GEOLOGY AND METALLOGENESIS OF THE PARKES - GRENFELL - WYALONG - CONDOBOLIN REGION, NEW SOUTH WALES

FORBES 1:250 000 GEOLOGICAL SHEET

FIELD CONFERENCE GUIDE

11 - 16 April 1999

Edited by
P Lyons and D Wallace

AGSO Record 1999/20

MINERAL RESOURCES
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DEPARTMENT OF INDUSTRY, SCIENCE & RESOURCES

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Department of Industry, Science & Resources

Minister for Industry, Science & Resources: Senator the Hon.Nick Minchin
Parliamentary Secretary: The Hon.Warren Entsch, MP
Secretary: Russell Higgins

Australian Geological Survey Organisation

Executive Director: Neil Williams

ISSN 1039-0073
ISBN 0 642273936

Cover illustration: Collage showing (i) regional magnetic image, (ii) epithermal quartz veining and breccia, Condobolin mining district (Photo: O Raymond AGSO), (iii) flooded open cut mine workings, London Victoria gold mine, Parkes (Photo: G Burton, NSWGS).

Bibliographic reference: Geology and Metallogenesis of the Parkes-Grenfell-Wyalong-Condobolin Region, New South Wales, Forbes 1:250 000 Geological Sheet and Conference Guide 11-16 April 1999. P. Lyons and D. Wallace (editors). AGSO Record 1999/20

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INTRODUCTION

The material presented in this report represents work completed as part of the National Geoscience Mapping Accord (NGMA), and was produced through the combined resources of the Australian Geological Survey Organisation (AGSO) and the New South Wales Geological Survey (NSWGS).

Mapping of the FORBES 1:250 000 Geological Sheet began in 1995 and was completed in 1998. Geological interpretation was enhanced through the use of airborne radiometric and magnetic survey data flown by AGSO at 400 meter line-spacing in 1995. The first edition of the FORBES geological map (Brunker, 1972) was produced by compilation of existing work and air photo interpretation, combined with reconnaissance field work. No explanatory notes were published. Following the first edition, minor revision of the geology was made for the FORBES metallogenic map (Bowman, 1976) which was accompanied by a compilation of mine data sheets (Bowman, 1977).

Field work completed for this edition has resulted in a major reinterpretation of the stratigraphy and structure of the FORBES 1:250 000 sheet area. This work greatly benefited from university thesis work and mineral exploration company work completed in the intervening years. Products presented at this field conference include the Forbes 1:250 000 geological and regolith map sheets together with the PARKES, GRENFELL, BOGAN GATE, MARSDEN, CONDOBOLIN and WYALONG 1:100 000 geological and regolith sheets. Accompanying Explanatory Notes for the FORBES 1:250 000 sheet will be commenced in late 1999. This guide, and the accompanying FORBES 1:250 000 geological sheet, represent a preliminary synthesis of the work completed and are intended to provide a basis for discussion and review.

Geological field mapping during the program was carried out by a team of geologists from AGSO and the NSWGS. Areas mapped by each geologist are shown on responsibility diagrams on each of map sheets. Responsibilities for the 1:100 000 map sheets are:

Parkes	Ollie Raymond, David Wallace (AGSO), Doone Wyborn[1], Gavin Young[1] (AGSO), Lawrence Sherwin (NSWGS).
Grenfell	Ollie Raymond, David Wallace, Gavin Young[1] (AGSO), Jan Krijnen[2] (NSWGS)
Bogan Gate	Lawrence Sherwin (NSWGS)
Marsden	Ollie Raymond, David Wallace (AGSO)
Condobolin	Martin Scott, Lawrence Sherwin (NSWGS)
Wyalong	Morrie Duggan, Patrick Lyons (AGSO)

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Regolith mapping at 1:100 000 scale was carried out by Roslyn Chan and David Gibson (CRC-LEME AGSO). The Mineral Deposit Data Base for the FORBES 1:250 000 sheet was updated and revised by Peter Downes and Gary Burton (NSWGS).

Palaeontological determinations were provided by Lawrence Sherwin, John Pickett and Ian Percival (NSWGS), and Gavin Young (AGSO). Michael Leys, Neil Watson and Dick Glen (NSWGS) provided additional interpretations of the regional geophysics. Lance Black (AGSO) carried out SHRIMP isotopic age determinations. Cartography was done by Neil Corby, Heike Apps, Andrew Johnson, Greg Michalowski, Ross Hill (AGSO) and Michael Healy (NSWGS) using ARCINFO software. Those responsible for the various parts of this report have been acknowledged in the text.

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FORBES FIELD CONFERENCE 11-16 APRIL 1999

Forbes Services Memorial Club, Templar Street, Forbes

PROGRAM

Presentation of the six Preliminary Edition 1:100K geological maps, 1:250K geological and basement geology maps and 1:250K regolith map of the Forbes sheet. A series of 1:100k regolith maps will accompany the corresponding geological maps as clear-film overlays.

On Sunday, 11 April 1999, the conference will open with introductory talks followed by a series of oral presentations highlighting significant aspects of the sheet area.

Field excursions examining sites of interest within the sheet area. The Field Conference Guide contains an overview summarising the oral presentations and notes to accompany field stops

Timetable for conference oral presentations on Sunday 11 April

12.00 noon–1.00 pm Registration of Conference participants

Introductory speeches (Chair: Morrie Duggan)

1.10	Welcome speech by Councillor Diane Decker, representing the Mayor of Forbes
1.20	Presentation by David Denham, Chief, Minerals Division, AGSO
1.30	Presentation by Ted Tyne, Assistant Director, Regional Geology and Geophysics, NSW Geological Survey

Scientific Presentations (Chair: Dennis Pogson)

1.40	Geological Overview	Lawrence Sherwin
2.00	Structural Outline	Patrick Lyons
2.20	Igneous Evolution	Ollie Raymond, David Wallace, Morrie Duggan
2.40	Mineral Deposits	Gary Burton, Peter Downes
3.00	Afternoon tea	
3.30	Geophysics	Michael Leys
3.50	Regolith Evolution	Roslyn Chan, David Gibson
4.10	Gilmore Project (overview)	Ken Lawrie
4.30	Digital Dataset Presentation	Ollie Raymond

FIELD EXCURSIONS

Monday	12 April	Condobolin and west Bogan Gate
Tuesday	13 April	Wyalong
Wednesday	14 April	South Bogan Gate and Marsden
Thursday	15 April	East Bogan Gate and north Parkes.
Friday	16 April	South Parkes and Grenfell

Thursday 15 April - 7.00 pm for 7.30 pm - Drinks and Conference Dinner at Forbes RSL Club

1. REGIONAL GEOLOGICAL OVERVIEW

Lawrence Sherwin, NSWGS

Introduction

The first edition of the Forbes 1:250 000 map was compiled from a rapid airphoto interpretation, followed by about one month's fieldwork by one geologist and supplemented by a few specialist papers and unpublished theses. This was a fairly normal procedure in the 1960s when there was an urgent need to provide a systematic geological map coverage of the State at a useful scale. This all happened just over thirty years ago at the start of the mining boom, the then responsible geologist resigning from the Geological Survey not long after returning from the field - just long enough to hand over his field notes and rough compilations. The resultant map, published without explanatory notes in 1972, contained additional, if unwitting, contributions from the cartographer and printer.

The second edition shows what a difference more time, staff, and modern techniques can make. Radiometric data have made possible a subdivision of the Quaternary that was, hitherto, utterly unsuspected. A mass of exploration company drilling has provided a reasonably clear picture of what is below the Cainozoic cover that is so extensive, covering approximately 80 percent of the map area.

Geological history

The oldest datable rocks in the map area are the Nelungaloo Volcanics, which cover a small area to the northwest of Parkes. These are overlain unconformably by the Early Ordovician (Lancefieldian to Bendigonian) Yarrimbah Chert. There is an appreciable break between the Yarimbah Chert and the overlying Goonumbla Volcanics, which extends through most of the Late Ordovician (Darriwilian to Bolindian). Near the end of the Ordovician, numerous quartz monzonite bodies, some having associated copper-gold mineralisation, intruded the volcanic pile. These volcanics are overlain with apparent conformity by the widespread Late Ordovician to Early Silurian (Bolindian to late Llandovery) Cotton Formation, a rather monotonous sequence of cherty quartzose siltstone. This siltstone sedimentation ceased by the end of the Llandovery and was followed after a short break, certainly before the late Wenlock (late Early Silurian), by deposition of the coarse Bocobidgle Conglomerate. The well-rounded clasts in this conglomerate show derivation from the Goonumbla Volcanics, the more cherty beds of the Cotton Formation and quartzites in the Girilambone Group and Kirribilli Formation.

This early Palaeozoic history applies with certitude only to the volcanic belt north of the Lachlan River between Gunningbland and Parkes. Thick, almost exclusively sedimentary sequences to the east of Parkes and Forbes, separated by major faults from the volcanics, have very little fossil control. One locality in the Mugincoble Chert, a probable member of the Kirribilli Formation, yielded conodonts of probable Darriwilian (Middle Ordovician) age. A chert from the much-altered Brangan Volcanics, north of Grenfell, yielded a much less specific Ordovician age. There is no evidence that the Mugincoble Chert follows a lengthy hiatus, as is the case with the Goonumbla Volcanics, but there is no clear indication of the upper and lower age limits of the Kirribilli Formation other than that it includes the Middle Ordovician Mugincoble Chert.

The Girilambone Group, in the west of the map area, is separated from the well-dated volcanics by a considerable expanse of younger strata. It contains no known fossil localities within the Forbes map area, although elsewhere it contains cherts with a conodont fauna comparable in age with that from the Mugincoble Chert.
In summary; for the Ordovician to Early Silurian, the calcalkaline volcanic belt north of the Lachlan River between Gunningbland and Parkes has an erosional break near the Cambro-Ordovician boundary, followed by an hiatus spanning most of the Early Ordovician (Chewtonian-Yapeenian). Volcanic activity resumed near the beginning of the Late Ordovician and continued until near the end of the Ordovician. Siliceous siltstone sedimentation continued until the end of the Early Silurian. The deeper water sequences either side of the volcanic belt are notably much more deformed and were accumulating for an undetermined time either side of the Middle Ordovician, although some laminite beds from the (?)upper part of the Girilambone Group and Kirribilli Formation resemble the Cotton Formation.

The depositional break following the Early Silurian is associated with emplacement of several granitic plutons in the vicinity of West Wyalong.

The mid Silurian (Wenlock) is represented by the Forbes Group, known only in the vicinity of Forbes and Parkes, although it has a close time equivalent in the mostly siliceous volcanic Douro Group east of Grenfell. The base of the Forbes Group, the Bocobidgle Conglomerate, indicates active erosion of older strata, including the Goonumbla Volcanics, but strike trends suggest little, if any, associated folding of the older strata. Deposition in both areas ended by or shortly after the start of the Ludlow (Late Silurian). The unfossiliferous Burcher Greywacke, north of West Wyalong, may have been deposited about this time.

There was some folding during the earlier Late Silurian (early Ludlow) because the contact of the Late Silurian-Early Devonian Derriwong Group is a low angle unconformity with the Forbes Group and Goonumbla Volcanics. In the vicinity of Condobolin, there is a very marked angular discordance between the Derriwong Group and tightly folded Girilambone Group rocks. Siliceous volcanism (Byong, Yarnel Volcanics) was widespread at about this time. Between Forbes and Bogan Gate the Derriwong Group was deposited in a shallow water marginal to marine environment (Calarie Sandstone, Cookeys Plains Formation), but south of and around Ootha, the environment was notably deeper (Ootha Subgroup). Another deep water but unfossiliferous sequence, the Moura Formation, east of Parkes, may have been deposited at about this time. The Derriwong Group was folded along northwest - southeast axes in mid Early Devonian time because it is unconformably overlain by late Early Devonian marginal siliciclastic sequences, such as the Yarra Yarra and Trundle Groups. This folding interval occurred at about the same time as emplacement of the Cookaburrugong Granodiorite in the west and siliceous volcanism of the Black range in the east.

The Yarra Yarra and Trundle Groups (?late Lochkovian - early Emsian) are much more restricted in distribution in comparison with the Derriwong Group and distinctly less marine in character. Indeed, on the Forbes 1:250 000 sheet area the Yarra Yarra Creek shows no evidence of marine conditions. The Trundle Group includes rhyolitic volcanic units and minor limestone deposition with a marine fauna very restricted in the variety of contained species. The Yarra Yarra Creek Group has a more obvious angular discordance with the underlying Derriwong Group than has the Trundle Group. Available evidence suggests that the Yarra Yarra and Trundle Groups were gently deformed about mid Devonian time into minor folds with east-west axes. At about this time also there was widespread intrusion of granites, including the large bodies in the vicinity of Eugowra.

In Middle Devonian time there was extensive siliceous volcanism in the east, represented by the Dulladerry and Warrumba Volcanics, which may be contemporary with some of the last granite intrusions.

The Late Devonian was characterised by widespread, mostly fluviatile, red bed and sandstone deposition of the Hervey Group. In the central region of the map area the Hervey Group rests with generally slight angular discordance on the Trundle Group. In the east it overlies unroofed Early Devonian intrusives, such as the Eugowra Granite, or rests paraconformably on the Middle Devonian Dulladerry and Warrumba Volcanics.

The Late Devonian Hervey Group was gently folded with subhorizontal sub meridional axes sometime between the Early Carboniferous and Jurassic. This deformation was possibly associated with some major north-south, west dipping thrust faults such as the Coolac - Narromine Fault and the Marsden Thrust. A plot of post-1900 earthquake epicentres indicates continuing activity along these faults.

The folding of the Hervey Group was completed before deposition of coarse fluvial gravels in the Late Mesozoic. These gravels are believed to mark old streams supplying sediment to what is now the Great Artesian/Australian Basin. By early Tertiary time the rivers, corresponding closely to the modern drainage system, had dissected valleys as much as 150 metres below the modern land surface. The alluvial filling of these valleys began in the Miocene, about the time that leucite basalts were erupted to the southwest of Condobolin. Thermoluminescence studies show that the Lachlan River still was still depositing large volumes of sediment in the late Pleistocene and forming much larger and smoother meanders than is now the case. The modern Lachlan River is depositing little sediment and has incised comparatively shorter wavelength angular meanders into the floodplain.

2. STRUCTURAL OUTLINE

Patrick Lyons, AGSO

Although some 80 percent of the sheet area is covered by regolith, aeromagnetic data show the location and geometry, at least in plan, of the major structures and magnetically discernible units. Also, construction of a reliable solid geology for the sheet area has allowed maximum ages of many of the major structures to be derived. Detailed ground work and an on-going U-Pb SHRIMP dating program is allowing further refinements of the understanding of the structural development of the region, and its context within the Lachlan Fold Belt, to be made.

The Forbes sheet area is dominated by a number of shear zones with LFB-wide significance and large folds that are probably related to their activation and reactivation.

Fault and shear zones

The most significant structure is the north-northwest trending Gilmore Fault Zone (GFZ), in the west of the sheet area, traceable from Wyalong in the south to Condobolin in the north. The GFZ is a major feature of the LFB and extends six hundred kilometres from the Long Plain-Indi Fault system, in Victoria, to an area east of Cobar. It separates the Central and Eastern Belts of the LFB (Glen, 1992) and has been considered by some to be a terrane boundary formed by thrusting of the Wagga-Omeo Complex over the volcanic arcs of the Eastern Belt (see Warren *et al.*, 1995, page 92 for references). Within the sheet area, the GFZ is best seen in sheared outcrops of the Siluro-Devonian Edols Conglomerate. Kinematic indicators within sheared portions of the Edols Conglomerate are somewhat contradictory. In the Booberoi Hills in the south, steeply dipping shear C-planes have recorded a west side up movement, but to the north, towards Manna Mountain, kinematic indicators show a largely sinstral movement with only a minor vertical component. The plan geometry of subsidiary structures, such as connecting, diverging, and rejoining splays, the latter mapped as the Booberoi Fault (Ingpen, 1990), support a major eastward thrusting event. However, a wedge of the Ordovician Girilambone Group, bound by the rejoining Booberoi Fault, strongly suggests a sinstral movement of at least 70 kilometres. Foster and Gray (in press) identify a major sinstral movement around 405 Ma, based on recently obtained Ar-Ar dates. In the Condobolin area there may be some evidence of dextral movement (Scott, this volume).

East of the Gilmore Fault Zone, the Marsden Thrust, newly discovered as a result of this mapping program, trends north-northeast, roughly parallel to the axis of the Tullamore Syncline. As a blind thrust it has been identified in regional magnetics and drill-core; Ordovician volcanics of the Lake Cowal complex were thrust eastwards over red beds of the Late Devonian Hervey Group. The Marsden Thrust is about five kilometres east of the GFZ and may be a termination splay activated during the Carboniferous.

The northeast trending Parkes Fault Zone is host to many of the Au deposits in the sheet area and is virtually outlined by their distribution (Figure 7.1). In outcrop it appears as a belt of intense strain in the Ordovician Kirribilli Formation but kinematic indicators are not well developed. A small sinstral offset, about a kilometre, of units of the Early Devonian Trundle Group at the southern tip of the Currowong Syncline establishes a minimum age for (re)activation around 400 Ma, coeval with a reactivation of the GFZ. The Parkes Thrust has been inferred to have formed during west-directed thrusting on an east dipping, pre-existing normal fault (Warren *et al.*, 1995). In the north of the sheet area, the Parkes Thrust links with the Coolac-Narromine Fault, which dips steeply to the east (Leven *et al.*, 1992).

The Coolac-Narromine Fault trends due north and disrupts, among others, Late Devonian Hervey group sediments suggesting a Carboniferous reactivation, although the direction of movement has not been established for this event. A new interpretation of geophysical datasets from the Cootamundra 1:250 000 sheet area shows that sinstral movement on the Coolac-Narromine Fault affected the Late Silurian Young Granodiorite (Bacchin *et al.*, 1999).

Minor faults in the east of the sheet area, the Eugowra and Bumberry Faults are probably Carboniferous as they disrupt Late Devonian units. The Eugowra Fault largely cuts a Siluro-Devonian I-type granite but may also cut Tertiary basalts. Analysis of earthquake data show that this structure is currently active. The Bumberry Fault has probably thrust volcanics of the Middle Devonian Rocky Ponds Group over Late Devonian Hervey Group rocks.

A number of small northwest trending faults variously offset units and major faults. These faults are part of a set widely recognised in the eastern Lachlan Fold Belt, which may have initiated during mid-Devonian east-west shortening (Glen, 1992).

Folds

West of the GFZ there are no identifiable regional folds. This may reflect the paucity of outcrop, or thelack of marker beds in the multiply deformed, tight to isoclinally folded beds of the Wagga and Girilambone Groups and the massive Burcher Greywacke. A fuller description of the fabric elements in these units is given below in Section 8.

East of the GFZ, the Late Devonian Hervey Group is folded around the Tullamore Syncline and a number of smaller structures, such as the Wheoga and Sugarloaf Synclines and the Goologong Anticline. The Tullamore Syncline is superimposed on the Currowong Syncline which folds Early Devonian sediments and volcanics. Scott (this volume) identified a broad F_4 fold in Girilambone Group sediments east of the GFZ.

Folding of Early Devonian units may be related to the thrusting or transpressional event recorded in the GFZ and the Parkes Thrust, which was followed by a period of magmatism east of the GFZ. The open folding of the Late Devonian Hervey Group was probably accompanied by reactivation of some, if not all, of the major faults. This Carboniferous deformation is probably due to high rates of plate convergence resulting in the New England Orogen (Fergusson and Coney, 1992).

3. METAMORPHIC MAP OF FORBES

L M Barron, NSWGS

Summary

A metamorphic map of the Forbes 1:250 000 region has been prepared by assessment of metamorphic mineral assemblages for 1900 samples from the map area. These samples and thin sections are held in the Petrology Collection and are supported by the ROCKS database. About 50% of the map face is deficient in sample points, particularly the flood plain of the Lachlan River from Forbes westward, and a north trending belt through Marsden.

The metamorphic map establishes broad patterns for regional metamorphic zones, with about 85% of the resolved area dominated by low-grade greenschist facies (zone M1: epidote/carbonate/albite). A further 10% is classified as M2 zone (prehnite/pumpellyite), restricted to the Gunningbland-Myall-Parkes and Yarrabandai districts, while about 5% is represented by small scattered domains with middle greenschist facies (zone M3: biotite/actinolite-tremolite). About 20% of the resolved area is involved in overlap of these metamorphic zones. This degree of overlap of metamorphic zones is similar to recent work on metamorphic maps over Bathurst and Dubbo, but overall, Forbes is generally at a lower grade than the other two map areas.

Samples on the Bathurst 250K map adjacent to Forbes need to be examined to resolve a mismatch in metamorphic zones along the common boundary.

Introduction

This work is ongoing, with the process evolving through the production of metamorphic maps for Bathurst (Barron, 1998) and Dubbo (Barron, in press). However, because the process uses a simple spreadsheet rather than GIS, it is not yet possible to discriminate prograde from retrograde metamorphic assemblages, so this work must be regarded as a preliminary effort in the broader aim to prepare a metamorphic map layer for the Lachlan Fold Belt. The original concept started with the Bathurst and Dubbo metamorphic grade map of Smith (1969). His work showed the distribution of six metamorphic grades, based on the presence or absence of key metamorphic minerals such as carbonate albite, chlorite, prehnite, pumpellyite, actinolite-tremolite, and biotite. There was no overlap between grades shown on Smith's (1969) map, but when 2000 rocks on Bathurst were reassessed in 1997, there was found to be such a high degree of overlap that the key minerals had to be grouped in pairs. Even with this summary grouping (dropping from six grades to three zones), the new metamorphic maps of Bathurst and Dubbo still had overlap on up to 20% of the resolved map face, in some cases representing overprinting but in other cases probably representing finely interleaved thrust packages from different metamorphic zones. The summary metamorphic map for Forbes establishes broad patterns for the regional metamorphic zones and for anomalous zones, with about 20% of the resolved area being involved in overlap.

Treatment of data

All of the available Forbes thin sections were examined specifically to assess their metamorphic history (latest and relict metamorphic assemblages). The interpreted metamorphic history is coded into a character string that records the sequence of metamorphic events, including the nature of the associated stress fields (neutral, compressive or extensional). Most of the Forbes samples are from the older part of the Petrology Collection so their location details are not very precise relative to the host stratigraphic unit - it is not yet possible to separate different metamorphic epochs. The metamorphic map is prepared from the metamorphic history string, not just the peak metamorphism, and the following four metamorphic zones are used:

- M1 (quarter-filled circle, ≡): clay/carbonate epidote sericite albite, both with and without foliation (Smith's Z1),
- M2 (half-filled circle, \\\): prehnite/pumpellyite, normally without foliation (Smith's Z2 and Z3),
- M3 (three quarter-filled circle, ///): actinolite/biotite, both with and without foliation (Smith's Z4 and Z5),
- MH (solid circle): akin to the *hornfels* envelope on an intrusive, represented by the presence of metamorphic diopside or garnet, or other phases such as cordierite, andalusite, or even other higher grade hornfels assemblages (olivine, cummingtonite, *etc.*).

Point maps for each metamorphic zone were produced using QuattroPro. As an aid to interpretation, each datapoint was buffered by placing a circle of influence around it. This marked out domains of influence where many points at the same metamorphic zone grade overlapped due to their circles of influence. Mineral assemblages interpreted to be due to regional metamorphism were given a large influence radius of 5 km, while other assemblages that may arise out of a more local effect (hornfelsing, fault-associated alteration, *etc.*) were given a smaller influence radius of 1 km. Metamorphic domains were then delineated using these buffered images overlain on the bedrock interpretive geology map, see Figure 3.1. Some small areas were outlined as having anomalous metamorphic assemblages, where the assemblage is higher or lower than expected, the difference not being explicable with regard to the local geology, for example, a hornfels with no known intrusive.

At this time, it has not been possible to develop a geological layer for this metamorphic map, but subject to the data, the edges of most metamorphic zones were taken to coincide with geological boundaries. It is clear that improved interaction between data-point metamorphic history and GIS-geology will improve the preparation and accuracy of metamorphic maps.

Results

About 85% of the resolved area on the FORBES map is dominated by low grade greenschist facies zone M1 (carbonate/epidote/albite, *etc.*) assemblages, in fact M1 is so characteristic of the Forbes map face that this metamorphic zone is fully mapped herein. This represents a significant change from the process used to construct the new Bathurst-Dubbo metamorphic maps: These were generated predominantly as M2+M3 terranes, and M1 areas near major faults were not shown because the associated point pattern was too incomplete to be coherent. The new Bathurst Dubbo metamorphic maps only show M1 domains which are within plutons or are identified as isolated anomalous lenses, totalling about 10% of the area. The Forbes metamorphic map is not like this because, overall, there are much larger areas within the M1 metamorphic zone.

The most significant domains of the M2 zone (prehnite/pumpellyite) occur in the Gunningbland-Myall-Parkes and Yarrabandai regions, occupying about 10% of the resolved areas. In most cases these M2 areas overlap with M1, but there are three small areas in the first region where the rocks appear to be M2 zone only. The boundary between the Forbes map and the Bathurst map to the east has not been merged satisfactorily. Along this boundary, the data from the Bathurst map tends to end in the M2 zone, but the first 20 km on the east margin of the Forbes map is in the M1 zone and excludes M2. The Forbes metamorphic map was constructed by examining every available thin section but the Bathurst metamorphic map was based on interpreting the database text on metamorphic minerals, and only 30% of the Bathurst records carried sufficient data to make an interpretation. Hence this mismatch can only be resolved by reexamination of thin sections from the western margin of the Bathurst map area.

Domains in the M3 zone occur as small scattered 10 km domains occupying about 5% of the resolved area, mostly overlapping with M1 zones but with four small areas of no overlap, three of these in the western quarter of the map.

Most of the larger intrusives (> 1 km) show scattered point evidence of being enveloped by a thermal aureole of 100-500 m depending on the size and composition of the intrusive. For the sake of clarity, these MH point data are not shown on the summary map.

Many intrusives appear in the samples examined, and a metamorphic zone for the larger intrusive bodies has been assigned. Mostly this is M1 zone, but M3 zone is recorded over the Wyalong Granite and the southern portion of the Eugowra Granite. Both of these M3 domains are free standing and immersed within M1 zone domains. The M3 assignment reflects subgraining and recrystallisation of biotite or tremolite/actinolite, probably caused by the syntectonic character of these bodies.

There are about 100 separated points shown as having anomalous characteristics on the Forbes metamorphic map. These points are too isolated to join into the mapped domains, while in most cases the grade is higher than that expected from the surrounding area. A third of these anomalous points occur in large areas of no outcrop. Presumably these represent small isolated outcrops.

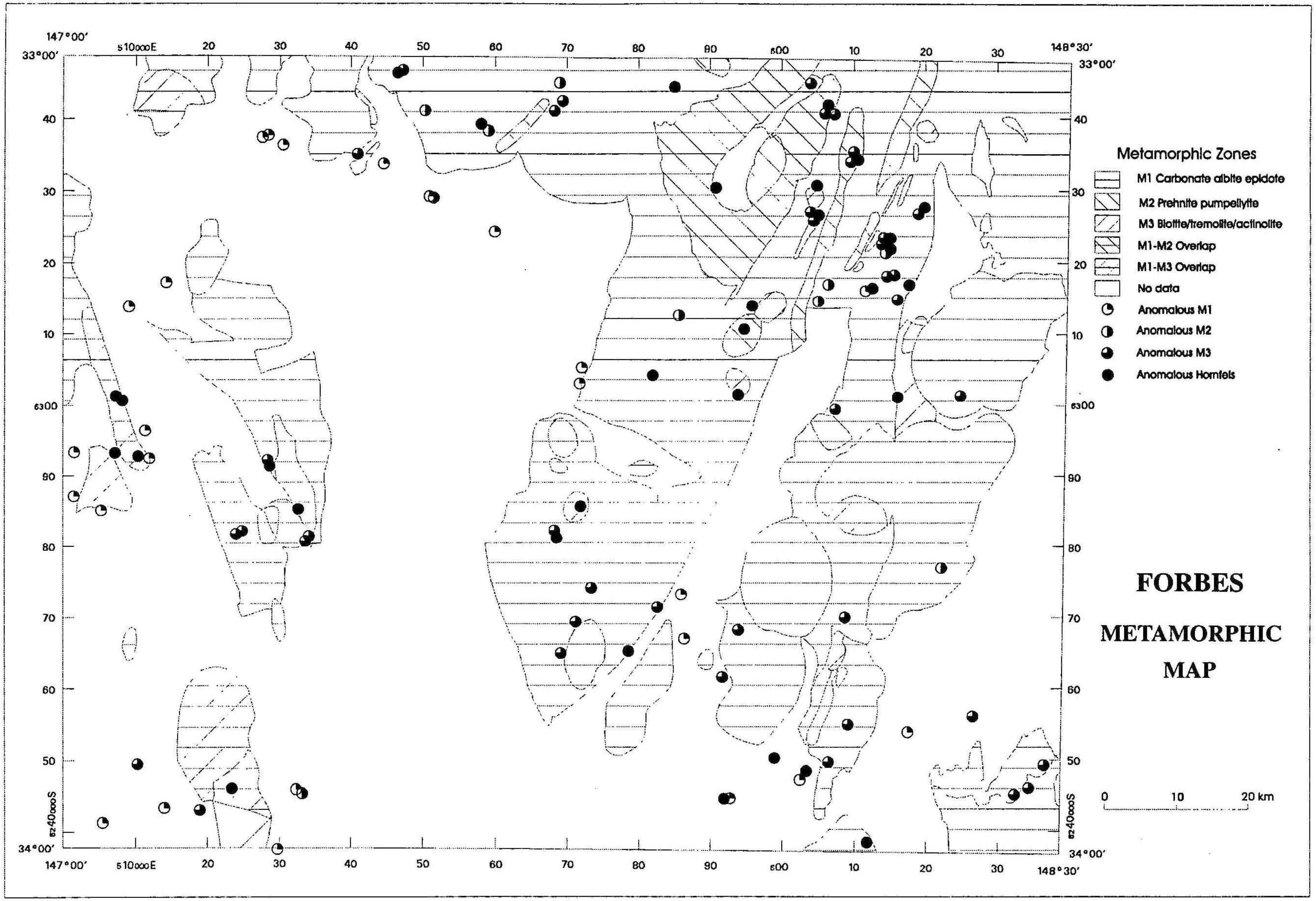


Figure 3.1. Metamorphic map of the Forbes 1:250 000 sheet area.

4. IGNEOUS EVOLUTION

4.1. Cambro-Ordovician

D A Wallace and M B Duggan, AGSO

The Forbes 1:250 000 Sheet covers the Central and Eastern Belts of the lithotectonic association of the Lachlan Orogen, which are divided by the Gilmore Suture (Glen, 1992). The major Ordovician mafic-intermediate volcanic associations of the sheet area lie within the Parkes-Tumut Zone of the Eastern Belt

The oldest recognised rock group in the sheet area is the Wambidgee Serpentinite. The only outcrop of this assemblage is a small, fault-bounded, 2 km-long slice of schistose serpentinite at the southeastern boundary of the sheet, where it represents the northern extremity of a discontinuous 100 km-long ophiolite belt of Cambro-Ordovician age extending north from the Cootamundra sheet area.

The Ordovician was a period of mafic-intermediate volcanism in a late-stage oceanic arc subduction setting (Müller, Rock and Groves, 1992). The most extensive development and generation of mafic-intermediate rocks occurred during the Late Ordovician where they were erupted during the final stage of oceanic arc subduction processes which ceased by the Early Silurian. The greatest volume and diversity of mafic-intermediate lavas occurs within the Forbes Anticline in the northern part of the sheet, centred around Parkes and Forbes, and extending into the Narromine sheet area; and also in the Lake Cowal Volcanic Complex. The rock assemblage identified in the Forbes Anticline provides a broad spectrum of mafic-igneous evolution in the area during the Ordovician. This episode began with the Nelungaloo Volcanics in the Early Ordovician, followed by a hiatus in the mid-late Ordovician, then a major volcanic episode in the Late Ordovician. The latter involved emplacement of the Parkes-Forbes alkalic volcanic assemblage - the Goonumbla Volcanics, Nash Hill Volcanics, Parkes Volcanics, and Goobang Volcanics. This phase ended with the generation of the more felsic Wombin Volcanics and related monzonites in the uppermost stratigraphic level of the volcanic succession. Recent work suggests that a major (Benambran) deformation in the Early Silurian may reflect collision of the arc with its back-arc basin (Glen, 1998).

A plot of K_2O *versus* SiO_2 (Le Bas *et al.*, 1986; Peccerillo and Taylor, 1976) using data published by Clarke (1990a) augmented by data from this survey, shows that the arc-related Ordovician assemblages fall between 45-60 wt% SiO_2 (Fig. 4.1.1).

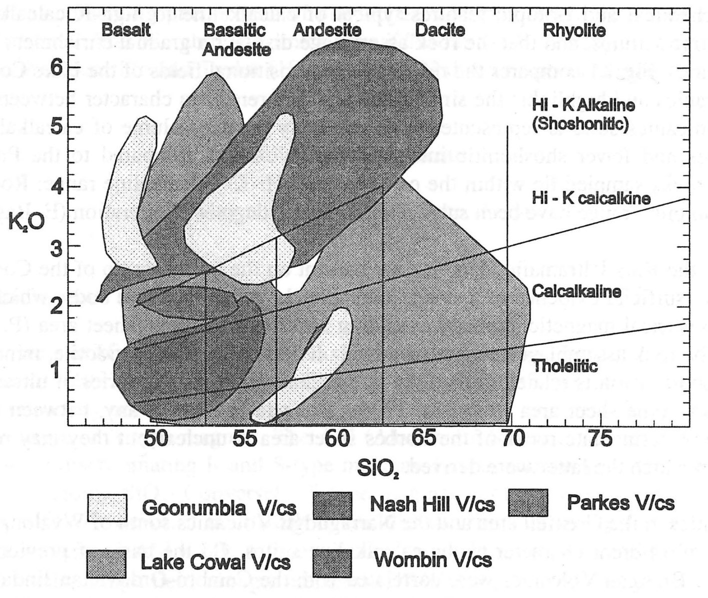


Figure 4.1.1. K2O *versus* SiO2 diagram of Parkes-Forbes volcanic units and Lake Cowal Volcanics

In terms of K_2O abundances the rocks range from tholeiitic to high K-alkaline (shoshonitic) in composition. With the exception of the Wombin Volcanics and related monzonites the Parkes-Forbes mafic-intermediate volcanic rocks, consisting of relatively fractionated basalts, basaltic andesites and a few andesites, reflect the dominantly calcalkaline character of the mixed assemblage (Fig 4.2). Of the individual units, the Goonumbla Volcanics cover a spectrum of compositions which include both tholeiitic and shoshonitic end members, the Nash Hill Volcanics are dominantly calcalkaline, the Parkes Volcanics are high-K calcalkaline, a suite from the Daroobalgie area, north of Forbes, are shoshonitic and the two analysed samples from the Nelungaloo Volcanics are a tholeiitic low-K basalt and a high-K calc-alkaline andesite. The Nash Hill Volcanics are distinguished from the other basaltic rock groups by their higher MgO (4-6%), anomalously high Th abundances up to 16 ppm and relative enrichment in light rare earths (Fig. 4.1.2). A strong thorium radiometric signature in airborne geophysical data for the Nash Hill Volcanics distinguishes this group from the K-dominant signature of the other members of the suite. This characteristic is corroborated by the presence of the thorium-bearing mineral allanite in thin sections of the Nash Hill Volcanics. Results from ongoing studies by CODES (University of Tasmania) shall no doubt refine the characteristics of the Parkes-Forbes Volcanic suite.

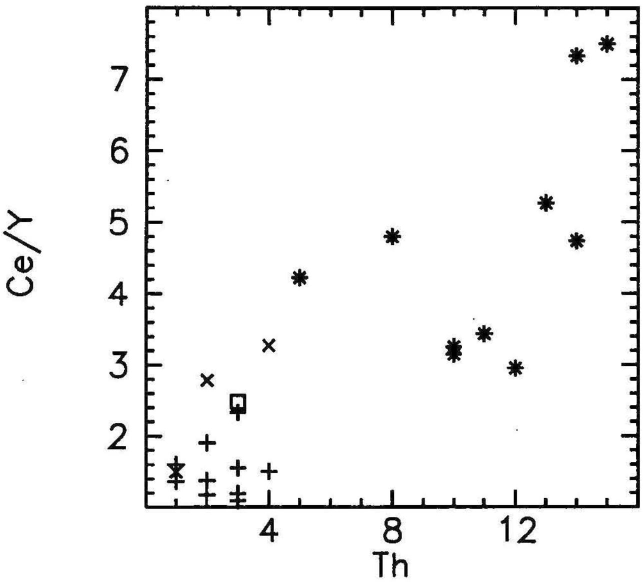


Figure 4.1.2. Ce/Y *versus* Th (ppm) for volcanic rocks. Stars - Nash Volcanics; Other symbols - Goonumbla Volcanics, Parkes Volcanics.

