse granitoid Agb at Noondie, and xenoliths of microgranodiorite of the Age type occur in the coarse granitoid between Noondie and Cashmere Downs homestead. In contrast, the Age granite pluton at Cashmere Downs homestead intrudes the neighbouring coarse Agb granitoid. The Age pluton contains strongly-oriented biotite flakes which define a foliation that cuts obliquely through xenoliths, schlieren, and folded and cleaved pegmatite veins (Fig. 13); in the pegmatite veins, the foliation is parallel to the axial plane of the folds. Xenoliths are disrupted and extensively boudinaged. The small body of Age on the eastern side of the Mount Elvire greenstone belt contains no xenoliths or schlieren.

Eastern zone (east of the Edale Fault)

The Eastern Zone is the smallest of the three zones, and consists entirely to medium of coarse-grained adamellite (Agb) and seriate-textured adamellite (Agv). Both types are massive, except along the margins of the Maynard Hills greenstone belt, where there is a tectonically foliated zone 1-2 km wide. Two lobate plutons of strongly foliated Agb intrude the southern and northern parts of the White Cloud gneiss zone. The northwestern contact of the main Agb body with the White Cloud gneiss zone is transitional; homogeneous adamellite passes westward into nebulitically-banded granitoid, annealed gneiss, and then into orthogneiss of the gneiss zone.

Chemistry

Results of major and trace element analyses of nine YOUANMI granitoids are shown in Table 3. On a $CaO-Na_2O-K_2O$ variation diagram (Fig. 14), the samples lie on a calc-alkaline trend from tonalite to adamellite. Three of the granitoids are dykes cutting the mafic rocks of the Windimurra Intrusion, and lie at the tonalitic end of the trend. The calc-alkaline trend of the granitoids in SIR SAMUEL (Bunting & Williams, 1979) is shown for comparison, together with some average granitoid compositions from Nockolds (1954). As in SIR SAMUEL, the YOUANMI granitoids are more sodic and less calcic than average granitoids. The S-I indices (mol $Al_2O_3/(Na_2O + K_2O + CaO$ less the CaO contained in the normative apatite); Chappell & White, 1974) of all the YOUANMI granitoids are less than 1.1, suggesting that the granitoids were derived from pre-existing igneous rock. The five adamellites from YOUANMI that were analysed have high Rb/Sr ratios, and contain above-average amounts of Rb, Ba, Pb, Th, and U (Table 4), which indicate an origin by anatexis of a sialic parent (Glikson, 1979). The exposures of banded gneiss that were disrupted by gneissic granodiorite mobilisate 3 km north of, and at Horse Fall Rocks (in the centre of the domal structure of the Central Zone), may be one such zone of anatexis.

TABLE 3: Chemical analyses of YOUANMI granitoids

BMR No.	79110090	79110114B	79110105	79110064A	79110053B
Diff. index	68.75	77.57	81.78	84.34	85.58
S.I. index	1.07	0.98	0.96	1.07	0.99
SiO_2 %	69.4	68.7	70.2	70.1	71.1
TiO_2	0.37	0.49	0.31	0.30	0.34
Al_2O_3	15.2	15.5	14.9	15.0	14.2
Fe_2O_3	0.95	1.04	0.96	1.34	1.03
FeO	2.48	1.77	1.12	0.67	1.14
MnO	0.03	0.03	0.02	0.03	0.02
MgO	1.50	1.10	0.82	0.71	0.64
CaO	4.07	3.18	2.75	2.02	1.83
Na_2O	4.12	5.08	5.04	5.03	4.16
K_2O	0.16	1.87	2.30	2.23	3.95
P_2O_5	0.10	0.18	0.10	0.12	0.10
H_2O^+	1.57	0.41	0.59	1.25	0.63
H_2O^-	0.23	0.16	0.16	0.07	0.16
CO_2	0.08	0.05	0.16	0.49	0.05
SO_3	0.04	<0.01	0.03	0.04	0.05
Total	100.3	99.6	99.5	99.4	99.4
V ppm	45	40	20	25	25
Cr	16	13	10	7	7
Co	7	4	4	2	<1
Cu	15	21	8	6	26
Zn	41	60	40	41	56
Rb	18	70	65	55	180
Sr	190	360	540	500	200
Y	10	6	6	8	14
Zr	170	230	150	140	240
Nb	6	4	4	<4	18
Ba	100	470	780	780	820
La	40	40	20	30	70
Ce	110	70	60	50	150
Pb	5	14	18	22	34
Th	16	10	14	14	38
U	4	<4	4	4	<4

Analyst: Amdel, Report AN4461/80. Methods: as for Table 1.

	Lat.	Long.
79110090 Microtonalite dyke	28°30'55"	118°31'15"
79110114B Tonalite xenolith	28°51'00"	119°23'00"
79110105 Microtonalite dyke	28°20'00"	118°33'20"
79110064A Tonalite dyke	28°21'20"	118°30'35"
79110053B Adamellite	28°26'40"	118°37'05"

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Table 3 continued

BMR No.	79110052	79110021	79110056	79110055
Diff. index	86.06	87.99	90.89	91.70
S.I. index	1.08	1.03	1.03	1.05
SiO_2 %	70.9	73.2	73.4	73.3
TiO_2	0.38	0.27	0.18	0.18
Al_2O_3	14.1	13.1	13.7	13.4
Fe_2O_3	1.15	0.91	0.80	0.75
FeO	1.35	1.18	0.47	0.84
MnO	0.04	0.04	0.02	0.02
MgO	0.66	0.58	0.29	0.24
CaO	1.41	1.23	1.02	0.79
Na_2O	4.12	3.53	4.15	3.37
K_2O	3.89	4.41	4.29	5.50
P_2O_5	0.18	0.05	0.05	0.07
H_2O^+	1.18	0.80	0.79	0.93
H_2O^-	0.19	0.17	0.12	0.07
CO_2	<0.02	<0.02	<0.02	0.06
SO_3	0.03	0.04	0.02	0.02
Total	99.6	99.5	99.3	99.5
V ppm	25	45	15	5
Cr	9	11	4	4
Co	2	5	<1	<1
Cu	12	19	7	6
Zn	62	38	38	38
Rb	190	60	220	200
Sr	220	150	140	110
Y	26	4	26	26
Zr	340	6	120	180
Nb	20	<4	18	10
Ba	1050	40	560	840
La	90	<20	40	60
Ce	150	20	50	130
Pb	65	12	34	50
Th	48	4	24	50
U	12	<4	4	20

	Lat.	Long.
79110052 Adamellite	28°24'55"	118°41'45"
79110021 Adamellite	28°38'00"	118°33'30"
79110056 Adamellite	28°20'25"	118°40'25"
79110055 Adamellite	28°16'35"	118°43'30"

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Table: 4 - Average amounts of large ion lithophile elements in five adamellites from YOUANMI, and in crustal granite and granodiorite

ELEMENT	YOUANMI ADAMELLITES	AVERAGE GRANODIORITE	AVERAGE GRANITE
Rb	170	120	150
Zr	177	140	180
Ba	662	500	600
Pb	39	15	20
Th	33	10	17
U	8	3	4.8
Rb/Sr	1.11	0.27	0.53

References: Turekian & Wedepohl (1961) and Taylor (1965).

ORTHOSCHIST, MYLONITE, AND EPIDOSITE

Retrogressively metamorphosed and sheared igneous rock (Aor) has been mapped in the northern part of the Youanmi Fault 15 km north-northeast of Atley homestead, and in the prominent north-northeasterly-striking fault in the Windimurra Intrusion. The retrogressed rocks include mylonitic sericite-quartz orthoschist, intensely sheared and partly recrystallised granodioritic gneiss, and schistose amphibolite. In the Windimurra Intrusion, the fault is marked by a prominent ridge of sericite-chlorite-andalusite-quartz orthoschist accompanied by a lesser amount of plagioclase-chlorite-quartz orthoschist. The quartz grains in these schists are large and embayed, and contain fluid inclusions with moving bubbles. The quartzose schists are flanked by fine-grained green actinolite schist and chlorite schist, which away from the fault pass into coarse-grained, sheared, uralitised gabbro.

Mylonite bordered by strongly-foliated gneiss fills the northern part of the Edale Fault 5 km west of Black Hill homestead; the mylonite is brown, green, grey, or black, and cherty in appearance. The southern parts of the Edale and Youanmi Faults are marked by prominent ridges of white vein quartz, commonly brecciated and recemented, and bordered by a few metres of sericite-

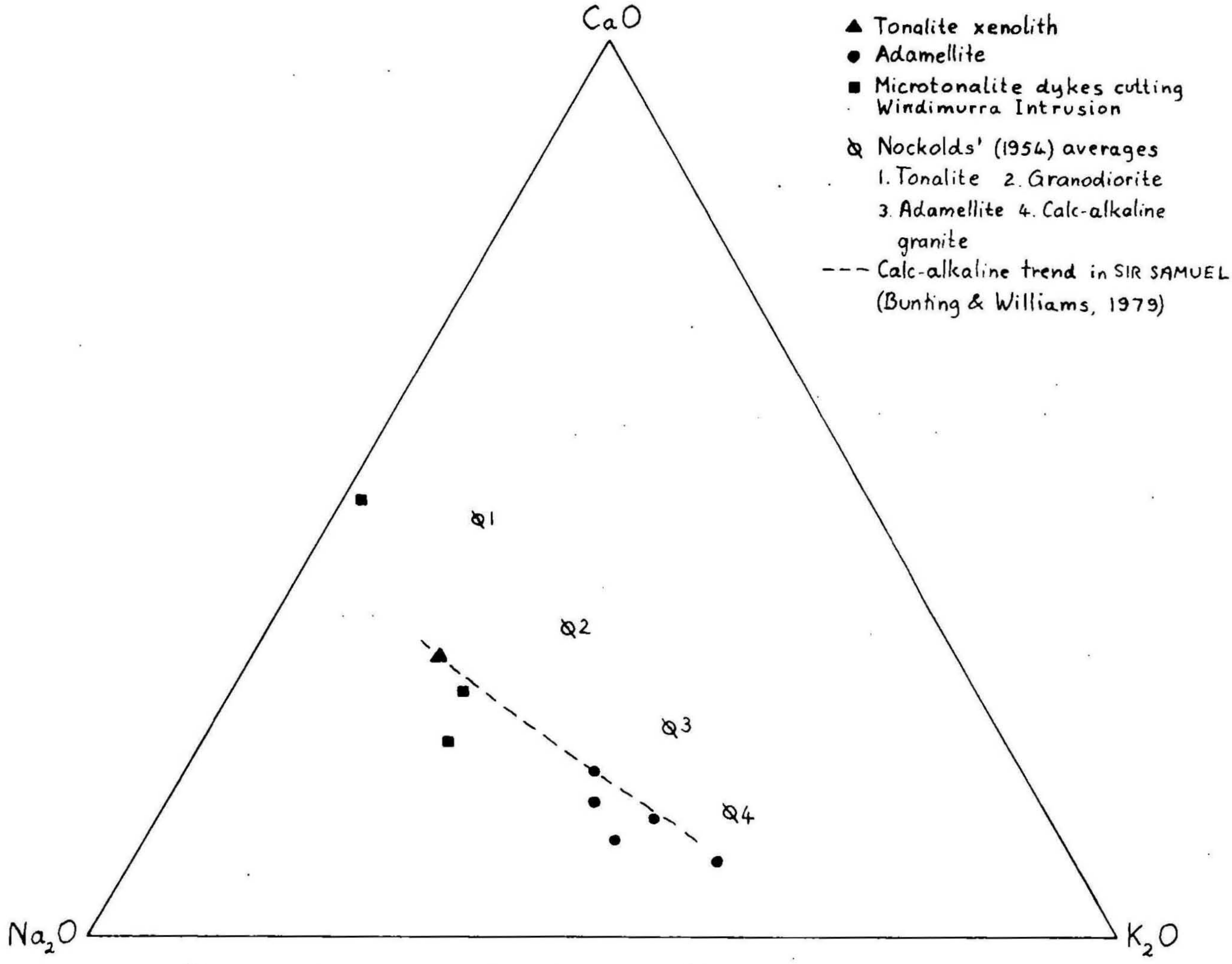

Fig. 14 Chemical variation diagram of **YOUANMI** granitoids

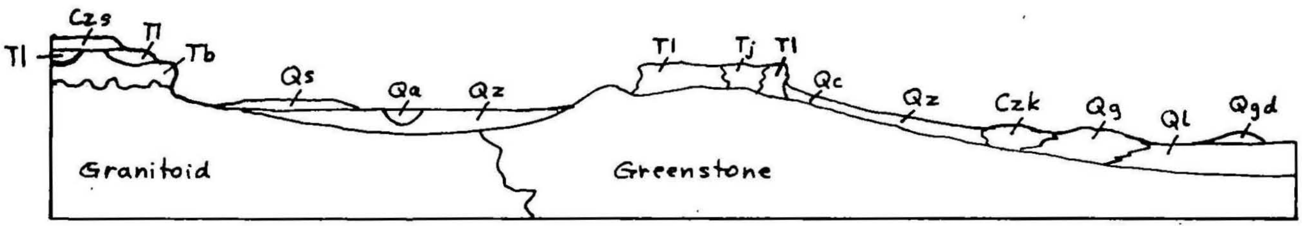

Fig. 15 - Cainozoic rock unit relationships, **YOUANMI**. Rock unit symbols as in reference on accompanying map.

quartz schist on either side. A thin laminated mylonite occurs along the Yuinmery Fault between the Yuinmery gneiss zone and the Youanmi greenstone belt.

Rare epidosite veinlets fill joints in the gneiss terrain, layered gabbro intrusions, granitoids, and dolerite dykes. The veinlets range in strike from 040° to 070°, and probably originated during deuteric alteration of the granitoid and dolerite bodies.

ARCHAEAN OR PROTEROZOIC ROCKS

Post-granite mafic dykes

Dolerite dykes, a few metres wide and striking about 075°, cut granitoids and greenstones in the western and northeastern parts of YOUANMI. Several plugs up to 300 m across occur along a line trending 115° from Sandstone to Mount Holmes. The mafic body at Mount Holmes itself is a flat-lying dolerite sheet capped by granite. The dyke-rocks are fine-grained, massive, and generally only slightly altered. They commonly consist of olivine (fresh, or partly-to-completely pseudomorphed by talc + magnetite ± serpentine), clino-pyroxene, orthopyroxene, and labradorite. Calcite and serpentine are accessory in some samples, and one sample contains a very fine-grained mesostasis of quartz + alkali feldspar + sericite. The labradorite in one sample is veined by chlorite. Some samples lack olivine and orthopyroxene, and are composed of augite, labradorite, and magnetite; the augite is partly or completely replaced by chlorite and actinolite. One olivine-free rock contains a micrographic intergrowth of quartz + alkali feldspar, and is cut by veinlets of epidosite.

CAINOZOIC ROCKS

Cainozoic deposits cover much of YOUANMI. Their stratigraphic relationships are shown in Figure 15.