No published material is available on the Lake Cowal Volcanics, but unpublished data suggest that the rock assemblage displays geochemical and isotopic features typical of calcalkaline to high-K calcalkaline island-arc rocks formed in intra-oceanic settings, and that the rock assemblage displays a gradual enrichment of HFSE elements (E. Bastrakov, pers comm.). Fig.4.1 compares the respective compositional fields of the Lake Cowal Volcanics and the Parkes-Forbes Volcanics and highlights the similarities and differences in character between the two assemblages. The Lake Cowal Volcanics suite is represented by a relatively greater volume of calcalkaline basaltic andesites, andesites and dacites and fewer shoshonitic intermediate-felsic rocks compared to the Parkes-Forbes rocks. In Fig.4.1 the freshest rocks sampled lie within the calcalkaline - Hi-K- calcalkaline range: Rocks from the more extreme high-K and tholeiitic range have been subjected to varying degrees of alteration (E. Bastrakov, pers. comm.).

Ordovician rocks of the Kars Ultramafic Complex are present on the northeast tip of the Condobolin sheet. These outcrops are the only surficial evidence of a small, incompletely zoned intrusive body, which is well defined by a distinct, almost symmetrical magnetic anomaly extending into the Narromine sheet area (P. Downes and G. Burton, this volume). The rock assemblage consists of mixed olivine pyroxenite, peridotite, minor dunite and a coarse pegmatite phase. The intrusion is related to the Late-Ordovician Alaskan-type series of ultramafic complexes such as Fifield in the Narromine sheet area (Sherwin, 1996). The relationship, if any, between the ultramafic assemblages and the mafic-intermediate rocks of the Forbes sheet area is unclear but they may represent the primitive mantle magmas from which the latter were derived.

The Brangan Volcanics in the Grenfell area and the Narragudgil Volcanics south of Wyalong represent Ordovician basaltic rocks of very different character to the calcalkaline suites. On the basis of previous work (Ryall, 1974; Bowman, 1977a) the Brangan Volcanics were correlated with the Cambro-Ordovician Jindalee Group, which was formally defined in the Cootamundra area (Basden 1982). Recognition of conodont *?Walliserodus sp* in chert associated with the Brangan Volcanics during this survey (I. Percival, NSWGS, pers comm) has established that the volcanics are of Ordovician age and therefore were erupted either contemporaneously with the Kirribilli Formation or represent a later period of oceanic basalt volcanism, possibly extending into the Silurian. Geochemically, the Brangan Volcanics are relatively primitive (MgO ~7%) olivine tholeiites, characterised by relatively high HFSE (TiO_2 ~ 1.8%), low K/Na ratios and flat light rare earths, all of which distinguish them from the calc-alkaline suites further west. These characteristics, reflected by a spidergram plot (Fig. 4.1.3), suggest that these MORB-type volcanics were derived from depleted asthenospheric mantle, possibly either in a well-developed back-arc basin or an intra-plate continental rift environment according to Shen Su Sun, AGSO (pers. comm.). A recently recognised sequence of mafic volcanic rocks with similar geochemical characteristics is the Narragudgil Volcanics, which crops out immediately south of Wyalong. The unit consists of fine to medium-grained basalts metamorphosed to greenschist or locally to amphibolite grade. The basalts have distinctive MORB-type chemical signatures on primordial mantle-normalised multi-element diagrams (spidergrams; Figure 4.3), including flat rare earth patterns and relative depletion in large ion lithophile element abundances. Warren *et al.* (1995) briefly mentioned the existence of these basalts and suggested that they had similarities to mafic rocks of the Jindalee Group. New geochemical data for the rocks broadly support this view, although comparisons are limited by the sparse and incomplete nature of published geochemical data (especially trace element data) for the Jindalee Group.

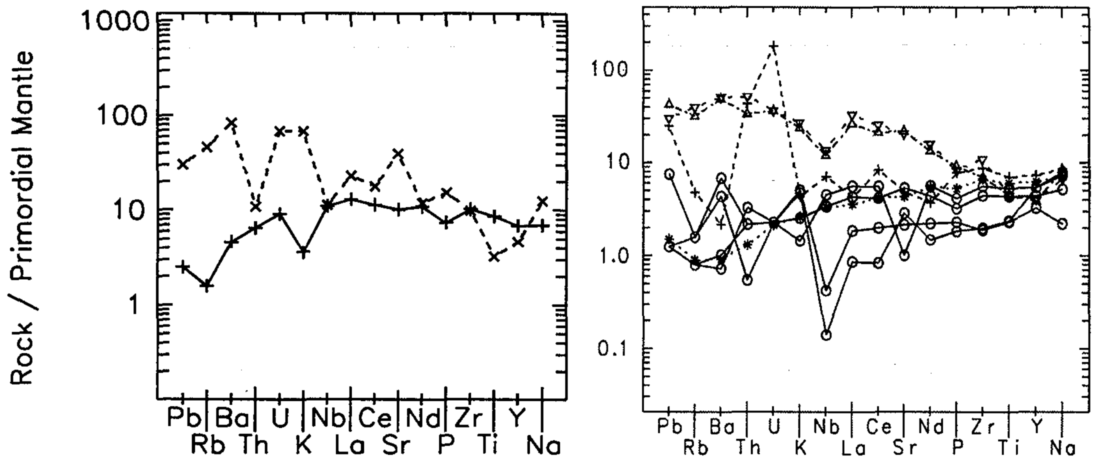


Figure 4.1.3 Primordial mantle-normalised trace element abundance diagrams (spidergrams). Left: solid line - Brangan Volcanics; dashed line – Goonumbla Volcanics. Right: O- Narragudgil Volcanics; + - basalt from Jindalee Volcanics (Warren *et al.*, 1995); Δ- Bland Diorite; ∇ - dyke intruding Narragudgil Volcanics; ✱- N-MORB (Sun & McDonough, 1988). Primordial element abundances are from Sun & McDonough (1988).

Wombin Volcanics are mostly latites and trachytes usually strongly porphyritic in plagioclase and to a lesser extent in hornblende, biotite and oxides. Intrusive rocks of the Wombin Volcanics are mainly quartz monzonites, monzonites, and monzodiorites containing phenocrysts of plagioclase with biotite and /or hornblende or pyroxene in a groundmass of alkali felspar. The Wombin Volcanics have K/Na ratios of ~ 1 and fall within the high-K Alkaline (shoshonitic) trend in the Peccerillo and Taylor (1996) K2O/SiO2 discrimination diagram (Fig. 4.1).

4.2. Post-Ordovician

Ollie Raymond and D A Wallace, AGSO

Classification of felsic igneous rocks

Felsic igneous rocks are classified here according to the S-, I- and A-type classifications of Chappell and White (1992) and Collins *et al.* (1982). These groups reflect the character of the predominantly sedimentary (S-type), igneous (I-type) and refractory or residual (A-type) source material of the magmas. However, there is still considerable debate as to the origin of A-type magmas. The ASI (Aluminium Saturation Index) *versus* SiO_2 diagram (Fig. 4.2.1) is a useful tool for discriminating I- and S-type magmas. I-type magmas generally have ASI < 1.1 with the ASI increasing with increasing SiO_2. Conversely, S-type magmas commonly have ASI > 1.1 with a decreasing trend with increasing SiO_2. However, it is difficult to use this discriminant in highly felsic or fractionated rocks where the two trends converge at ASI ≈ 1.1. A-type magmas generally have characteristically high Ga/Al_2O_3 ratios (Fig. 4.2.2) and high levels of high field strength elements (HFSE; e.g., Zr, Nb, Y), rare earth elements (REE), and other elements such as flourine and zinc. Strongly fractionated I- and S-type granites and peralkaline granites, however, can exhibit some of these characteristics (Fig. 4.2.2). Distinctive mineralogy, such as hornblende and ilmenite (I-type); garnet, cordierite and muscovite (S-type); and allanite, halogen-rich apatite, flourite or sodic amphiboles (A-type) can also be useful in determining the affinity of felsic igneous rocks, but are not necessarily diagnostic.

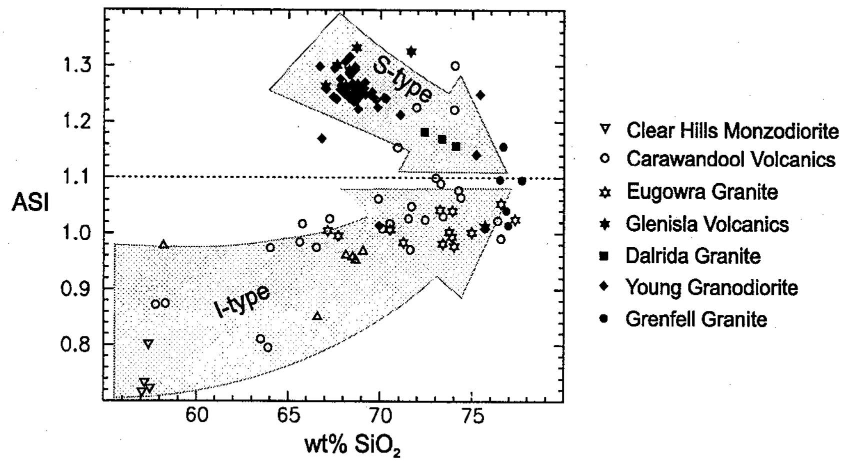


Figure 4.2.1. ASI (Aluminium Saturation Index) *versus* SiO_2 plot.

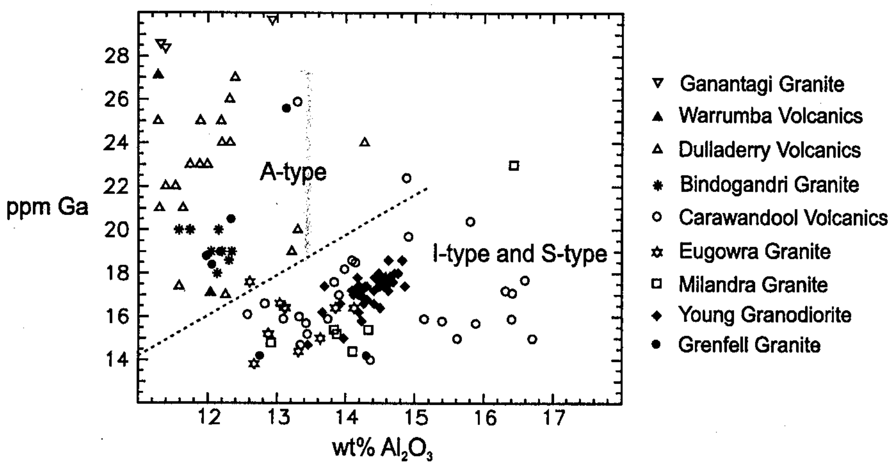


Figure 4.2.2. Ga *versus* Al_2O_3 plot. The A-type field may include highly fractionated granites (e.g., Grenfell Granite) and peralkaline granites (e.g., Ganantagi Granite).

The degree of fractionation and oxidation state of a magma is important for determining the probability of associated mineralisation (Blevin and Chappell, 1996). Fractionation can be measured by ratios of elements removed or concentrated by the processes of fractional crystallisation, such as the Rb/Sr ratio (Fig. 4.2.3). Other elements such as Ba, Th and Zr may also exhibit fractionation trends in felsic magmas.

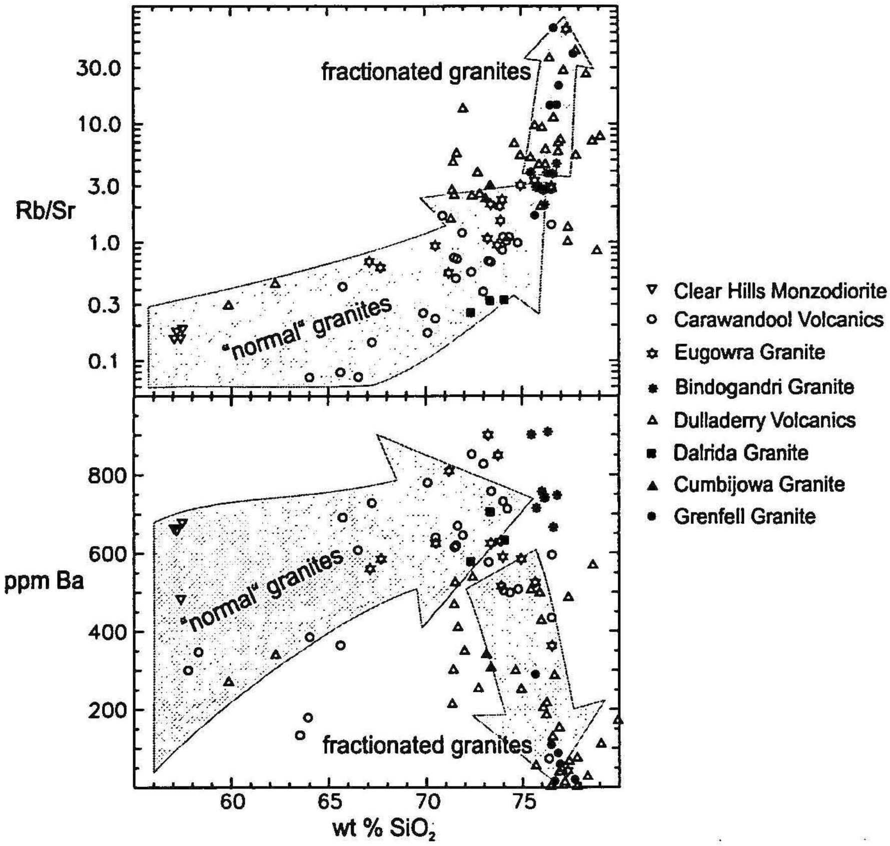


Figure 4.2.3. Rb/Sr *versus* SiO_2, and Ba *versus* SiO_2 plots as measures of fractionation.

The oxidation state of a magma can be estimated by the ratio of oxidised to reduced iron in the magma (Champion and Heinemann, 1994) (Fig. 4.2.4). Redox conditions can have a strong bearing on the ore metals concentrated during fractionation (Blevin and Chappell, 1996). Cu, Mo and Au are generally associated with more oxidised magmas, with Sn and W associated with more reduced and more fractionated magmas.

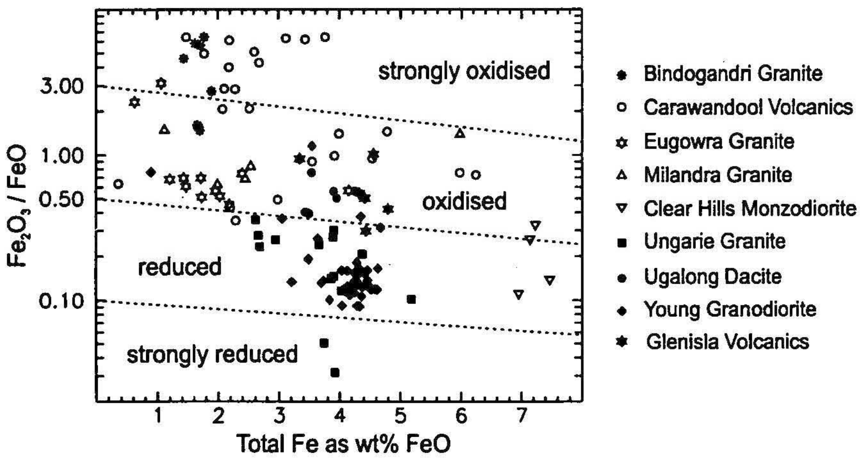


Figure 4.2.4. $Fe2O_3/FeO$ *versus* total Fe plot as a measure of oxidation state.

Early Silurian

Following the cessation of mafic-intermediate magmatism across the eastern Lachlan Fold Belt (LFB) in the earliest Silurian, there was a marked change in style and composition of magmatism. Thickening of the crust during Ordovician subduction was followed by a major heating of this crust in the early Silurian. Huge volumes of predominantly felsic magma were intruded and extruded in the LFB during the Silurian and Devonian periods.

Early Silurian magmatism on the Forbes 1:250 000 sheet occurs in the west of the sheet, primarily west of the Gilmore Fault Zone; and in the far east of the sheet, east of the Coolac-Narromine fault zone. In the east, the S-type felsic volcanics of the Douro Group were extruded. The small volume of these volcanics on the Forbes 1:250 000 sheet represents only the western edge of a large belt of early Silurian S-type ignimbritic volcanics (i.e., Canowindra, Hawkins and Laidlaw Volcanics) which extend from near Wellington in the north to the Canberra region in the south. The volcanics were sourced from subvolcanic plutons such as the Cowra Granodiorite near Cowra. The Douro Group is represented by the Illunie and Glenisla Volcanics on the Forbes 1:250 000 sheet. The Glenisla and Illunie Volcanics are both primarily rhyodacitic ignimbrites, with abundant coarse-grained phenocrysts of quartz, plagioclase and biotite. Garnet and cordierite also occur, but the cordierite is generally completely altered. The presence of limestone and sedimentary lenses within the Illunie Volcanics indicates they were erupted in a submarine environment. In general, alteration of the Illunie Volcanics precludes geochemical analysis. However, the less altered Glenisla Volcanics are unfractionated S-types, with high ASI, low Sr, and they are weakly to moderately oxidised (Fig. 4.2.4)

In the region west of the Gilmore fault zone, the Ordovician Wagga Group metasediments were intruded by a suite of primarily S-type and lesser I-type granitoids with associated volcanics. SHRIMP U-Pb zircon dating has indicated that the majority of this magmatic phase was tightly constrained to the Llandovery, with some minor intrusions as young as Wenlock. The S-type granites include the Ungarie Granite, Charcoal Tank Granite, Calleen Granodiorite and Billy's Lookout Granite. I-types include the Bland Diorite and some minor phases of the Ungarie Granite. The S-type granites typically contain muscovite, biotite and cordierite. The Ungarie Granite is generally a uniform, typical S-type granite, but several isolated outcrops are hornblende-bearing and have I-type geochemical characteristics of higher CaO and Th, and lower Rb and Y. It is possible that these outcrops represent a separate intrusive phase although this is not evident on the basis of either regional magnetic or SHRIMP U-Pb zircon age data. The Charcoal Tank Granite is distinctive in that its margins are gradational with the migmatitic metasediments it intrudes. Its anomalously low CaO, low Na_2O, and low Sr geochemistry also suggests that the granite is derived locally from melting of the surrounding sediments and has moved little from its place of original melting.

The S-type Ugalong Dacite, which occurs at the northern margin of the Ungarie Granite, has the same Llandovery age as the adjacent granite. However, the Ugalong Dacite is probably not co-magmatic with the granite, having significantly lower MgO, Sr and Cr overall, and higher Al_2O_3, CaO and Na_2O in less siliceous rocks. The dacite is also a predominantly oxidised magma relative to the more reduced Ungarie Granite (Fig. 4.2.4). The more porphyritic examples of the Ugalong Dacite are similar to the Douro Group volcanics further east, with abundant phenocrysts of plagioclase, resorbed quartz and biotite. The Ina Volcanics, which occur in the Burcher area, are slightly younger than the Ugalong Dacite, but have similar porphyritic characteristics to the Ugalong Dacite and Douro Group. No geochemical analyses are available as yet for the Ina Volcanics.

The I-type Bland Diorite is a poorly outcropping diorite-tonalite complex immediately north and east of Wyalong. Aeromagnetic data suggest that the Bland Diorite intruded the Narragudgil Volcanics and U-Pb SHRIMP geochronology gives an early Silurian age for the intrusion. Also intruding the Narragudgil Volcanics is a suite of andesite and diorite dykes. These are considered to be sub-volcanic equivalents of the Gidginbung Volcanics, which do not crop out as part of the stratigraphic succession on the Forbes sheet. The geochemical characteristics, including relative enrichment in incompatible elements (both large ion lithophile and high field strength elements) and small but distinct relative depletions in Nb, P and Ti, suggest calc-alkaline or shoshonitic affinities. The Gidginbung Volcanics host significant gold mineralisation, including the Gidginbung deposit north of Temora. U-Pb dating of zircons from the Gidginbung Mine indicates a Late Ordovician or Early Silurian age (Perkins *et al.*, 1990). The diorites show similar geochemical characteristics to the dyke rocks, including identical element enrichment patterns at the same SiO_2 content (Figure 4.2.3), and are clearly petrogenetically related to them.

Siluro-Devonian

Magmatism around the Silurian-Devonian boundary was widely dispersed around the Forbes 1:250 000 sheet. The Young Granodiorite is a very large, mainly unfractionated, reduced S-type granitoid (Fig. 4.2.1, 4.2.2, 4.2.4), extending from the southeast corner of the Grenfell 1:100 000 sheet for over 120 km to the south. Numerous analyses of this granodiorite show that it has a remarkably uniform composition for such a large intrusion. In detail, however, lithologies range from a predominant biotite granodiorite to aplite, and textures range from porphyritic to equigranular. The granodiorite is similar in many respects to the Silurian granites exposed in the west of the Forbes 1:250 000 sheet.

Recent SHRIMP U-Pb zircon dating of the Mortray Hill Granite (L.Black, pers. comm.) suggests that the Bogalong Suite, which includes the Mortray Hill, Rosehill, Lucy Hill, Hill 60, and Glenroy Granites, is of Siluro-Devonian age. The Bogalong Suite consists of non-magnetic, generally reduced S-type granites with varying degrees of fractionation. The granites contain significant tin mineralisation with common tourmaline alteration and development of marginal greisens. It is probable that the Bogalong granites are exposed near the top of the intrusions and the northern parts of batholith are covered by a thin veneer of Kirribilli Formation. Three isolated outcrops of clinopyroxene-bearing tonalite occur with the Bogalong Suite granites. It is not clear why these small bodies of such distinctly different composition and I-type source rock occur within this fractionated S-type batholith.

The Caragabal Granite, intruded into Kirribilli Formation south-east of Wirrinya, is an oxidised I-type granite with high levels of HFS elements such as Ti, Zr, Nb and Y. Some analyses of this granite suggests a minor degree of fractionation, but in general it appears to be an unfractionated pluton. The granite is associated with some minor gabbroic intrusions at its southern margin.

The Byong Volcanics[1] of the Derriwong Group near Bogan Gate represent a phase of probable I-type, submarine felsic volcanism during the latest Silurian – earliest Devonian. The volcanics have a generally I-type trend on an ASI-SiO_2 plot (Fig. 4.2.1), but there is much scatter in the available major and trace element data. The volcanics are, however, predominantly unfractionated, strongly oxidised, plagioclase-phyric, high K rhyolites with very low levels of U and Th. The Yarnel Volcanics on the Condobolin 1:100 000 sheet are thought to be laterally equivalent to the Byong Volcanics.

Some minor S-type felsic volcanism also occurred at this time within the Euglo Formation on the western margin of the Condobolin 1:100 000 sheet. The volcanics are predominantly porphyritic, flow banded, cordierite-bearing rhyolites. The Euglo Formation was intruded by the Cookaburragong Granodiorite in the early Devonian. This non-magnetic granite contains accessory tourmaline and, although no geochemical data are currently available, is probably an S-type.

Early Devonian

Volcanism

The Kadungle and Carawandool Volcanics of the Trundle Group are I-type volcanics (Figs. 4.2.1, 4.2.2) of predominantly felsic composition and are not dissimilar to the older Byong Volcanics. The Kadungle Volcanics crop out in the northern parts of the Bogan Gate 1:100 000 sheet, folded around the Tullamore Syncline. The Carawandool Volcanics crop out some 50 km further south. Interpretation of regional aeromagnetic data suggests that the two volcanic units may be continuous at depth beneath a substantial cover of Cainozoic alluvium and Hervey Group sediments. The volcanics are predominantly rhyolitic to dacitic lavas with lesser volcaniclastic units. Minor basaltic to andesitic lavas also occur, most notably in the lower parts of the Carawandool Volcanics.

Sediments interbedded with the Kadungle Volcanics indicate at least a partly marine environment for their eruption, while the Carawandool Volcanics were erupted in a subaerial environment, possibly in a continental rift setting. A single εNd analysis of basalt from the Carawandool Volcanics returned a value of +8.1 (Raymond and Sun, 1998). This strongly positive value suggests a primitive, mantle-like source for these volcanics. The felsic rocks of the Kadungle and Carawandool Volcanics are unfractionated, oxidised I-types (Figs. 4.2.3, 4.2.4) with high to very high Zr and TiO_2, and low Th and Rb. There are, however, some notable differences in their compositions. The Kadungle Volcanics have higher Na_2O, very low CaO and K_2O, and have an unusual and distinctive low V composition.

In the east of the Forbes 1:250 000 sheet, two small volcanic units of presumed early Devonian age occur; the Coonambro and Warrangong Volcanics. Neither of theses units have tightly constrained ages and they have tentatively been included in the Black Range Group which includes the Mountain Creek Volcanics to the southeast of the Forbes 1:250 000 sheet area. The volcanics range from rhyolite to andesite in composition and include lavas and ignimbrites. The Warrangong Volcanics are intruded by the Crowther Monzodiorite, and the Coonambro Volcanics are intruded by an unnamed diorite body. Both volcanic units are unfractionated, hornblende-bearing I-types. The Coonambro Volcanics have high TiO_2 and characteristic very high Sc concentrations. The one geochemical analysis of the Warrangong Volcanics is inconclusive, but actually has S-type characteristics. Many thin andesitic dykes, possibly derived from the Warrangong Volcanics, intrude the adjacent Young Granodiorite.

Plutonism

In the east of the Forbes 1:250 000 sheet, the relatively minor early Devonian volcanism is overshadowed by the major plutonic event which produced large volumes of I-type and minor S-type magmas. The I-type granitoids mainly occur east of the Coolac-Narromine Fault Zone and comprise the Eugowra Batholith, a major component of the high temperature Boggy Plain Supersuite (Wyborn *et al.*, 1987). The batholith contains the Eugowra, Lords, Milandra, Loch Lomond and Stump Hole granites and the Clear Hills Monzodiorite. The individual plutons range widely from mafic to very felsic compositions, with only the Loch Lomond Granite and parts of the Eugowra Granite being fractionated (Fig. 4.2.3). The batholith on the whole is fairly strongly magnetic and of oxidised composition. The notable exception is the Clear Hills Monzodiorite, which is a moderately reduced and relatively

[1] The Milpose Volcanics, as described by Krynen *et al.* (1990) east of Bogan Gate, are now interpreted to be the eastern extension of the Byong Volcanics.

weakly magnetic intrusion despite its relatively mafic composition (Fig. 4.2.4). The S-type Cumbijowa Granite occurs west of the Coolac-Narromine Fault Zone just to the west of the Eugowra Batholith and is a non-magnetic, reduced, and moderately fractionated pluton.

Other intrusives of the early Devonian include the Porters Mount Tonalite and Dalrida Granite (both SHRIMP U-Pb zircon dated), and the Bundaburrah and Berendebba which are assumed to be of similar age. The Porters Mount Tonalite on the Marsden 1:100 000 sheet, is a small, composite, dyke-like intrusion with an associated hydrothermal breccia pipe alteration zone. Several other similar but buried dyke-like intrusions are inferred from magnetic data southeast of Porters Mount. The εNd composition of the alteration breccia associated with the Porters Mount Tonalite (+6.5; Wyborn and Sun, 1993) was previously thought to indicate an Ordovician age for the intrusive. However, it is now clear that some early Devonian magmas had similar compositions to those produced in the Ordovician (Raymond and Sun, 1998) and may have similar metallogenic potential.

The Dalrida, Bundaburrah, Berendebba and Wirrinya granites are all near elliptical-shaped Devonian intrusions which occur in a north-south corridor through the middle of the Marsden 1:100 000 sheet. The intrusions form erosional lows and are mainly covered by alluvial sediments, up 100 metres thick. Their subsurface extents are interpreted from regional magnetic data. The Dalrida Granite is a zoned but unfractionated S-type granite (Fig. 4.2.1, 4.2.3) which intrudes the Carawandool Volcanics. The granite was intruded just after broad folding of the volcanics at around 400 Ma and is not related to them. The Bundaburra Granodiorite also intrudes the Carawandool Volcanics but may be related to that magmatic phase, being an unfractionated I-type intrusion with similar trace element characteristics to the volcanics. However, the granodiorite has a very unusual mineralogy, containing both orthopyroxene and clinopyroxene in a relatively felsic magma (~68% SiO_2). The Berendebba Granite is the southernmost of the Marsden 1:100 000 sheet granites, but is completely buried by alluvial sediments. A single chemical analysis of a float boulder suggests the granite may be of S-type composition. However, its highly magnetic character may be more consistent with an I-type composition.

The Broula Granite, which occurs on the boundary of the Grenfell and Cowra 1:100 000 sheets, intrudes the Young Granodiorite, and may be as young as middle Devonian. The Broula Granite is a magnetic, largely elliptical pluton, with a composition unique to the region. The granite is extremely high in U, Th and K and hence has a very strong radiometric response. It also contains very high levels of HFSE such as Zr and Nb. Despite these extreme chemical characteristics, the granite appears not to be fractionated and suggests an extremely refractory source rock.

Middle to Late Devonian

A marked change in igneous activity occurred in the eastern LFB in the middle Devonian when A-type felsic to bimodal volcanism occurred in subaerial continental rift settings at widely spaced locations. The formation of an extensional regime may have resulted from the relaxing of the compressional stresses of Early Devonian deformation in the LFB. The Boyd Volcanic Complex on the south coast of NSW, and the Dulladerry and Warrumba Volcanics in the central west of NSW are examples of this type of volcanism.

Only a small part of the Dulladery Volcanics occurs in the northeast corner of the Parkes 1:100 000 sheet. They extend north to Tomingly and east towards Manildra. The volcanics are predominantly rhyolitic ignimbrites, lavas and epiclastic sediments, with minor intercalated dacite, andesite and basalt. The Warrumba Volcanics, on the Grenfell 1:100 000 sheet, are similarly comprised of rhyolitic lavas and ignimbrite, with a thin basaltic layer at the top of the sequence. The main ignimbrites in each volcanic sequence, the Curumbenya and Coomaloo Ignimbrites, are remarkably similar in their strongly welded nature, having abundant small quartz and K-feldspar phenocrysts, and having only a minor lithic component. The generally fine-grained nature of these ignimbrites suggests a particularly explosive eruptive episode.

Chemically, the volcanics have characteristically high Ga/Al_2O_3 ratios (Fig. 4.2.2) and very high HFSE contents, notably Zr. The Dulladerry Volcanics also display evidence of fractionation in their variably low Ba content and high Rb/Sr ratio (Fig. 4.2.3). This evidence of fractionation is considered unusual for A-type magmas (Whalen, Currie and Chappell, 1987), although it has been invoked in A-type magmas near Temora (Wormald and Price, 1988). The apparent scarcity of fractionation and the low water content of A-type magmas has resulted in them being considered poorly prospective for mineralisation. However, it should be noted that epithermal alteration ± gold mineralisation occurs in each of the Dulladerry, Warrumba and Boyd Volcanics.

The Dulladerry Volcanics are thought to be co-magmatic with the Bindogandri Granite. This high silica, granophyric granite is a high level, subvolcanic pluton with myarolitic cavities. Its Ga/Al_2O_3 ratios are high (although not as extreme as the Dulladerry Volcanics; Fig. 4.2.2) and it has high levels of HFSE, Zn and F. Trace fluorite also occurs in the granite. The Warrumba Volcanics may be related to the nearby Grenfell Granite, which has recently been dated as Middle Devonian (L.Black, pers. comm.). The Grenfell Granite is a non-magnetic, weakly oxidised, strongly fractionated granite of possible A-type composition. The adjacent Cemetery Granite is an extremely fractionated aplitic granite and possibly represents a late stage fractionate derived from crystallisation of the Grenfell Granite. The extent of fractionation of the Grenfell and Cemetery granites (Fig. 4.2.3) means that geochemical methods of determining their source rock character are inconclusive (Fig. 4.2.1). Although the Grenfell Granite plots in the A-type field on a Ga/Al_2O_3 diagram (Fig. 4.2.2), fractionated I- and S-type granites can also plot in this field.

Other granites of A-type to peralkaline compositions include the Wirrinya and Ganantagi granites (Fig. 4.2.2). Neither of these granites have constraints on their ages apart from their intruding early Devonian rocks. They have been tentatively placed in the middle to late Devonian due to the prevalence of A-type and peralkaline magmatism at that time in the eastern Lachlan Fold Belt. The A-type Wirrinya Granite approaches peralkaline compositions (Al/K+Na = 0.9) and does not outcrop apart from a couple of small apophyses and dykes marginal to the main body as defined from regional magnetics. The small peralkaline Ganantagi Granite outcrops prominently west of Bogan Gate, but is essentially non-magnetic. Both the Wirrinya and Ganantagi intrusions are high level granophyric granites with miarolitic cavities. The Wirrinya Granite contains minor sodic hornblende and minor flourite filling the cavities. The Ganantagi Granite contains abundant late-crystallising aegerine-augite and arfvedsonite, as well as calcite in cavities.

Carboniferous to Cainozoic

Following the late Devonian, igneous activity virtually ceased on the Forbes 1:250 000 sheet. The extensive Carboniferous felsic plutonism on the Bathurst 1:250 000 sheet did not proceed west of Orange. However, some east-west trending dolerite dykes south of Condobolin are interpreted to be of Carboniferous age.

Minor mafic volcanism of Miocene age occurs at the eastern and western margins of the Forbes 1:250 000 sheet as part of the extensive continental mafic volcanic episode in eastern Australia in the Tertiary. In the east of the sheet, a narrow valley-fill olivine basalt flow, which flowed some 50 km from its source at Mount Canobolas near Orange, occurs beneath recent alluvial sediments in the Eugowra area. In the west, the Weebar Hill Leucitite, south-west of Condobolin, was extruded, forming a layered pile of lava flows, scoria and breccias. This ultramafic lava contains clinopyroxene, olivine, Fe-Ti oxides and up to 23% leucite crystals enclosed in a glassy groundmass. Cundari (1973) suggested a mantle source at depths greater than 100 km for the leucitite, with intrusion along deep-seated crustal structures (possibly the Gilmore Fault Zone) which were reactivated in the Tertiary.

5. REGOLITH AND LANDSCAPE MAPPING AND EVOLUTION

David Gibson and Roslyn Chan

Introduction

The term regolith generally includes all earth materials between fresh rock and fresh air, which have been affected by processes operating at, or near, the earth's surface. In addition, we emphasise bedrock units which have a geomorphic context, e.g., Mesozoic/Cainozoic sedimentary rocks and lavas. The regolith is in effect the zone of interaction between the lithosphere and the biosphere, hydrosphere, and atmosphere. There are two major types of regolith: 1) *In situ* regolith, which encompasses weathered bedrock retaining its original volume and structure (saprolite), and the collapsed remains of weathered bedrock, which are interpreted not to have moved laterally other than by local bioturbation (e.g., residual deposits and some lags); 2) Transported regolith, which includes terrestrial sediments moved by water, wind, and gravity. Regolith also includes weathered rock and sediments cemented by silica, iron, carbonate, *etc.*, to form various hardpans and duricrusts.

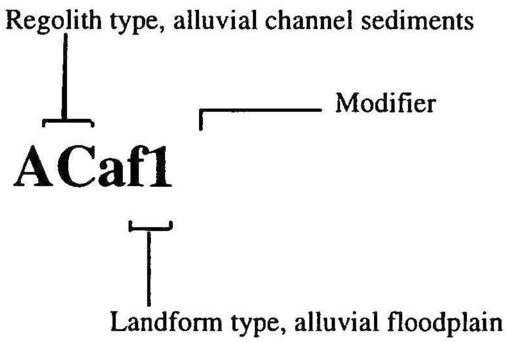
Regolith is intrinsically related to the landsurface and the processes that occur there. For example, the depth of and degree of weathering of *in situ* regolith is dependent not only on the properties of the parent fresh bedrock, but also the depth to water table and chemistry of groundwater, both present and past. Processes that depend on the interaction between landform and climate deposit transported regolith at the earth's surface. Regolith is preserved when the rate of production of regolith material, by deposition or lowering of the weathering front at the fresh bedrock-saprolite interface, is greater than the rate of erosion of the regolith mantle.

Regolith mapping techniques

It is not easy to map regolith components (sand, clay, *etc.*) as materials in their own right, especially in three dimensions, unless there is a large amount of exposure, drillhole data, *etc.* Much of Australia is covered by red dirt that tends to look the same no matter where it came from, or how it got there. Both mineral explorers and environmental managers, the major potential users of regolith information, need to know how transported regolith was deposited and transported and, if possible, where it came from. Therefore, in mapping regolith, we generally use landform boundaries to place regolith materials in context. The polygon approach to landform mapping is well established, with landsystem mapping pioneered by the CSIRO Division of Land Use Research in the 1940s and 1950s, and landform-based soils and land capability mapping done by many government agencies.