Tertiary and undifferentiated

Ferricrete or laterite (Tl) occurs as brown pisolitic limonite overlying silcrete on granite or gneiss, or as red-brown or black massive hematitic rock over mafic greenstone. It is most extensive in the Sandstone, Windimurra, Youanmi, and Cook Well greenstone belts. In the granitoid and gneiss terrains, it passes up into thickly-vegetated yellow sandplain with limonite pisoliths (Czs). The sandplain is a residual deposit, formed by weathering of the pisolitic ferricrete. It covers large parts of YOUANMI and is continually undergoing aeolian reworking and dune formation.

Duricrust (Tb) denotes undifferentiated weathering products on granitoid or gneissic terrain. It ranges from partly silicified kaolinised rock to completely silicified rock, or silcrete, and includes a thin layer of nodular or pisolitic laterite above the silcrete.

Jasperoidal chalcedony (Tj) and siliceous limonite cap ultramafic rock, from which they formed during weathering. Magnesite nodules commonly accompany the chalcedony. The unit is most abundant in the southern part of the Sandstone greenstone belt.

Calcrete (Czk) up to 8 m thick has been deposited from groundwater in the lower reaches of the larger drainage channels, particularly on the northern margin of Lake Noondie. According to Mann & Horwitz (1979), the calcrete is deposited at or below the water table when the solubility of calcite is exceeded, following concentration of groundwater by evaporation and evapotranspiration. Subsequently, the calcrete may be partly silicified to chalcedony, and may also act as a site for precipitation of the uranium mineral, carnotite.

Quaternary

Mixed colluvium and alluvium (Qz) about 1 m thick is the most extensive of the superficial deposits in YOUANMI, and forms broad mulga-covered plains overlying a pebbly-clay hardpan. The unit is pale yellow-brown over granitic rocks, and dark red-brown or mauve-brown over greenstones. Near areas of exposed bedrock, ferricrete, or siliceous duricrust, the unit grades into coarse, gravelly colluvium and scree (Qc); along the major drainage channels to Lake Noondie, it passes into active alluvium (Qa) with dense mulga.

The salt or playa lake areas have three types of associated Quaternary deposits. The lakes themselves are filled with alluvial mud and clay (Ql) (up to 50 m thick in boreholes), accompanied by halite and gypsum; after heavy rain, a thin sheet of water may cover their surfaces. A mixed unit (Qg) comprising silt, clay, and gravel in clay pans and red-brown to white sand in dunes, occurs along the margins of the playa lakes. Dunes (Qgd), consisting mostly of gypsum and red clayey sand derived from the lake and lake margin sediments, overlie the lake sediments.

Aeolian sand (Qs), characterised by a cover of spinifex and eucalypts, overlies granitic terrain in the northern and eastern parts of YOUANMI.

STRUCTURE

The structure of the YOUANMI map-area is dominated by two major faults, the Youanmi Fault in the west and the Edale Fault in the east (see Interpretation of Precambrian Geology map). These faults extend across the Sheet area, and continue into adjoining areas to the north and south. The Yuinmery Fault branches off the Youanmi Fault. Other faults are present along the eastern side of the Windimurra Intrusion, the southern side of the western segment of the Youanmi greenstone belt, and beside and within the Mount Elvire greenstone belt. The offset segments of the Youanmi greenstone belt indicate that about 15 km of left-lateral strike-slip movement occurred along the Youanmi Fault. A segment of White Cloud gneiss zone centred about 30 km southeast of Bulga Downs homestead, together with the small ultramafic outcrop of the Cook Well greenstone belt at the northern end of the gneiss segment, indicate that about 8 km of right-lateral strike-slip movement occurred along the Edale Fault. Hence, the two faults are a conjugate pair of first order wrench faults (Moody & Hill, 1956), which formed in response to principal comprehensive stress directed north-south.

The absence of the Youanmi greenstone belt on the eastern side of the Yuinmery Fault suggests upward movement of the Yuimery gneiss zone. Hence the Yuinmery Fault is probably a high-angle reverse fault, and this is supported by the gently north-plunging, Z-verging folds in the gneiss adjacent to the fault 5 km south-southwest of Yuinmery homestead. However, small-scale right-lateral wrench faults striking northeasterly in banded gneiss 4 km west-southwest of Yuinmery homestead, and rotated microcline augen indicating right-lateral shear in gneiss 5 km north-northwest of Jay Bore, suggest that a small amount of strike-slip movement subsequently took place along the Yuinmery Fault during the later wrench-faulting that formed the Youanmi and Edale Faults. The closely-spaced northwesterly-striking fracture cleavage in the banded gneiss of the Yuinmery-Noondie area probably formed during the strike-slip movement also.

Most dolerite dykes in YOUANMI strike about 070°, but a few strike at about 110°, including the line of dolerite plugs between Sandstone and Mount Holmes. The line of plugs is not offset by the Edale Fault, indicating that intrusion of the dolerite took place after first-order wrench faulting had ceased. The two strike directions of the dolerites are parallel to the second-

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order wrench fault directions of the Youanmi-Edale Fault system, and it is possible that these incipient fault directions opened up during rebound of the region following relaxation of the meridional compression, thereby allowing ingress of mafic magma.

The Mount Elvire greenstone belt is divided into two parts by a major north-northwesterly-striking fault that parallels the Edale Fault. Although the sequences in the two parts are similar (Fig. 8) there are sufficient differences to suggest that the two sequences have been juxtaposed from originally more widely separate locations. These differences include the presence only in the northern sequence of recrystallised chert, chert-pebble conglomerate, and acid volcanic rock, and, in contrast, the presence of shale only in the southern sequence. Hence, the fault dividing the two parts of the belt may be a strike-slip fault. If the two parts were originally a single longitudinal belt, the suggested displacement is about 20 km (right-lateral). The faults along the margins of the Mount Elvire belt are probably dip-slip faults.

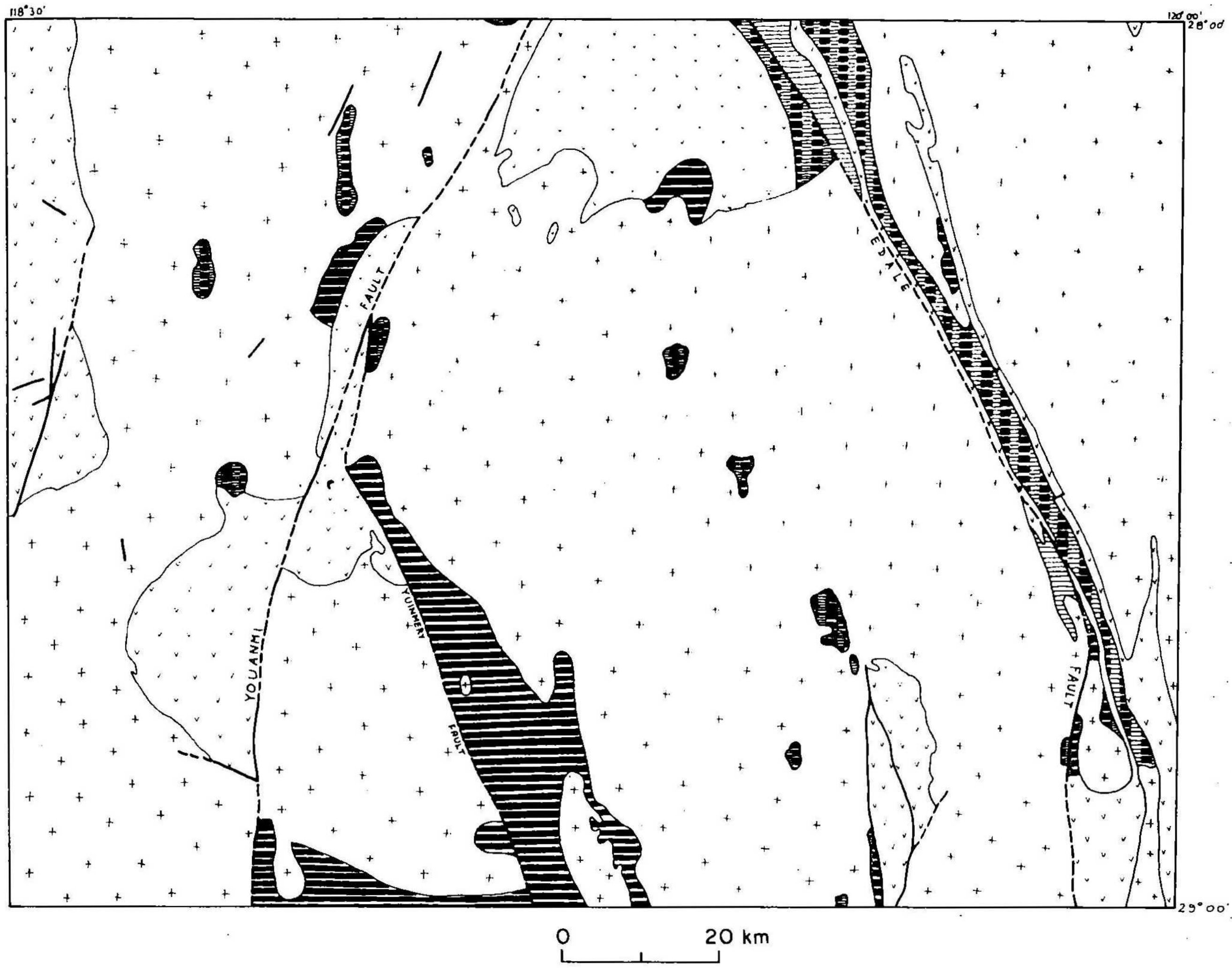
The north-northeasterly-striking fault along the eastern margin of the layered Windimurra Intrusion separates a small eastern segment, in which the layering strikes east-northeasterly, from the main part of the Intrusion, where the layering strikes in a northerly direction. Analysis on a stereographic projection of the difference in attitude of the layering indicates that the eastern segment tilted 50° downward to the north. The north-northeasterly-striking zone of strongly foliated granitoid between the Windimurra Intrusion near Yagar and the Youanmi Fault near Jones Bore may be a zone of shearing across which the tilting gradually died out.

METAMORPHISM

Metamorphic mineral assemblages in all thin-sectioned samples from YOUANMI were assigned to the very low (prehnite-pumpellyite and lower green-schist facies), low (middle and upper greenschist), medium (lower and middle amphibolite), and high grade (middle and upper amphibolite) domains defined for the Yilgarn Block by Binns & others (1975). The results are shown in Figures 16 and 17.

Gneiss zones

The gneiss zones in YOUANMI have been affected by two episodes of regional metamorphism. The first was a medium to high-grade progressive episode



Granitoid

Greenstone and layered mafic intrusions

High grade

High or medium grade (mineral assemblages compatible with either domain) } metamorphic domains

Medium grade

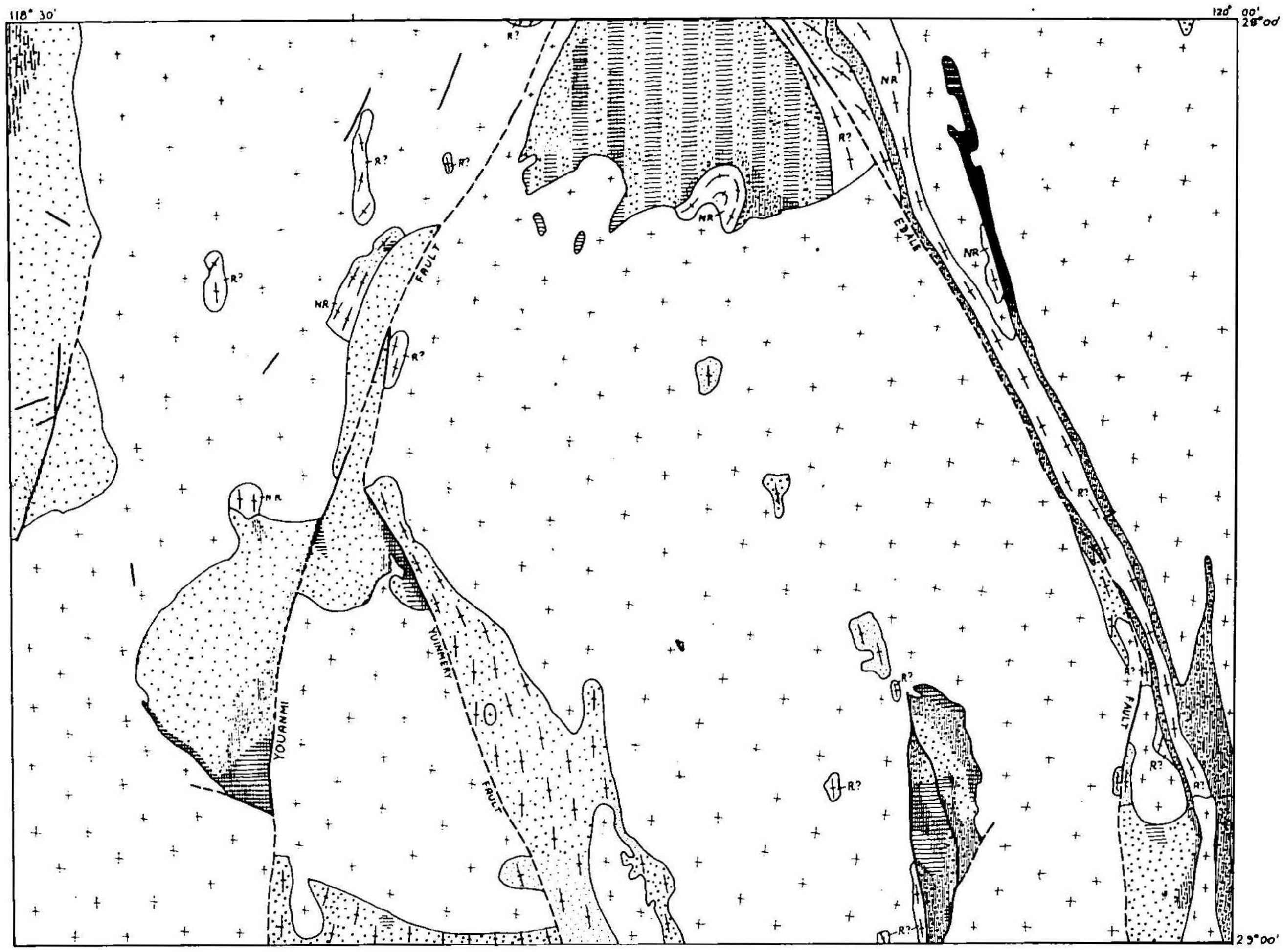
Geological boundary

Fault (dashed where inferred)

NOMENCLATURE OF DOMAINS FOLLOWS BINNS & OTHERS (1975), AND DOES NOT CORRESPOND TO CLASSIFICATION OF WINKLER (1979)

Record 1981/23 16/H50-4/9

Fig. 16 Metamorphic map of YOUANMI, showing prograde domains in gneiss zone.