Thus, regolith maps have an underlying landscape basis, in contrast to geological maps, which have an underlying time and rock unit basis. Polygons on a geological map are linked to the reference, which gives details of stratigraphy, rock types, and age. Unless the map is a solid geology interpretation, the fact that a polygon is shown implies that the rock actually crops out, or is identifiable beneath shallow cover. With regolith maps, most polygons are defined by landscape elements. The reference gives a brief description of the landscape, a description of the main regolith components that occur within that landscape, and the relative importance of these components and their association with landforms. There is no time connotation, as regolith contains elements of depositional stratigraphy, weathering, cementation, and erosion, which can occur before, during, or after surficial deposition. However, the units are subdivided in the map reference on the basis of whether the most important surface regolith is transported or *in situ*. Transported regolith is further subdivided on the basis of mode of transport or deposition of the sediments (alluvial, aeolian, colluvial, *etc.*), and whether the associated landscape is depositional, erosional, or stagnant. *In situ* regolith is generally subdivided on the basis of whether it is saprolite or residual material (disaggregated material remaining in place after partial removal of weathering products by leaching, winnowing, *etc.*), and to what degree weathering of saprolite has taken place. Induration by iron, silica, carbonates, *etc.* can modify both sediments and weathered bedrock, especially in the more porous regolith zones.

On AGSO-CRC LEME regolith-landform maps, each polygon, or regolith landform unit (RLU), has a multi-letter code to describe its major regolith and landform types. The capital letters describe the regolith and the lower case letters describe the landform. For example, alluvial channel sediments being actively deposited on a river floodplain would be expressed in the following manner:



The numerical suffix at the end of the RLU code is a modifier that allows subdivision of polygons with broadly similar dominant regolith and landforms into several groups. This is useful to show subtle but nevertheless important differences, such as grainsize of sediments, type of soil present, nature of saprolite (e.g., mottled, bleached), *etc*.

Regolith and landform codes used on the FORBES 1:250 000 regolith landform map are:

Regolith codes

A	Alluvial sediments
C	Colluvial sediments (undifferentiated)
CH	Colluvial sediments (sheet flow deposits)
IS	Aeolian sand
L	Lake and swamp deposits
S	Saprolite (degree of weathering unknown or variable)
SS	Slightly weathered saprolite
SH	Highly weathered saprolite
UC	Clay of unknown origin

Landform codes

ap	Alluvial plain
af	Floodplain
as	Stagnant alluvial plain
al	Terraced alluvial plain
fa	Alluvial fan
pd	Depositional plain
pl	Lake
aw	Swamp
ud	Sand dune
us	Sand sheet
uw	Sand wedge
ei	Pediment
ep	Erosional plain (< 9 m relief)
er	Rises (9-30 m relief)
el	Low hills (30-90 m relief)
eh	Hills (90-300 m relief)
em	Mountains (> 300 m relief)
v	Remnants of volcanic landforms

A landform-regolith map may be constructed by reversing the regolith and landform symbols and colouring the map on the basis of the landform symbols, thus emphasising the landform classes present. Further details of regolith definition, mapping techniques, and AGSO's RTMAP regolith database are given by Pain *et al.* (1991). In addition to the RTUs, the preliminary Forbes Regolith-Landform map shows the extent of magnetically defined palaeodrainage deposits in the Wyalong area, as interpreted from magnetic imagery, as either green lines for narrow drainage lines, or a green stipple for broader areas. A magnetic palaeodrainage interpretation of the full Forbes 1:250 000 sheet area is yet to be completed.

Landforms

A landscape map derived from the 1:250 000 regolith landform map is presented in the Appendix (Fig. 1). Figure 5.2 contains summary information adapted from the NSW Water Resources Commission data on valley profiles across the Lachlan and Bland palaeovalleys. The relationship between regolith and landforms can be expressed as topo-sequences, in a similar way to catenas in soil science. Two topo-sequences representing transects across the Forbes sheet area are shown in Figure 5.3.

Alluvial RTUs reflect several topographic types. Floodplains are periodically inundated, implying continuing erosion and deposition. Areas mapped as undifferentiated alluvial plains are only occasionally inundated, implying slow deposition. Stagnant alluvial plains are slightly higher and beyond the reach of floodwaters of the main alluvial systems. They are interpreted to have minimal deposition or erosion, mostly by sheetwash, under present conditions, with local gullying along watercourses. Gilgai have formed over many areas of this landform. Terraced alluvial plains occur along the Lachlan River upstream of the Eugowra-Gooloogong area. Here, the Lachlan River is incising its alluvial deposits. Gently inclined alluvial fans adjoining areas of high relief have been mapped. They are characterised by locally derived sediment deposited by small migrating watercourses.

The shallow and ephemeral Lake Cowal has been mapped as lacustrine, but other areas of internal drainage are depicted as swamps. Shoreline deposits to the east of Lake Cowal have been included within the lacustrine unit.

Aeolian landforms include small locally derived sand dunes, mostly on the Lachlan alluvial plains, sand wedges, and a larger area of aeolian sand north of Wyalong. The distribution of small dunes has been taken from dunes depicted on the 1:100 000 geological maps, and a preliminary version of the Forbes soils landscape map provided by the NSW Department of Land and Water Conservation. However, numerous areas of aeolian sand depicted on the 1:100 000 geological maps to the east of Lake Cowal have been omitted. These have been mapped from interpretation of radiometric imagery, and our fieldwork shows that at least some of these areas are characterised by clay soils rather than sand. The sand wedges consist of aeolian sand trapped along the western side of steep ridges, e.g., the sand banked up on Jemalong Ridge. They take the appearance of colluvial slopes, but the composition of the sand and the geometry of the deposits imply an allochthanous aeolian source. The larger area of aeolian sand north of Wyalong includes sandsheets and several dunes, and is interpreted to have been derived from sandy deposits in the Wyalong palaeovalley, and partly covers the palaeovalley deposits (see below).

Erosional landforms have been mapped on the basis of relief and morphology. Most erosional landforms have a veneer of sediment over saprolite, with possible thicker sediment in valley floors. Many of the erosional units depicted on the map are composite, with a complex interplay between *in situ* regolith and a surface layer of transported material of variable thickness. Rather than try and show the latter, which is not easily mapped and presented at 1:250 000, we have emphasised the erosional nature of these units.

Larger pediments (low relief surfaces cut on rock) have been depicted around areas of steeper relief. These have a veneer of sediment, interpreted to be mostly colluvium, over saprolite. Erosional plains, rises, and low hills make up many units. These have complex interplays of outcrop areas on local crests and slopes, sediment-clad pediment slopes, inclined depositional plains with a sediment veneer, and valley floors with thicker sediment. Valleys in these areas have a general U-shaped cross-section, indicating that most of the associated sediment is colluvium, deposited by sheetwash on valley sides, rather than alluvium deposited by the main watercourse. This has important ramifications for geochemical soil sampling as the valley side colluvium is locally derived, in contrast to the narrow alluvial zone proper.

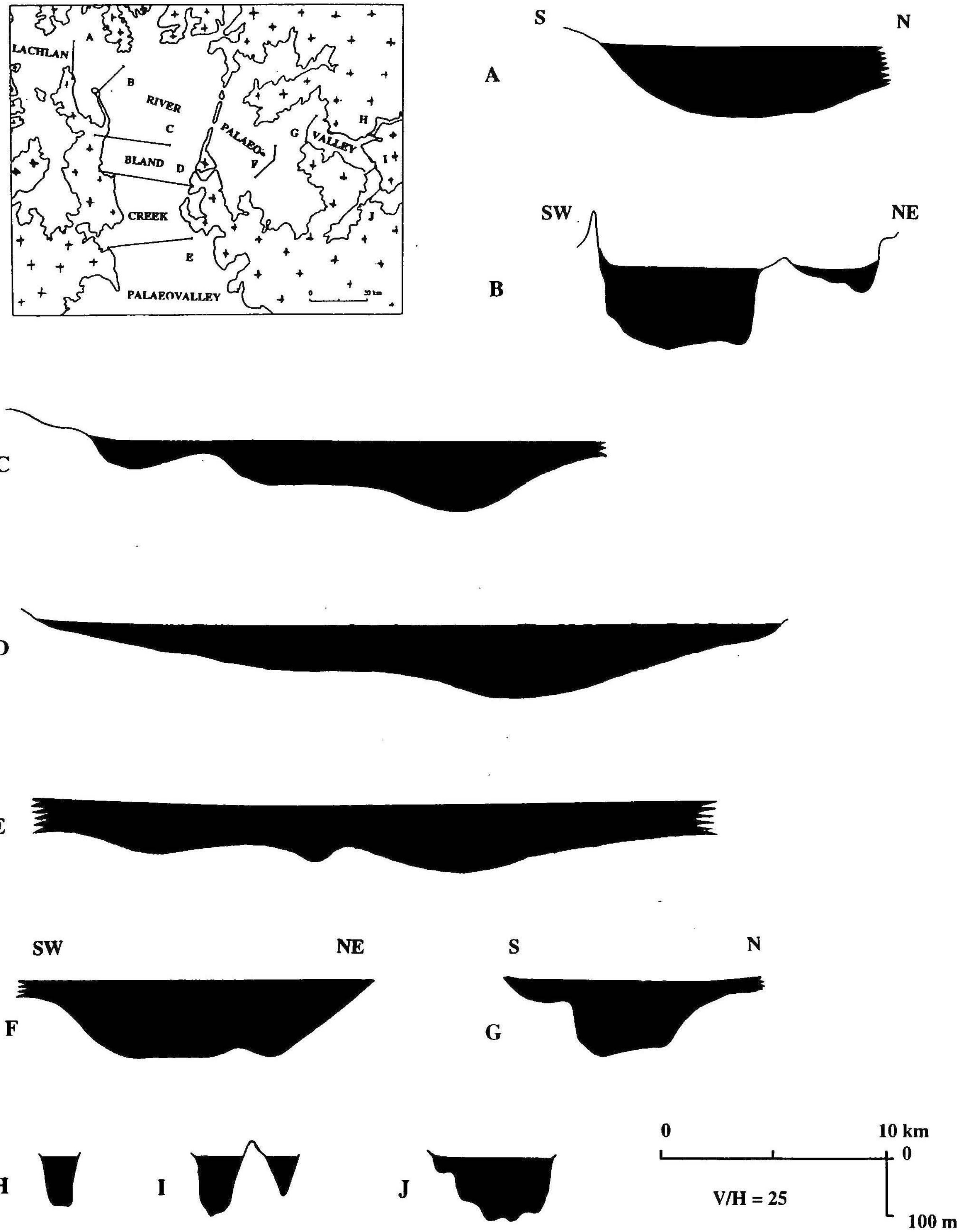


Figure 5.2. Valley profiles of the Lachlan and Bland palaeovalleys derived from NSW Water Resources Comission data.

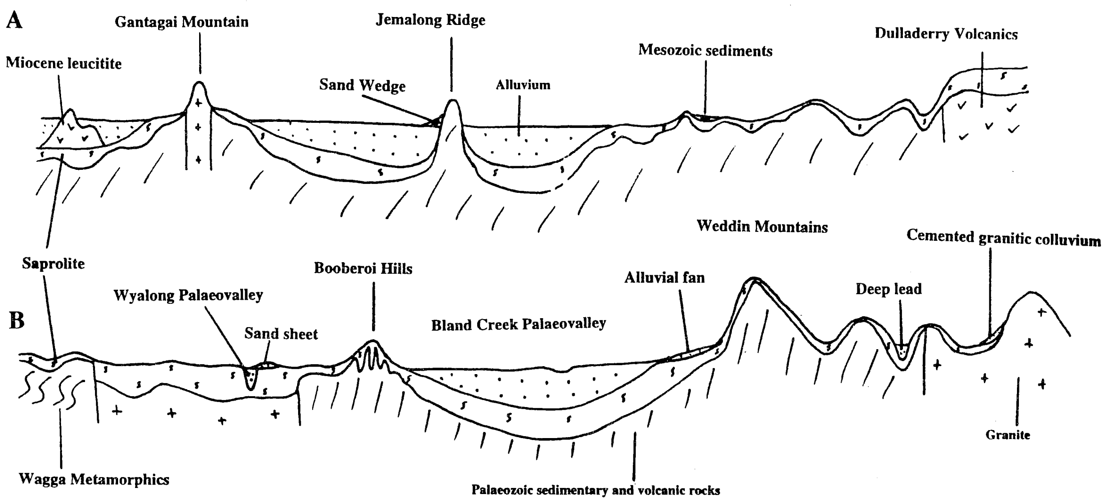


Figure 5.3. Sketch regolith sections across Forbes 1:250 000 sheet area. A. Condobolin to Parkes. B. West Wyalong to Grenfell. Thin transported regolith units omitted.

There may be narrow, deeply incised, alluviated palaeovalleys in some areas; for example, the deep leads known to exist around Parkes. However, away from areas actively explored for deep alluvial gold, little is known about the extent of these previously incised valleys. At this stage, little is known about the thickness of fill in the Wyalong palaeovalley (Lawrie *et al.*, in press).

Steeper landscapes generally have thinner transported regolith. However, even in steep mountainous areas, soils are formed in colluvial deposits, and many watercourses have alluvial bedload deposits. In the far northeast of the sheet area, a high elevation plateau-like area formed on Dulladerry Volcanics has regolith of sandy colluvial to residual deposits overlying highly weathered bedrock.

The remnants of volcanic landforms occur in the far east of the sheet area in the valley of Mandagery Creek, and southwest of Condobolin. The eastern occurrence is part of the Toogong flow from the 12 Ma Canobolas Volcano, 45 kilometres to the east. The basalt crops out at about 300 m beside Mandagery Creek. Basalt from this flow has also been intersected in water bores near the base of the 86 m thick fill of the Mandagery Creek valley at Eugowra (Williamson, 1986). Interpretation of magnetic imagery suggests that this flow is present within the valley fill sediments over much of the Mandagery valley within the Forbes sheet area. This distribution indicates that the lower part of the Mandagery valley was already incised and beginning to be alluviated by 12 Ma, but that its gradient was far steeper than today: about 90 m over a 13 km valley segment, compared with about 20 m for the modern valley floor.

Leucitite lavas crop out south of Condobolin. The lavas were extruded onto the mid-Late Miocene dissected landscape, and have since been partly buried by alluvium. Only the highest parts of the flows are now exposed, as inliers. Geophysical data suggest that an area about 7 km diameter is underlain by lavas. The hills are most probably not erosional remnants of a widespread, thick lava mass, but result from inflation of localised flows.

Regolith materials

Alluvium

We have subdivided the alluvial plains associated with the Lachlan River, and Bland, Goobang, Mandagery, and Humbug Creeks on the basis of gamma spectrometric response and polygons adapted from a preliminary version of the Forbes Soils Landscape Map prepared by the NSW Department of Land and Water Conservation. The youngest soils in floodplain areas are generally grey clays with a high radiometric response. Further from the main Lachlan River channel, areas with red earth and clay soils and high radiometric response correspond to areas flooded infrequently; these are mapped as alluvial plains. Low response areas generally also have red earth soils, but are not subject to flooding. These have been mapped as stagnant alluvial plains, and are interpreted to be more leached than areas with higher response. Upstream of the Eugowra-Gooloogong area, the Lachlan River has incised its deposits to form terraces. All these alluvial areas have mostly very low topographic gradients and have thick alluvium filling wide palaeovalleys. The deposits can be considered to be upstream equivalents of younger Murray Basin sediments. The polygons are based on surface materials, with no reference to the underlying sediment, details of which are known only from water bore drilling.

Major areas of alluvium in local flat-floored valleys in the Grenfell area, and the upstream portion of Goobang Creek, have been mapped. At Grenfell, the alluvium partly fills steeply incised valleys with moderate to high gradient profiles. These drain south, then west to the Bland Creek alluvial plains. The alluvium in the upstream portion of Goobang Creek has a distinct high potassium radiometric response (reflecting sediment derived from high response bedrock units), and has been delineated on the basis of this signature.

Some areas of alluvial fans have been mapped adjacent to areas of higher relief (e.g., west of the Weddin Mountains), based on airphoto interpretation and radiometric signature. Gilgai have formed in many places on the broad alluvial plains. These areas have been depicted as a separate unit, as they represent areas with swelling clay soils, and present engineering problems for roads and buildings.

Deep, narrow, sediment-filled palaeovalleys are known to be present in some erosional areas. The sediment in these is assumed to be alluvium, although Wilson and McNally (1996) have interpreted much of the sediment fill of the Parkes deep leads to be deposited by debris flows. Gold-bearing deep leads have been depicted on the Forbes 1:250 000 Metallogenic Map (Bowman, 1976), but downstream continuations of these have not been mapped, due to low economic importance, difficulty in recognising their locations from surface observations, and lack of historical documentation.

Certain palaeodrainage deposits contain magnetic minerals, rendering them visible on magnetic imagery. Some of these deposits, in the Wyalong area, have been outlined on the regolith landforms map. The largest area of magnetic sediments occurs in the Wyalong palaeovalley and its tributaries, shown as a green stipple on the map. On high resolution AGSO magnetic imagery acquired in late 1998, the main valley can be traced for over 22 km, and the magnetic valley deposits are up to 1 km wide (Lawrie *et al.*, in press). The palaeovalley has been cut into granite weathered to 50–100 m, and is present in a low relief erosional landscape. The sediments are exposed in trenches at the West Wyalong tip where they consist of about 4 m of highly weathered, mottled clay, sharply overlain by about 75 cm of poorly cemented iron-stained conglomerate grading up to 2-3 m of sandstone and siltstone. The base of the sediments is not exposed. Most of the detrital grains in the conglomerate are magnetic pisoliths, with minor ferruginous rock fragments, and small quartz pebbles. Magnetic susceptibility of the conglomerate ranges up to $30\,000 \times 10^{-5}$ SI.

Thickness of the palaeovalley sediments is not known at present, and we are not aware of any exploration drillholes or water bores that have penetrated the sediments. Company data from the area of the expected downstream extension of the palaeovalley beneath the Bland Creek alluvial plain indicate that the depth of incision of the valley may reach 60 m at its downstream end. A CRC LEME-AGSO high-resolution seismic survey is planned to help determine the 3D geometry of the palaeovalley. In some areas, modern drainage follows the palaeovalley course. However, there are indications of topographic inversion in the headwater areas of the palaeovalley, and there has been major diversion of drainage by the accumulation of aeolian sand in an area north of Wyalong (discussed further in the section on aeolian sand).

The age of the valley fill sediment is not known. We have taken samples for palaeomagnetic dating of weathering, but there are no results, yet. We consider that the palaeovalley probably filled during the latter part of the time of alluviation of the Lachlan River palaeovalley system, so a Pleistocene depositional age is expected.

Other minor magnetic drainage deposits are shown as green lines on the map. These have not been investigated.

Colluvium

Colluvium is present as a veneer over much of the lower relief erosional units in the sheet area. We interpret this to be transported and deposited mainly by sheet flow that covers much of the lower relief erosional areas during heavy rain. As there is a fine mosaic of colluvial and saprolite dominated areas within these units, we have variously depicted them as being saprolite or colluvial dominated rather than mapping out the detailed distribution. An exception to this is the colluvium mapped on pediments surrounding areas of steeper relief. This has been delineated as two separate units, depending on whether the source is granitic or sediments-volcanics. In some areas (e.g., Billys Lookout north of Wyalong, and Gantagai Mountain in the Bogan Gate 1:100 000 sheet area), resistant granites form the hills, but sedimentary rocks underlie the surrounding pediments. The radiometric response indicates that the colluvium on the pediments is mostly granite-derived, and unrelated to the underlying rock. Partly cemented, granite-derived, sandy and gravelly colluvium is also interpreted to form a veneer over bedrock on eroding footslopes to granite hills north of Grenfell. This sort of material has also been observed around granite hills north of Temora, south of the sheet area.

Colluvium in areas of steeper landforms has generally been moved by gravity, either as creep or debris flow deposits. Soils in these areas have formed mostly in colluvial deposits.

Aeolian sediments

Aeolian sand is mostly present in local small dunes, mostly on the alluvial plains, and as wedges built up on the western sides of steep ridges. Most of the sand is probably locally derived from swamps, lakes, and sandy levees associated with modern Lachlan floodplain drainage, although aeolian sand north of Wyalong appears to be associated with the relatively narrow Wyalong palaeovalley. High potassium areas east of Lake Cowal, showing on radiometric images, may correspond with the remains of a lunette adjoining a palaeolake larger than is present today. Ground truthing of these areas has so far proved inconclusive, with some areas corresponding with sand, but others with heavy clay. Northeast of Wyalong, an area of aeolian sand overlies alluvial deposits of the Wyalong palaeovalley, described by Lawrie *et al.* (in press). We interpret this sand to have been locally derived from the palaeovalley sediments, and appears to have caused the diversion of modern drainage from the palaeovalley in this area.

Lacustrine and swamp sediments

Lacustrine and swamp sediments are generally fine-grained with heavy, grey clay soils. Possible sandier shoreline deposits immediately east of Lake Cowal are also depicted. Most of these deposits overlie the generally thick alluvial fill of the Lachlan valley, but saprolite is present at shallower depths beneath the western part of Lake Cowal.

Saprolite

The development of saprolite depends on local conditions such as bedrock lithology and its susceptibility to weathering, and topographic position. We have only limited data on the degree of weathering, so many of the bedrock dominated areas have been mapped as having undifferentiated saprolite. Mining records show that the granite in the Wyalong area is generally highly weathered to a depth of 50 m or more thus, we have shown polygons of highly weathered saprolite in this area. Many of the bedded Palaeozoic units have highly variable weathering. For example, the Edols conglomerate, which forms ridges northeast of West Wyalong, consists of interbedded highly weathered mudstone, slightly weathered conglomerate, and variably weathered sandstone. Company exploration data and logs of water bores indicate that much of the bedrock beneath the thick alluvial sediments of the Lachlan palaeovalley and its tributaries is highly weathered, with thicknesses of up to about 50 m in the Bland palaeovalley.

Residual deposits

We have not specifically identified residual deposits but some lags are probably truly residual, and there is a gradation from residual to colluvial material as sediments begin to be transported by slope processes.

Regolith of unknown origin

Areas of gilgai in erosional settings have been mapped as having regolith of unknown origin. We have not studied the clayey soil of the gilgai , and this material could either be of colluvial, alluvial, or residual origin.

Regional context of regolith development

The following is a synopsis of our current understanding of landscape regolith development in the region, encompassing the northern Lachlan Fold Belt area, and extending east, over the Sydney Basin. Further details can be found in Chan (1999) and Gibson and Chan (1999). The oldest recorded weathering in the area is at Northparkes mine (just north of the Forbes sheet area), where Pillans *et al.* (1998) recorded an interpreted Carboniferous palaeomagnetic pole in highly weathered Late Ordovician monzonite. These authors concluded that weathering of saprolite in the area has been an ongoing process since at least late the Palaeozoic. O'Sullivan *et al.* (1998) have combined these data with apatite fission track data from samples gathered from the mine and surrounding area. They conclude that the rocks in the mine area were near the surface and undergoing weathering in the Early to Middle Carboniferous, then buried under a Late Carboniferous to Late Permian sequence which was thick enough to raise temperatures to more than110° C. Note that there is no preserved record of Permian sedimentation in the Forbes area to confirm the fission track data. Further south, at Illabo (between Junee and Cootamundra), remnants of *Glossopteris*-bearing sediment have been recorded (Warren *et al.*, 1995), though we could not locate this material at the mapped field location. Rapid cooling in the Late Permian to Early Triassic indicates vigorous erosion, possibly related to the Hunter-Bowen Orogeny. O'Sullivan *et al* concluded that relative stability followed, until erosion during the early Tertiary removed a further kilometre of cover rock. O'Sullivan (pers. comm., March 1999) indicates that more recent detailed interpretation of data indicates a period of moderate reheating (about 20° C, equivalent to about 700 m of sediment deposition at current thermal gradient of 28° C/km) during the Early to Late Cretaceous, leading up to the early Tertiary cooling event.

We have previously considered it most likely that the sediments of the Surat Basin originally extended over much of eastern NSW and that uplift associated with the initiation of rifting of the proto-Tasman Sea, at 95 Ma, gave rise to a palaeoslope to the northwest over the north Lachlan Fold Belt area, giving rise to initial erosion of the sediment (Chan, 1999; Gibson and Chan, 1999). This conclusion is based on our analysis of drainage evolution, and apatite fission track data provided by Raza *et al.* (in press) and O'Sullivan *et al.* (1995). The fission track data indicate an eroded section of 1-2 km in the southeast portion of the Surat Basin near Coonabarabran, and rapid denudation (several kilometres over a few million years) over what is now the Great Divide of southeastern Australia at about 95 Ma. We consider that the fast rates of denudation would be attainable only if poorly consolidated sediments, such as would be present in a southward extension of the Surat Basin, rather than the harder and more consolidated rocks of the Lachlan Fold Belt, were being eroded.

The total original thickness of Mesozoic sediments that may have extended across the Forbes sheet area is not well constrained. However, the interpretation of apatite fission track data outlined in the discussion of the Northparkes area (above) suggests that it may have been in the order of a half to one kilometre, and our model of drainage evolution is based on superimposition of drainage from a veneer of Mesozoic sediment, requiring at least a minimal thickness. Apatite fission track data (P. O'Sullivan, pers. comm., 1999) show that the major 95 Ma cooling episode recorded further east, in the Bathurst area, becomes less marked to the west, and is not recorded in the Forbes sheet area. However, the early Tertiary cooling event referred to above, in discussion of the Northparkes area, has been recorded across a wide area of western NSW. In areas where Mesozoic rocks are preserved, such as at Gunningbland, west of Parkes, this cooling must represent erosion of these or younger sediments. Elsewhere, the interpreted amount of Tertiary erosion gives an upper limit to the possible original thickness of Mesozoic cover.

Drainage in the pre-Mesozoic sedimentation landscape was to the north, as shown by palaeocurrent directions in the lower parts of the Surat Basin sequence preserved near Molong (about 50 km east of Parkes; Gibson and Chan, 1999) and Gunningbland (Bogan Gate 1:100 000 sheet area). Local relief prior to sedimentation at Molong was up to 100 m. In the Forbes sheet area, there are also indications of prior relief, with basement strike ridges protruding through remnants of Mesozoic sediments in the northeast of the Bogan Gate 1:100 000 sheet area. At the end of sedimentation in the Surat Basin in the Forbes sheet area, drainage was probably still to the north, with rivers flowing over a broad floodplain, possibly with some strike ridges of Lachlan Fold Belt rocks protruding. Rapid uplift of the eastern margin of the present-day Australian landmass, at the onset of rifting associated with the breakaway of the Pacifica landmass at about 95 Ma, is suggested by apatite fission track data. We interpret that this uplift induced a general northwest slope over central NSW (normal to the line of rifting), terminated deposition in the Surat Basin, and initiated erosion. The new palaeoslope would have been accompanied by the migration of rivers across the floodplain until they were flowing generally to the northwest. We interpret that one of these rivers was the palaeo-Lachlan, which eroded through the Surat Basin sediments, superimposing its course across the structural grain of the Lachlan Fold Belt. Some tributaries, such as the palaeo-Goobang and Mandagery Creeks, also had the erosive power to superimpose their courses across the structure of the underlying rocks. Others, such as the palaeo-Bland Creek, established their courses in either newly eroded or exhumed strike-controlled valleys.

This establishment of a new drainage pattern occurred prior to the initiation of the Murray Basin as a thermal sag during the Palaeocene. Continued subsidence of the Murray Basin created new low base levels, and accelerated the incision of major rivers flowing across the area. By the Late Eocene, the Lachlan and Murrumbidgee Rivers were entering the topographically depressed Murray Basin via gorges, as evidenced by Late Eocene sediments in the base of thick (*ca* 140 m) valley fills near Narrandera and Hillston (Martin, 1991). Nickpoint migration would have extended gorge erosion upstream. There are two control points for the timing of this incision on the Forbes sheet area. Jemalong Gap (downstream from Forbes) was eroded to 140 m below present floodplain level by at least the Late Miocene, as shown by sediments with a *T. bellus* zone palynoflora (late Early to mid Late Miocene, about 17-9 Ma – absolute age from AGSO STRATDATA database, 1999) at the base of the 140 m sedimentary section at this location (Martin, 1991). Secondly, a basalt flow from the 12 Ma Canobolas volcano, near Orange, is present near the base of the 86 m thick alluvial fill beneath Mandagery Creek at Eugowra (Williamson, 1986). Rapid incision of gorges in response to lowered base levels is a well-known phenomenon in landscape development, with headward advancement of nick points occurring far more rapidly than valley widening or erosion of drainage divides (e.g., Nott *et al.*, 1996). Williamson (1986) and Anderson *et al.* (1993) have described the morphology of the buried Lachlan palaeovalley in detail.

As part of the gorge development phenomenon, many tributaries of the palaeo-Lachlan also incised their courses (e.g., Mandagery, Goobang, and Bland Creeks). However, the nature of the incised palaeovalleys varied. The palaeo-Mandagery and Goobang Creeks eroded steep narrow valleys across the general north-trending bedrock structure of the areas, but the palaeo-Bland Creek eroded a broad, generally strike-aligned valley. In general terms, we consider that the rocks in the area of Bland Creek must have been exceptionally soft for the palaeo-Blank Creek to erode such a wide valley.

It is possible that the broad depositional area centred on Bland Creek is a Cainozoic graben or structurally downwarped area. However, seismic and drillhole sections across the valley in the vicinity of Lake Cowal and Marsden (Anderson *et al.*, 1993) show that the sediment-bedrock interface has a distinct valley form, with the base of the alluvial section at about 120 m depth. This would be the expected level if the valley was formed by erosion by the palaeo Bland Creek and its tributaries, with local erosion base level controlled by the depth of incision of the palaeo-Lachlan River.

Major alluviation of the incised palaeovalleys commenced in the Late Miocene (Martin, 1991) over a probable variably weathered bedrock terrain. Weathering is likely to have been ongoing, and perhaps accelerated, during sedimentation, resulting in deeply weathered bedrock covered by thick sediment. The alluvial fill has been divided into the Late Miocene to Pliocene Lachlan Formation, separated from the Pleistocene Cowra Formation by an erosional hiatus (Williamson, 1969; 1986). These formations are not well defined, and have been recognised only in the immediate environs of the Lachlan palaeovalley. The Lachlan Formation is more reduced, and contains well-rounded quartz gravels, implying reworking of older sedimentary deposits. The Cowra Formation is more oxidised, and contains gravels with varied clasts, implying a local bedrock source. It is probable that the palaeovalley was widened by erosion during the depositional hiatus, thus giving the buried 'valley-in-valley' form present in several sections.

Alluviation occurred at much the same time as the Murray Basin filled up. However, it is probable that sedimentation in the palaeovalley was controlled not only by rising base levels in the basin, but by climatic controls (hence vegetation, sediment balance and discharge) in the upper catchment as conditions became drier from Late Miocene (e.g., Martin, 1991). Thus alluviation probably occurred as a result of two independent time transgressive mechanisms operating at opposite ends of the river system.

The balance between erosion and deposition along the Lachlan River has probably varied considerably over time. At present, it appears that the river is incising into the Cowra Formation upstream of the Eugowra-Gooloogong area, leaving terraces up to 40 m above river level. Downstream, there has been little incision, but there are large areas of stagnant alluvial plains with well-formed red earth soils, as well as depositional areas with younger alluvial soils.

6. GEOPHYSICS

Michael Leys, NSWGS

Introduction

The Australian Geological Survey Organisation (AGSO) acquired airborne magnetic and radiometric data over the Forbes 1:250 000 sheet area in 1993 as part of the National Geoscience Mapping Accord. The data were to assist with mapping of the Second Edition Forbes 1:250 000 Geological Sheet. The use of both geophysical and geological data for regional geological mapping was pioneered in mapping of the Bathurst and Dubbo 1:250 000 sheets and was further developed with the Forbes 1:250 000 sheet mapping.

The airborne geophysical survey was designed to provide regional mapping resolution data (interline spacing 400 m) over the whole Forbes 1:250 000 sheet area. A small area in the north of the Parkes 1:100 000 sheet was flown with an interline spacing of 200 m, as this area is a particularly significant mineral province, and also to provide test data for new processing techniques being developed at AGSO.

Geological mapping was undertaken by staff from the Australian Geological Survey Organisation (AGSO) and the Geological Survey of New South Wales (GSNSW).

The geophysical data were acquired for three reasons:

1. to assist in the Second Edition mapping of the Forbes 1:250 000 scale geological map;
2. to make available a high quality dataset covering an area of high exploration prospectively;
3. to extend the areas thought to be prospective for the discovery of economic mineral deposits.

Survey specifications

The 1993 survey was flown as part of the National Geoscience Mapping Accord (NGMA) - a project to produce regional geological and geophysical coverage over parts of Australia likely to contain economic mineralisation. The recent advances in geophysical instrumentation, navigation, and data capture have allowed regional datasets to be efficiently collected at resolutions only previously applied to exploration leases. Full details of the airborne data acquisition are given in Franklin (1993). The general survey specifications are shown below:

Date of survey	2nd March to 9th May 1993
Mean Terrain Clearance	100 m, nominal terrain clearance
Flight Line Spacing (line kilometres)	200 m and 400 m (49 055 km)
Magnetometers	Geometrics G833 helium magnetometer (aircraft) Geometrics G866 base station magnetometer
Scintillometer	2 × DET1024 crystal detectors (33.56 litres total)
Navigation	GPS
Flight path recovery	vertically mounted video camera.
Data acquisition	Digital, using AGSO-written software.

Previous work

The previously available regional geophysical dataset was acquired by AGSO in the early 1960s as part of a program to produce a magnetic map of Australia. The flying height of 150 m and flight line spacing of 1.6 km was chosen to allow all of Australia to be flown within the prevailing logistical and financial constraints. The resultant dataset clearly shows the main geological framework of Australia but was never intended as a detailed mapping tool.

In order to be useful for detailed mapping of geological units, geophysical data must be obtained at a resolution finer than the size of the units being mapped. Many units have dimensions smaller than the 1.6 km interline spacing of the 1961 survey, severely limiting the value of the data for mapping.

The 1993 survey

The 1993 high-resolution survey was flown at a mean terrain clearance of 100 m with an interline spacing of 400 m. Magnetic measurements were made every 0.1 seconds (approximately seven metres apart) with a caesium vapour magnetometer. The spectrometer was read every second (approximately 70 m apart) and used a 33 litre thallium activated sodium iodide crystal detector. Data of this resolution can be reliably gridded at a cell size of 50 × 50 m providing sufficient detail to be used directly in geological mapping.

Radiometric data were further processed with noise reduction filters developed by AGSO. These filters enabled resolution of structural features in a areas of extensive regolith cover.

Standard images

The images described below formed the "standard image" suite used for most interpretations. It is important in forming a geological interpretation from geophysical data that all available information, including geological data, be included in the interpretation. For this reason, a number of different image types were used including:

Total Magnetic Intensity (TMI) with sun angle illumination (colour). An appropriate "sun angle illumination" filter can significantly highlight low amplitude linear features. It is especially effective in enhancing features trending approximately at right angles to the direction of the sun illumination. In the Forbes sheet area, the prevailing geological trend is north-south, requiring sun illumination from east or west. Easterly illuminations were generally used.

Sun angle illuminated images are a combination of the raw TMI data, as a pseudocolour layer, and a sun angle enhanced image presented as a grey scale layer. The resulting combined image reveals low amplitude linear features, which are not evident in raw TMI images

TMI images employing sun angle filters suffer the disadvantage that they produce an asymmetric anomaly pattern, which can confuse the position of the source of the anomaly.

First and second vertical derivative of TMI. Vertical derivative images emphasise near surface features and are useful in tracing unit boundaries and structural features. They do not distort the shape of anomalies but may emphasise high frequency noise in areas of low amplitude anomalies. The first derivative narrows the apparent width of anomalies to more closely match the actual width of the source. The second vertical derivative further narrows the apparent anomaly width but can further emphasise high frequency noise. Both first and second order vertical derivative images display a narrower dynamic range than the unfiltered data, thus further enhancing subtle anomalies.

Single channel radioelement. Total count, potassium, thorium, and uranium data channels were displayed separately, and in combination, to solve particular problems. Images were made as pseudocolour, greyscale, and using two colour lookup tables. Trachyte intrusions south of Forbes were mapped and classified using this technique.

Radiometrics - (K, Th, U). While individual energy window images are useful in particular areas, a combined Red-Green-Blue (RGB) image is, overall, a more useful image for mapping. In a combined RGB image, values for the potassium, uranium and thorium energy windows are plotted together, as different colours in a combined image., The count rate from each of the three selected radioelement windows is mapped to the brightness of a single colour (K red, Th green, U blue) and provides a versatile image, which contains most of the radioelement data.

Colour mixing in RGB images

There are two ways in which colours may be mixed – either additive or subtractive. The mixing of dyes or inks is described as subtractive colour mixing. The mixing of coloured light is called additive colour mixing. A television tube or computer colour monitor uses additive mixing, whereas an artist working with oils, or a computer colour ink jet printer, uses subtractive colour mixing.