Granitoid		NR	Not retrograded
High grade	metamorphic domain	R?	No information on retrograde effects
Medium grade		——	Geological boundary
Low grade		——	Fault (dashed where inferred)
Very low grade			Dynamic style domain (absence indicates static style domain)
Gneiss zone			

NOMENCLATURE OF DOMAINS FOLLOWS BINNS & OTHERS (1975) AND DOES NOT CORRESPOND TO CLASSIFICATION OF WINKLER (1979)

Record 1981/23 16/H50-4/10

Fig. 17 Metamorphic map of YOUANMI, showing prograde domains in greenstone belts and layered mafic intrusions, and retrograde domains in gneiss zones

(Fig. 16), and the second was a low-grade retrogressive episode (Fig. 17). The progressive metamorphism formed the biotite-quartz-feldspar assemblage found in the bulk of the gneisses, pyroxene-amphibole-plagioclase in amphibolite (Ana), and (pyroxene)-amphibole-magnetite-quartz in banded iron formation (Ani). In general, the mineral assemblage of most of the gneisses is compatible with medium or high grades of Binns & others (1975), but where more diagnostic rock-types are present, such as amphibolite or banded iron formation, a more positive assignment can be made. Thus, the presence of clinopyroxene in these rock types indicates that the Yuinmery and Thomson Bore gneiss zones, the gneiss dome 5 km southeast of Dandaraga homestead, and the small outcrop 7 km west of Daly Outcamp are all high grade. In contrast, oligoclase in banded gneiss at the northwestern end of the White Cloud gneiss zone suggests that this zone is medium grade.

Effects of the later retrograde metamorphism are widespread, but incomplete. Most samples of gneiss contain streaks and patches of epidote, sericite, chlorite, and rare prehnite; hornblende surrounds pyroxene in amphibolite. The rocks are generally only partly affected by the retrogression, but amphibolite in the ultramafic outcrop (Anu) 10 km east of Rainy Bore consists wholly of retrogressive minerals (actinolite-andesine-quartz-sphene). While recognising that, except for that one Anu outcrop, reconstitution of the gneisses is far from complete, and that chemical equilibrium was not attained during the retrogression, the retrograde minerals do indicate apparent metamorphic grades; these grades are depicted in Figure 17. The presence of epidote and chlorite in the gneisses suggests that most of the retrograde metamorphism took place under conditions transitional from very low to low grade. Where biotite has altered to chlorite, the rocks are assigned to the very low grade domain, but where biotite is unaltered they are assigned to the low grade domain. Occurrences of chlorite and prehnite in gneiss near White Well and Edale Bore clearly indicate very low grade metamorphism in those areas. Two outcrops of amphibolite, one in the Thomson Bore gneiss zone the other 10 km east of Rainy Bore, show retrogression of clinopyroxene to hornblende, i.e. high grade to medium grade, whereas the enclosing gneiss shows retrogression of biotite to chlorite, plagioclase to epidote, and clinopyroxene to epidote, i.e. high or medium grade to low grade. The apparent contradiction in metamorphic grades may be a further indication of lack of attainment of equilibrium during the retrogressive metamorphism.

Greenstone belts and layered mafic-ultramafic intrusions

In contrast to the gneiss zones, the greenstone belts and layered mafic-ultramafic intrusions (Fig. 17) show evidence of only one episode of regional metamorphism, generally of low grade. One very low grade assemblage (stilpnomelane-epidote-actinolite) was recorded from the southwestern corner of the Sandstone greenstone belt. Medium grade metamorphic areas are known in the mainly ultramafic regions of both portions of the faulted YOUANMI greenstone belt, in several parts of the Mount Elvire belt, and in the southern part of the Cook Well belt. High grade assemblages are present only at the northern end of the Maynard Hills greenstone belt, in pelitic rocks containing andalusite, cordierite, and garnet. The abundance of iron-amphibole in banded iron formation in the Sandstone belt indicates medium grade for much of the belt, although actinolitic amphibole on both eastern and western margins indicates low grade (perhaps retrogression) in those areas. The layered mafic-ultramafic intrusions at Windimurra, Youanmi, and Atley are largely unmetamorphosed, but where they are, the assemblages are of low grade. As noted by Binns & others (1975), many samples of the metamorphosed gabbroids show complete retrogression of pyroxene to uralitic amphibole, whereas the plagioclase is unaffected. Binns & others concluded that such rocks had not passed through an early phase of very low grade alteration, but formed their low grade assemblage directly, once peak metamorphic temperatures had become established.

Binns & others (1975) also introduced the concept of static and dynamic metamorphic styles in the Yilgarn Block. The static style is represented by preservation of primary textures and structures, and lack of preferred mineral orientation. The dynamic style is characterised by penetrative foliation and/or lineation. The areas showing the two styles in YOUANMI (compiled from field notes) are shown in Figure 17; the static style is present in the layered mafic intrusions and in the wider parts of greenstone belts, whereas the dynamic style occurs beside and along major faults, and in the narrow, tightly-folded greenstone belts, the two styles do not appear to correlate well with the metamorphic grade, although in the YOUNAMI belt the medium grade areas are dynamic (schistose) whereas the low grade eastern portion of the belt is static. The Cook Well and Maynard Hills belts are dynamic and mainly low grade, except for the high grade portion at the northern end of the Maynard Hills belt; the Sandstone belt has a low or medium grade, largely static interior, but low grade dynamic (schistose) margins. The Mount Elvire belt has a mixture of low grade, both static and dynamic, and medium grade, both static and dynamic, metamorphic assemblages.

Granitoids

Secondary minerals are present in nearly every sample of granitoid collected in YOUANMI, and include sericite, epidote, chlorite, and rare prehnite. The existence of chlorite and prehnite indicates very low grade alteration, in contrast to the gneiss zones, where biotite is commonly unaltered. The secondary minerals in the granitoids are probably of metamorphic origin, and were formed during the emplacement of the granitoids.

MINERAL OCCURRENCES

GOLD

About 27 t of gold (approximately a 1.1 m cube) has been produced from mines in and around YOUANMI. Nearly half of this gold came from the Sandstone area and another third from the Youanmi area (Table 5). In the Sandstone greenstone belt, host rocks for the gold include: vein quartz in amphibolite at Bellchambers mine; ultramafic rocks in the Nungarra area; basalt, dolerite, and banded iron formation in the Sandstone, Maninga Marley, and Hancocks areas; basalt and chert at Raffertys Patch; and quartz veins in komatiitic basalt around Six Mile Bore. At Youanmi, the gold was in quartz veins in sheared felsic volcanics, tuff, and banded iron formation; at Currans, in serpentinised peridotite; at Paynesville, in quartz veins in felsic tuff; and at Windsor Castle, in quartz veins in mylonised gabbro. All the mines are now abandoned (Youanmi was the last to close, in 1947), but alluvial prospecting using metal detectors continues intermittently in the Sandstone area, particularly around Six Mile Well.

BASE METALS

Base-metal occurrences in YOUANMI are classified according to the scheme of Marston (1979).