In subtractive colour mixing (dyes or inks), the three primary colours are cyan (a pale blue) magenta (a purple), and yellow. In additive colour mixing (light) the three primary colours are red, green and blue (RGB). Composite geophysical images are commonly made as RGB images where the colour mixing is additive, as for the mixing of light

RGB images present three channels of information, each of which has a different dynamic range. For the Forbes radioelement dataset, the approximate range in counts per second (cps) for the three radioelements are, potassium 0 to 500 cps, thorium 0 to 400 cps and uranium 0 to 70 cps. In creating images, the range of the three colours is divided into 256 steps. In RGB images, the brightness of a particular colour equates to its relative abundance - a dark red colour indicates a low level of potassium, with little or no thorium or uranium. Bright red indicates a high level of potassium with little or no levels of uranium or thorium . Similarly, a dark green indicates low thorium and little or no levels of potassium or uranium while bright green indicates a high level of thorium and little or no levels of potassium or uranium. The same pattern applies for the blue colour and the uranium radioelement. When more than one radioelement is present, the situation becomes more complex. Examples are given below:

Potassium	*Thorium*	*Uranium*	*Resultant Colour*
(Red)	*(Green)*	*(Blue)*	
High	Low	Low	Red
Low	High	Low	Green
Low	Low	High	Blue
High	High	Low	Yellow
High	Low	High	Magenta (purple)
Low	High	High	Cyan (light blue)
High	High	High	White

3D images

Three dimensional (3D) images provide a way to combine data of different types so that the relationship between the two datasets may be observed. To create these images, one parameter forms a three dimensional surface and a second parameter is represented by a colour layer which is "draped" over that surface. For example, a 3D surface of magnetics with a radioelement "colour drape" clearly shows the relationship radioelement anomalies to magnetic anomalies seen as a 3D surface. The resulting image can be displayed either as a 2D representation on the computer screen or paper, or viewed on-screen with Crystal Eyes 3D viewing glasses, which produce a 3D image in a similar way to stereoscopic aerial photograph pairs. Stereo presentations are particularly useful in highlighting relationships between different data types.

For the Forbes mapping project, the combination of elevation and radiometric data was useful in showing the relationship between radioelement anomalies and the landscape.

Geophysical signatures

Magnetic signatures

The magnetic data have been particularly helpful in mapping Forbes as large parts of the sheet area are covered by regolith. In the east, the Early Devonian granites, which include the Eugowra Granite, are clearly seen as areas of moderate to high magnetic intensity. However, some granites of this age, to the southwest in the Grenfell 1:100 000 Sheet area, are not magnetic and are, therefore, not clearly defined from the magnetic data. These low- or non-magnetic granites are generally circular; the more magnetic granites are more angular in shape and possibly fault bounded.

Also in the east are the Devonian sediments of the Hervey Group. These sandstones are particularly non-magnetic and produce an extremely quiet magnetic anomaly pattern wherever they occur.

To the west of the Eugowra Granite, a major fault zone (the Coolac-Narromine fault complex) can be clearly seen in the magnetic data. The anomaly pattern here clearly shows many linear features, which are possibly faults.

The Ordovician Volcanics in the west of the Parkes and in the east of the Bogan Gate 1:100 000 sheet areas are of major economic significance as they host the mineralisation of the Northparkes Mine. They are clearly seen as a zone of moderate to high magnetic intensity. The internal structure of the complex is apparent in the magnetic images.

The Cowal complex and the Fairholme Igneous Complex on the Wyalong and Condobolin 1:100 000 sheets are clearly seen as moderate to high magnetic intensity. Both of these features are significant for their mineral potential. The magnetic data clearly show zoning and possible faulting within these features.

The Silurian granites in the southwestern corner of the Wyalong 1:100 000 sheet area are notable for the low amplitude magnetic anomaly pattern they produce. Indications of structure within the granites are given by the magnetic data, but the general pattern is one of low magnetic amplitude with low amplitude internal linear features.

Radiometric signatures

Large areas of the Forbes 1:250 000 sheet are by regolith. For this reason, the radiometric data are of limited use for bedrock mapping over much of the sheet as it reflects only the top 30 cm or so, which is often transported and bears little relationship to the underlying rock units.

The highest radioelement concentrations are found in the east of the sheet. The Devonian Dulladerry Volcanics in the northeast, and the Devonian granites, including the Eugowra Granite, all emit high levels of radiation for potassium, thorium and uranium. The considerable variation between and within the units has helped in their subdivision.

The east of the sheet also contains the units with the lowest radioelement concentrations. The Devonian Hervey Group is generally of very low flux, although close examination will show that some of the horizons within it produce small radioelement anomalies and may be used as markers for determining structure and stratigraphy.

In the northwest of the Parkes 1:100 000 sheet area, the Ordovician Volcanics show either a clear potassium anomaly (red in RGB images), or a generally low anomaly pattern (black to dark red). Smaller volcanic bodies to the west are distinguishable from the main body of the Ordovician Volcanics by their low potassium, high thorium anomaly pattern.

The Lachlan River flows across the Forbes 1:250 000 sheet approximately from east to west. It has a very large flood plain, which is generally identified by its moderate to high anomaly in all three elements. Field examination has indicated that the more recently disturbed sediments, near the present day course of the river, are characterised by higher levels of potassium radiation.

Data availability

The magnetic, radiometric, digital terrain, and gravity datasets are available in whole, or part, from AGSO. Data may be purchased as hardcopy images and contours, and in digital form as profiles and grids. Contact AGSO on (02) 6249 9111 for further information on the availability and cost of these data.

7. MINERAL OCCURRENCES IN THE FORBES DISTRICT

P M Downes and G R Burton, NSWGS

Introduction

This chapter briefly outlines the major metalliferous mineralisation styles, and gives summary descriptions of some representative examples of mineral occurrences present in the Forbes sheet area. Some styles of mineralisation, such as placer deposits, are only briefly discussed. Neither industrial minerals nor construction materials are discussed, nor are historical data or descriptions of workings included. This discussion focuses on primary mineralisation styles. Further details about individual mineral occurrences and districts can be found in Bowman (1977a,b), and the data are included in the Geological Survey's New South Wales Metallic Mineral Occurrence (METMIN) database (Downes, 1999).

The Forbes 1:250 000 sheet area has a history of mining starting in the 1850s when rich shallow alluvial gold placers were discovered. By the early 1860s, mining of the auriferous quartz veins was being attempted at a number of sites; however, interest quickly waned. It was the discovery of deep leads, mainly in the Parkes-Forbes and Grenfell areas, that highlighted the potential of the area. Subsequently a number of significant hard rock gold deposits were identified and mined mainly during the period 1880 to 1914. The Forbes sheet area has produced significant gold and copper with minor manganese, lead, zinc, iron, clay, and other commodities. In total, the area has identified metalliferous resources and past production valued over $2 billion (net present value).

A wide range of mineral deposit styles are present in the Forbes sheet area. Styles include: structurally controlled gold (and base metal) mineralisation; Ordovician intrusive-related copper-gold mineralisation; copper-gold and iron mineralisation associated with the Early Devonian Young Granodiorite; epithermal style gold-silver-copper-lead-zinc mineralisation Condobolin; a number of auriferous placer deposits, ranging in age from ?Tertiary to Recent, have been identified.

As part of the 1:100 000 scale geological mapping of the Forbes sheet area, the mineral occurrence dataset was upgraded from that compiled by Bowman (1977a). The present study was essentially office-based, although some field verification was carried out. This process has resulted in the subdivision of some occurrences, and the addition of new occurrences to the original dataset. Furthermore, the information about each occurrence was reviewed, and in many cases substantially revised. As of January 1999, the 'METMIN' database contained records for over 450 metallic mineral occurrences for the Forbes sheet area. The database also contains details on approximately 100 industrial mineral and construction material occurrence sites. The METMIN database holds information on the location, mineralogy, host rocks, past production, published resources and references for individual mineral occurrences, and provides a link to the compilation by Bowman (1977b) and the special publication on the Parkes area by Clarke (1990b).

Many of the sites identified in the Forbes 1:250 000 sheet area are simply mineral occurrences with no known historical production or identified resource. However, at least 100 sites have had either significant production or contain known resources. The area contains a number of deposits that are either very large in terms of historic production (e.g., London-Victoria and Mallee Bull), or contain large delineated mineral resources (e.g., Endeavour 42 at Lake Cowal).

Mineralisation in the Forbes sheet area

In the following discussion, mineral occurrences in the Forbes sheet area have been grouped on the basis of deposit style, geological association, and age. The groupings include the Ordovician intrusive related copper-gold mineralisation (including skarns and porphyries), orogenic mesothermal gold occurrences, deposits associated with post Ordovician intrusive events, e.g., with the Silurian-Devonian granites (including skarns), and deposits associated with potassic Devonian-Carboniferous granites. Finally, mention is made of the minor or miscellaneous ungrouped styles and the various placer occurrences.

Mineralisation in the Forbes 1:250 000 sheet area is dominated by a number of major associations, which are related to major geological events. Some of the events directly related to mineralisation include:

- A major magmatic event in the Late Ordovician to earliest Silurian, giving rise to porphyry copper-gold and related mineralisation.
- Felsic volcanism in the mid Silurian
- The emplacement of magmas and lavas in the Late Silurian or earliest Devonian
- Felsic volcanism in the early Devonian
- The development of magmas and lavas in the Early Devonian, which gave rise to a variety of intrusive related mineralisation. Some of these units are related to the Boggy Plains Supersuite.

- The Tabberabberan Orogeny the Middle Devonian that remobilised some gold and base-metals into structurally controlled deposits.
- The Kanimblan Orogeny in the Late Devonian-Early Carboniferous that may have remobilised gold and base metals into structurally controlled sites.
- Uplift and erosion at various times, resulting in gold placer deposits.

Major deposits within the sheet area include the Endeavour 42 deposit at Lake Cowal and the London-Victoria mine. Historic mining areas include the Parkes-Forbes, Grenfell, Condobolin, West Wyalong, Ironbarks, and Bumbaldry areas. The distribution of mineral occurrences is shown in Figure 7.1. The main feature of Figure 7.1 is that the bulk of mineral occurrences on the Forbes 1:250 000 sheet are associated with major shear zones and Ordovician volcanics.

Structurally controlled mineralisation

Structurally controlled gold and base metal mineralisation occurs throughout the Forbes sheet area with over 250 occurrences being identified. The geological setting and style of these occurrences is largely controlled by the competency of the host rocks, the depth of burial at time of mineralisation, and the host rock chemistry. The deposit styles include mineralised zones located in dilatant sites within faults and shears, such as the London-Victoria mine, and mineralisation located in sites where a competency contrast has been important.

Significant gold and base metal production has taken place in the Parkes-Forbes, West Wyalong, and Grenfell areas. Other significant occurrences include the structurally controlled Endeavour 42 deposit at Lake Cowal. These areas are described below. Details of these and other occurrences are given in the METMIN Database (Downes, 1999).

Parkes-Forbes

Mineralisation in the Parkes-Forbes area has been described by a number of authors including Andrews (1910), Bowman (1977a,b), Rollan (1984), Lindsay-Park (1985), and Clarke (1990b). Here structurally controlled gold mineralisation is typically hosted in auriferous-sulphide-quartz-calcite veins within Late Ordovician sediments and volcanics. The occurrences are confined to a narrow north-northeast trending belt, which is characterised by intense faulting and shearing. The mineralisation is commonly associated with brecciated veins and stockworks. The major ore minerals are gold, pyrite, and arsenopyrite with minor tetrahedrite, pyrrhotite, and galena. Clarke (1990b) noted that pervasive wall rock alteration comprising carbonate, chlorite, sericite, quartz, and pyrite was a common feature of the more significant occurrences. These were generally hosted by volcanics (lavas or fine-grained volcaniclastics).

Andrews (1910) distinguished two groups of lode gold occurrences in the Parkes-Forbes area based on the host rock lithology. These were occurrences associated with "intrusive andesites" (Lachlan, Koh-i-noor, Phoenix, Bushmans, *etc.*) and those in zones of "crushing" (London-Victoria, Mount Morgan, New Haven, Band of Hope, *etc.*). The second group of occurrences lies to the west of the "andesite" related occurrences. Clarke (1990b) observed that competency contrast between various rock units was a major control to mineralisation style and noted that finer clastic units behave in a less competent manner. He grouped the occurrences into four classes:

- Occurrences associated with near-vertical, longitudinal, shears and fractures parallel to the regional structural grain.
- Occurrences associated with moderately steeply dipping shears and fractures crosscutting the regional structural grain.
- Mineralisation associated with saddle reefs.
- Disseminated occurrences.

In addition, Clarke (1990b) observed that, in places, the Mugincoble Chert was anomalous in gold and suggested that some of the gold was derived from exhalative fluids discharged down the slope of the volcanic arc and deposited on the deep sea floor.

The largest gold producer is the Parkes gold mine, located approximately six kilometres southwest of Parkes. The mine, which covers the historic London-Victoria line of lode, has been described by Rollan (1984) and Clarke (1990b). The Victoria deposit was discovered in 1873 and worked from 1876, while the London mine was worked from around 1877 to 1909. The workings extended to a depth of 80 m and it is reported that 155 kg of gold was produced prior to 1988 (Clarke 1990b). Opencut mining operations commenced in 1988 and ceased in 1991. Treatment operations ceased in 1996 with a total of approximately 3 million tonnes of ore having been milled at an average grade of 1.5 g/t Au (approximately 4.5 t Au). A resource totalling 670 000 tonnes at 2.4 g/t Au remains (Michelago Resources NL Quarterly report to 31/12/1998).

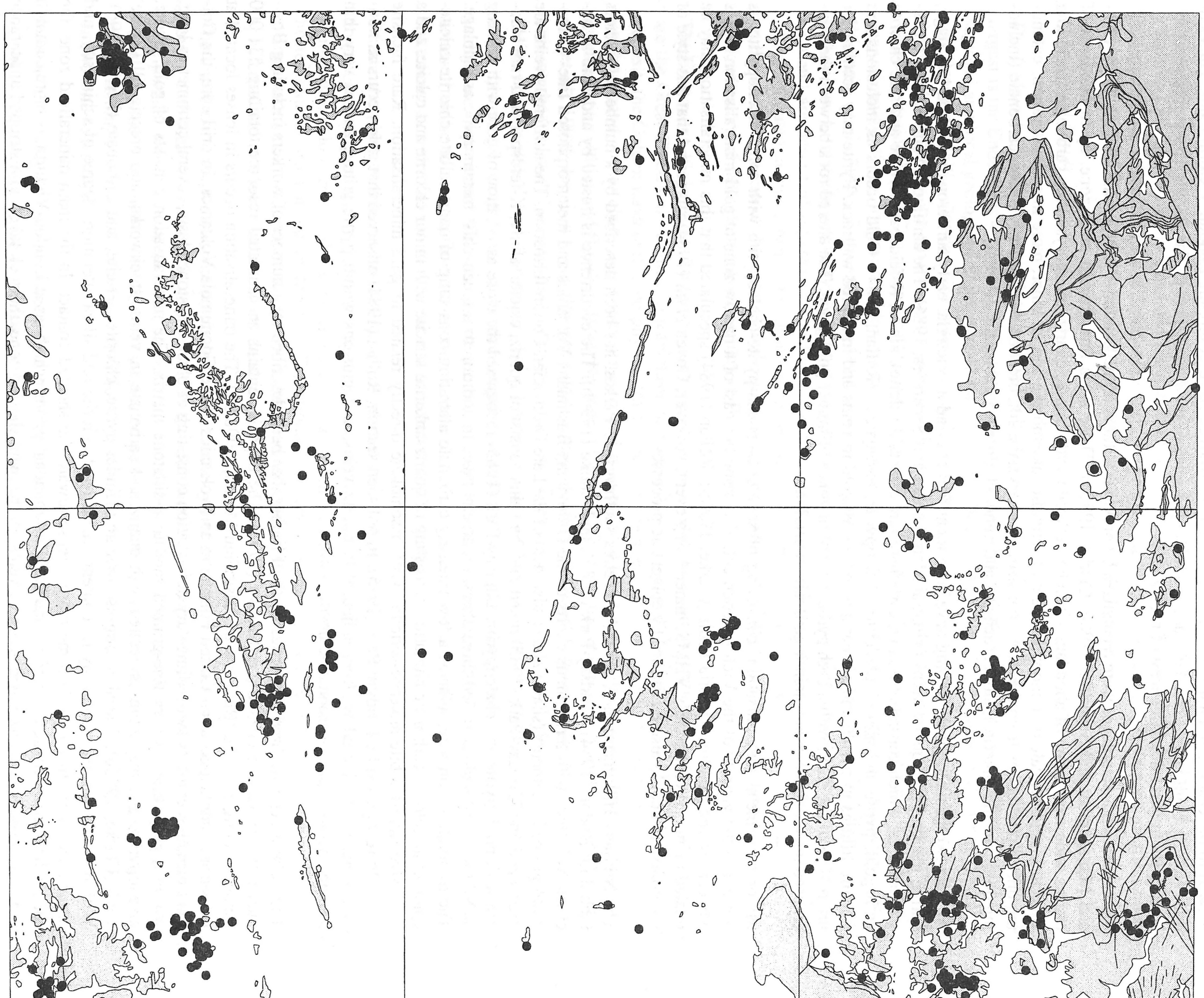


Figure 7.1 Distribution of mineral occurrences relative to outcrop on the Forbes 1:250 000 sheet.

Mineralisation in the London-Victoria lode is hosted by an anastomosing shear zone within metamorphosed intercalated pyroclastic and volcanic derived sediments with rare porphyritic lavas. The pyroclastic rocks include andesitic and trachyandesitic to trachytic tuffs, which form part of the Ordovician Bushmans Formation. To the west of the shear are mudstones and lithic sandstones of the Silurian Mumbidgle Formation and conglomerates of the Bocobidgle Conglomerate. The mineralised zone is up to 35 m wide in the vicinity of the London mine; individual mineralised lenses overlap, extend for up to 100 m along strike and down dip, and are up to 10 m wide. The lenses are contained within a sericite-carbonate (ankerite)-pyrite-quartz alteration zone up to 100 m wide and 3 km long, located to the east of, and adjacent to, the north-south striking, 70° east dipping London-Victoria Fault. The London-Victoria Fault is a reverse fault and is probably a splay of the Parkes Thrust. The Parkes Thrust intersects the surface about two kilometres west of the mine.

Two alteration assemblages were recognised by previous authors at the London-Victoria mine (Rollan, 1984; Mineral Management and Securities, 1986; Clarke, 1990b). These are a fine grained outer zone, up to hundreds of metres wide, consisting of abundant secondary chlorite with biotite, quartz, microcrystalline carbonate (including ankerite), epidote, calcite, clinopyroxene and actinolite assemblage and an inner, more intense alteration, extending only a few metres from the veins, consisting of pervasive silicification with sericite, pyrite, carbonate (including dolomite and ankerite), albite, fuchsite, and minor chlorite assemblage.

At least two generations of veining have been identified at London-Victoria: early auriferous veins and late stage, barren metamorphic quartz veins (Mineral Management and Securities, 1986). The auriferous veins exhibit crack-seal textures, which consist of quartz, carbonate (ankerite and calcite), albite, K-feldspar, sericite and rare chlorite with gold, pyrite and minor sphalerite, chalcopyrite, and galena (Rollan, 1984). Gold occurs as inclusions and fracture fillings in pyrite, and as fine-grained native gold in veins and in altered wallrock. Pyrite may account for up to 10% of the rock, with a high pyrite content in zones of higher gold grade. The altered rock between the mineralised lenses also contains minor gold mineralisation.

Minor base metal mineralisation, consisting of sphalerite-galena-pyrite-chalcopyrite with some arsenopyrite, is present in the vicinity of the Victoria open cut. This zone lies east of a narrow zone of gold mineralisation and is adjacent to the London-Victoria Fault (Clarke, 1990b). Rollan (1984) speculated that this mineralisation may be related to an earlier, possibly VHMS, mineralising event, however, Govett *et al.* (1984) suggested that this style of mineralisation could also be formed by epigenetic processes.

The Nibblers Hill occurrence, seven kilometres southwest of Parkes, has been described by a number of authors including Rollan (1984), Lindsay-Park (1985), and Clarke (1990b). The occurrence is hosted by andesitic to trachytic volcanics with ferruginous cherts of the Ordovician Bushmans Volcanics and metamorphosed fine- to medium-grained sediments (shales and sandstones) of the Late Ordovician Cotton formation. The auriferous veins are brecciated and Lindsay-Park (1985) noted that the veins consist of quartz, calcite, albite, K-feldspar, and rare chlorite with gold, pyrite and chalcopyrite. Lindsay-Park (1985) recognised the close association of gold with faulting at Nibblers Hill and identified three alteration assemblages in addition to a greenschist metamorphic assemblage. The three alteration assemblages: a low intensity carbonate alteration consisting of quartz-albite-chlorite-calcite-epidote; an intense carbonate alteration consisting of quartz-ankerite-sericite with minor chlorite and calcite, and a pervasive quartz-albite-ankerite-sericite-pyrite assemblage directly related to gold mineralisation. Rare fuchsite was also recognised by Lindsay-Park (1985). In polished section, Rollan (1984) observed that gold occurs as minute grains in the altered wallrock adjacent to quartz veins, as inclusions within pyrite grains, and as very thin stringers within quartz-carbonate-chlorite veins.

The Calarie deposit, three kilometres north of Forbes, has been described by a number of workers including Bowman (1977a), Clarke (1990b), and Rowe (1998). The deposit contains an estimated resource totalling 531 000 tonnes grading 3 g/t Au (Registrar of Australian Mining, 1998/99). The mineralisation occurs in lenses located at the sheared contact between Cotton Formation and volcanics of the Goonumbla Volcanics. In drill core, the Cotton Formation exhibits syn-sedimentary deformation consisting of black claystone clasts, several centimetres long, within a grey, fine- to very fine-grained sandstone-siltstone matrix. The mineralisation consists of gold, pyrite, arsenopyrite, and magnetite associated with quartz and carbonate in veins, stockworks, and breccia fill (Rowe, 1998, Clarke, 1990b). The alteration assemblage includes pyrite, chlorite, sericite, and carbonate (Ferris, 1996). Within the Cotton Formation, pyrite content, intensity of chlorite and silica alteration, degree of schistosity, and abundance of fracturing all become more intense toward the sheared contact. In the main mineralised zone, the rock is heavily brecciated, silicified, and contains abundant pyrite, which, as at London-Victoria, is more common in the host rock than in quartz±carbonate veins. In the main sheared zone, the rock takes on a stripped appearance with alternating chlorite-rich rock and quartz with some pyrite in parallel layers; on the other side of the shear the andesite is silicified and chloritised, and contains minor disseminated pyrite. The mineralised zones range from less than one centimetre to greater than 10 metres wide, and extend for several tens of metres down-plunge (Clarke, 1990b). The mineralisation is overprinted by later, barren veins.

Clarke (1990b) proposed a meta-hydrothermal origin for the gold mineralisation and suggested that there was no relationship between the gold mineralisation and the "intrusive andesites" as previously envisaged by Bowman

(1977a). Most vein deposits lie along, or near, contacts between volcanic and non-volcanic rocks, suggesting that competency contrast played a major role in localising structures. This in turn, has focused fluid flow into dilatant sites with gold mineralisation being introduced late in the deformation history; the timing of mineralisation at the London-Victoria mine probably being post Silurian (Clarke, 1990b). He also proposed that gold was sourced from mantle-derived Late Ordovician shoshonitic volcanics. Although the London-Victoria mineralisation is hosted by rocks of Ordovician age, the Pb isotope signature of the deposit clearly shows that the Pb contained within the deposit was sourced from both the Ordovician mantle-derived volcanics and younger crustal sediments. Based on the Pb isotope signature, Carr *et al.* (1995) suggest that the mineralising event occurred around 400 Ma (Early Devonian). This is supported by field evidence from the Calarie mine area where the mineralised structure truncates the Late Silurian-Early Devonian Calarie Sandstone (Sherwin, pers. comm., 1999). Newcrest Mining (1992) interpreted the mineralisation at London-Victoria as post-dating the major reverse movement on the London-Victoria Fault and it may have formed during a later sinstral strike-slip movement.

Lake Cowal (gold)

The Ordovician Lake Cowal Volcanic Complex hosts four structurally controlled gold occurrences of, which the largest is the Endeavour 42 deposit, with a total resource of 66.4 Mt grading 1.5 g/t Au (ASX report 30/6/98). The regional and local geology of Endeavour 42 has been described by Miles (1993), McInnes *et al.* (1998), and Miles and Brooker (1998). The complex consists of calc-alkaline to shoshonitic volcanic rocks and related sediments deposited in a deep water environment (Miles and Brooker, 1998) and is unconformably overlain, in parts, by the Siluro-Devonian Edols Conglomerate (Derriwong Group). The Lake Cowal Volcanic Complex is oval in plan, approximately 40 km long and 15 km wide, and has been defined by its distinct regional magnetic signature (McInnes *et al.*, 1998). The complex was intruded by diorites and granodiorites during the Middle to early Late Ordovician. Low grade porphyry copper mineralisation occurs in a number of places within the granodiorite intrusion and are described separately. The four structurally controlled gold occurrences (Endeavour 40, 41, 42, and 46) are situated in embayments within an elongate dioritic to gabbroic body, located in a strongly deformed belt, on the western margin of the Lake Cowal volcanic complex (Miles and Brooker, 1998). The area is covered by a thick sequence of lake sediments of Tertiary to Recent age.

The Endeavour 42 deposit is hosted by three significant volcanic units and an intrusive diorite. The volcanic units are the Great Flood unit, a vitric volcaniclastic debris unit, interpreted by McInnes *et al.* (1998) as a mass-flow deposit; the Golden Lava unit, a porphyritic trachyandesite, interbedded with a hyaloclastite with fragments ranging from sand size to clasts larger than a metre, and is interpreted to be a submarine lava with associated quench fragmentation (Miles and Brooker, 1998; Brooker, Miles and Thornett, unpublished data, 1995 - quoted in McInnes *et al.*, 1998); the Cowal conglomerate unit, a massive to graded, clast-supported, polymictic volcanic debris unit interbedded with laminated siltstone and mudstone. This last unit is interpreted to be a mass flow debris unit (Miles and Brooker, 1998). The Muddy Lake diorite, intrudes the lower part of the volcanic sequence and has been dated by Perkins, using the K-Ar method (unpublished data, 1993 - quoted in McInnes *et al.*, 1998) at 456±5 Ma (early Late Ordovician). This date is interpreted to be the minimum age of the intrusion. Later intrusions include a series of mafic to intermediate dykes, which Miles (1993) suggest were emplaced into active fault zones, as the dyke margins show signs of movement and are often strongly altered.

Within the primary zone at Endeavour 42, gold mineralisation occurs in narrow dilatant veins and within fault zones consisting of quartz-carbonate-sulphide and carbonate-sulphides±quartz (Miles and Brooker, 1998). Less commonly, gold occurs with pyrite stringers and disseminations, shear-hosted chlorite-carbonate veins and shear-hosted quartz-carbonate-sulphide veins. The sulphides consist of pyrite, sphalerite, chalcopyrite, galena, and pyrrhotite with small amounts of visible gold. McInnes *et al.* (1998) note that the highest gold grades occur with sphalerite, and to a lesser extent, with adularia.

The auriferous quartz-carbonate-sulphide and carbonate-quartz-sulphide veins occur throughout the deposit and have a consistent strike of 305° and dip 35° to the southwest (Miles and Brooker, 1998). The veins are typically have parallel-sides, with some of the larger veins containing comb textures, indicative of open-space fills. Additionally, some veins within the diorite display a crude banding. Miles and Brooker (1998) also note that the density of veining is generally highest in the Golden Lava unit although the mineralised veins within the Muddy Lake diorite tend to be thicker.

Four alteration styles have been identified at the Endeavour 42 by Miles and Brooker (1998) and McInnes *et al.* (1998): a pervasive chlorite-carbonate-hematite±epidote assemblage developed throughout the Lake Cowal volcanic complex; a silica-sericite±carbonate assemblage up to several metres thick, associated with faults; a patchy adularia-silica assemblage almost entirely restricted to the Golden lava unit; a chlorite-carbonate-pyrite assemblage that cross-cuts the first two assemblages and is spatially associated with the adularia-silica alteration or with adularisation of albite phenocrysts. This last assemblage is best developed within the Golden Lava unit, especially along its base, and within the Cowal conglomerate. Miles and Brooker (1998) note that all the alteration assemblages, with the exception of the chlorite-carbonate-pyrite assemblage, appear to pre-date the mineralised veins.

Some of the chlorite-carbonate-pyrite alteration is associated with, and cuts across, auriferous quartz-sulphide dilatant veins, although the alteration is more commonly cut by these veins (Miles and Brooker, 1998).

McInnes *et al.* (1998) describe the gold-bearing veins as generally associated with one of two alteration styles at Endeavour 42: ankerite-quartz-pyrite-sphalerite-chalcopyrite-galena veins, which are associated with ankerite-quartz-sericite-carbonate alteration; and quartz, potassium-feldspar, pyrite, sphalerite, chalcopyrite veins associated with the chlorite-carbonate-pyrite alteration.

McInnes *et al.* (1998) and Miles and Brooker (1998) propose that the Endeavour 42 deposit is structurally controlled with the mineralised dilatational vein arrays occurring predominantly adjacent to north trending faults. They suggest that local fault geometry and competency contrast have been the major controls to mineralisation, with the Golden Lava unit being the preferred host. Archibald (unpublished data, 1991 quoted in McInnes *et al.*, 1998) suggested that these mineralised structures may be modelled by a Riedel shear array, which Brooker, Miles and Thornett (unpublished data, 1995 - quoted in McInnes *et al.*, 1998) suggest formed as an oblique sinstral shear array, generated in response to a northwest-southeast compressive event.

Perkins (unpublished data, 1993 - quoted in McInnes *et al.*, 1998) dated the intrusions at Endeavour 42 at 456±5 Ma (K-Ar method) and at Endeavour 39 at 465.7±1 Ma (Ar-Ar method). In addition, Perkins, *et al.* (1995) dated sericite from the sericite-silica±carbonate alteration at Endeavour 42 mineralisation at 439.0±4.5 Ma (Ar-Ar method). Based on this dating, McInnes *et al.* (1998) and Miles and Brooker (1998) suggest that there is a significant 15 Ma gap between intrusion of the granodiorite-diorite and the gold mineralising event. However, the alteration assemblage that was dated has been recognised by these authors as pre-dating the gold mineralisation. This leaves open the possibility that the gold mineralisation at Endeavour 42 gold mineralisation may be significantly younger than previously indicated.

McInnes *et al.* (1998) and Miles and Brooker (1998) note that the Endeavour 42 mineralisation has geometrical relationships and mineralisation styles typical of shear hosted gold deposits, with the distribution of gold controlled by dilatational zones formed during the evolution of a fault system. These workers also note that the Endeavour 42 mineralisation has features that are typical of low sulphidation or adularia-sericite epithermal systems and cite the vein styles, mineralogy, gangue associations, structural relationships and alteration assemblages to support this. The greater than 15 Ma gap between intrusion of the granodiorite-diorite and the age of the mineralisation makes it unlikely that the mineralisation is related to a porphyry copper-epithermal event, rather, it supports the concept that the deposit is typical of shear-hosted mineralisation. The alteration assemblages and preliminary studies of the fluid chemistry suggest the mineralising fluids were low salinity and low temperature (< 150° C) (Miles and Brooker, 1998). These features are more typical of metamorphic fluids, which again supports the shear-hosted model. The Pb isotope data for the Endeavour 42 mineralisation (Carr *et al.*, 1995), which indicates an Ordovician mantle signature, is consistent with the interpretation that the metallic elements were derived from the Ordovician host rocks.

West Wyalong

Gold mineralisation was discovered at West Wyalong in 1893. Mining ceased in 1920 with a reported total production of 13.86 tonnes of gold from 340 000 tonnes of ore at an average grade of 41 g/t Au (Timms, 1993) The mineralisation has been described by a number of workers including Watt (1899), Degeling (1974), and Bowman (1977a). It is contained within about 25 mineralised zones, each consisting of narrow (generally ≤ 0.5 m), auriferous quartz veins within chloritised faults or shears. The mineralised structures strike north-north-east, and dip steeply to the east, with the mineralisation occurring in shoots that typically dip steeply east and pitch south. An exception to this is the Pioneer zone, which strikes approximately east-west. Watt (1899) described the veins as lenticular and noted that "spur" veins are common, while Timms (1993) reported that the veins exhibit pinch and swell structures. The majority of the mineralised veins are hosted by the Silurian, S-type, locally foliated, Ungarie Granite. Suppel *et al.* (1986) note that some of the mineralisation is hosted by quartz diorites of the Silurian Bland Diorite, which they interpret to be I- type. Some veins, such as Pine Hill, occur within the Ordovician Gidginbung Volcanics.

The veins consist of quartz with colloidal silica, minor calcite, and gypsum (Watt 1899). McLean (pers. comm., 1999) describes the veins as typically massive or vuggy, with rare breccia textures. The textures within the veins include comb textures and chlorite laminations, while the breccias are described as matrix-poor crackle (breccias), to matrix-rich with angular or rounded milled clasts. Slickenlines, defined by chlorite, are rare. McLean (pers. comm., 1999) considers these textures to reflect silica deposition within a dilational setting under relatively steady kinematic conditions.

In addition to gold, the veins contain pyrite, galena, sphalerite and chalcopyrite while the secondary minerals include cerussite, pyrolusite, copper carbonates, and native copper. The silver mineral, iodyrite, has also been identified from the Lucknow mine-Pine Hill Reef (McLean, pers. comm., 1999). Marlow (1996) suggests that the mineralisation is a Au-Ag-Pb-As-Bi-Te metal assemblage. Gold occurs as grains both within the wallrock and the veins, and as inclusions and filling micro-fractures within pyrite (SEM data, Marlow, 1996). Microprobe analysis of individual gold grains indicate a gold fineness values averaging 860 GFN (35 analyses, range 760 to 950 - Marlow, 1996). Schwebel (1982) reported that white quartz containing very little visible mineralisation was found to contain significant gold. However, Timms (1993) noted that old reports indicate a correlation between the amount of pyrite present and the gold grade. McLean (pers. comm., 1999) suggests that the Wyalong mineralisation belongs to the plutonic class of gold deposits (Morrison, 1991). However, this writer observes that the mineralisation is more typical of shear-hosted occurrences. Degeling (1974) noted that the highest gold grades generally occur at the intersection between the main mineralised structure and subsidiary structures. McLean (pers. comm., 1999) observed that alteration is restricted to major shears and is of very limited extent. Within the Ungarie Granite, the alteration consists of a sericite-chlorite-pyrite assemblage and, within the Bland diorite, the alteration consists of a sericite-chlorite-pyrite-epidote-actinolite assemblage. According to McLean (pers. comm., 1999) the alteration mineralogy indicates that the mineralisation formed at the epithermal-mesothermal temperature boundary, and that the fluids were neutral to slightly acidic.

The mineralisation at West Wyalong represents a shear-hosted style that has preferentially developed within the competent Ungarie Granite. Timms (1993) suggested that the mineralised structures were closely related to faults associated with the Gilmore Fault Zone. The Gilmore Fault Zone, which separates the Silurian Ungarie Granite from the Ordovician Gidginbung Volcanics, has had a long history of movement commencing in the Early Silurian (Benambran Orogeny) and has undergone significant later reactivation. However, Glen (pers. comm., 1999) suggested that the mineralised structures are possibly Carboniferous in age, this is supported by Pb isotope data that indicate a mixing of Pb derived from mantle and crustal sources. Futhermore, the data plot within the Devonian Granites field of Carr *et al.* (1995), and they propose a Late Devonian to Early Carboniferous age (Kanimblan Orogeny) for the mineralisation (LFB modal 350 Ma). If this is correct, then it is unlikely that the mineralisation is related to any major movement on the Gilmore Fault Zone.

Grenfell

The Grenfell gold field was discovered in 1866 and produced approximately 10 tonnes of gold with approximately half the total production coming from vein-hosted occurrences (Bowman, 1977a, Diemar, 1986). The major mine in the area was the Young O'Briens Reef. The majority of the mineralised veins are located within a quartz-feldspar porphyry, the Silurian Glenisla Volcanics, to the east of the town, though some vein-type mineralisation also occurs in the slates and phyllites of the Ordovician Kirribilli Formation. The porphyry intruded the Kirribilli Formation and has a faulted contact with the Devonian Cemetery Granite on its western side. The auriferous veins consist of quartz and minor calcite with minor arsenopyrite, pyrite, chalcopyrite, galena, and gold (Bowman, 1977a).

Within the porphyry, the veins strike northeast to east and dip between 45° and 80° to the northwest. Most veins are less than a metre wide, though some are up to 3 m, and are generally lenticular in plan (Bowman, 1977a). Post-mineralisation, northwest-trending faults cut the mineralised lodes. Diemar (1986) and Bowman (1977a) noted that the most productive veins are within the most intensely faulted porphyry. Bowman (1977a) observed that the veins replace host rock along zones of fracturing, noting that veins commonly grade into altered and silicified porphyry at depth. Often, only one wall of the vein is well defined while the other grades into the host rock. The alteration is poorly documented, however, it seems to consist of silicification with varying amounts of calcite, pyrite, and possibly chlorite (Diemar, 1986).

Most of the veins within the Kirribilli Formation are narrow, short, lenticular, and carry only minor gold. They strike northeast and are located near small porphyry bodies (Diemar, 1986, Bowman, 1977a).

The origin of the mineralisation at Grenfell is not clear. The mineralisation may have formed from late-stage fluids associated with the intrusion of the porphyry, or it may have formed within dilational zones formed within, and adjacent to, porphyry bodies (due to a competency contrast) after intrusion of the porphyry, and as part of a later deformation. The observation by Bowman (1977a) that the most productive veins are associated with the most intensive zones of faulting within the porphyry supports the latter view. Vein development may be related to the north-northwest-trending fault separating the Cemetery Granite from the Glenisla Volcanics (porphyry) and Grenfell Granite. This would suggest that the veins are Devonian or younger. No mineralisation occurs within the Cemetery Granite, and only one occurrence (Star Gully) is within the Devonian Grenfell Granite. Carr *et al.* (1995) noted that the Pb isotope signature for the Grenfell mineralisation falls within the field of Devonian granite related deposits.

The Warraderry area, 14 km northeast of Grenfell, also contains mineralised quartz veins associated with quartz-feldspar porphyry dykes (McLean, 1997, Mullholland, 1935), which intruded the Kirribilli Formation. The dykes and the veins strike north-northwest, parallel to the regional cleavage. The veins have high arsenic contents. (McLean, 1997). Mapping by Golden Cross shows workings within both the Kirribilli Formation and the porphyries. McLean (1997) considered that the mineralisation was concentrated along the contact between porphyry and country rock.

Pinnacles-Ironbarks area

About 30 kilometres south of Forbes is the Pinnacles-Ironbarks area. The area extends for about 15 kilometres in a north-northeast direction, and may represent the southerly extension of the Parkes-Forbes gold belt. The mineralisation occurs within crenulated and kinked phyllite of the Ordovician Kirribilli Formation. Also present are small felsic intrusions. The mineralisation consists mainly of pyrite and native gold in quartz veins with minor carbonates (including siderite), which Rafty and Hemming (1997b) described as having "epithermal" textures. Wallrock alteration is minor, if at all present, and consists of silicification, sericitisation and chloritisation. Rampe (1992b) also notes the presence of a sericite-pyrite-silica (-quartz) assemblage.

The mineralised zones strike north-northeast and dip vertically or subvertically (Bowman, 1977a). They consist of quartz veining and stockworks, up to 8 m wide, with the individual quartz veins up to a metre wide and occurring in zones between 2 m and 45 m wide. The veins are between 20 m and 450 m long (Rafty and Hemming, 1997). The veins both parallel and cut across the dominant foliation, which trends 020° and has a steep easterly dip.

The origin of the mineralisation is not clear. Bowman (1977a) considered three possibilities including an association with "intrusive" andesites (as proposed for the Parkes-Forbes area), that the mineralisation was epigenetic and derived from metamorphic fluids, or; as his preferred model, that the veins are associated with the Silurian Caragabal Granite, which is located, to the south, between three and ten kilometres distant from the veins. Rafty and Hemming (1997) favoured the epigenetic model but did not discuss it in detail. As the veins post-date the formation of the dominant foliation, Raymond (pers. comm., 1999) suggests that the foliation is most probably Carboniferous (Kanimblan), based on the Parkes Fault Zone and its effected on rocks at least as young as the Siluro-Devonian Derriwong Group. Therefore, the Silurian Cargabal Granite is an unlikely source for mineralisation.

Ordovician porphyry copper-gold and related mineralisation

Significant porphyry copper-gold mineralisation is associated with Ordovician magmatism in central New South Wales. Major deposits include the Cadia and Northparkes mines, which lie outside the sheet area. The Ordovician volcanics are prospective as they were formed from mantle-derived magmas, remaining undersaturated with respect to sulphur until late in the magmatic cycle, which resulted in a concentration of copper and gold in the late stage magmatic fluids (Wallace and Wyborn, 1997). The volcanic belt hosting the Northparkes mine also contains significant occurrences in the Forbes sheet area. Two major volcanic centres have been identified: the Goonumbla Volcanic Complex, which also hosts the Northparkes mine north of the sheet boundary, and the Lake Cowal Volcanic Complex, which hosts the Endeavour 39, Endeavour 35, and Marsden porphyry copper-gold occurrences near Lake Cowal and the structurally controlled Cowal gold deposit (Endeavour 42, described above).

Goonumbla

The Goonumbla porphyry copper mineralisation and its geological setting have been described by a number of workers, including Jones (1985), Heithersay (1986), Heithersay *et al.* (1990), Muller *et al.* (1994), Heithersay and Walshe (1995), and Hooper *et al.* (1996). The Late Ordovician Goonumbla Volcanics, which host the porphyry copper-gold and skarn type mineralisation, is located within a circular aeromagnetic and gravity feature some 22 kilometres in diameter, which Jones (1985) interpreted as a collapsed caldera.

The complex is bisected by the northern boundary of the Forbes 1:250 000 sheet with the Northparkes copper-gold mine (Endeavour 22, 26 North, 27, and 48 deposits) located on the Narromine sheet and the Endeavour 44, Endeavour 6 (Gunningbland copper mine), and Endeavour 7 occurrences located on the Forbes sheet. The porphyry-type mineralisation at Goonumbla consists of sub-vertical pipe-like intrusions of quartz monzonite porphyry within the (interpreted) caldera structure. In general, the mineralisation occurs as disseminations and within fractures and veins in both the intrusions and the surrounding volcanics. The strongest mineralisation is associated with quartz stockwork veining within a central, potassic alteration zone (Heithersay *et al.*, 1990). Pervasive sericitic alteration and widespread propylitic alteration have been identified. The sericitic alteration is regional in scale, and appears to be related to major structures and contact zones of the intrusive. A mineral zonation has been identified with a poorly defined outer pyritic zone surrounding a chalcopyrite dominant zone, which in turn, surrounds an inner, higher grade, central bornite-dominated zone (Heithersay *et al.*, 1990).

The Endeavour 26 North occurrence has been described by Heithersay and co-workers (Heithersay, 1986, Heithersay *et al.*, 1990, Heithersay and Walshe, 1995) as consisting of a bornite-dominated quartz-stockwork pipe, with a vertical extent exceeding 900 metres, centred on two adjacent porphyry intrusions. The sulphide minerals include pyrite, bornite, chalcopyrite, and digenite. Heithersay and Walshe (1995) have identified eleven separate stages of alteration paragenesis and zonation .

Further south, in the Forbes sheet area, skarn related copper and gold-lead-zinc mineralisation has been identified adjacent to, but outside, the southern margin of the Goonumbla caldera structure at Endeavour 44, Gunningbland copper mine (Endeavour 6), and Endeavour 7. The Endeavour 44 gold-lead-zinc mineralisation is located 13 kilometres north of Gunningbland and contains an estimated resource totalling 2 Mt grading 3.81 g/t Au (indicated-inferred) with an additional 200 000 tonnes of deeper mineralisation grading 11 g/t Au (Registrar of Australian Mining, 1993-94). The high grade mineralisation consists of semi-massive pyrite and marcasite with interstitial galena and sphalerite. Gold is associated with hessite, which formed in association with galena. The mineralisation is hosted by Late Ordovician limestones and reworked volcanic sediments of the Goonumbla Volcanics, which are overlain by Late Devonian sediments of the Hervey Group.

The mineralisation at Endeavour 44 is described by Jones (1991) who identified a programmed-retrograde skarn assemblage associated with the intrusion of oxidised, highly fractionated microsyenite dykes and sills. This was followed by faulting and late stage epithermal gold-telluride deposition. The initial stage identified by Jones (1991) was the development of an early contact metamorphism producing marble and a calc-silicate hornfels. Subsequently, a massive garnet (grossular and andradite)-wollastonite±vesuvianite prograde assemblage formed with minor apatite, titanite, and haematite. The prograde skarn is either layered, or has a massive, patchy texture. The initial retrograde assemblage consisted of the development of epidote, chlorite, calcite, and quartz. Rutile, titanite, prehnite, and magnetite also form part of the initial retrograde assemblage, along with haematite. Subsequently, pyrite, sphalerite, chalcopyrite, bornite, chalcocite, and galena were deposited. Gold, hessite, altaite, petzite, tennanite, and sericite formed late in the retrograde stage. Gold-bearing vein and breccia mineralisation also developed, with associated sericitic alteration and silicification. Veins of quartz, calcite, and K-feldspar commonly cross-cutting, and are often mineralised. The hanging wall volcanics are frequently altered to epidote and, in places, overprinted by garnet skarn.

Perkins *et al.* (1995) dated alteration sericite from the retrograde skarn assemblage at Endeavour 44 at 440.0±1.1 Ma. This date is in excellent agreement with the age of the Goonumbla porphyry copper-gold system (439.2±1.2 Ma - Perkins, 1990). Investigations by Carr *et al.* (1995) on the nearby Endeavour 7 mineralisation confirms that the metals were sourced from the mantle-derived Ordovician shoshonitic volcanics and the data also support a pre-440 Ma age for the mineralising system.

The Gunningbland Copper mine (Endeavour 6) was first worked in 1898. Here, the mineralisation is hosted by a limestone unit within a sequence of lithic and crystal tuffs, agglomerate, and fine- to medium-grained sedimentary rocks. These rocks are interpreted to be part of the Siluro-Devonian Milpose Volcanics. Most of the mineralisation is stratabound and confined to the calc-silicate skarn unit, which is up to 30 m thick. This skarn unit consists of variable amounts of grossular garnet, chlorite, haematite, epidote, vesuvianite, calcite, wollastonite, quartz, and magnetite. This is surrounded by a magnetite-rich volcanic sandstone that forms the footwall and hanging wall to the calc-silicate unit. Economic mineralisation occurs in discontinuous lenses of varying size (O'Neill, 1982) and contain magnetite, pyrite, chalcopyrite, bornite, sphalerite, galena, molybdenite, and arsenopyrite (Bowman, 1977a). The mineralised zones are generally stratabound and confined to the calc-silicate unit, however, there are some narrow, transgressive, calcite stringers carrying minor pyrite and chalcopyrite in the adjacent wallrocks (O'Neill, 1982). Some skarn development (garnet, vesuvianite, chlorite) occurs in the rocks forming the hanging wall to the limestone (Heithersay and Ren, 1992).

Alteration comprises incipient to massively pervasive epidote. Incipient epidote alteration is associated with intense magnetite development that may have formed earlier in the paragenetic sequence. Massive epidote coexists with pyrite ± haematite, which is a more oxidised assemblage than the epidote-magnetite. A second style of alteration is sericitic (sericite+quartz). Mineralisation in vein-breccia zones is always associated with magnetite-destructive quartz-sericite-sulphide alteration (Heithersay and Ren, 1992).

At Endeavour 6, the skarn is considered to have formed through the contact metamorphism of a limestone unit by a monzonite-microsyenite porphyry (Heithersay and Ren, 1992; O'Neill, 1982), thought to have been emplaced at around 440 Ma. However, if this is the case, the host rocks can not be part of the Siluro-Devonian Milpose Volcanics.

Lake Cowal (porphyries)

In addition to the structurally controlled gold mineralisation at Lake Cowal, low-grade porphyry copper-gold mineralisation has been identified at the Endeavour 39 and Endeavour 35 prospects located to the south and southwest of the lake. The mineralisation is hosted by the Ordovician Lake Cowal Volcanic Complex, which has been described previously. The complex consists of calc-alkaline to shoshonitic volcanic rocks and related sediments deposited in a deep-water environment (Miles and Brooker, 1998) and is unconformably overlain by rocks of the Siluro-Devonian Derriwong Group. The unexposed Lake Cowal Volcanic Complex is oval in plan, approximately 40 km long and 15 km wide, and is defined by a distinct regional magnetic high anomaly (McInnes *et al.*, 1998). The complex has been intruded by diorites and granodiorites of middle to early Late Ordovician age. The area is covered by a thick sequence Cainozoic lacustrine sediments.

Initial drilling, by Geopeko, in the Lake Cowal area intersected low-grade mineralisation (0.2-0.35% Cu) at the Endeavour 39 prospect, five kilometres south of the Endeavour 42 deposit. This mineralisation, hosted by granodiorite with a marginal diorite phase (Perkins *et al*, 1995), has been described by Love (1985a) as consisting of chalcopyrite±magnetite-bearing quartz veins, sulphide-albite±magnetite stringers, and minor disseminated chalcopyrite and pyrite in altered granodiorite. In addition, structurally controlled zones of sericite-pyrite-chalcopyrite±epidote are present. A number of differing alteration styles have also been described by Love (1985a). These include an early sericite-pyrite (sericitic) assemblage, which correlates with the porphyritic phase of the granodiorite, a potassic alteration consisting of pink K-feldspar, which surrounds the chalcopyrite bearing quartz veins, and a moderate to intense, structurally controlled, late sericitic alteration, which surrounds quartz-carbonate-chlorite-sulphide±epidote filled shears and fault related veins. This last alteration assemblage is controlled by north-south and northwest trending structures and overprints and destroys earlier assemblages (Love, 1985a).

Perkins (unpublished data, 1993 - quoted in Miles and Brooker, 1998) dated the granodiorite at Endeavour 39, by the Ar-Ar method, at 465.7±1 Ma (Middle Ordovician). In addition, sericite from the occurrence has been dated at 439.6±4.5 Ma (Ar-Ar method - Perkins, *et al.*, 1995).

Love (1985a) and Miles and Brooker (1998) interpret the Endeavour 39 mineralisation as forming part of a large low-grade porphyry-type Cu-Au system. The mineralisation was formed from high salinity fluids (E Bastrakov pers. comm., 1995 - quoted in Miles and Brooker, 1998) during the Middle Ordovician.

The Endeavour 35 copper-gold mineralisation, located immediately to the south of Lake Cowal, has been described by Love (1985a,b). The host rocks consists of an interbedded sequence of andesitic, dacitic, and trachytic volcanics (Love, 1985b), which form part of the Ordovician Lake Cowal Volcanic Complex. The host rocks have undergone varying degrees of pervasive argillic alteration with some silicification and subsequent shearing. The mineralisation consists of disseminated pyrite and chalcocite. The chalcocite is interpreted to be secondary (Love, 1985b). The alteration assemblage includes montmorillonite, cryptocrystalline and microcrystalline silica, sericite, kaolinite and alunite, with minor pyrophyllite and illite, and up to 10% disseminated pyrite (Love, 1985b). The Endeavour 35 mineralisation is interpreted to form part of an advanced argillic alteration zone peripheral to the intrusive complex (Miles and Brooker, 1998).

Marsden

The Marsden copper-gold prospect is located 15 km southeast of Endeavour 42, and the mineralised zone is located under 100-120 m of Quaternary cover. The following description is based on information supplied by Fraser MacCorquodale (pers. comm., 1998), Newcrest Mining, Ltd (pers. comm., 1999), and observations made on drill core.

The host rocks at Marsden consist of a complex of intrusive quartz diorite, diorite, monzodiorite with lesser andesite porphyry, granodiorite porphyry, and monzonite dykes and volcanics, of the Ordovician Lake Cowal volcanic complex. The complex, and the mineralisation, are faulted to the east, and at depth, by a shallow, west dipping, thrust. Movement on this thrust has resulted in the Ordovician units being thrust over rocks of the Late Devonian Hervey Group, although Sherwin (pers. comm., 1999) suggests that the rocks beneath the fault may be the Late Devonian Tottenham Shale. To the west, the intrusive complex is bound by andesitic porphyries.

All the rock units within the intrusive complex have undergone pervasive biotite (potassic) alteration. The alteration assemblage includes biotite, albite, actinolite, quartz, magnetite, chalcopyrite, and bornite. Veins associated with the potassic alteration are dominated by quartz, calcite, and chalcopyrite. Accessory minerals include orthoclase, biotite, actinolite, magnetite, apatite, bornite, pyrite, molybdenite, haematite, epidote, and rare fluorite. The thickness of the veins ranges from less than 1 mm to 10 mm wide. The propylitic alteration is weakly to moderately developed, and occurs within the potassic zone; the propylitic alteration occurs as a low intensity retrogressive overprint consisting of chlorite, calcite, leucoxene, prehnite, and epidote. The intensity of the propylitic alteration increases towards the western edges of the diorite intrusive complex and into the adjacent wallrock. The potassic and propylitic assemblages are overprinted by structurally controlled sericitic and argillic alteration with late stage quartz-pyrite-chalcopyrite-chlorite veins and quartz-calcite-pyrite-sphalerite-sericite-chalcopyrite veins. All the alteration assemblages are cut by calcite-laumontite-fluorite veins.

The mineralisation is hosted by quartz diorites and consists of a sheeted vein to stockwork system comprising of quartz-calcite-chalcopyrite veins and disseminations. The width of the veins varies from less than 1 mm to 10 mm wide. Rare bornite is also present. Three vein directions have been observed in the core: a vein-set approximately perpendicular to the core axis; at 30° to the core axis; and parallel to the core axis. The vein-set parallel to the core axis is interpreted to be late stage. Chalcopyrite occurs both in the vein centres and as disseminations in the wall rocks. The mineralisation has been faulted off to the east, and at depth, and diminishes to west.

Post-Ordovician skarns and intrusive related mineralisation

There are a number of skarns and intrusive-related occurrences related to post-Ordovician magmatism in the Forbes sheet area. These include the Bumberry skarn occurrences, which are located 18 kilometres west southwest of Cowra. In this area, there are a number of minor skarn, sulphide, copper-gold, and iron occurrences associated with the Late Silurian to Early Devonian Young Granodiorite. The majority of the deposits are located in the Forbes sheet area, however, those in the Bathurst sheet area include the Broula Iron mine and the Robinson deposit. The Broula Iron mine consists of magnetite with abundant pyrite and traces of chalcopyrite (Stevens, 1975). The mineralisation is hosted by hornfels and metamorphosed limestones within the Early Silurian Canowindra Volcanics, which was been intruded by hornblende biotite granodiorite, hornblende pyroxene-rich granodiorite, and microgranites of the Young Granodiorite. Rangott and Kennedy (1989) relogged one of two diamond holes drilled by King Mountain Mining NL and described the skarns as including calc-silicate skarns, magnetite-rich skarns, garnet-diopside rich carbonate rocks and a clinopyroxene bearing marble. The skarns contain a range of prograde and retrograde minerals including garnet, diopside, amphibole, epidote, chlorite, magnetite, pyrite, quartz, and carbonates (including calcite). The magnetite skarn assemblage includes magnetite, minor garnet, calcite, epidote and pyrite.

Epithermal mineralisation

Epithermal style mineralisation has been identified at Condobolin and in the Bumbaldry area.

Bumbaldry

The Bumbaldry area is located 26 kilometres east of Grenfell. The area contains a number of gold and copper occurrences including the Broula King mine, the Cowfell mine and the Claypit alteration zone. These have been described by a number of authors including Bowman (1977a), Smith (1985), Minfo (1988), and Rangott and Kennedy (1989). The mineralisation is hosted by rocks of the Silurian Illunie Volcanics, while the Young Granodiorite intruded the volcanics to the south of the Broula King area.

The Broula King gold mine consists of at least five north-northwest trending zones, which dip moderately to the west, and two easterly trending zones, which dip vertically. The deposit contains a defined resource totalling 210 000 tonnes at 2.6 g/t Au (Minfo, 1988). The epithermal style mineralisation is hosted by altered felsic to intermediate volcanics, volcaniclastic sediments, and carbonate units of the Illunie Volcanics. Two styles of mineralisation have been described in Minfo (1988). These are interstitial fine-grained gold within highly silicified wallrock and coarse-grained gold located on the edges of thin quartz veins up to 1.5 metres thick. The sulphides associated with the mineralised veins include pyrite, galena, and sphalerite, with lesser chalcopyrite. Patchy disseminated pyrite is associated with the altered volcanics and sericitic alteration overprints the area. In places, a strong argillic alteration has been identified. The reefs consist of quartz veins and stockworks. Crack-seal type textures have not been described from the dilational veins, although Smith (1985) noted that some veins were shear related.

Smith (1985) proposed that the fluids, which formed the deposit, were metamorphic in origin, and that brittle deformation had occurred both prior to the mineralising event and as a result of high fluid pressures. This contrasts with later workers who describe the mineralisation as epithermal. England (1995) suggested that the mineralisation formed as part of a moderately high sulphur system, at low to moderate temperatures, which probably overprinted an earlier porphyry stage. This is supported by the presence of quartz phenocrysts with veils of secondary (aqueous) inclusions containing small vapour bubbles and ?halite daughter crystals (England, 1995).

The Claypit alteration zone, 2 km west of Bumbaldry, occurs at the contact of the Silurian Illunie Volcanics and the middle Devonian Warrumba Volcanics, and has been described by Rangott and Kennedy (1989). The zone is hosted by altered porphyritic rhyolite flows and crystal tuffs with minor volcaniclastics, tuffaceous sediments, ignimbrites and limestone lenses. The prospect consists of an extensive advanced argillic alteration zone with zones of chalcedonic silica that are extensively and variably fractured and brecciated. These are surrounded by a weak argillic alteration halo and an outermost propylitic alteration zone. In places the alteration zone is anomalous in gold with minor lead, zinc, copper, silver, antimony and arsenic. Glaser (1988) identified fine-grained chalcopyrite, galena, sphalerite, pyrite, haematite, titanomagnetite, barite and possibly discrete silver minerals within the Claypit alteration zone. Glaser (1988) suggested that boiling had taken place within the alteration zone, although the evidence was somewhat tentative. In addition, preliminary observations on fluid inclusions, by Glaser (1988), suggested that the alteration system formed from relatively low temperature fluids with a salinity of less than23% NaCl. The alteration of the Warrumba Volcanics indicates that the Claypit alteration zone is of Middle Devonian age. It could also be possible that the alteration at Broula King, which is wholly within the Illunie Volcanics, is also Middle Devonian.

Condobolin

Epithermal gold-silver-lead-zinc-copper mineralisation is present near Condobolin. The mineralisation consists of auriferous and base metal-rich quartz veins hosted by kinked and crenulated, sandy to silty phyllites of the ?Cambrian to Late Ordovician Girilambone Group, which in this area attain biotite grade metamorphism. Some of the veins are auriferous only (e.g., Surprise and Gold Paint mines), while others are predominantly lead-zinc-silver-rich (e.g., Potters mine). The mineralisation is generally found in silicified zones, up to 2 m wide, consisting of cross-cutting quartz veins, with single veins up to several centimetres wide. The veins vary from massive to, more commonly, crystalline. In places they contain a layered/banded texture, which is crustiform or colloform, to botryoidal in places. Some veins contain breccia fragments with angular fragments of earlier vein quartz and silicified wallrock within a matrix of quartz±sulphide. The majority of vein-zones strike northeast and dip to the southeast, (45° to vertical), mainly parallel to the S_2 foliation. However, where S_2 is flat-lying, the zones still trend northeast and, in places, the veins are parallel to S_3 (kink axis).

The mineralisation consists of disseminated, stringy to semi-massive, generally fine-grained pyrite with lesser galena, sphalerite, chalcopyrite, bornite and arsenopyrite, and native gold. The mineralisation is located in discontinuous zones and shoots within the quartz veins, and also within adjacent wallrock. Secondary minerals include cerussite and copper carbonates (azurite, malachite). The gangue minerals include quartz, minor colloidal silica, and chlorite. The chlorite occurs as fine-grained clots up to several centimetres long. The wallrock is variably silicified and chloritised and contains disseminated, fine- to medium-grained pyrite (and arsenopyrite?), which weathers to a porous, sinter-like rock.

The Mascotte gold-silver-lead-zinc mineralisation is described by Rafty and Hemming (1997) as being contained in an zone 80 m wide and a kilometre long, with outcropping quartz lodes, between one and two metres wide, and striking northeast and dipping 50° to the southeast. The veins themselves consist of saccharoidal, brecciated, comb-textured quartz with silica replacement of carbonate and boxworks after sulphide. The sulphides include disseminated to stringy, fine- to medium-grained, pyrite with lesser galena and sphalerite. These occur within both the altered wall rock and the quartz veins. The wallrock is silicified and chloritised and cut by quartz veinlets several millimetres wide. Breccias are present and consist of quartz and chlorite fragments, up to about 50 mm long, in a fine-grained matrix rich in pyrite, with sphalerite and galena.

Bowman (1977a) suggested that there was a metal zonation at Condobolin with base metal sulphide occurrences occupying a central east-west trending zone (e.g., Au, Pb, Zn, Ag, Cu at the Phoenix mine) with an gold rich halo surrounding it (e.g., Surprise mine). Work by Rafty and Hemming (1997) supports this with gold-lead soil geochemical anomalies being found at the Red Paint, Mascotte and Piebald mines surrounded by a low grade gold-zinc-lead halo. Conquest Mining also noted a horizontal and vertical zonation of metals with a Au-Cu±As and a Pb-Zn-Ag±As zonation (Rafty and Hemming, 1998).

Bowman (1977a) proposed that the Condobolin mineralisation was formed by hydrothermal fluids emanating from a granite and suggested the possible zonation, predominance of lead over copper and zinc, vein-form, and deformed sediments as supporting this concept. However, he noted that the nearest exposed granite, the Silurian Ungarie Granite, crops out approximately 25 kilometres to the southwest. By contrast, Rafty and Hemming (1997) suggested that either the veins are related to the Devonian felsic volcanism to the north of Condobolin, or due to the emplacement of a granite at depth. They described the veins as epithermal to mesothermal, and cite the dominance of base metals over gold, the presence of boiling textures, and the lack of extensive chalcedonic and bladed carbonate textures to support this. These textures imply that the mineralisation formed at very shallow levels. A vast area of silica flooding located toward the Potters mine area, with adjacent quartz veining and strongly brecciated and chloritised metasediment, was suggested by Conquest as being related to magmatic processes at depth.

Another possible model is that the mineralisation was formed as the result of a tectonothermal, or uplift, event without the involvement of magmatic heat sources. This may have involved the movement of fluids (either meteorically and/or metamorphically derived), which leached metals from either the host rocks and/or from crustal sources, and emplaced them into dilatant sites within a structural corridor. The area has undergone biotite grade regional metamorphism (Barron pers. comm., 1999), however, Ashley (quoted in Rafty and Hemming, 1997) observed that the vein textures and structural setting were not those usually found with structurally controlled (metamorphic or orogenic related) mineralisation. The observed colloform and carbonate replacement textures, possible metal zonation, and presence of boiling textures are suggestive of an epithermal style, however, the heat source and source of the fluids has yet to be determined.

The mineralisation at Condobolin post-dates the crenulation cleavage in the Girilambone Group, which is considered to have formed during the Benambran Orogeny. Scott (pers. comm., 1998) observed that the mineralisation post-dated the Condobolin Fault and the main deformation and metamorphism of the Girilambone Group, and suggested that the mineralisation was developed during the Middle to Late Silurian. This is supported by the presence of clasts of epithermal vein material and Girilambone Group phyllites in the Late Silurian to Early Devonian Edols Conglomerate, which unconformably overlies the Girilambone Group. If these clasts are derived from the Condobolin vein system, it constrains the timing of the mineralising event to between the Late Ordovician and Late Silurian. This is supported by Pb isotope data from the Potters mine, which suggest a Pb modal age of between 420-430 Ma (Early Silurian) (Dean, 1995). The timing of mineralisation at Condobolin has significant implications for the timing of similar mineralisation along the Gilmore Fault Zone further south.

Placer deposits

Significant gold and minor tin has been recovered from placer deposits located within the Forbes sheet area. Most of the alluvial gold was won from shallow, generally small, Tertiary to Recent gravels associated with present and former drainage. Unfortunately, little production data exist, as most of the work was undertaken prior to the establishment of the Mines Department in 1875.

The most prominent area for the production of alluvial gold was the Forbes-Parkes area where gold was discovered in 1861, and within two years approximately 9.3 tonnes of gold were recovered, mostly from rich deep leads (Bowman, 1977a). A second prominent area was the Grenfell district where gold was recovered from the basal units of a number of the Tertiary deep leads. Bowman (1977a) reported that cassiterite was also present in the Grenfell deep leads and suggested that it was derived from the Bald Hills tin-bismuth district.

The Wyalong Goldfield is unusual in that no alluvial gold occurrences were discovered in the area despite extensive early prospecting.

Other occurrences

A number of significant occurrence types have not been discussed. These include a number of barite-copper occurrences such the Cookeys Plains occurrence (Ward, 1985) and miscellaneous molybdenum, tungsten, antimony and mercury occurrences. Details of these and other occurrences are included in the Metallic Mineral Occurrence database (METMIN). Some of these occurrences have also been described by Bowman (1977a,b).

Kars

Alaskan-type platinum mineralisation is associated with ultramafic units of the Kars intrusive complex, located 12 kilometres east of Ootha. The main complex is a small, incompletely symmetrical zoned intrusion with platinum associated with zones of mixed ultramafic rocks. The mineralisation occurs in a linear zone trending approximately east-west along the central axis of the Kars intrusive complex. The zone may contain 2.8 tonnes of platinum at an average grade of 0.42 g/t Pt. Beneath the base of oxidation, widespread low-grade platinum is associated with zones of mixed olivine pyroxenite, peridotite, minor dunite, and a coarse pegmatitic phase (Lachlan Resources and Platinum Search, 1995). Alluvial platinum occurs nearby but is not economic (Richardson, 1994).

Fairholme

The Fairholme Project is located to the north of Nerang Cowal and covers three individual mineralised zones: the Boundary, Gateway and Dungarvan occurrences, which are hosted by Ordovician rocks of the Fairholme Igneous Complex. The complex is overlain by up to 120 metres of Quaternary cover. The following information has been summarised from McIntosh and MacCorquodale (1997) and data supplied by Newcrest Mining, Ltd staff (pers. comm., 1999).

The Boundary copper-gold mineralisation, located 20 kilometres north of the Endeavour 42 deposit, is hosted by andesitic to basaltic vesicular lavas, volcaniclastics, and fine-grained argillaceous sediments, which have been intruded by latite porphyries, andesite porphyries, and microdiorite. These rocks are interpreted to form part of the Ordovician Fairholme Igneous Complex. Andesitic lavas dominate, they are variably porphyritic, and consist of pyroxene, pyroxene-plagioclase and pyroxene-hornblende assemblages. Many are strongly vesicular. Some of the rocks are fragmental, having been formed by reworking of debris from the andesitic lavas. The intrusives at the prospect consist of plagioclase-hornblende latite porphyries that contain an oxidised ferromagnesian assemblage (hornblende-magnetite-titanite) and pyroxene-hornblende microdiorites. Wyborn (pers. comm., 1999) has determined that the diorites are shoshonitic. Post-mineralisation dolerite dykes cut the Ordovician rocks.

At Boundary, a low intensity, selective to pervasive, propylitic (albite-chlorite-epidote±magnetite ±actinolite) alteration is present. This alteration has filled amygdales with epidote, chlorite, actinolite, magnetite, K-feldspar, pyrite, chalcopyrite, calcite, and axinite. Abundant epidote veinlets are present as well as rare axinite veins. Overprinting the low intensity propylitic alteration is an intense propylitic alteration (epidote-calcite±sericite) assemblage and, less commonly, a potassic (epidote-K feldspar) assemblage. The axinite veins appear to be associated with the more intense alteration zones. The alteration suggests that the Boundary area forms part of the upper and outer zone of a porphyry copper-gold alteration system. It may be part of a system in, which the latite porphyries represent the uppermost intrusive fingers.

The Boundary mineralisation consists of disseminated pyrite in heavily chloritised volcanic rock together with fine-grained chalcopyrite and bornite intimately grown with disseminated (replacement) epidote. Pale mauve axinite may also be present. Most of the mineralisation occurs as vesicle fillings, however, some occurs in ragged patches and veins. Chalcopyrite and pyrite occur in the vesicles (up to 5 mm across) with albite and epidote. The mineralisation is considered to have formed by the redistribution of locally derived copper during low-grade metamorphism (McIntosh, 1996).

The Gateway occurrence is located two kilometres east of the Boundary Prospect and lies just to the west of the Booberoi Fault. The mineralisation occurs within a north trending zone, covering an area of 2 km × 500 m, and consists of low level copper and gold mineralisation within highly deformed and altered Ordovician rocks, which include mineralised, laminated, tuffaceous, schistose metasediments dominated by meta-argillites, tuffaceous meta-argillites (quartz-sericite-pyrite schists), primary volcanics, and minor porphyries and diorites. A sericitic alteration is the most intense alteration and consists of an assemblage including pyrite as well as sericite–silica–albite–chlorite–carbonate. The main zone of sericitic alteration is over 1.5 kilometres long. This grades into a pervasive chlorite–epidote-carbonate alteration. Disseminated pyrite, lesser pyrite veinlets, and rare chalcopyrite are associated with the sericite alteration. Later tension gash quartz veins are not mineralised. Deformation and shearing was focussed in the sericite–chlorite–pyrite zones. This has lead to the formation of a well developed cleavage and the remobilisation and recrystallisation of the pyrite and carbonate. Within these highly deformed zones only relict primary textures are present.

Dungarvan is a weakly mineralised copper system, located three kilometres south of the Boundary Prospect. The mineralisation is hosted by intermediate to mafic volcanics and volcaniclastics intruded by diorite and more mafic intrusives. These rocks have undergone pervasive propylitic alteration, resulting in a epidote, actinolite, calcite, chlorite, leucoxene, and magnetite assemblage. Fracture-fill quartz– carbonate–epidote–chlorite veins are common. Drill hole DR13 intersected 11 m at 0.21 g/t Au and 20 m at 0.12% Cu, while hole DR12 intersected 160 m at 0.1% Cu with the mineralisation being hosted in a volcanic breccia.

Eurow-Vychan mine

The Eurow-Vychan copper-gold deposit is 12 kilometres northwest of Eugowra and contains an estimated resource of 375 000 tonnes at 1.0 g/t Au, 1.6% Cu, 28 g/t Zn, 131 g/t Pb and 71 g/t Ag (Coenraads, 1996). The mineralised zone straddles the contact between quartz-feldspar-biotite-cordierite porphyritic rhyodacite of the Silurian Glenisla Volcanics and the Devonian Eugowra Granite. Coenraads (1996) described the host sequence as consisting of conformable layers of coarse-grained quartz-biotite schist, quartz hornfels, fine- to coarse-grained biotite schist, and black hornfels. The mineralisation consists of disseminated to massive pyrite and chalcopyrite, with lesser sphalerite, magnetite, and minor galena in a quartz gangue. The zone is tabular and grossly concordant with the enclosing rocks, although discordant "spur" lodes are present (Rampe, 1992a). The zone strikes 335°, dips 70° to the southwest, extends for 450 m along strike, and averages 3.4 m in width (range < 1 m to 6 m) (Coenraads, 1996).

Rampe (1992a) also reported that the copper-gold mineralisation was associated with shallow-dipping, east- to northeast-trending shears, which occur predominantly in the granite at the sediment-granite contact. Gold grades appear to be higher in the hangingwall side of the contact to the southwest, especially where flat shears predominate.

The style of the mineralisation present at Eurow is unknown. Two possible models are that the mineralisation is exhalative in origin with the mineralisation having been remobilised into later shears, or that the deposit was originally an epigenetic vein occurrence.

Alteration systems

A number of alteration zones are located in the Forbes sheet area. These include the previously described Claypit zone, the Porters Mount zone, and Currowong Hill zone. The Porters Mount alteration zone is located about 15 km southwest of Wirrinya and hosted by rocks of the Devonian Porters Mount Diorite, which intruded the Devonian Pullabooka Formation. The alteration zone consists of a silica-tourmaline-sericite breccia with elevated As, Sb, Sn, Cu, and Ag contents, however, no significant mineralisation has, yet, been found (Ferris and Harley, 1993, Burrell, 1996). The breccia is interpreted to be associated with a porphyry system at depth (Burrell, 1996, BHP Gold Mines Ltd, 1989).

Raymond (this volume) has reviewed the Currowong alteration zone, six kilometres west of Wirrinya, and the following description is derived from his work.

> An epithermal alteration zone is centred about 6 km west of Wirrinya around a prominent outcrop of strongly silica-alunite (advanced argillic) altered rhyolite. The fact that the road is diverted around this outcrop is testament to the intensity of the siliceous alteration. In the Currowong Hills, immediately east of this location, variably altered rhyolites were first noted in 1982 by geologists from Samedan . The alteration zone forms a thin, largely flat lying, sheet around 2 km^2 (Edgar, 1990). Edgar (1990) described five alteration assemblages of quartz ± alunite ± haematite ± sericite ± kaolinite ± illite ± limonite (after sulphides). He also noted that quartz + kaolinite occurred largely peripheral to quartz + alunite, and a

vertical zonation from quartz + alunite to quartz + haematite ± alunite at shallower depths. Samedan (1982) geologists also reported minor pyrophyllite, diaspore, zunyite, and jarosite, but Edgar (1990) noted that pyrophyllite and diaspore were absent from the alteration assemblages.

The alteration style ranges from intensely and pervasively silicified breccias with up to 40% alunite, to weak silicification and sericitisation of rhyolites. Minor vughs and some late stage quartz veining are also developed, but the alteration is generally pervasive and not vein-dominated. There is only minor development of disseminated pyrite ± arsenopyrite mineralisation, and that is now largely replaced by limonite. Rare gossanous outcrops occur.

The alteration exposed at Currowong Hills has many features characteristic of high sulphidation epithermal systems (Heald *et al.*, 1987; White and Hedenquist, 1990). However, Edgar (1990) concluded that the alteration was caused by mixing of gases, boiled off a near neutral pH, low sulphur,, chloride bearing fluid, with near-surface meteoric waters. Gold mineralisation could possibly be expected at some depth below the currently exposed alteration. No economic mineralisation has been found at Currowong Hills despite the efforts, since 1982, of nine exploration companies. However, the area to the west and southwest of Currowong Hills is largely covered by alluvial sediments, and the scattered outcrops in the area show evidence of pervasive to patchy silicification and disseminated sulphides. It is probable that epithermal alteration is widespread beneath the alluvial cover.