Type A: Stratabound mineralisation in supracrustal rocks

(i) Deposits in medium to high-grade metamorphic rocks

Copper minerals have been recorded from at least ten localities in YOUANMI, but there has been no production. The most promising occurrences are

Table 5. Summary of reported gold production, in and around YOUANMI

GOLDFIELD	DISTRICT	LOCALITY	ALLUVIAL (kg)	DOLLIED (kg)	ORE TREATED (t)	GOLD RE-COVERED (kg)	AVERAGE GRADE (g/t)	TOTAL GOLD RECOVERED (kg)
		Sandstone	1.612	194.526	731 781.93	14 381.503	19.652	14 577.641
		Youanmi	0.044	4.532	749 594.83	8 575.217	11.439	8 579.793
		Maninga Marley	-	10.991	64 938.74	1 563.340	24.074	1 574.331
EAST MURCHISON	BLACK RANGE	Hancocks	0.131	221.178	43 013.43	1 240.809	28.847	1 462.118
		Nungarra	2.370	75.000	17 815.77	206.361	11.583	283.731
		Currans	0.567	7.846	9 512.02	122.668	12.828	131.081
		Bellchambers	-	3.477	5 620.84	114.725	20.410	118.202
MURCHISON	MT. MAGNET	Paynesville (including Windsor)	0.105	66.983	1 395.38	77.398	55.467	144.486
			4.829	584.533	1 623 672.94	26 282.021	16.187	26 871.383

the Freddie Well prospect, 20 km southwest of Youanmi, and a similar prospect at Pincher Hill, 15 km south of Youanmi. At Freddie Well (Marston, 1979), thin horizons of fine to medium-grained sulphide-quartz rock (freddite) are contained in sericite-quartz schist intruded by granitoid and by layered gabbro. The sulphides include pyrrhotite, cobaltiferous pyrite, sphalerite, and chalcopyrite, and make up to 50 percent of the freddite in places. Exploration has indicated resources of 500 000 t averaging 10 percent Zn and 0.25 percent Cu.

At Pincher Hill, beds of chert, freddite, and banded iron formation crop out in annular fashion around a dome of metamorphosed acid volcanics, mainly chloritised dacitic lapilli tuff. Pyrite is common in the siliceous beds and volcanic rocks, whereas sphalerite forms local concentrations (Sargeant, 1978).

Freddite also occurs at the contact of dolerite and a dyke of tonalite aplite 2 km west-northwest of Youanmi Downs homestead. Exposures of freddite in the Cooliboo Bore-Stone Tank Bore area do not appear to have been prospected.

The Yuinmery copper prospect (lat. 28°35'00"S, long. 118°54'35"E; Marston, 1979) is associated with similar rocks to those of the Pincher Hill zinc prospect; these rocks comprise disseminated pyrite-pyrrhotite-magnetite-chalcopyrite in metamorphosed chert, banded iron formation, and felsic pyroclastic rocks, overlying tholeiitic metabasalt and intruded by gabbro and granophyre. Thin zones of massive iron sulphide are also present. The deposit is low-grade, and mineralised intersections (up to 26 m) usually average less than 1 percent Cu; a 1.3 m intersection in chert and banded iron formation assayed 3.5 percent Cu and 910 ppm Zn.

(ii) Deposits in metasedimentary rocks unrelated to felsic volcanism

The Mount Alfred prospect (28°49'40"S, 119°59'05"E; Marston, 1979) occurs in chlorite-feldspar-quartz schist, slate, chert, banded iron formation, and mafic meta-igneous rocks. Thin malachite-chlorite schist assays up to 19 percent Cu, and is associated with pyritic siltstone and magnesite, both assaying up to 4 percent Cu. The occurrence is small, supergene, and not economic.

Type C: Cupriferous quartz veins and shears

The Fitz Bore prospect (28°37'25"S, 118°54'00"E: Marston, 1979) is a malachite-stained quartz vein in a shear zone in metagabbro. One drillhole intersected 0.3 m of 0.7 percent Cu. A similar occurrence is located at Windsor Castle gold mine, and a third, containing azurite as well, at the northeastern end of Lake Barlee, 8 km south of The Stock Well.

Hallberg & others (1976) record chalcopyrite and galena in quartz veins cutting banded iron formation and 'acid sediments' (presumably siltstone and shale) at Sandstone.

Type E: Copper-nickel mineralisation in gabbroid complexes.

The Youangarra (or Curran Well) prospect (28°48'55"S, 118°45'30"E; Marston, 1979) comprises copper-nickel gossans in a gabbro-pyroxenite body intruding metasedimentary rocks. One drillhole encountered 8.18 m at 0.62 percent Cu and 0.33 percent Ni.

NICKEL

Ultramafic rocks in Youanmi have been extensively investigated by exploration companies, and were found to contain normal background amounts of nickel but no economic concentrations.

URANIUM

Calcrete and playa lake sediments at the northwestern end of Lake Noondie, the northeastern end of Lake Barlee, and the Paynesville, Stag Well, Yalgoo Well, and Sandie Well areas contain up to 400 ppm uranium as carnotite, but no economic deposits have been found.

IRON

Tabular beds of hematite in the Brooking Hills are up to 700 m long and 70 m wide, and assuming a depth of 30 m, resources are estimated at 3 000 000 t at 60 percent Fe (Harwood, 1967). Farther north, Connolly (1959) described a lens of hematite on the west side of Mount Richardson with estimated resources of 230 000 t at 67 percent Fe. In the banded iron formations of the general region around Mount Richardson and Mount Forrest, Connolly (1959) indicated iron ore resources of abour 60 000 000 t 37 percent Fe.

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VANADIUM

Magnetite seams in the Windimurra Intrusion between Recruit Flats and Canegrass Well contain up to 0.43 percent V_2O_5 (Marlow, 1974), but no economic deposits have been located. Similarly uneconomic seams of vanadiferous magnetite are present in the Youanmi Intrusion. Magnetite segregations in the Atley intrusion between Unaly Hill and 5 km north of Victory Bore (Atley) are currently being investigated.

ARSENIC

Soils in the Red Knob-Volprecht Well area contain up to 80 ppm As, and the underlying mafic igneous rocks, sediments, and calcrete contain up to 3000 ppm As. Between Middle Well and Daly Outcamp, the soil contains up to 57 ppm As, and coincides with a ridge of ferruginous chert containing up to 210 ppm As (Stevens, 1976).

ECONOMIC POTENTIAL

The most prospective metals in YOUANMI appear to be uranium, zinc, and gold. The 1:2500 000 contour map of radioactivity published by BMR in 1972* shows that the most radioactive area - over 300 counts per second compared to an average of 100 or less for the entire area - coincides with calcrete and playa lake sediments overlying the body of massive fine-grained granodiorite (Age) between Yuinmery homestead and Eighteen Mile Bore. The radioactivity may derive ultimately from the abundant sphene in the granodiorite. The playa sediments and calcrete were being prospected during 1979, other areas of calcrete, at Youanme Well, and between Old Station Bore and Miller Bore show no anomalous radioactivity. Slightly anomalous granitoid areas (about 250 cps) which may be prospective for uranium include the areas of Agb granitoid at Four Corners Well (Dandaraga), the Age granitoid around Midway Bore (Youangarra), and two bodies of porphyitic granitoid Agl, one between Bungarrow Bore and Wyemandoo Well, the other at Yalinga Bore. An analysed sample of granitoid from Yalinga Bore

* Radiometric data for the map were obtained from an airborne inboard twin crystal MEL scintillometer with a sensitivity of 50 c.p.s., using a time constant of 10 seconds at an altitude of 150 m (Gerdes & others, 1970).

contains 12 ppm U. In contrast, the analysed granitoid with the greatest uranium content, 20 ppm, is coarse-grained Agb from 5 km southwest of Mitchell Well, in an area which shows no particularly anomalous radioactivity (100-150 cps).

The Pincher Hill zinc prospect was being explored during 1979, but results were not available at the time of writing (March 1981). A sample of pyritic metadacite from the northern end of Pincher Hill contained 880 ppm Pb, 130 ppm Zn, and 620 ppm Zr.

All the greenstone belts are prospective for gold, but the known distribution and production suggest that the mafic-ultramafic rocks of the Sandstone belt, and the felsic volcanics and sediments of the Youanmi belt are the most prospective. Coarse alluvial gold of the Sandstone district has been found in recent years by prospectors using metal detectors, but this technique has had much less success with the finer-grained gold of the Youanmi area.

Ultramafic rocks between Mount Klempz and Nungarra in the Sandstone greenstone belt, and between Nine Mile Bore and Little Well in the eastern part of the Youanmi belt, do not appear to have been prospected for nickel. However, the absence of high nickel values in other ultramafic areas in YOUANMI, and the location of YOUANMI outside the zone of known major nickel deposits (which is situated east of the Mount Ida Lineament in the neighbouring LEONORA and SIR SAMUEL areas), reduces the prospectivity of the untested ultramafics.

WATER RESOURCES

Because of the low rainfall in YOUANMI, groundwater is the main source of water for pastoral and domestic use. The salinity of the water in most of the bores and wells was measured during the 1979 field season, and the results are shown in Figure 18. The least saline water, generally containing less than 3000 mg (total dissolved solids)/l occurs farthest from the salt lakes in shallow aquifers in colluvium and alluvium on or near the watersheds particularly over granitic terrain. Water from aquifers near or over greenstones contains up to 5000 mg/l, and in localised areas 9000 mg/l. Calcrete aquifers yield water containing up to 13 000 mg/l.

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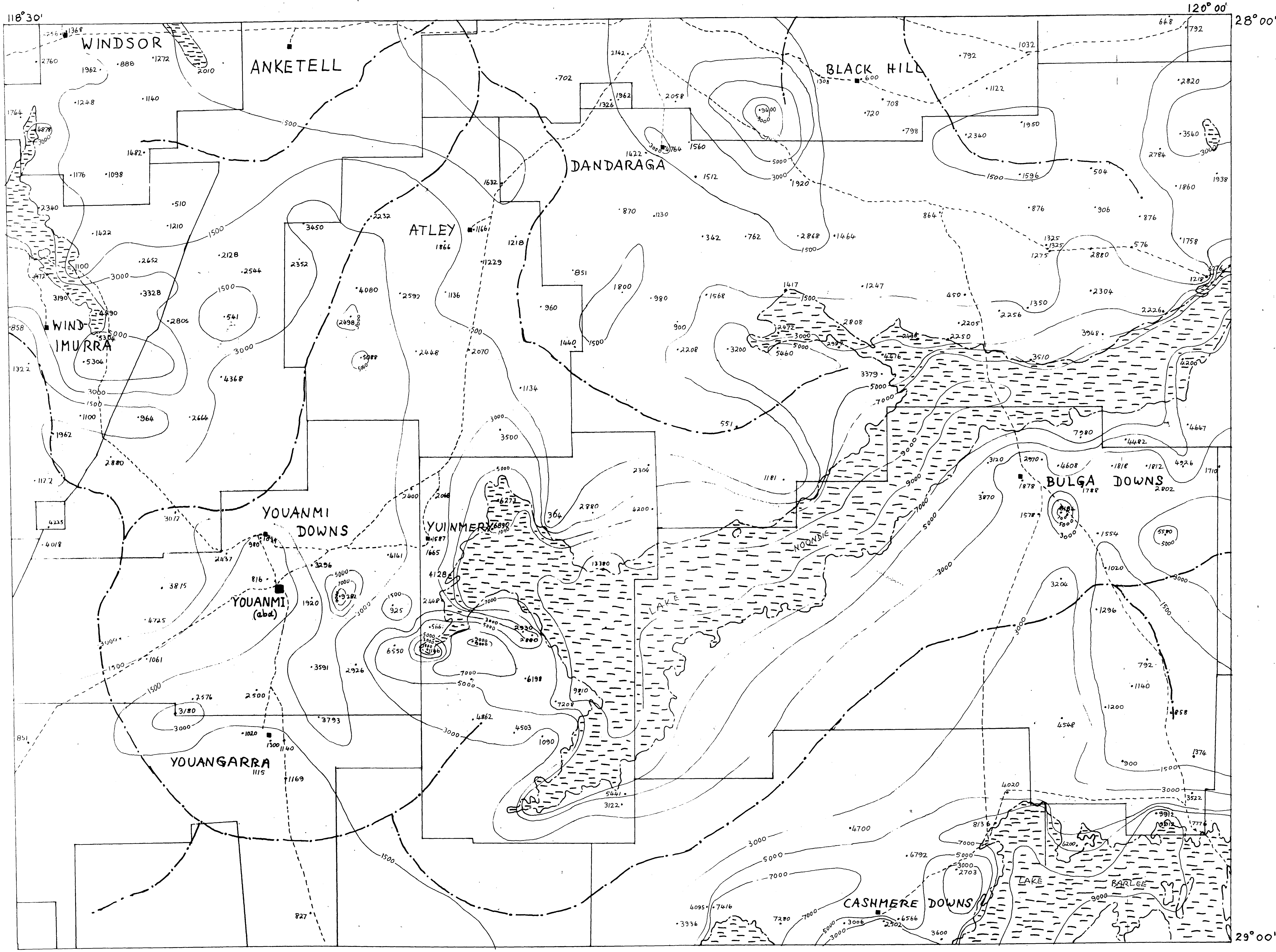
Figure 18

GROUNDWATER SALINITY

YOUANMI SHEET AREA



0 10 20 KM

- Saline alluvial and aeolian deposits
- Watershed
- 3296 Field salinity of wells and bores in milligrams per litre total dissolved solids
- Station homestead
- Pastoral lease or government reserve boundary
- Formed road
- 3000 Salinity contour (generalised)
- Townsite

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APPENDIX 1: CO-ORDINATES OF LOCALITIES MENTIONED IN TEXT

Locality name	Latitude (d)	Latitude (m)	Latitude (s)	Longitude (d)	Longitude (m)	Longitude (s)
Atley homestead	28	13	35	119	04	00
Barrambie (Sandstone sheet)	27	31	20	119	11	00
Bell Rockhole	28	48	50	119	30	10
Bellchambers mine	28	09	50	119	08	10
Black Hill homestead	28	04	05	119	32	30
Black Range	28	08	00	119	09	00
Brooking Hills	28	58	00	119	59	00
Browns Soak (Barlee sheet)	29	00	30	118	46	55
Bulga Downs homestead	28	29	50	119	44	30
Bungarrow Bore	28	36	30	118	41	00
Cabaret Bore	28	45	10	119	55	40
Canegrass Well	28	19	20	118	00	05
Cashmere Downs homestead	28	58	10	119	34	10
Cook Well	28	28	45	119	45	55
Cooliboo Bore	28	48	35	118	42	40
Curran Well	28	49	15	118	47	00
Curran's mine	28	48	05	118	47	25
Dandaraga homestead	28	08	35	119	18	05
Daly Outcamp	28	15	10	119	46	30
Denham Bore	28	50	25	119	57	05
Deep Bore	28	26	15	118	33	15
Edale Bore	28	48	20	119	52	00
Eighteen Mile Bore	28	32	00	119	13	00
Elspon Well	28	18	00	119	40	25
Fennell Well	28	42	50	119	03	50
Fitz Bore	28	37	15	118	54	20
Forty Five Bore	28	55	40	119	38	12
Four Corners Well (Dandaraga)	28	18	50	119	45	00
Freddie Well	28	44	50	118	41	55
Freshwater Well	28	46	25	119	08	55
Hancock's mine	28	02	05	119	20	00
Hell Gates Well	28	07	40	119	40	30