Discussion

A widespread Ordovician magmatic event is recognised in central New South Wales. This event lasted from approximately 480 Ma to 440 Ma (Perkins *et al.*, 1995). Work by Wyborn *et al.* (e.g., Wyborn and Sun, 1993; Wallace and Wyborn, 1997), has shown that this event involved the development of mantle-derived magmas that were strongly oxidised, potassium-rich, and sulphur-undersaturated during their early stages. The magmas were able to retain their precious metals (gold, platinum and palladium) in the melt until late in their history. This enhanced the concentration of these metals in the late stage magmas and resulted in the development of significant intrusive related copper and gold mineralisation. This is supported by Carr *et al.* (1996) who showed that mantle-derived Pb isotope signatures are a characteristic of mineralisation associated with this magmatic event. Significant copper-gold mineralisation, such as the Goonumbla (Northparkes) and Cowal porphyry copper-gold occurrences, were formed as part of this event. The Endeavour 39 porphyry at Lake Cowal formed around 465.7±1 Ma (Middle Ordovician) (Perkins unpublished data, 1993 - quoted in Miles and Brooker, 1998) and the Goonumbla porphyries formed at the end of this event (approximately 440 Ma -Perkins *et al.*, 1995).

Structurally controlled gold mineralisation occurs throughout the Forbes sheet area. The geological setting and style of these occurrences is largely controlled by the competency of the host rocks, the depth of burial at time of mineralisation, and the host rock chemistry. The occurrences can be divided on the basis of the rheology of the host rocks and the depth of burial at the time of deformation: mineralised zones located in dilatant sites within faults and shears in competent host rocks, such as the West Wyalong occurrences, and mineralisation located in sites where a competency contrast has been important, such as in the Parkes area.

Andrews (1910) and Bowman (1977a) suggested that there was a genetic relationship between the "intrusive andesites" and gold mineralisation in the Parkes-Forbes area. However, Clarke (1990b) proposed that many of the igneous rocks in the area were volcanic rather than intrusive and, therefore, a direct genetic relationship between the "andesites" and gold mineralisation, as seen by Andrews (1910) and Bowman (1977a), could not be supported. Clarke (1990b) suggested the mineralisation was formed by metamorphic dewatering during deformation and proposed a two-stage model for gold deposition: submarine volcanic exhalative activity released hot, low salinity fluids enriched in gold that mixed with sea water and precipitated fine-grained (?auriferous) sulphides, and possibly native gold, on the sea floor; subsequent deformation, under lower greenschist facies conditions, and associated hydrothermal activity, remobilised and concentrated the gold into favourable structural sites. Clarke (1990b) also suggested that the elements associated with the London-Victoria mineralisation were typical of epithermal gold deposits and the relationship between base metals and gold reflected a syngenetic stratiform style of mineralisation unrelated to the epigenetic gold mineralisation. It was acknowledged, however, that the evidence could also support the concept of a single epigenetic mineralising event that deposited both the base metals and gold. It seems more probable that gold and base metals were sourced from the Ordovician shoshonitic volcanics, which Wyborn *et al.* have shown were enriched in copper and gold, and the adjacent rocks, during regional deformation. The enriched fluids carried the metals to structurally favourable sites where gold and copper were deposited. Most of the vein deposits lie at, or near, contacts between volcanic and non-volcanic rocks, suggesting that a competency contrast has played a major role in localising mineralisation, and the Pb isotope signature of the London-Victoria mineralisation clearly shows this. The Pb contained within the deposit was sourced from both the Ordovician mantle-derived volcanics and younger crustal sediments.

Clarke (1990b) suggested that mineralisation in the Parkes-Forbes area occurred late in the deformation history, with the timing of mineralisation at the London-Victoria mine probably being post Silurian. This is supported by

Carr *et al.* (1995) who suggest that the mineralising event occurred around 400 Ma (Early Devonian), based on Pb isotope data. This is supported by field evidence from the Calarie mine area where the mineralised structure truncates the Late Silurian-Early Devonian Calarie Sandstone (Sherwin, pers. comm., 1999). In general, however, the timing of gold mineralisation in the Forbes sheet area is poorly constrained. Sericite, which pre-dates the gold mineralisation event at Endeavour 42, has been dated by Perkins, *et al.* (1995) at 439.0±4.5 Ma (Ar-Ar method), though no younger limit to the age of the mineralisation has been established. The mineralisation at West Wyalong is post Silurian with Carr *et al.* (1995) suggesting a Late Devonian-Early Carboniferous age (Kanimblan Orogeny), based on Pb model ages (350 Ma). This is supported by Glen (pers. comm., 1999) who suggested that the mineralised structures are possibly Carboniferous. Similarly, the available information for the Grenfell mineralisation would support a Devonian or younger age.

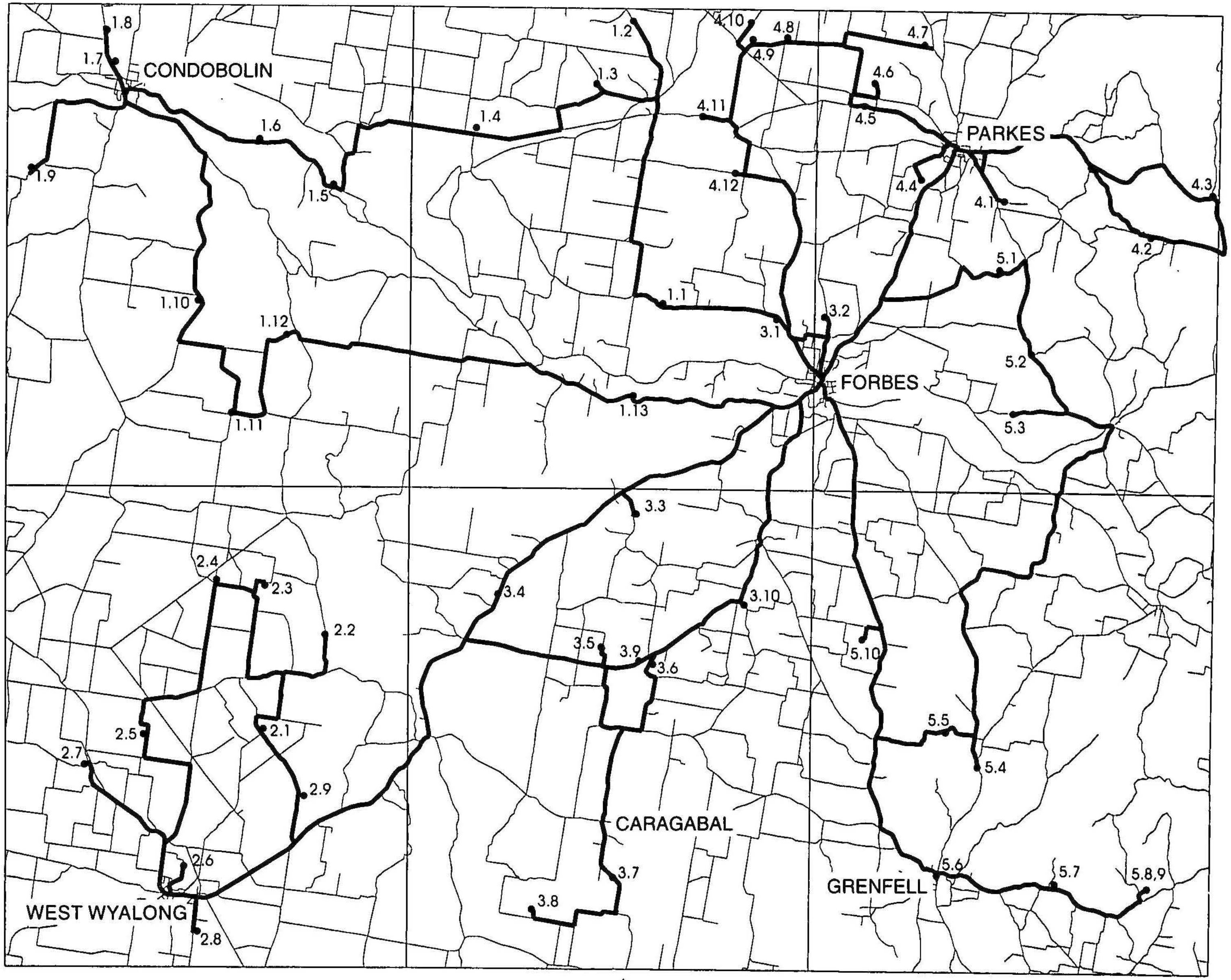
The epithermal mineralisation at Condobolin post-dates the crenulation cleavage developed in the Girilambone Group that formed during the Early Silurian Benambran Orogeny. Clasts of epithermal vein material and Girilambone Group phyllites are present in the Late Silurian to Early Devonian Edols Conglomerate, which unconformably overlies the Girilambone Group. Based on this, Scott (pers. comm., 1998) proposed a Middle to Late Silurian age for the mineralisation. This is supported by Pb isotope data from the Potters mine, which suggest an Early Silurian age (420-430 Ma - Dean, 1995). The nature of the mineralisation at Condobolin has yet to be resolved. Two models have been proposed: the veins are related to the felsic volcanism during the Devonian, or the emplacement of a granite at depth (Rafty and Hemming, 1997); and mineralisation was the result of a tectonothermal, event or uplift, without the involvement of magmatic heat sources. The timing of the mineralisation, as constrained by the Late Silurian to Early Devonian Edols Conglomerate, precludes the mineralisation being associated with Devonian magmatism. The presence of colloform and carbonate replacement textures, possible metal zonation, and presence of boiling textures imply that the mineralisation formed at very shallow levels. The shallow level of the mineralisation does not support the tectonothermal model as Barron (pers. comm., 1999 suggests that the Girilambone Group would have undergone three to four kilometres of uplift based on the biotite grade regional metamorphic assemblage. Ashley (quoted in Rafty and Hemming, 1997) noted that the vein textures and structural setting were not those usually found with structurally controlled (metamorphic or orogenic related) mineralisation. Obvious epithermal textures, such as colloform, crustiform, and comb quartz, are not common in the *in situ* veins at Condobolin. Many of the observed epithermal textures were noted in clasts found in the overlying Edols Conglomerate and these clasts may have been sourced from outside the Condobolin area. This opens the possibility that the Condobolin mineralisation is not epithermal but was formed by metamorphically derived fluids generated during the Benambran orogeny. A second possibility is that the mineralisation may have been formed by post Silurian epithermal event.

Conclusion

Over 400 metallic mineral occurrences are recorded in the Forbes 1:250 000 sheet area. These occurrences encompass a variety of mineralising processes in a range of geological settings extending from the Early Ordovician to Recent. The district contains numerous structurally controlled gold deposits, as well as Ordovician intrusive related copper-gold mineralisation, post Ordovician intrusive related skarns, epithermal style deposits, and various gold placer occurrences. The recognition of the Ordovician intrusive related copper-gold mineralisation, such as at Lake Cowal and Marsden, has highlighted the prospectivity of the sheet area. A significant point arising from recent investigations is that Ordovician magmatism is probably the primary source of the gold and copper in the Forbes sheet area. Subsequent magmatism and deformation has mostly served to remobilise copper and gold into appropriate structural sites.

Acknowledgments

A number of people have assisted in the compilation of information relating to mineral occurrences in the Forbes sheet area. They include Gary Burton, Marya Khrystoforova, Bill Chesnut, and Peter Downes who have extensively revised and updated the Forbes METMIN dataset. These notes have drawn extensively on previous work by Bowman (1977a,b), Clarke (1990b), and published and unpublished company reports and theses. The notes were edited by Bill Chesnut, Ollie Raymond, and Patrick Lyons. Special thanks must go to Gordon McLean of Golden Cross Operations Pty Ltd for his contribution to the section on West Wyalong; to Garry Hemming of Conquest Mining NL for comments on the Condobolin area; to Greg Bray for information on the Eurow-Vychan area; and to Fraser MacCorquodale of Newcrest Mining Ltd for details on the Marsden and Fairholme areas. The contribution by Norths Ltd for permission to include details on the Lake Cowal and Goonumbla areas must also be acknowledged.



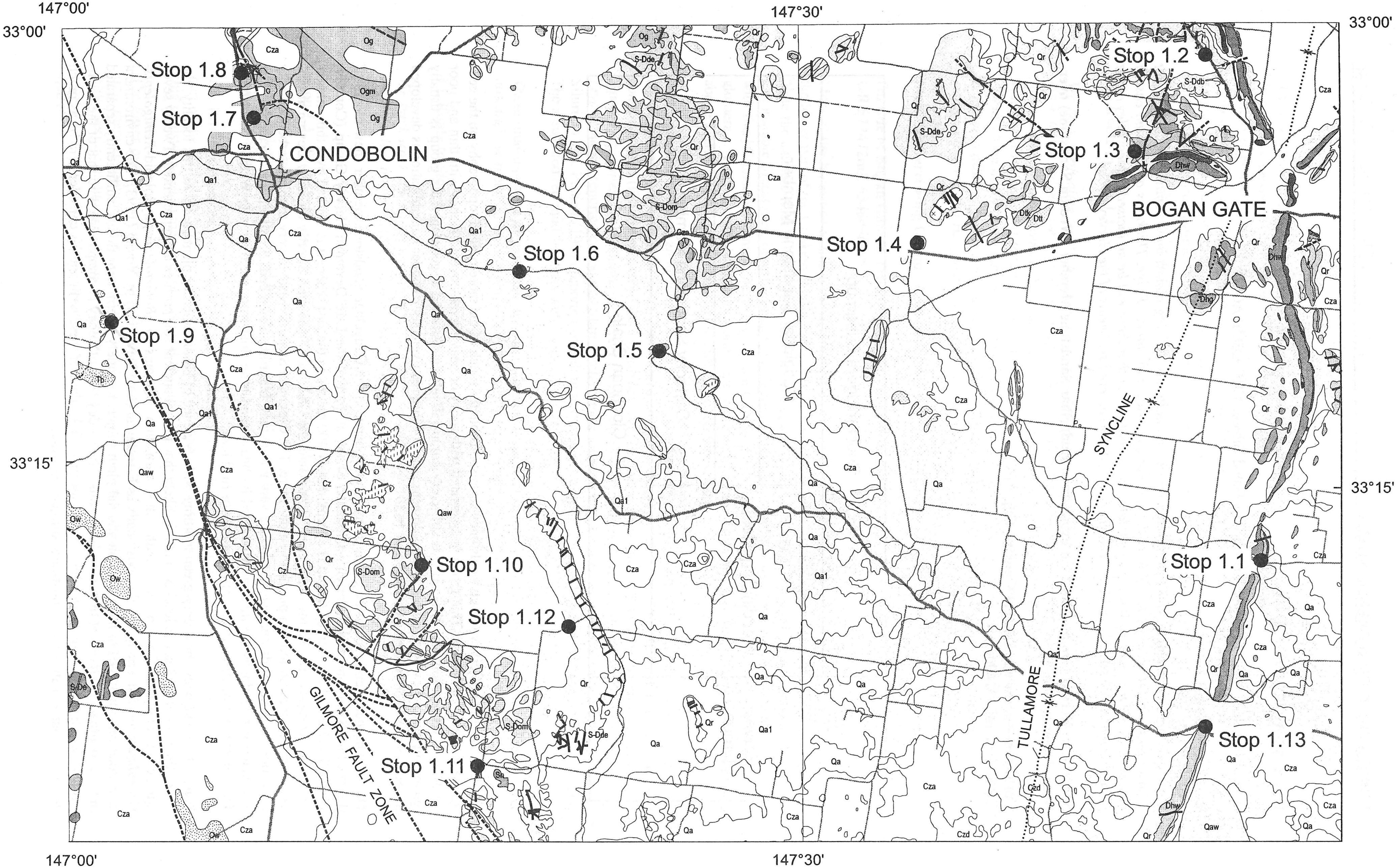
Excursion stops on the Forbes 1:250 000 sheet

DAY 1

Depart Forbes RSL 8:00 am

Stop	Duration mins		Author
1.1	20	Hervey Group	Sherwin
1.2	20	Cookey Plains Fm, limestone	Sherwin
1.3	20	Bird Flat Member	Sherwin
1.4	20	Cookeys Plains, fossils, Yarra-bandai	Sherwin
1.5	20	Mulguthrie Fm, south of Ootha	Sherwin
1.6	20	Yarnel Volanics and sand dunes	Sherwin
LUNCH	45	Condobolin Dam	
1.7	50	Condobolin epithermal mineralisation	Scott/Burton
1.8	15	Edols Fm-Girilambone Gp unconformity	Scott
1.9	20	Weebar Hill leucitite	Scott
1.10	15	Yarnel Volcanics	Sherwin
1.11	15	Ina Volcanics	Duggan/Lyons
1.12	15	Regolith, east of Bogandillon Swamp	Chan/Gibson
1.13	15	Regolith, Jemalong Gap	Chan/Gibson

Arrive Forbes RSL 6.10 pm



DAY 1 EXCURSION STOPS

Day 1 12 April 1999

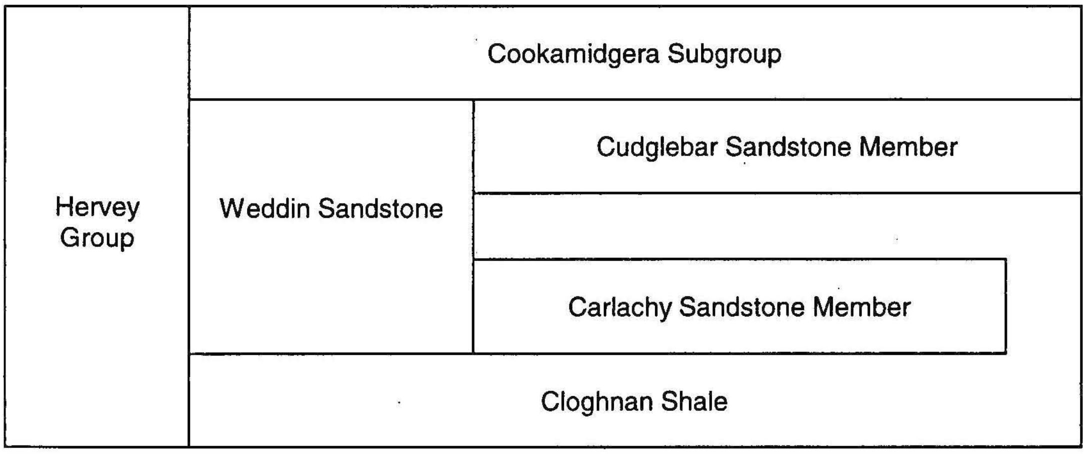
Inter-stop regolith notes have been provided by David Gibson, CRC-LEME AGSO

En Route to Stop 1.1

We leave Forbes, crossing generally low relief erosional landforms, passing almost imperceptively onto stagnant alluvial plains before coming to a gap in the Jemalong/Corridgery/Gunning Ridge. Thickness of alluvium east of the gap is 20-40 m; to the west we have no data, as yet, but expect that there will be an incised palaeovalley of the palaeo-Goobang Creek. The ridge is made up of variably weathered sediments of the Hervey Group.

STOP 1.1: Hervey Group - Road cut exposure of Cudgelbar Sandstone Member (Weddin Sandstone) overlying Cloghnan Shale.

Cutting on Burrawang Road at Gunning Gap
GR 575300mE 6314000mN



The Late Devonian Hervey Group sandstones are responsible for much of the more rugged topography on the central west slopes and plains. This group is associated with rocky or heavy scree covered slopes with thin and poor sandy soil, one reason why these ridges still carry comparatively undisturbed vegetation. This group is usually ignored in mineral exploration but a few kilometres east of Eugowra vein style copper mineralisation is developed in some of the finer grained grey sandstone beds.

This cutting has a good exposure of the sharp contact between the Cudgelbar Sandstone member (new name) of the Weddin Sandstone and underlying Cloghnan Shale, all part of the Late Devonian Hervey Group (Conolly, 1965). The base of the Hervey Group is approximately 400 metres to the east where it is marked by a thin, impersistent quartz sandstone. To the north, near Bogan Gate, the Cloghnan Shale rests directly on Early Devonian volcanics, which are also reddish purple in colour there. The Cloghnan Shale consists of very friable interbedded silty mudstone and fine sandstone, which produce very rare natural outcrops. Some beds are distinctly calcareous. The associated gentle slopes are invariably covered by heavy sandstone float from the overlying Weddin Sandstone. The mudstone is quarried in several locations for road base.

Some of the red beds show grey-green mottling with evidence of bioturbation or plant roots. At this locality, the top of the Cloghnan Shale is leached and it is likely that several ancient soil profiles are represented. Twenty seven kilometres along strike, to the south, this formation contains a *Bothriolepis*-phyllolepid-*Remigolepis*-*Groenlandaspis* fish fauna, dated provisionally as Famennian (Late Devonian) by Young (1993). The environment of deposition is believed to have been an alluvial plain subject to widely intermittent floods, sufficiently separated in time to allow development of new soil horizons. The muddy silty lithology is comparable with that of the Lachlan riverine plain to the south, visible from this locality. The colour of these sediments is considered to be as much due to the source material as to post-depositional oxidation.

The overlying Cudgelbar Sandstone Member is mostly cross-bedded and generally "cleaner" than those in underlying Early Devonian, and older, formations. The basal half-metre of medium- to coarse-grained massive sandstone is overlain by a conglomerate of subangular to rounded quartz pebbles up to 6 cm diameter. Cross-bedded units in the conglomerate are as much as 1.5 metres thick. The majority of these sands are believed to be fluvial in origin, though deposited in a more energetic environment than that responsible for the Cloghnan Shale. The change in deposition from silty muds to sandstone and conglomerate is not just a local feature, the Weddin Sandstone being widespread for more than 50 kilometres north and south of this stop.

En Route to Stop 1.2

We turn north after crossing Goobang Creek, crossing alluvial plains to the west of Gunning Ridge. The plains close to the ridge have a gradient of up to 20 m/km sloping up to the ridge, far steeper than the main alluvial plain, and have an extremely low radiometric response. They are probably made up of coalescing low angle alluvial fans with sediment locally derived from the ridge, with an input of aeolian sand trapped against the ridge. About 16 km north of the turn off we come onto colluvial slopes around low hills of Hervey Group sediments. We come onto alluvial plains again at Bogan Gate village, and continue north on the plains for another 7 km before rising onto erosional rises and low hills around Stop 2

Stop 1.2: Derriwong Group - Cookeys Plains Formation - limestone lenses

On side of Bogan Gate to Trundle road, 11 km N of Bogan Gate
GR 572472mE 6346466mN

Most of the limestone at this locality has been disrupted by road works. This limestone lens is typical of many in the lower part of the Cookeys Plains Formation, just above the basal Edols Conglomerate of the Derriwong Group. Note the calcrete float in the less disturbed surface; about all that is visible of most limestone bodies in this area. Comparable limestones, in terms of age and likely depth of deposition, are present 14 km to the east, interbedded with the Milpose Volcanics and overlying the Calarie Sandstone, which is a fluvial analogue of the Edols Conglomerate. Laterally the limestone grades into marl and calcareous sandstone. The Cookeys Plains Formation above these limestone lenses consists of siltstones and fine sandstones.

This limestone contains an abundant fauna of globular tabulate colonies and rugose corals, stromatoporoids, and algae, indicative of a shallow water depositional environment. Some colonies of the stromatoporoid *Plexodictyon conophoroides* (Etheridge) extend for a metre or more. Pickett and Ingpen (1990) report the presence of the corals *Squameofavosites* sp., *Heliolites daintreei* (Nicholson and Etheridge), *Parastriatopora* sp., *Cystiphyllum* sp. and *Tryplasma* sp. reported conodonts from similar limestone lenses in this area as indicating a latest Ludlovian (Late Silurian) age. Pickett (1992) reported conodont assemblages as young as the *woschmidti* zone or Early Devonian. The associated red mud suggests well-oxygenated conditions.

These limestones are of particular economic interest because at several localities they have been altered to skarns hosting base metal mineralisation. One such skarn will be Stop 4.9 on Thursday.

En Route to Stop 1.3

We back track, then turn west over colluvial slopes south of hills of Hervey Group sediments. Stop 1.3 is within the hills. It is interpreted that aeolian sand wedges are present on the northwest side of the hills.

Stop 1.3. Trundle Group - Kadungle Volcanics, Bird Flat Member

East Cookeys Plains National Forest, 7 km NW of Bogan Gate
GR 567850mE 6339766mN

The Bird Flat Member is the youngest unit of the Kadungle Volcanics in this area. It is separated from the lower part of the Kadungle Volcanics by a coarse-grained, thickly cross bedded quartz sandstone. There are outcrops of this sandstone just to the north of this locality.

The lower part of the Bird Flat Member is distinctly fragmentary with some crude bedding in places. In thin section, there are obvious shards and angular volcanolithic fragments including vitric trachytic-phonolitic tuff, ignimbrite, perlitic phonolite, and alkali rhyolite. The upper part, near the escarpment crossing the roadway, has typical rhyolitic flow banding. These volcanics are markedly red in colour in comparison with those lower in the sequence.

The age of the upper part of the Trundle Group, which includes the Bird Flat Member, is uncertain for want of fossils but is believed to be late Early Devonian (Pragian-Emsian). Fossils in the lower part include the Early Devonian brachiopod *Spinella pittmani* and conodonts spanning the Lochkovian-Pragian boundary (Pickett, 1992). The red colour of these volcanics is at least partly responsible for the colour of the redbeds in the immediately overlying Hervey Group.

En Route to Stop 1.4

We continue on the colluvial slopes, then come back onto the alluvial plain, with several low rises of Devonian sediment subcrop. The northern parts of the Lachlan alluvial plains here, and west of Stop 4, are characterised by saline scalds, and sodic soils are present (high Na content as cations on clays rather than free salt). These present land management problems, as the soils are dispersive and erode rapidly, and are nutrient deficient. On airphotos, the area presents a smooth photopattern, uninterrupted by remnants of old channels, etc. Stop 4 is in an area of erosional rises near Yarrabandai silos.

Stop 1.4. Derriwong Group - Cookeys Plains Formation

Gravel pits on Yarrabandai Hill.
GR 554159mE 6334720mN

This low hill is typical of the topography developed on the siltstone and fine sandstone which comprises the bulk of the Cookeys Plains Formation. The prominent hill 2 km to the northeast is the aegirine alkali Ganantagai Granite. The heavily timbered range commencing 7 km to the north is the Edols Range, the type area for the Edols Conglomerate, which dips below the northern extension of the outcrops at this locality. The prominent pyramidal hill about 5 km to the south is an end-on view of the Seven Sisters Range, an alkali rhyolite possibly intrusive into the Cookeys Plains Formation and co-magmatic with the Ganantagai Granite.

The laminate siltstone and fine sandstone at this locality is typical of the Cookeys Plains Formation, only excepting the darker than usual colour. Some bands are very fossiliferous with concentrated bryozoan fragments and brachiopods, including *Baturria* sp., *Howellella* cf. *pyramidalis* McKellar, *Retziella capricornae* McKellar, *Leptostrophia (Mitchella)* sp. and *Iridostrophia* sp. This fauna has its closest counterpart in the Late Silurian faunas of the Canberra - Yass district (Strusz, 1984) and the Armagh district near Rockhampton in Queensland (McKellar, 1969), although the age range of conodont assemblages from the Derriwong Group (Pickett, 1992) suggests that it extends into the Early Devonian.

In thin section, the sandstone appears well sorted, with angular quartz and lithic grains, and much of the detritus at this locality probably derived from the Girilambone Group. The environment was clearly marine and sufficiently quiet to allow deposition of laminae but energetic enough to disarticulate and rework the fossils.

En Route to Stop 1.5

We cross more of the alluvial plain with sodic soils, and then come onto erosional plains and rises around Ootha silos. Turning south, we cross another 3 km of erosional landscape before coming onto the alluvial plain, with several inliers of Mulguthrie Formation. Stop 5 is on one of these 'islands'.

Stop 1.5. Derriwong Group - Ootha Subgroup, Mulguthrie Formation

Quarry at "Mulguthrie", 8 km S of Ootha
GR 537550mE 6327950N

In common with the Cookeys Plains Formation, the Mulguthrie Formation has very poor natural outcrop and in this area forms barely perceptible rises. The exposures in this quarry are mostly olive grey mudstone with minor siltstone and fine sandstone. To the northwest of Ootha, sandstone beds are more common and the topographic expression of this formation is, correspondingly, greater.

The Mulguthrie Formation differs from the Cookeys Plains Formation in being muddier with thicker, more massive bedding, with grading visible in some of the coarser beds. The Mulguthrie Formation is well cleaved throughout most of the area covered by the Condobolin 1:100 000 sheet. In the finer-grained, massive beds it can be difficult to recognise bedding at all, except where marked by fossiliferous bands consisting almost wholly of the small brachiopod *Notanoplia* cf. *panifica* Garratt. Many of these brachiopods have articulated, if gaping, valves; indicative of calm depositional conditions. The Mulguthrie Formation, like the Cookeys Plains Formation, overlies the Edols Conglomerate but was deposited in a deeper environment. The dominant detrital grains are angular quartz but some sands have identifiable metamorphic lithic grains, almost certainly from the Girilambone Group.

En Route to Stop 1.6

We continue across the alluvial plains. A rise to the south of the road about 5 km from Stop 5 is a small sand dune. The alluvial plains in this area are characterised by grey alluvial soils. The area is frequently flooded. Stop 6 is at bedrock rises skirted by aeolian sand. The aeolian sand presents a land management problem, as the noxious weed, spiny burrgrass, favours this environment. It is a menace to stock, penetrating skin and causing swellings and ulcers, and making wool exceptionally difficult to handle. Because of this association, we have endeavoured to show all sand dune areas on the regolith landform map.

Stop 1.6. Derriwong Group - Yarnel Volcanics and Cainozoic sand dunes

Outcrop on roadside with flanking sand dunes.
GR 528820mE 6333000N

The location of this isolated hill in an alluvial plain makes it difficult to relate the outcrop here to the subsurface Palaeozoic geology. The siliceous nature of the volcanics suggests a relationship with the Yarnel Volcanics of the Ootha Subgroup, although the agglomeratic texture is unlike any seen in outcrops elsewhere. Some 4 km to the north is a similar isolated hill of siliceous volcanics that is a rhyolitic tuff more typical of the Yarnel Volcanics. It is possible that the outcrop at this locality is a rare example of proximal tuff in the Yarnel Volcanics. The radiometric readings are closely comparable with those of both Yarnel Volcanics and Mulguthrie Formation.

The red brown, well sorted sand piled against this hill is believed to be wind deposited, the height of the deposit being some 20 metres above the alluvial plain, well above any recorded flood levels. Point bar sand deposits along this part of the Lachlan River flood plain, such as that about 2 km west of this locality, have no more than 2-3 metres relief.

En Route to Stop 1.7

We cross more of the Lachlan floodplain, with scattered dunes, before passing onto erosional landscapes immediately north of the Lachlan River at Condobolin. Here, as at Forbes, the river is right at the northern margin of the alluvial plain, and the location of the modern river bears no relationship to the axis of the buried palaeovalley. Stops 7 and 8 are in erosional landscapes north of Condobolin.

Stop 1.7 The Condobolin gold-base metal district - the Red Paint, Mascotte and Julia Reubens workings
GR 511800mE 6342600mN

The Condobolin gold-base metal district comprises northeast-trending quartz veins with mineralisation consisting of pyrite, chalcopyrite, galena and sphalerite. Refer to the section on mineral occurrences of the Forbes sheet area for more information.

At the first locality (Red Paint workings, 511859, 6342667), trenches and shallow pits occur along a northeasterly trending line (Fig. 8.1). The pits were dug on siliceous wallrock (silty to sandy phyllite) with crystalline quartz veins, several millimetres to centimetres wide, which contain micaceous, angular wallrock fragments. There is minor fine- to medium-grained disseminated sulphide in the quartz veins and the silicified wallrock (mainly pyrite with lesser galena). The silicified zone ranges from about 0.5 m to 1 m wide, strikes 060° and dips 65° southeast, parallel to the S_2 foliation.

RAB drilling by Conquest Mining at the Red Paint mine returned a best intersection of 1 m at 2.51 ppm Au (26-27 m) and 1 m at 1000 ppm Zn (18-19 m). On the whole, samples averaged 1.85 g/t Au, 61 ppm Cu, 1225 ppm Pb, 66 ppm Zn, < 1 ppm Ag and 953 ppm As (Rafty and Hemming, 1997).

At the second locality (Mascotte Vein, 511989, 6343017) there are four deep shafts and numerous shallow pits on a line trending 055°. The deepest shaft is 94 m deep (Bowman, 1977b). While there is no exposure of the veins themselves, much can be inferred from the mullock. The wallrock is silicified and chloritised and cut by quartz veinlets several millimetres wide. Disseminated to stringy, fine- to medium-grained pyrite, and lesser galena and sphalerite, occur within the host rock and quartz veins. Breccias are also present, and comprise quartz and chlorite fragments, up to 50 mm long, in a fine-grained matrix rich in pyrite, with lesser sphalerite and galena.

Conquest Mining (Rafty and Hemming, 1997) drilled the Mascotte vein system, encountering a mineralised interval about 30 m wide, which contained intersections of 6 m at 2.99 ppm Au, 1.23% Pb, 2.21% Zn, 2 m at 1469 ppm Pb and 2315 ppm Zn, 1 m at 8.77 ppm Au, 2.8% Pb, 1.6% Zn and 1 m at 4 ppm Au. The high values were adjacent to stoped areas. They described the Mascotte area as being an 80 m wide zone, about 1 km long, with 1 to 2 m wide outcropping quartz lodes, striking northeast and dipping 50° southeast. They described the veins as comprising saccharoidal, brecciated, comb-textured quartz with silica replacement of carbonate and boxworks after sulphide. On the whole the vein system averaged 1.03 g/t Au, 87 ppm Cu, 8241 ppm Pb, 175 ppm Zn, 7 ppm Ag, 5724 ppm As (Rafty and Hemming, 1997). Oxidation depth is about 42 m. The Mascotte mine has a recorded production of 5.115kg Au, 12.722kg Ag and 37t of Pb with average grades of 15.3g Au/t, 1% Cu, 10-20% Pb and 244.8g Ag/t.

At the third locality (Julia Reubens GR 511566mE 6342973mN) there is a deep underlay shaft. The mineralised zone strikes 060° and dips to the southeast, possibly becoming less steep with depth. Shallow pits to the southwest trend 055°. In one pit there is a siliceous zone, about 150 mm wide, comprising quartz veins up to 10 mm wide. The zone is parallel to S_2, trends northeast and dips southeast. Julia Ruebens was RAB drilled by Conquest Mining and returned a best assay of 2 m at 3025 ppm Pb (8-10 m) and 1 m at 1580 ppm Pb (27-28 m) (Rafty and Hemming, 1997).

At the fourth locality (Julia Reubens GR 511735mE 6342903mN) there is exposure of a quartz vein and accompanying silicified zone in a pit about 1 m deep. The vein is comprised of crystalline quartz with a central vuggy zone, and is about 20 mm wide. It trends 055°, 90° and is oriented parallel to the kink axis in kinked phyllites. To the west of the vein, the wallrock is silicified for about 0.35 m and may have contained disseminated sulphides, now leached out. This is one example where the veins are not parallel to the S_2 foliation. Elsewhere, veins trend northeasterly regardless of the orientation of the fabric in the wallrock, suggesting that the kink axis has not been a localising factor either.

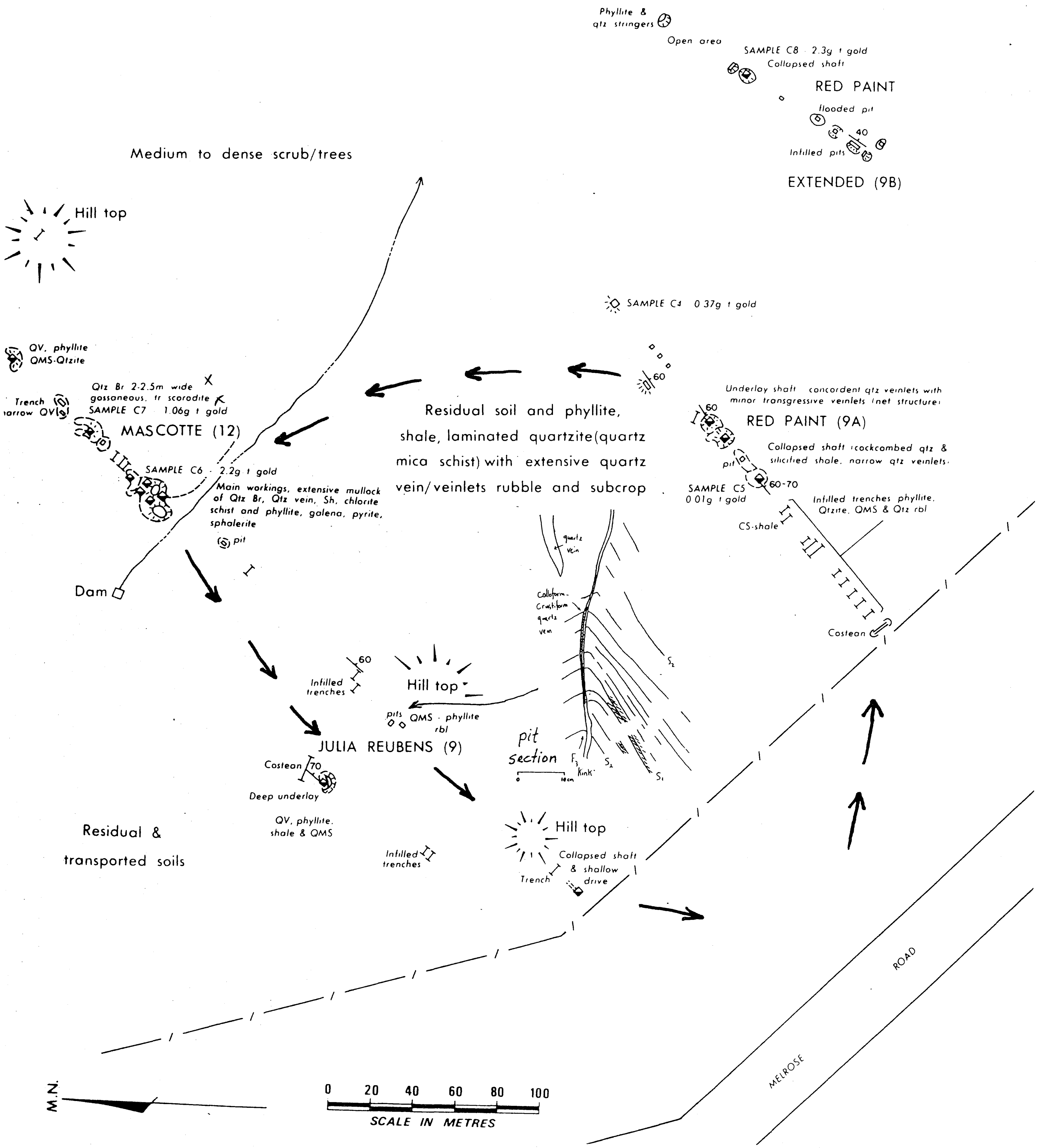


Figure 8.1. Sketch map showing Red Paint, Macotte, and Julia Reubens working in the Condobolin gold-base metal district.

Stop 1.8 Unconformity between the Edols Conglomerate and the Girilambone Group

Roadbase quarry 8 kmNNW of Condobolin, off the road signposted to Mount Tilga and Pistol Club.

GR 511650mE 6346950mN

Although the contact between the Girilambone Group and the unconformably overlying Edols Conglomerate is not exposed, the two units crop out within a couple of metres of each other. Close to the contact, clasts in the Edols Conglomerate are large, poorly sorted, angular, dominantly lithic and locally derived, but up sequence the clast size diminishes to 5-10 mm, sorting improves and the clasts are dominantly rounded milky quartz pebbles. Disarticulated brachiopods and crinoid stems are found in basal conglomerate near this locality, but the best age constraint on the Edols Conglomerate is a minimum of Pridoli (Sherwin, 1997).

The conglomerate contains deformed clasts of Girilambone Group with quartz-mica metamorphic segregation cleavage S_2 crenulated by S_3 cleavage, and milky quartz veins. This constrains the D_1, D_2, D_3 deformations of the Girilambone Group to pre-Pridolian and post-Gisbornian, and is indicative of the Early Silurian Benambran Orogeny. Other clasts include vein quartz with crustiform-colloform epithermal textures, constraining age of epithermal veining in the Condobolin gold-base metal district (Stop 1.7) to pre-Pridolian. A Ludlovian age is indicated, in agreement with the ~420 ma model Pb isotope age for alteration at the Five Mile Hill prospect (Fig. 8.2; after Dean 1995).

The Edols Conglomerate is relatively unmetamorphosed and crops out in shallow NW-plunging open F_4 folds, with S_4 cleavage not evident at the mesoscopic scale. The age of F_4 folding is constrained to the Lochkovian, post Derriwong Group and pre Yarra Yarra Creek Group (Sherwin, 1997). Structural analysis of the extent of F_4 folding on S_2 in the Girilambone Group has been investigated adjacent to the basal Edols Conglomerate. F_4 folding of S_2 in the underlying Girilambone Group is evident for up to 500 m from the unconformity surface, with greatest reorientation along the F_4 limbs and lesser affects around the fold nose. This locality on the F_4 limb shows greatest rotation of S_2 from this NW-trending domain.

The shallow plunge and limb dips of F4 folds and the abundance of epithermal quartz vein clasts derived from shallow depths, indicates the landform north of Condobolin resembles the Ludlow-Pridoli unconformity landscape onto which the basal Edols Conglomerate was deposited.

A Silurian- Early Devonian history of the Conbobolin district is summarised below.

late Lochkovian	Cessation of D_4 with later deformations developed in a different stress regime, and deposition of Yarra Yarra Creek Group.
middle Lochkovian	D_4 deformation with a continued σ^1 orientation of NE-SW. NW-plunging open folds adjacent to a dextral reverse steeply west-dipping fault trending 340°-160°, with greatest strain adjacent to this fault and within the Gilmore Fault Zone. NNW-trending S_4, a 1-10 mm spaced rough anastomosing cleavage, formed in the Edols Conglomerate within the Gilmore Fault Zone.
early Lochkovian - Pridoli	An extensional basin oriented NW-SE develops, with local erosion of the underlying Girilambone Group and epithermal veins at the surface. Transport of locally eroded clasts and deposition within the Edols Conglomerate, followed by deposition of the felsic Yarnel Volcanics and siltstone-dominated Mulguthrie Formation. Deposition of equivalent units to the NNW, the Mount Susannah Conglomerate, Mineral Hill Volcanics and Talingaboolba Formation of Kopyje Group (Suppel and Pogson 1993, Sherwin 1997).
Ludlow	Acting on the Gilmore Fault Zone and the area of Girilambone Group to the east, the principal compression σ^1 is oriented NE-SW and principal extension σ^3 oriented NW-SE. Intrusion of mineralised quartz veins with epithermal textures developed near the surface, along a dilational zone dominantly trending 055°-235°.
Llandovery	Benambran D_1, D_2, D_3 deformation and metamorphism of the Girilambone Group.

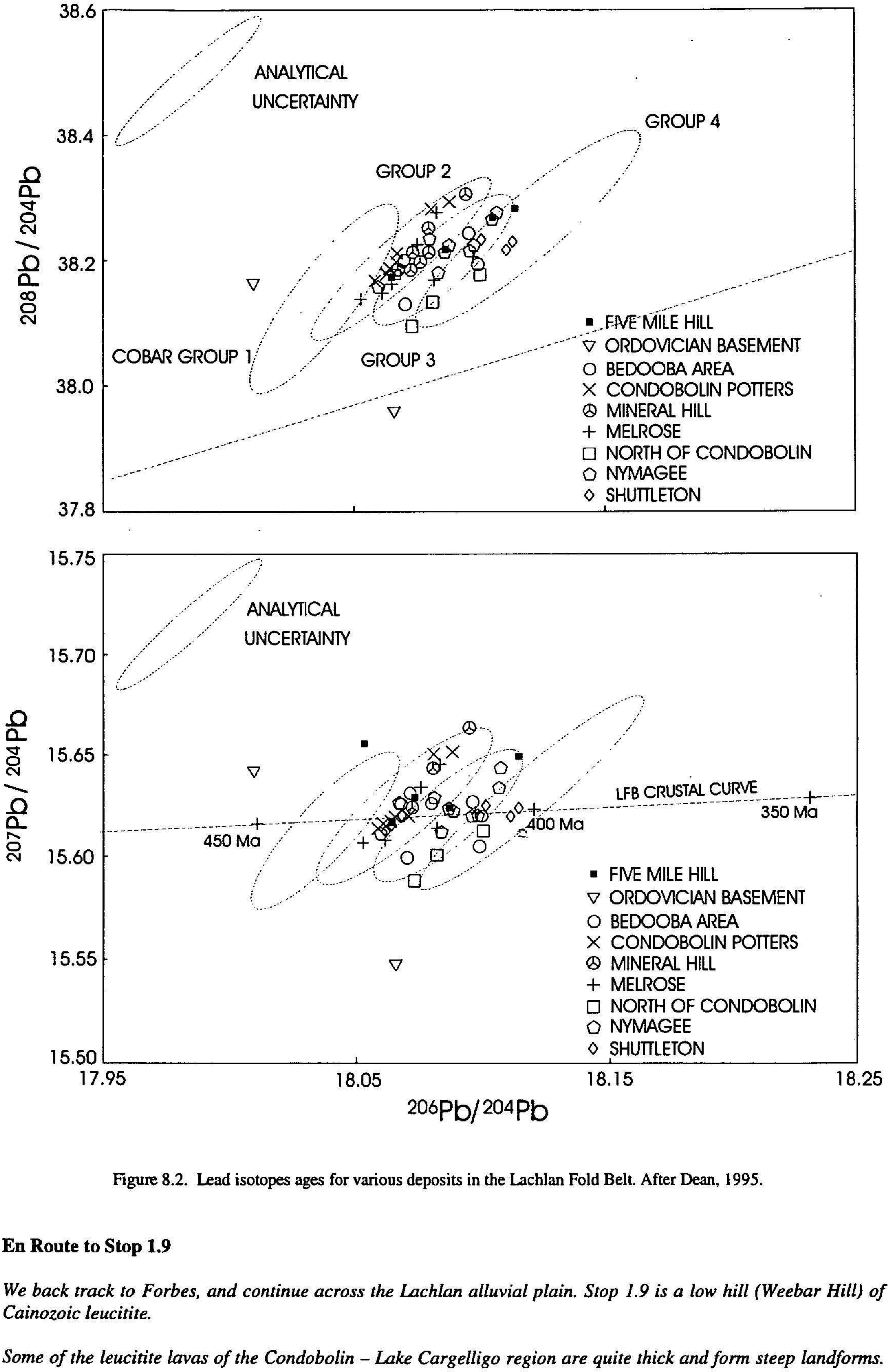


Figure 8.2. Lead isotopes ages for various deposits in the Lachlan Fold Belt. After Dean, 1995.

En Route to Stop 1.9

We back track to Forbes, and continue across the Lachlan alluvial plain. Stop 1.9 is a low hill (Weebar Hill) of Cainozoic leucitite.

Some of the leucitite lavas of the Condobolin – Lake Cargelligo region are quite thick and form steep landforms. These are not erosional remnants of a widespread, thick lava mass, but result from inflation of localised flows. The lavas postdate the incision of the Lachlan palaeovalley, which had most probably eroded to its deepest extent by Early Miocene, but predate the main alluviation, from Late Miocene onwards. Therefore, the lavas around Stop 9 were extruded onto the mid-late Miocene dissected landscape, and have since been partly 'drowned' in the sediments. Only the highest parts of the flows are now exposed, as 'islands'. Geophysics suggests that an area *about 7 km diameter is underlain by lavas. There is a very sharp boundary between the steep northern slope of Weebar Hill and the surrounding alluvial plain, suggesting that the leucitite-alluvium contact continues steeply downwards.*

Stop 1.9 Weebar Hill Leucitite

Condobolin Basalt Quarry, on "Milby" property
GR 509950mE 6329950mN

The Weebar Hill Leucitite is the most easterly of the Miocene leucite-bearing lavas in New South Wales (Cundari, 1973). Two distinctive hills which rise above the surrounding alluvial plain, are the eroded remnants of volcanic intrusive centres at Wallaroi Hill and Weebar Hill. Wallaroi Hill has lava flow ridges and scoria-lava contacts sloping away from the topographic high. Weebar Hill is a topographically high ridge with a magnetic high adjacent to the 212 m spot height, which is presumed to be an intrusive pipe sourcing surrounding flows. The flows extend 5 km from the Weebar Hill intrusive centre, as determined from the surrounding aeromagnetic anomaly and drilling by North Ltd (Burrell, 1994). Younger Cainozoic flood plain alluvium has been deposited by the Lachlan River- Wallaroi Creek system above the Weebar Hill Leucitite, except for these isolated topographically-higher outliers of the flows.

A layered volcanic stratigraphy of leucitite lava flows and flow-banded scoria flow front/top breccias are exposed in the quarry. The lava flows have vertical columnar jointing and in combination with weathering forms spheroidal boulders at the surface. The lava flows have high magnetic susceptibilities of $300\text{-}3000 \times 10^{-5}$SI units, and vesicular breccias have values of $30\text{-}400 \times 10^{-5}$SI. High potassium contents in the volcanics produce deep pink anomalies on RGB radiometric images.

Leucitite is an ultra-alkaline volcanic which has no essential feldspar (< 10%) and has leucite ($KAlSi_2O_6$) as the essential feldspathoid (>10%), and in NSW where their colour indexes are generally above 70 they can be considered as ultramafic rocks (Cundari, 1973). Modal analyses by Cundari (1973) reveal leucitites at Weebar Hill have between 14-23% leucite, 38-42% clinopyroxene, 15-22% olivine and 11-18% Fe, Ti oxides. Leucite crystals are colourless and generally < 1 mm diameter, clinopyroxene forms small crystals ranging from brownish salite to green diopsidic augite, olivine is porphyritic, magnesium rich and has minor iddingsite replacement, and magnetite is the common accessory Fe oxide (Cundari, 1973, Barron, 1998). The leucitite has a grey-black aphanitic groundmass, and also contains minor phlogopite, blue-yellow zeolite infilling of vesicles (Barron, 1998).

A mantle source for leucitite in NSW at a depth >100 and crystallisation at >700°C under pressures < 2kb is suggested by Cundari (1973). Deep-seated crustal structures of the basement complex, reactivated in late Cainozoic time by faulting and differential vertical movements, are suggested by Cundari (1973) as essential for the movement of 'leucitite magma' to the surface. Geological mapping and interpretation of the Forbes 1:250 000 aeromagnetic images indicate the Gilmore Fault Zone has acted as a dilational conduit for the Weebar Hill Leucitite (Scott, 1999), and also for olivine leucitite 22 NNW along strike (Suppel and Pogson, 1993). A K/Ar date of 12.6±0.4 Ma determined by Wellman *et al.* (1970) for a leucitite lava flow from a ridge at Weebar Hill, indicates the dilation occurred in the Miocene

Hard rock aggregate was produced at the Condobolin Basalt Quarry in 1969 (Bowman, 1977b), but according to the landowner it ceased operation due to difficulties in its crushing. However, loose boulders from the quarry are still used by the Lachlan Shire Council as decorative stones in gardens at Condobolin. If the crushing problem could be solved, there seems potential for supplying aggregate locally, particularly as it is presently transported over 100 km from Wyalong (Stop 2.6).

En Route to Stop 1.10

We backtrack to Condobolin, traversing the alluvial plain till we cross Walleroi Creek, an anabranch of the Lachlan. We rise onto foot-slopes of low hills and rises to the west; Bogandillon Swamp, a large local depositional basin, is to the south.

Stop 1.10 Extensive scraped area on W side of Condobolin to Burcher road.
GR 522343mE 6315052mN

These outcrops are typical of the Yarnel Volcanics, even as far distant as Ootha. The fresh rock is dark grey to black with a characteristic off-white to light grey weathering rind. When strongly cleaved and weathered it is difficult to separate these volcanics from similarly cleaved and weathered sediments of the Mulguthrie Formation. Because these volcanics are so fine grained, almost glassy, it is only in thin section that they are identifiable as distal vitric rhyolitic tuff. Staining shows the rock has a high K content.

The timbered hills 4 km to the northwest are formed by the Darbeys Ridge Conglomerate (Yarra Yarra Creek Group) which rests unconformably on the Derriwong Group. The timbered ridge 9 km to the east is the Edols Conglomerate.

En Route to Stop 1.11

We skirt Bogandillon Swamp on erosional plains and rises and turn south to Stop 1.11, which is immediately east of an inlet of the extensive alluvial plain of Humbug Creek.

Stop 1.11. Ina Volcanics
GR 528300mE 6296750mN

The principal rock type in the Ina Volcanics is a reworked rhyolitic tuff or volcanigenic sandstone. The rock consists of euhedral to subhedral crystals and broken fragments of quartz, orthoclase, minor plagioclase and lithic grains, in a recrystallised matrix of the same minerals, together with white mica and a trace of zircon. A volcanic component is evident from glass shards preserved in the matrix and an abundance of partially resorbed euhedral quartz phenocrysts. However, a substantial plutonic and metamorphic detrital component is also present, represented by grains of micaceous schist, recrystallised chert, angular quartz with undulose extinction and subgrain development, deformed biotite, and microcline microperthite. Extensive development of muscovite has occurred during recrystallisation and metamorphism of the shard-rich matrix.

En Route to Stop 1.12

Backtrack to Bogandillon Swamp, and turn east across a stagnant alluvial plain.

Stop 1.12. Sand wedge East of Bogandillon Swamp
GR 532000mE 6310500mN

The western slopes of a north-northwest trending ridge of Edols Conglomerate are composed of aeolian sand, which has been trapped by the ridge and probably sourced locally from Bogandillon Swamp and surrounding floodplain areas. Several other meridional ridges in the Forbes Sheet area (most notably the Jemalong/Corridgery Ridge) have similar sand wedges on their western sides. Locally, the sand has built up to the level of passes through the ridges, as at this locality. It is theoretically possible that aeolian materials could also be trapped on the E side of the ridges, due to eddies and wind shadows, but none have been identified in the area. Further south, in the Junee and Young areas, aeolian dust (parna) is preserved on the eastern (lee) side of hills. This dust probably has a distant source, rather than the local source for the sand in the Forbes sheet area.

En Route to Stop 1.13

After crossing the ridge at Stop 1.12, we cross the Jemalong-Wyldes plains area, marked by heavy red brown earth soils, with a low radiometric signature indicating a stagnant leached alluvial plain. This is an irrigation area with saline groundwaters close to the surface, and rising watertables, thus posing a geo-environmental problem. As we join the Lachlan Valley Way we come on to younger alluvial soils near the Lachlan River.

Stop 1.13 Jemalong Gap
GR 572000mE 6303800mN

The palaeo-Lachlan River flowed through Jemalong Gap, with floor of the incised palaeovalley about 140 m below the level of the modern floodplain. To put this in perspective, Jemalong Ridge to the south rises 100-135 m above the surrounding plain. As the alluviated gap is only 1.5 km wide, the palaeotopography must have been quite imposing. See Figure 8.3. Jemalong Ridge and its extensions to the north also form an extensive barrier to groundwater movement. To the east, the groundwater is generally of good quality (Williamson, 1986), but to the west, groundwater is saline in many places (Anderson *et al.*, 1993). It appears that salinity has been introduced to the main Lachlan palaeovalley from the Bland Creek palaeovalley southwest of the Ridge. The oldest sediments in the palaeovalley fill have been dated as Early to Late Miocene by palynological examination of borehole cuttings (Martin, 1991). However, there is either a condensed sequence, or hiatus, between these and Late Miocene-Pleistocene sediments which make up most of the deeper valley fill.

Stop 1.13 to Forbes

Return to Forbes on alluvial plains, passing north of a small inlier of Derriwong Group sandstone. Contours shown in Figure 8.3 show that this was at one stage the tip of a steep hill some 120 m above the palaeo-Lachlan River!

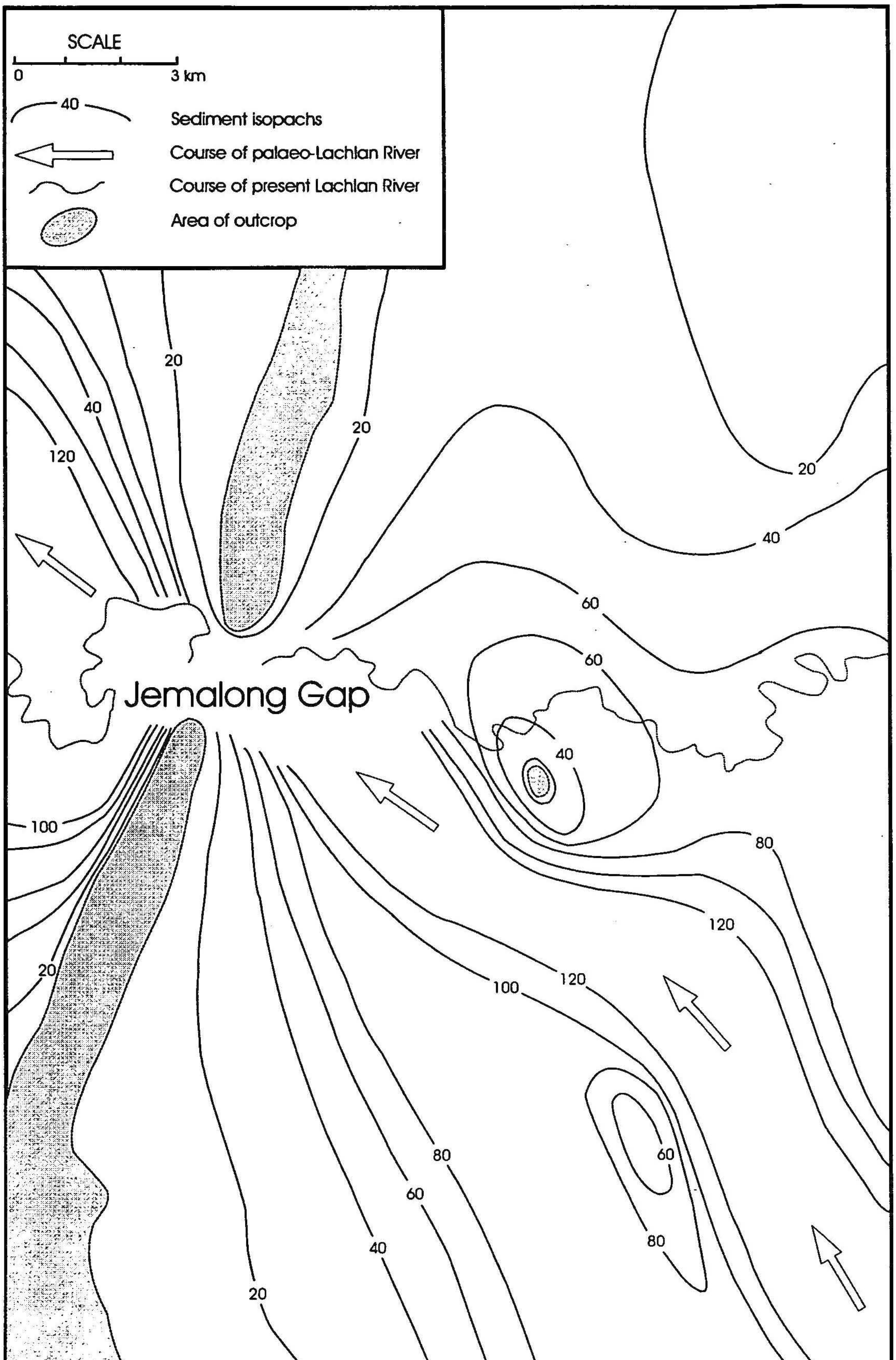


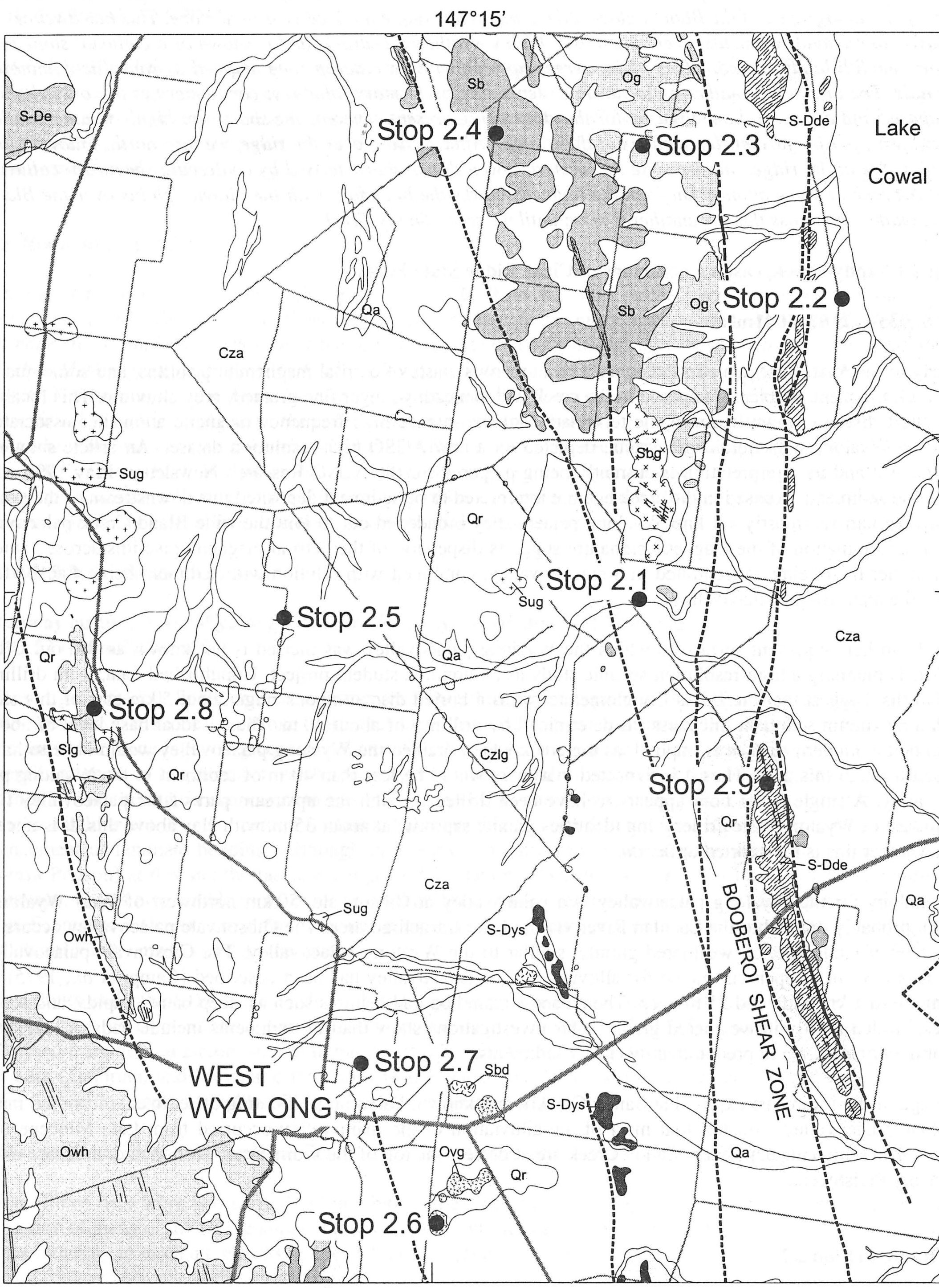
Figure 8.3. Sediment isopachs in the vicinity of Jemalong Gap.

DAY 2

Depart Forbes RSL 8:00 am

Stop	Duration mins		Author
2.1	0:10	Clear Ridge/Sandy Creek	Chan/Gibson
2.2	0:10	Lake Cowal	Lyons
2.3	0:55	Girilambone Group	Lyons
2.4	0:15	Burcher Greywacke	Lyons
2.5	0:15	Cunnington's Lane, regolith	Chan/Gibson
Lunch	1:30	Mine recreation area, Wyalong	
2.6	0:30	Narragudgil Volcanics	Duggan
2.7	0:15	Wyalong Tip, regolith	Chan/Gibson
2.8	0:25	Wagga Gp-Ungarie Granite, contact	Duggan
2.9	0:40	Booberoi Fault	Lyons

Arrive Forbes RSL 6.30 pm



DAY 2 EXCURSION STOPS

Day 2 13 April 1999

En Route to Stop 2.1

See notes Day 3 notes for details of route between Forbes and Jemalong Ridge. After crossing the broad alluvial plain west and south of Lake Cowal, the Mid-Western Highway passes over a narrow ridge, the Booberoi Hills. A break of slope 2 ½ km east of the hills marks the boundary between the depositional domain (thick alluvium burying the topography of the Bland palaeovalley), and a low angle inclined erosional slope. This has a veneer of colluvial to residual sediments, overlying mostly highly weathered bedrock, and is shown as a colluvial slope unit on the regolith landform map. This plain merges upslope with an outcrop zone mapped as saprolite-dominated low hills. The degree of weathering is variable, depending on primary lithology; conglomerates are only slightly weathered and appear to be the reason for the ridge being present, whereas the shales are highly weathered. See notes for Stop 9 for further descriptions of these rocks. After passing over the ridge, we turn north, following the western side of the ridge, and traverse the western lower slopes characterised by coalescing sheetwash colluvial fans. A break of slope about 9 km from the highway marks the boundary with the alluvial plains over the Bland palaeovalley. We cross this for another 6 ½ km until we reach Sandy Creek.

Stop 2.1 Sandy Creek, eastern boundary of Clear Ridge State Forest

GR 529334mE 6265041mN

Poorly to moderately cemented sandstone, with numerous clasts of detrital maghemite pisoliths, and some quartz and rock fragment pebbles, is exposed in the creek bed, beneath younger fine-grained, grey alluvium. This locality is a short distance downstream of the termination of the intense high frequency magnetic anomalies associated with the Wyalong palaeodrainage system, depicted on a new AGSO high-resolution dataset. An article showing this dataset and its interpretation is currently being prepared for the AGSO Research Newsletter, May 1999 edition. The sediments exposed in the creek bed are interpreted to be sediment deposited just downstream of the point where the narrow (mostly < 1 km) Wyalong palaeovalley broadened out to join the wide Bland Creek palaeovalley. The termination of the magnetic signature suggests dispersion of the detrital magnetic pisoliths across a wide area, rather than being concentrated in a narrow valley, combined with dilution with sediment being transported down the main Bland palaeovalley.

The depth below present surface to which the Wyalong palaeovalley was incised is not known as yet, but CRC LEME is planning a high-resolution seismic study as an honours student project. Unpublished data, from drilling by Norths, suggest that the Edols Conglomerate forms a buried discontinuous ridge about 5 km east of this site, with a maximum sediment thickness (as determined by drilling) of about 40 m. Thus, a local base level of about 40 m below modern surface is implied, as the creek which drained the Wyalong palaeovalley would have to have passed through this area. Thus it is expected that there would be less than 40 m of sediment in the Wyalong palaeovalley. A single water bore appears to have been drilled through the upstream part of the palaeovalley fill, northwest of Wyalong. The drillers' log identifies granite saprolite at about 35 m, with clay above this. It is uncertain whether this is transported or *in situ*.

An analogy for the Wyalong palaeovalley is a palaeovalley at Gibsonvale, 50 km northwest of West Wyalong, which probably drained to the Lachlan River via the Lake Cargelligo area. The Gibsonvale palaeovalley occurs in a low relief landscape, on weathered granite, similar to the Wyalong palaeovalley. The Gibsonvale palaeovalley deposits have been open cut mined for alluvial tin. The palaeovalley has been described (Campi *et al.*, 1975) as being up to 1 km wide and 35 m deep. The palaeo-stream bed had features such as steep banks, rapids, and scour holes, eroded mostly in weathered granite. Our investigations show that the sediments include beds of magnetic pisolith conglomerate in predominantly clayey sediments.

The age of the sediments exposed at Sandy Creek is not known. Palynological dating of sediments from the main Lachlan palaeovalley indicates that most of the alluviation of the main valley occurred from Late Miocene onwards. The sediments exposed at Sandy Creek are at or near the top of the sedimentary section and, thus, are most probably Pleistocene.

En Route to Stop 2.2

We skirt Billy's Lookout hill (a small body of near-fresh granite) on colluvial slopes underlain by Ordovician metasediments, but mostly with a veneer of potassium-rich granite-derived colluvium, as shown by radiometrics (Will soil samples from this area reflect the chemistry of the granite or the underlying metasediments? What are the implications for geochemical prospecting?). After turning east and crossing the West Wyalong-Burcher railway, we pass onto a low relief undulating landscape, punctuated by a single north-trending bedrock ridge. In contrast to the areas further to the south, this is not part of the Bland Creek palaeovalley, but consists of relatively thin colluvium/alluvium over weathered bedrock. Only the eastern part of the modern Lake Cowal overlies thick *alluvial fill of the palaeovalley. It is fortuitous for Norths that the Lake Cowal deposit was not eroded to a greater extent during the erosion of the Bland Creek palaeovalley. If so, it would be partly removed, and now under a thicker transported cover.*

STOP 2.2: Lake Cowal and proposed minesite of Endeavour 42 Au deposit

Road west of Lake Cowal, 34 km NNW of Wyalong
GR: 536900mE 6276200N

Lake Cowal, and the proposed minesite, are about a kilometre to the east. As the area is completely covered by Cainozoic sediments, of average thickness around 40 m with some palaeo-channels up to 120 m deep, the guides to ore were the similarities between the magnetic signatures of the Cowal Volcanics and the host rocks of the Northparkes (Goonumbla) deposit. Miles and Brooker (1998) provide a description of the geology and mineralisation of the Endeavour 42.

En Route to Stop 2.3

After back tracking, we pass through a gap in Billy's Lookout hill. Soils on the steeper granite outcrop areas are sandy and granite-derived. A small amount of gold was won last century from quartz veins in the Ordovician metasediments around the north side of the hill, and associated alluvial deposits. Some of these are marked on the Forbes Metallogenic map as deep leads. Mining records indicate that gold was won from wash at about 9 m depth. The deep leads are located beneath the modern valley floors and so were easy for the early miners to locate. In other words, in the past, the valleys were more incised, but have now partly alluviated, but not to the extent where the valleys have been almost totally infilled, as is the case with the Wyalong palaeovalley. After crossing Billy's Lookout hill and the colluvial slope to the west (~1 km), we turn north and cross erosional rises with subcrop of weathered Silurian and Ordovician greywacke, with some low hills west of the road. Transported regolith is probably mostly limited to thin colluvium, with thicker alluvium in valley floors.

STOP 2.3: Girilambone Group

Railway cutting, West Wyalong - Burcher Railway, 36 km due N of Wyalong
GR: 529700mE 6281800N

These tightly folded, finely banded, quartz-mica metasediments are typical of the Ordovician Girilambone Group, although minor siltstone, sandstone, and chert units also occur in this unit in the Wyalong 1:100 000 sheet area. Metamorphic grade is lower greenschist facies. Out crop is generally poor, but the distinctive banding allows unit identification in all but the most weathered or altered outcrop and sub-crop. The fine banding, often enhanced and etched by weathering, is equivalent to S_{G2} of Pogson (1991) and is apparently parallel to S_0, suggesting an early isoclinal fold event. It is not certain (to this author) whether S_{G2} is a differentiated cleavage or a metamorphic enhancement of laminate bedding. Although thin section examination produced no evidence for the presence S_{G1} (*sensu* Pogson) at this site the fabric catalogue established by Pogson has been maintained. A spaced crenulation cleavage, S_{G3}, is also visible in outcrop. Some kink bands have overprinted these earlier fabrics but their regional significance is not clear. They may indicate an increase in the strain gradient caused by movement on the nearby Booberoi Fault, some 2-3 km to the east.

Conodonts and radiolaria found in the Cobar district suggest a Darriwillian-Gisbornian depositional age (about 460 Ma) for the Girilambone Group (Stewart and Glen, 1986; Iwata *et al.*, 1995). Recently acquired U-Pb data, obtained from detrital zircons in a psammitic unit (GR 528800mE 6282100mN) constrain a maximum age of Mid to Late Cambrian, and ultramafic intrusions in the Narromine 1:250 000sheet area constrain a minimum age of Mid Eastonian (zircon U-Pb448±4 Ma; Elliott and Martin, 1991).

Hitherto, the existence Girilambone Group rocks has not been recognised south of the Lachlan River.

Note: Since field work was carried out in 1996-7, upgrading of the railway line has, unfortunately caused the destruction of many of the fine features of this site as the cutting was replaned. We may have to wait another 70 years for weathering to re-etch the rocks and reveal the fine details.

En Route to Stop 2.4

Again, we pass over rises and low hills on weathered bedrock, with a veneer of colluvium and alluvium.

STOP 2.4: Burcher Greywacke

Lake View State Forest, 33 km N of Wyalong
GR: 523900mE 6279900N

The Burcher Greywacke is a massive quartz-lithic greywacke containing minor silty lenses and rip-up clasts, metamorphosed to lower greenschist facies. It contains the *Blow Clear Member* of poorly sorted lithic conglomerate and the *Sandal Formation* of sandstone, siltstone, and chert. Most of the out crops are curiously fresh. The origin of a prominent a linear magnetic anomaly, associated with a darkened soil colour, is but it is similar to a larger anomaly to the west . Bedding dips steeply, with a NNW trend, but the massive sandstones have acted as passive bodies during deformation and contain no structural elements. In the siltstone, bedding is parallel to S_1 and a weakly developed S_2 has been observed at a locality about 8 km to the south-southwest (GR 525900mE 6271700mN). The contact with the underlying Girilambone Group is not exposed but is interpreted (on the slimmest of evidence!) to be an unconformity. The western margin of the Burcher Greywacke is not exposed, either, but magnetics indicate that the unit is terminated by the Gilmore Fault Zone with the Wagga Group thrust over.