Locality name	Latitude (d)	(m)	(s)	Longitude (d)	(m)	(s)
Hayes Well	28	14	00	119	07	35
Horse Fall Rocks	28	41	25	119	32	35
Iron Knob Bore	28	06	00	119	25	20
Jay Bore	28	58	40	119	19	00
Jew Well	28	12	20	119	15	00
Jones Bore	28	19	00	118	45	00
Kayline Bore	28	02	30	119	40	00
Kevin Bore	28	43	50	119	12	00
Kohler Well (Bulga Downs)	28	29	07	119	51	10
Kohler Well (Dandaraga)	28	25	00	119	21	40
Kurrajong Bore	28	31	40	119	47	20
Lake Barlee	28	56	00	119	46	00
Lake Noondie	28	36	00	119	22	00
Little Noondie Hill	28	41	35	119	08	05
Little Well	28	36	00	119	02	15
Maninga Marley	28	10	00	119	28	50
Matris Bore	28	48	10	119	42	00
Maynard Hills	28	28	00	119	48	45
Middle Well	28	19	00	119	42	50
Midway Bore (Youangarra)	28	46	30	118	31	00
Miller Bore	28	21	55	119	34	15
Mistletoe Well	28	33	40	119	55	05
Mitchell Well	28	15	00	118	45	45
Mooloo Pool	28	56	45	119	16	25
Mount Alfred	28	52	00	119	59	30
Mount Dwyer	28	09	20	119	29	30
Mount Elvire (Barlee Sheet)	29	15	00	119	39	00
Mount Forest	28	44	30	119	56	35
Mount Holmes	28	14	00	119	58	25
Mount Klempz	28	06	20	119	16	40
Mount Richardson	28	47	40	119	59	15
Nine Mile Bore	28	37	50	118	58	15
Noondie	28	40	10	119	06	55

Locality name	Latitude (d)	(m)	(s)	Longitude (d)	(m)	(s)
Nungarra	28	04	50	119	15	00
Old Station Bore	28	20	30	119	36	35
Palagea Rockholes	28	26	50	118	37	00
Paynesville	28	02	00	118	31	00
Perseverance Bore	28	21	40	118	56	00
Pincher Hill	28	44	50	118	47	20
Pincher Well	28	43	15	118	48	00
Poison Rocks	28	42	00	118	31	00
Porcupine Well	28	30	00	119	27	00
Rafferty's Patch	28	06	30	119	23	20
Rainy Bore	28	57	55	118	52	05
Ram Bore	28	39	05	118	43	40
Ray Rocks	28	55	30	119	06	30
Recruit Flats	28	18	20	118	33	00
Red Knob	28	11	15	119	42	20
Sandie Well	28	18	30	118	36	45
Sandstone (Sandstone sheet)	27	59	40	119	18	00
Seventy One Mile Bore	28	12	40	118	56	45
Six Mile Well	28	05	25	119	19	15
Smith Well	28	34	45	118	55	50
Southern Cross Well	28	35	15	118	52	15
Stag Well	28	15	40	118	34	50
Stone Tank Bore	28	46	05	118	46	50
The Stock Well	28	52	50	118	57	10
Thomson Bore	28	17	20	118	55	40
Tom Well	28	50	50	119	15	00
Unaly Hill	28	22	40	118	57	00
Victory Bore (Atley)	28	17	40	118	59	00
Visitors Bore	28	35	55	119	50	50
Volprecht Well	28	10	45	119	40	00
Walgarry Rockhole	28	57	00	119	01	50
Webster Well (Anketell)	28	08	45	118	54	45
Webster Well (Windimurra)	28	29	20	118	32	00

Locality name	Latitude (d)	Latitude (m)	Latitude (s)	Longitude (d)	Longitude (m)	Longitude (s)
White Cloud Bore	28	38	15	119	50	25
White Well (Dandaraga)	28	21	35	119	23	00
Windimurra homestead	28	19	45	118	32	55
Windsor Castle mine	28	00	50	118	34	30
Windsor homestead	28	00	50	118	34	15
Wyemandoo Well	28	32	20	118	32	45
Yagar	28	30	40	118	40	10
Yalgoo Well	28	02	40	118	44	20
Yalinga Bore	28	25	15	118	43	25
Youanme Well	28	37	35	119	01	40
Youanmi	28	37	00	118	49	40
Youanmi Downs homestead	28	33	30	118	48	10
Yuinmery homestead	28	33	45	119	01	00

APPENDIX 2: DEFINITIONS OF ROCK UNITS

Windimurra Intrusion (Adjw)

Derivation of name: Windimurra homestead (lat. 28°19'35"S, long, 118°32'50"E), western part of YOUANMI.

Distribution: Northwestern part of YOUANMI, and extending into KIRKALOCKA, CUE, and SANDSTONE. Total area 2120 km^2 (exclusive of 200 km^2 of overlying felsic volcanics).

Type locality: Series of north-south ridges extending east-west over 3 km between lat. 28°17'30"S, long, 118°32'30"E, and lat. 28°17'30"S, long 118°34'00"E, 4 km north of Windimurra homestead.

Lithology: Intrusion comprises scores of layers about 1-50 m thick composed of gabbro, dolerite, norite, olivine norite, clinopyroxene norite, melagabbro, leucogabbro, leuconorite, hypersthene melagabbro, pyroxenite, anorthosite, and magnetite rock; layers and masses of gabbro pegmatite, and veins of microdolerite and microdiorite are also regarded as part of the Intrusion. Cumulate textures are well preserved. Original igneous assemblage preserved in many places; elsewhere partly or completely metamorphosed to greenschist facies.

Relationships: Intrudes and hornfelses sedimentary country rock and felsic volcanic rocks of Kantie Murdanna Volcanics (Baxter, J.L., Lipple, S.L., & Marston, R.J., 1980 - Explanatory notes on the Kirkalocka 1:250 000 geological sheet, Western Australia. Geological Survey of Western Australia, Record 1980/3 (unpublished)). Intruded by plutonic and hypabyssal granitoids, and by east-west dolerite dykes.

Age: The intrusive granitoid dykes give Rb-Sr whole-rock isotopic dates in excess of 2500 m.y.; therefore the Windimurra Intrusion is Archaean (A. Ahmat and J. de Laeter, personal communication, 1980).

Correlation: Co-magmatic with Youanmi Intrusion, a similar layered mafic intrusion 15 km southeast of the Windimurra Intrusion.

Synonomy: Windimurra Complex - de la Hunty, L.E., 1970 - Report of Department of Mines, Western Australia for 1969, 53.

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Youanmi Intrusion (Adj)

Derivation of name: Youanmi townsite (lat. 28°37'00"S, long. 118°50'00"E), southwestern part of YOUANMI.

Distribution: Oval area about 20 km by 10 km extending southwest from Youanmi townsite to Freddie Well.

Type locality: Small well exposed prominent rocky hill about 800 m across and 10 m high situated at lat. 28°38'25"S, long, 118°43'00"E, 11 km southwest of Youanmi townsite.

Lithology: numerous layers up to about 10 m thick composed of gabbro leucogabbro, norite, melagabbro, pyroxenite, anorthosite, and magnetite. Original igneous assemblage preserved at type locality; commonly metamorphosed to greenschist facies elsewhere.

Relationships: Intrudes metamorphosed felsic volcanics at Freddie Well zinc prospect, 3 km west of Freddie Well. Intruded by lepidolite-bearing granite pegmatite.

Age: Presumed to be coeval with Windimurra Intrusion; Archaean.

Correlation: Co-magmatic with Windimurra Intrusion, 15 km to the northwest.

Synonomy: None.