At this site, the typically fresh, massive nature of the Burcher Greywacke is apparent. Note, however, the presence of buff-coloured weathered rock as well. Graded bedding, silty lenses, and rip-up clasts can be seen in the fresh outcrop and boulders.

The age of the Burcher Greywacke is constrained. It contains detrital zircons of Early Silurian age and it is intruded by the Mid Silurian Billy's Lookout Granite. Kemezys (1976) reports the presence of rare crinoid stems in the massive greywacke but no fossil description is given.

En Route to Stop 2.5

From 2 to 8 km south of Stop 2.4 we pass along the edge of an extensive alluvial area to the west and north, with thick alluvium in the buried palaeovalley of Humbug Creek. Relief remains very low for much of the route, but saprolite exposures in farm dams and roadside cuts shows that there is little thickness of cover sediment. Closer to Stop 2.5 we climb a ½ degree slope, into what is clearly recognisable as an erosional terrain.

Stop 2.5 Granitic saprolite amd magnetic lag, Cunnington's Lane
GR 5164611mE 6265007mN

Excavations reveal soil overlying very highly weathered mega-mottled granitic saprolite. Yellow-brown goethitic nodules are growing in the saprolite, and darker brown magnetic pisoliths are present at the surface as a sparse lag. In this general area, it appears that the magnetic pisoliths originate from erosion of the goethitic nodules and ferruginous concentrations in mottles in the saprolite. The original goethite and ?hematite appear to be transformed to maghemite (an iron oxide with a spinel structure, which is highly magnetic) as the fragments are transported at the surface. Heat in the presence of organic matter is a known way of transforming goethite to maghemite, and bushfires have been suggested as a possible process. However, the pisoliths have not been studied in this area, and it is not certain whether maghemite is in fact present.

We consider that sites like this are the source of the detrital magnetic pisoliths in the palaeovalley deposits, having been transported into the valleys by sheetwash, alluvial action, and creep. Old mining records suggest that the depth of weathering of the granite in this general area is at least 60 m. On radiometric images, much of the highly weathered granite area shows as being Th-rich. This is interpreted to result from the leaching of K and U, and the concentration of Th by association with Fe in the pisolitic lag, and ferruginous mottles in the saprolite.

The question arises as to whether the highly weathered granite represents a certain primary lithology which was highly susceptible to weathering, rocks with extensive grain fracturing allowing the ingress of water (hence weathering), or rocks which have been hydrothermally altered. We cannot presently answer this question.

En Route to Stop 2.6

We cross erosional plains and rises, with rare exposures of granitic saprolite in roadside cuts, and occasional areas of pisolith lag. This is still an erosional landscape, despite its apparent flatness. The best way to see minor relief is to look along fence lines, roads, railway lines, etc. Valley floors have a broad U-shape, indicating that most sediment in the valleys is derived by transport (most probably sheetwash) down valley sides, rather than by transport as alluvium down the valley by the watercourse itself. This has important implications for soil geochemical sampling. Nearing Stop 2.6. alluvial plains over part of the Bland Creek palaeovalley are present to the west and south. Company data suggest a considerable thickness of sediment in some of this area.

STOP 2.6: Narragudgil Volcanics intruded by andesite dykes

Miller's Quarry, 6 km S of Wyalong
GR 522100mE 6388400mN

Miller's Quarry provides excellent exposures of a sequence of metabasaltic rocks (the Narragudgil Volcanics) cut by a variety of dykes of intermediate (andesite-diorite) composition. The Narragudgil Volcanics consist of fine-grained basaltic rocks metamorphosed to upper greenschist or locally to lower amphibolite grade. In the quarry exposures, the metabasalts and are characterised by a pervasive, sub-vertical structural fabric in the form of anastomosing planes of high strain up to a few cm wide separating sheets of massive, essentially undeformed metabasalt, typically 20-40 cm across, giving a superficial appearance of a sheeted dyke complex. No conclusive evidence of original bedding or flow boundaries has been observed. Geochemically, the volcanics have major and trace element signatures characteristic of MORB-type basalts and show affinities to mafic rocks of the Jindalee Group south and east of Cootamundra.

The dykes are massive, typically 2 metres across (range 1-3 metres), sub-vertical, and are either parallel to the structural fabric of the metabasalts or cut it at low angles. They are highly variable in texture and grainsize. Coarser grained (diorite) dykes consist of equant hornblende (after clinopyroxene) and plagioclase crystals in an intergranular mosaic of quartz, plagioclase, hornblende, biotite and opaques. Other dykes consist of phenocrysts of hornblende (after clinopyroxene) and/or plagioclase (containing abundant inclusions of hornblende or epidote) in a groundmass of the same minerals, quartz and opaques. The mineralogical features and textural recrystallisation show clearly that the dykes predate the greenschist/amphibolite metamorphic event. The dykes range in composition from andesite to dacite and, in contrast to the basalts, show geochemical characteristics consistent with calc-alkaline or shoshonitic affinities. They are believed to be shallow intrusive (sub-volcanic) equivalents of the Gidginbung Volcanics and may be related to emplacement of the Bland Diorite.

Stop 2.7. West Wyalong Garbage Tip

GR 519317mE 6248006mN

Trenches at the tip are about 7 m deep. To date, trenches have been cut wholly within sediments. Access to the current trench will depend on rubbish level and smell. The most western trench, dug in December 1998, was studied and sampled before it came into use. The top 3 – 3 ½ m of the sediment are poorly to moderately cemented sand and silt, with increasing pebble content down to conglomerate about 75 cm thick. Most clasts in the conglomerate are magnetic pisoliths to about 10 mm, but larger ferruginised rock fragments to about 50 mm, and very rare quartz pebbles are also present. Sedimentary structures such as cross bedding and cut and fill structures are preserved. The sediments are mostly oxidised red, but are bleached along plant root zones, reflecting the reducing nature of the immediate root environs. The base of the conglomerate is marked by a sharp, undulating contact with sedimentary clays, with some sandy and minor pebbly beds. The clays are heavily mottled, with iron-rich segregations in the mottles. Again, zones around tree roots are bleached. Hand augering has confirmed that the clays extend for at least 1 m below the base of the trench. The clays have been sampled for palaeomagnetic dating of weathering, but results are not yet available.

The most western trench, which will be in use until about mid 1999, will be the last one dug at the current site. A new parcel of land, immediately east of the current site, is being developed. Highly weathered granite saprolite is exposed at the eastern edge of the new site. Old gold mine shafts are present – one mine was worked by an old-timer until 10-15 years ago, according to the previous owner of the land that is now owned by Bland Shire Council.

The new detailed AGSO magnetic imagery clearly shows that the tip site is within a tributary of the main Wyalong palaeovalley. However, there is little indication at the surface, apart from ubiquitous lag of magnetic pisoliths, that this is an infilled valley. Little wonder that the miners of 100 years ago decided that there was nowhere to look for shallow alluvial gold or deep leads in the area, despite rich bedrock lodes mined down to 350 m.

Further downstream, in the area of the main palaeovalley, there has been a major diversion of drainage since deposition of the palaeovalley sediments. The headwaters of the palaeo Sandy Creek now floweast and pass south of the Booberoi Hills, rather than swinging to the north and passing to their north. This diversion appears to be due to the buildup of aeolian sand blown from the palaeovalley drainage by the dominant southwesterly winds of the region. This blocked the palaeovalley and forced the drainage to evulse to a new course. The modern creek downstream from where it leaves the palaeovalley still has a sandy bedload that periodically blocks the channel, causing rapid changes in channel location, and farm management problems (pers. comm., Mark Leary, NSW Department of Land and Water Conservation, West Wyalong).

En Route to Stop 2.8

We cross gently undulating erosional plains and rises, with colluvial and lesser alluvial sediments mantling granitic saprolite exposed in roadside cuts. The lower part of the landscape consists of co-alluvial plains with up to several metres of sediment that includes detrital ferruginous pisoliths. From 5 to 6 km from West Wyalong we cross the Wyalong palaeovalley. A recent road cutting through a low rise about 8 km from West Wyalong exposes less weathered granitic saprolite, with some corestones. A small area of K-rich response on the radiometrics corresponds with this rise. Elsewhere the response is Th-rich, grading to very low response in all channels.

STOP 2.8: Contact between Wagga Group metasediments and Ungarie Granite

Unnamed creek crossing Rootes Lane, 3 km S of Calleen
GR 509900mE 6258800mN

The contact between Wagga Group and Ungarie Granite is complex and variable from purely intrusive, as seen at this stop, to fault controlled with development of mylonite. An example of the latter is observable on the western side of a low hill 9 km WNW of Wyalong. Metasediments of the Wagga Group increase significantly in metamorphic grade as the contact with the Ungarie Granite is approached. The metasediments reach biotite grade within about 2 km of the contact and grade then increases rapidly so that migmatitic structures are widely developed in outcrops near the contact.

At this locality, exposures in the creek bed show abundant angular xenoliths of migmatite and muscovite-biotite schist of the Wagga Group set in granodiorite. The xenolith blocks are typically rectangular in profile and appear to show little or no preferred orientation. At one point, xenoliths predominate and the enclosing granite is reduced to a network of veins and elongate pods. The granodiorite is massive or displays only a very subtle foliation. At this point the Wagga Group forms a screen of country rock about 800 metres wide separating the main mass of the Ungarie Granite from another elongate body of granite which is compositionally indistinguishable from the Ungarie Granite and most likely part of the same intrusion.

En Route to Stop 2.9

We retrace our route to Wyalong, then northeast along the Mid-Western Highway. About 3 km from Wyalong, a subtle break in slope marks the boundary between the erosional landscape to the west and the depositional plains on the sedimentary fill of the Bland Creek palaeovalley. An area of red soils and gilgai about 1 km before the turn to the north to Stop 2.9 indicates that deposition here is very slow or stagnant, and that swelling clays are present.

Stop 2.9: Booberoi Fault Zone

Wyrra State Forest, Booberoi Hills, 17 km NE of Wyalong
GR 534300mE 6258600mN

The Booberoi Fault (named by Ingpen, 1995) is a rejoining splay fault from the Gilmore Fault Zone to the west. It has a high magnetic signature showing as a continuous structure, about two to three km wide, extending at least from Gibber Hill, about 30 km southest of Wyalong (in the Cootamundra sheet area) to Kerribrew Ridge, about 5 km southwest of Manna Mountain. The high magnetics are probably due to the presence of volcanics, or volcanically derived sediments, but only sheared Late Silurian-Early Devonian Edols Conglomerate (Sherwin, 1996) is preserved in outcrop. Mesoscopic kinematic indicators show at least two movement episodes: a horizontal sinstral movement and a near vertical reverse (west side up) movement; however, no overprinting relationships have been found. Kinematic indicators at this locality show the reverse movement. It is not clear whether these two movement directs are components of a transpressional fault motion. The amount of displacement is not known but the inlier of Girilambone Group rocks between Billy's Lookout and Burcher has possibly been detached and shunted southwards from, at least, the Girilambone Group rocks north of Condobolin, giving a minimum horizontal displacement of about 70 km. Although shearing must have occurred during the late or post-Pridolian to have deformed the Edols Conglomerate, drilling at Newcrest's Marsden Prospect has shown that the Cowal Volcanics are thrust over the Late Devonian Hervey Group and it is possible that the Booberoi Fault Zone was, at least, partially reactivated during this event. Magnetic and drill hole information show that the western margin of the Cowal Volcanics have been also been affected, although to a lesser degree, by shearing on the fault zone.

At this locality, the sheared Edols Conglomerate shows stretched quartzite and vein-quartz pebbles in a quartz-white mica-chlorite matrix, which was probably a muddy sandstone. The movement direction can be discerned from the asymmetry of the matrix surrounding the pebbles and the mineral elongation within the matrix. The long axes of pebbles is generally parallel to the movement direction. Northwards along the shear zone, the plunge of theses axes becomes more horizontal so that at Womboyne Mountain they plunge about 30° to the north. *Winged objects* may be found in the float or dislodged from the outcrop.

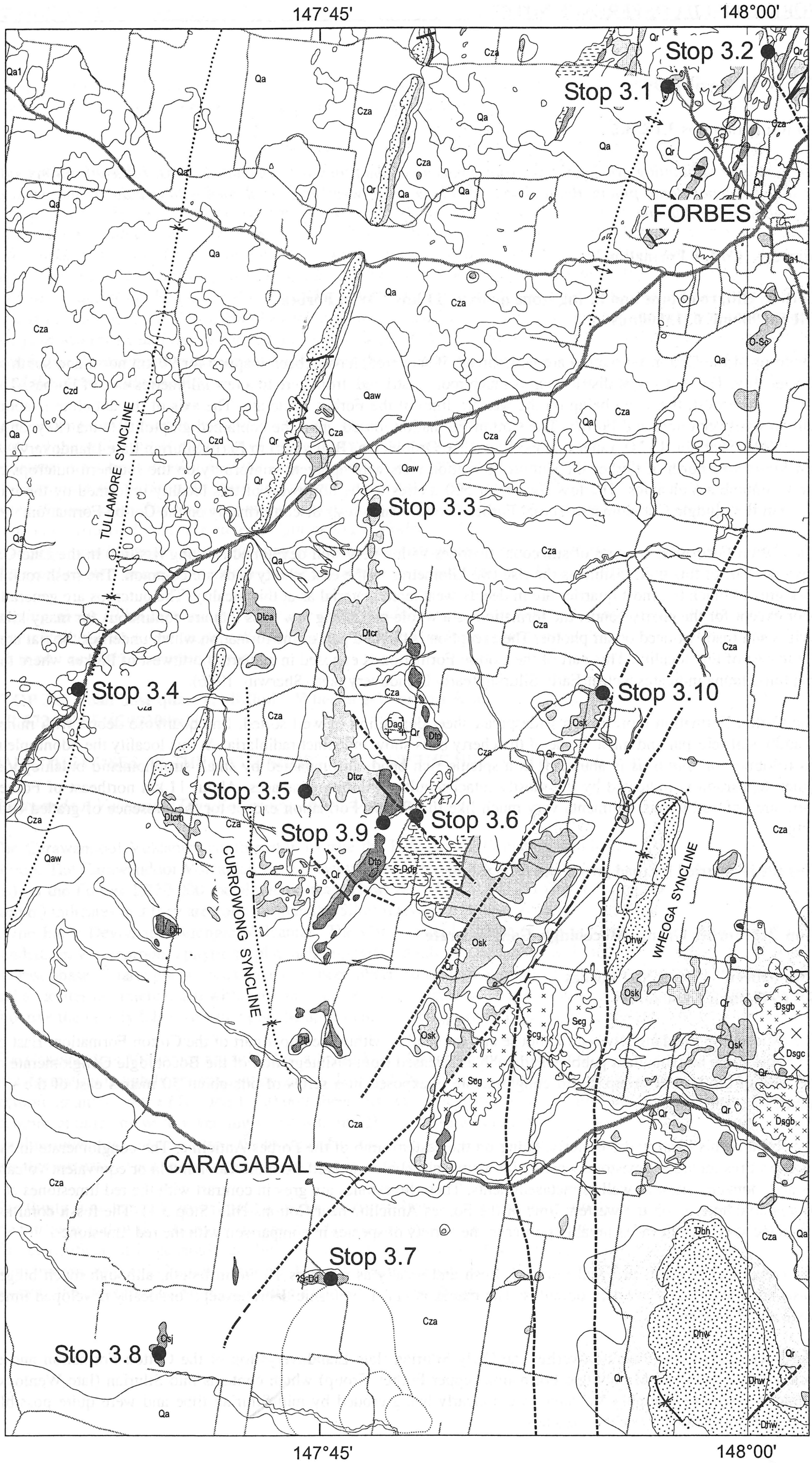
This site also affords an excellent view of the surrounding country side, especially the alluvial plains of the Bland system to the east.

DAY 3

Depart Forbes RSL 8:00 am

Stop	Duration mins		Author
3.1	30	Cotton Fm, quarry	Sherwin
3.2	40	Bocobidgle Conglomerate north of Forbes	Sherwin
3.3	40	Carawandool Volcanics, quarry	Raymond
3.4	20	Newell Highway, regolith	Chan/Gibson
3.5	20	Epithermal alteration in Carawandool Volcanics	Raymond/Burton
3.6	30	Cookeys Plains Fm near Wirrinya	Raymond
LUNCH	45	Caragabal	
3.7	30	Berendebba Granite contact aureole	Wallace
3.8	30	Jingerangle Fm	Sherwin/ Wallace
3.9	30	Pullabooka Fm near Wirrinya	Raymond
3.10	20	Kirribilli Fm near Pinnacles	Raymond/Burton

Arrive Forbes RSL 5.40 pm



DAY 3 EXCURSION STOPS

Day 3 14 April 1999

En Route to Stops 3.1& 3.2

We pass over undulating erosional rises with a mosaic of small bedrock dominated areas, colluvial aprons, and co-alluvial depositional plains. Bedrock is probably variably weathered. U-shaped valleys indicate that most of the sediment is colluvium.

Stop 3.1. Cotton Formation

Cottons Hill, road base and facing stone quarry, 11 km NW of Forbes
GR 586900mE 6313500mN

Outcrops of the Cotton Formation are widespread, if scattered, having been mapped for 90 km north and south of this locality. The east - west distribution is much more restricted, from here to a few kilometres east of Forbes. The dip is to the west, the strata being on the western limb of the Forbes Anticline. The axis of the anticline is about half way between here and Forbes. The Cotton Formation, based upon the contained graptolite fauna (Krynen *et al.*, 1990a; Sherwin, 1974), ranges in age from Late Ordovician (Bolindian) to Early Silurian (late Llandovery). A few kilometres north of Forbes the Cotton Formation rests with apparent conformity on the southern outcrops of the Goonumbla Volcanics. The low rise about 500 metres to the northwest of this locality is formed by the mid Silurian Bocobidgle Conglomerate (basal Forbes Group) which rests disconformably on the Cotton Formation.

The Cotton Formation consists of siliceous siltstones with a very well developed bedding fissility. In the Late Ordovician part of this unit, visible as the rise two kilometres to the east, cherty beds are common. The fresh rock is dark grey to black but most quarries are in deeply weathered material as at this locality. The outcrops are generally poor except for the cherty bands, the formation as a whole producing low rises that are continuous for many kilometres and readily traced on air photos. The exception is the mid part of the formation which underlies the flat area to the east of this locality. This part of the Cotton Formation is exposed in a quarry northwest of Parkes where the graptolite fauna indicates a clear Early Silurian (early Llandovery) age (Sherwin, 1976).

The Cotton Formation represents a widespread sheet deposition of well sorted, fine quartzose debris with minor quantities of feldspar and mica. Some of the cherty beds show indistinct radiolaria. At this locality the odontopleurid trilobite *Sinespinaspis* is abundant in a spicule rich band, accompanied by small strophomenid brachiopods. Quiet deposition is indicated by the mostly intact moulted trilobite carapaces. About 11 km northeast of Forbes there are unfossiliferous sediments very much like the Cotton Formation except for the presence of graded bedding.

This site is quarried for road gravel and facing stone.

Stop 3.2 Forbes Group - Bocobidgle Conglomerate

"Bimbadeen" - 8 km N of Forbes
GR 694720mE 6314060mN

The exposure in the dam between the house and the road is within the upper part of the Cotton Formation. East of the house there are abundant pebbles and cobbles released from disintegration of the Bocobidgle Conglomerate at the base of the Forbes group. Solid conglomerate is exposed in a series of pits about 50 metres east of the silo southeast of the house.

The strata at this locality dip easterly, being on the eastern limb of the Forbes Anticline. The conglomerate in the pit exposures includes limestone lenses with abundant pebbles derived from the Goonumbla or equivalent volcanics and monzodiorites, as well as metasediments. These limestones are grey in contrast with the red limestones at a comparable horizon on the western limb of the Forbes Anticline near Cottons Hill (Stop 3.1). The fossil coral assemblage at "Bimbadeen" is notably poorer in the variety of species in comparison with the red limestones.

The conglomerate clasts are well rounded, fresh and locally as much as 10 cm in length, although much bigger clasts are known in the western outcrops. The matrix is mostly volcanic debris except for locally developed limestone as at this stop.

The Bocobidgle Conglomerate overlies the Early Silurian (late Llandovery) top of the Cotton Formation and is overlain in turn by the Mumbidgle Formation (upper Forbes Group) which contains mid Silurian (late Wenlock) graptolites. The Goonumbla Volcanics were clearly being eroded by mid Silurian time and were quite possibly emergent, surrounded by pebble beaches.

The poor outcrops of mudstone east of the pits are of the Mumbidgle Formation (upper Forbes Group). The high ridge to the east is formed by the Siluro-Devonian Calarie Sandstone at the base of the Derriwong Group.

En Route to Stop 3.3

We pass back to Forbes on erosional rises with a veneer of sediment, then onto alluvium over the Lachlan palaeovalley. Several palaeo-hilltops now occur as slight rises from the alluvial plain south of Lake Forbes. Deep lead gold workings south of Forbes were mined to 65 m depth (the limits of water exclusion and pumping), indicating that a steep incised topography was present before alluviation, with slopes (now buried) far steeper than those in modern erosional landscapes of the area. The deep leads would have been steep gullies draining to the incised palaeo-Lachlan River. A flux of gold bearing sediment would have passed down the gullies, with coarser sediment and gold winnowed and trapped as a thin bedload deposit. As the palaeovalley alluviated, the 'wash' would have been buried by sediment mostly deposited by the palaeo-Lachlan as it moved across its floodplain, and gradually filled the incised palaeovalley.

After leaving south Forbes, we cross the Lachlan palaeovalley. Modern sediments are mostly fine-grained, but much of the valley fill is made up of sands and gravels, indicating a far different sort of river in the past. The sediments have been divided into the Late Miocene to Pliocene Lachlan Formation, and the Pleistocene Cowra Formation on the basis of drillhole and palynological data (Williamson, 1986). There is an erosional hiatus between the two units. The former is more reduced (grey clays), and has mostly quartzose pebbles, whereas the latter is more oxidised, and has mixed origin pebbles. Modern sediments in the near vicinity of the river generally have grey, poorly formed soils, reflecting continued deposition and young age. Further to the south, soils become older and redder, and radiometric response becomes lower, indicating leaching of radiogenic elements.

Starting about 19 km from south Forbes, we cross Bundaburrah Cowal Swamp for about 4 km, then climb almost imperceptibly onto a low angle colluvial slope around low hills and rises east of the main Jemalong Ridge. Stop 3.3 is on one of these erosional rises.

STOP 3.3 Road base quarry, "Bilbul", Wheelong-Wirrinya Road
GR 572600mE 6290200mN

PARK THE BUSES AT THE GATE. SHORT WALK UP THE HILL TO THE QUARRY.

Carawandool Volcanics (Trundle Group) - Early Devonian

The Carawandool Volcanics conformably overlie the Pullabooka Formation within the Early Devonian Trundle Group. The Carawandool Volcanics were previously included in the Milpose Volcanics (now the Byong Volcanics) on the Forbes 1:250 000 metallogenic map. However, SHRIMP U-Pb zircon dating (L. Black, AGSO, pers. comm.) indicates that they are younger than the Siluro-Devonian Byong Volcanics and are, more likely, equivalent to the Early Devonian Kadungle Volcanics. The Carawandool Volcanics are predominantly comprised of flow banded, grey to maroon, aphyric to plagioclase-phyric, rhyolite to dacite lavas. K-feldspar occurs rarely as a phenocryst phase. Quartz phenocrysts have only been observed as detrital grains in epiclastic sediments. Minor basalts and andesites are intercalated with, and intrude, the felsic volcanics. The thin basalt horizons are strongly magnetic and give the largely felsic volcanic pile the appearance of being strongly magnetic in regional magnetic data.

The Carawandool Volcanics are folded in a broad Early Devonian syncline, the Currowong Syncline. The timing of deformation is tightly constrained by zircon dating of the volcanics and the Dalrida Granite, one of several post-tectonic granites on the Marsden 1:100 000 sheet. The volcanics, and adjacent units, are intruded by several post-tectonic granites of widely varying compositions. The granites all crop out very poorly, typically forming topographic lows covered by up to 100 metres of transported alluvial material. However, the subsurface extents of granites are easily seen in the regional magnetic data.

The thinly flow banded, grey rhyolites in the quarry at Stop 3.3 are aphyric to finely plagioclase-phyric lavas. At the northern end of the quarry, some spectacular, coarse, spherulitic devitrification textures are exposed (Fig. 8.4). The devitrification is generally confined to distinct layers in the flow banding, with spherulites ranging in size from microscopic to 2-3 cm in diameter. Lithophysae and devitrificaion textures resembling perlitic cracking also occur in the lavas, but quarrying operations might not permit these to be seen.

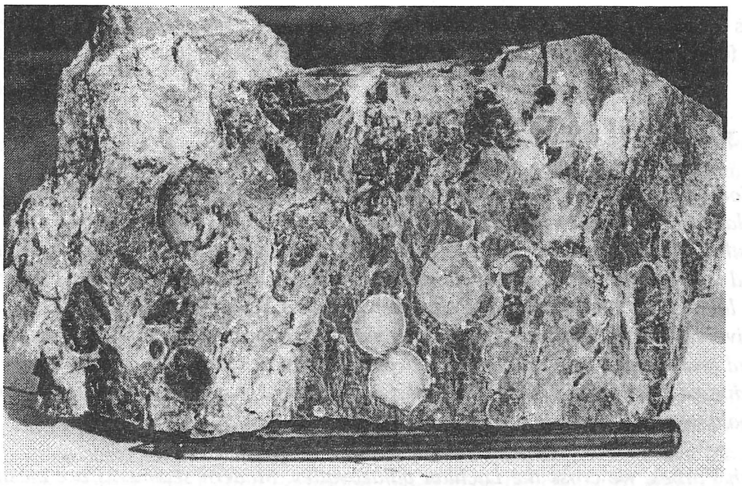


Figure 8.4. Spherulites (now silicified) developed in a devitrified rhyolite lava of the Carawandool Volcanics

En Route to Stop 3.4

After passing through a gap in the Jemalong Range, originally incised to below modern ground level, and subsequently buried during alluviation, we pass over stagnant alluvial plains characterised by red earth and red clay soils. High K patches on radiometrics in this area suggest the remnants of a sandy lunette bordering the eastern rim of a palaeo-Lake Cowal much larger than is preserved today. However, ground truthing of these areas has been enigmatic, with some red patches definitely coinciding with sand, and others with heavy clay.

Stop 3.4. Sand Dune
GR 556900mE 6281500mN

A brief stop to view, from a distance, a small sand dune to the east of the road. Dunes similar to this are scattered over the Lachlan alluvial plain, and represent sand mobilised from natural river levées, *etc.*, by westerly winds and redeposited as small dunes. Once formed, the shape of the dune ensures wind eddies that then deposit more sand, thus enlarging the dune. The absolute origin of the dunes probably involves a high chaos factor, with small perturbations in the landscape trapping the first sand.

En Route to Stop 3.5

While travelling on the Back Marsden Road between Stops 3.4 and 3.5, we pass about 6 km north of the Porters Mount prospect. At Porters Mount, on the western limb of the Currowong Syncline, quartzites of the Pullabooka Formation are intruded by the Early Devonian Porters Mount Tonalite (SHRIMP U-Pb zircon age), a north-trending dyke-like intrusion. Aeromagnetic data suggest that several other large dykes also intrude the Pullabooka Formation southeast of Porters Mount. The Porters Mount intrusion is associated with a prominently outcropping hydrothermal breccia pipe developed within the quartzites, with intense but not widespread quartz - dravite (Mg-tourmaline) - illite alteration (Fig. 8.5). Significant jarosite also occurs, probably as a weathering product of finely disseminated sulphides. The surrounding quartzites show weak to moderate tourmalinisation. The breccia zone and altered intrusive contain patchy sub-economic gold mineralisation.

Isotopic analysis of the alteration breccia by Wyborn and Sun (1993) obtained a Nd value of +6.5. This strongly positive value was interpreted to indicate Ordovician magmatic-related mineralisation. However, the recent mapping of the Pullabooka Formation and zircon dating of the Porters Mount Tonalite have revealed a Devonian age for the mineralisation. This, and other examples of geochemical similarities between some Ordovician and Early Devonian magmatism and mineralisation (Raymond and Sun, 1998), serves to highlight the potential of the Early Devonian as a metallogenic period in the Lachlan Fold Belt.

Figure 8.5. Quartz-tourmaline-illite alteration breccia developed within quartzites of the Pullabooka Formation at Porters Mount.

En Route to Stops 3.5, 3.6

We cross more of the stagnant Lachlan alluvial plain, then turn east, crossing an area of low hills and rises about 9 km from the highway. A further 5 km of alluvium is crossed before turning north to Stop 3.5, crossing colluvial slopes around steep hills to the northeast. The nearby Stops3. 6 and 3.7 are also at the margins of local hills.

STOP 3.5 Road cutting, Hastings-Trigalana Road, 6 km west of Wirrinya GR 568800mE 6274800mN

Currowong Hills epithermal alteration zone within the Carawandool Volcanics

An epithermal alteration zone is centred about 6 km west of Wirrinya around a prominent outcrop of strongly silica-alunite (advanced argillic) altered rhyolite. The fact that the road is diverted around this outcrop is testament to the intensity of the siliceous alteration. In the Currowong Hills[2], immediately east of this location, variably altered rhyolites were first noted in 1982 by geologists from Samedan . The alteration zone forms a thin, largely flat lying, sheet around 2 km^2 (Edgar, 1990). Edgar (1990) described five alteration assemblages of quartz ± alunite ± hematite ± sericite ± kaolinite ± illite ± limonite (after sulphides). He also noted that quartz + kaolinite occurred largely peripheral to quartz + alunite, and a vertical zonation from quartz + alunite to quartz + hematite ± alunite at shallower depths. Samedan (1982) geologists also reported minor pyrophyllite, diaspore, zunyite, and jarosite, but Edgar (1990) noted that pyrophyllite and diaspore were absent from the alteration assemblages.

The alteration style ranges from intensely and pervasively silicified breccias with up to 40% alunite, to weak silicification and sericitisation of rhyolites. Minor vughs and some late stage quartz veining are also developed, but the alteration is generally pervasive and not vein dominated. There is only minor development of disseminated pyrite ± arsenopyrite mineralisation, and that is now largely replaced by limonite. Rare gossanous outcrops occur. The alteration exposed at Currowong Hills has many features characteristic of high sulphidation epithermal systems (Heald *et al.*, 1987; White and Hedenquist, 1990). However, Edgar (1990) concluded that the alteration was caused by mixing of gases, boiled off a near neutral pH, low sulphidation, chloride bearing fluid, with near-surface meteoric waters. The character of the alteration at Currowong Hills suggests it was formed in the uppermost parts of an epithermal system, above the boiling zone. Gold mineralisation, possibly concentrated near a boiling zone, may be expected at some depth below the currently exposed alteration system.

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[2] Often misspelt "Currawong" in previous literature.

No economic mineralisation has been found at Currowong Hills despite the efforts, since 1982, of nine exploration companies. However, the area to the west and south-west of Currowong Hills is largely covered by alluvial sediments, and the scattered outcrops in the area show evidence of pervasive to patchy silicification and disseminated sulphides. It is probable that epithermal alteration is widespread beneath the alluvial cover.

Besides the intensely altered rhyolite, some large boulders of fresh maroon rhyolite are piled up at the southern end of the road cutting. This rock type is fairly typical of the maroon lavas which occur south of the Back Marsden Road, in contrast to the predominantly grey rhyolites which occur north of the road. It is not clear why there is such a distinction in the rhyolite colours, but it may reflect two separate vent sources for the lavas.

STOP 3.6 Quarry just south of Wirrinya
GR 574500mE 6273250mN

CLIMB OVER THE FENCE INTO THE QUARRY

Cookeys Plains Formation, Derriwong Group (Late Silurian - Early Devonian)

The Cookeys Plains Formation at Stop 3.6 consists of laminated to thick-bedded siltstones and lesser fine-grained sandstones. The weathered surfaces of the finer-grained sediments are smooth and rounded, a feature commonly found in fine-grained sediments of the Derriwong Group, such as the Cookeys Plains Formation, Yiddah Formation, and Ootha Subgroup. An east-west trending basalt dyke, presumably from the overlying Carawandool Volcanics, intruded the sediments at this locality. Trace low angle cross bedding indicates younging to the west.

Here, the Cookeys Plains Formation is only very weakly foliated, parallel to bedding. The foliation increases in intensity towards the north-north-east trending Parkes Fault Zone, about 8 km to the east . The Cookeys Plains Formation, and Edols Conglomerate near Wirrinya, were previously mapped as Ordovician sediments (Brunker, 1972). However, the discovery of limestone clasts in the Edols Conglomerate, about 5 km south-east of Wirrinya, bearing Siluro-Devonian conodonts and fragmentary shelly fossils indicates a younger age for these rocks. The Cookeys Plains Formation conformably overlies the Edols Conglomerate, the basal member of the Derriwong Group, and is overlain by the Pullabooka Formation of the Trundle Group. Some previous published and unpublished maps (e.g. Bowman, 1976) interpreted a faulted contact between the Cookeys Plains and Pullabooka Formations in the Wirrinya region. However, there is no evidence of deformation near the contact, in either formation, and an unconformable relationship is suggested here. The unconformity marks a change from the relatively deep marine environment of the Cookeys Plains Formation to the fluvial environment of the Pullabooka Formation.

The Cookeys Plains Formation at Stop 3.6 can be compared to the rocks exposed at Stop 3.7, which are interpreted to be similar Derriwong Group sediments within the contact aureole of a buried granite.

En Route to Stop 3.7

We pass south over erosional rises to low hills, interspersed with alluvial plains, to Caragabal. Immediately north of the grain silos and railhead at Caragabal, exposures in a large 6 m deep borrow pit reveal that the sediment beneath the alluvial plains varies from mud to coarse sand, and is quite well bedded. The coarse sands are angular and poorly sorted. A granitic source (such as the Young Granodiorite in the Grenfell-Young area) is implied. Ferruginous nodules up to 5 mm are present in the finer sediments, and regolith carbonate (calcrete) nodules up to 5 cm are common, mostly in the top 2 m. Rare, subrounded pebbles of ferruginised rock fragments and quartz, both up to 3 cm, are present. A small erosional area with bedrock subcrop is crossed immediately south of Caragabal, before reaching an erosional rise with flanking colluvial slopes at Stop 3.7.

Stop 3.7 Contact aureole of Berendebba Granite
GR0569776 6248333

The road section here intersects the northern margin of hornfelsed Derriwong Group sediments, which are country rock to the Berendebba Granite. There are no outcrops of the granite but the subsurface extent of the body is well defined by its distinctness on images of airborne magnetic data. The Berendebba Granite is the southernmost of three possibly related plutons, which also include the Wirrinya Granite and Dalrida Granite, both of which are A-type granites. On the basis of interpretation from airborne geophysics the Berendebba Granite is estimated as a about 70 kms^2 in area with dual nested cores at its southeastern extremity.

The hornfels zone is about 300 m wide. The proximity of the granite boundary is evidenced by a zone of grey andalusite hornfels at the southern end of the outcrop giveing way northwards to progressively lower grade sediments of the Derriwong Group. In thin section the andalusite usually appears as prismatic pseudomorphs with identifiable chiastolite cores: margins of the andalusites have undergone retrogressive alteration, contain abundant tiny biotite flakes and are usually altered to clay minerals. The Siluro-Devonian Derriwong Group are widespread in the Forbes 1:250 000 sheet area. The sediments here comprise mainly laminated to thick bedded siltstones and sandstones. Bedding is mostly parallel laminated, with minor small scale cross beds. The smooth, rounded weathering surfaces of the thicker siltstone beds are typical of the outcrop style of uncleaved Derriwong Group siltsones.

En Route to Stop 3.8

We pass over more alluvial plains before reaching Stop 3.8, another erosional rise (or 'island' in a sea of alluvium)

Stop 3.8 Jingerangle Formation
GR 560497mE 6244235mN

A thick sequence of east dipping, thinly laminated, colour-banded mudstones and siltstones, often silicified, with minor sandstones. These are currently being quarried by the Blandshire Council for road aggregate. This exposure is the representative locality of the Late Ordovician Jingerangle Group A Late Ordovician age probably Bolindian, was ascribed to the unit on the basis of fossil evidence both at this locality and from outcrop west of "Bundilla " homestead on the Cootamundra 1:250 000 map sheet (Sherwin, 1984; 1985). These rocks are considered to be the equivalent of the Cotton Formation in the Forbes and Parkes area (Warren *et al.*, 1995), although there is no evidence.in this area for Early Silurian equivalents of the Cotton Formation. This is as much likely to be a result of the very limited outcrop as any other reason. Note the laminate siltstone lithology which is so much like the Cotton Formation, seen at stop 3.1. This stop differs in the presence of coarse, poorly sorted beds which contain massive fossils such as sponges, corals and what might have been calcareous algae, indicating slumping of shallow water sediments, most likely from the photic zone. The nautiloid fossils occur in the laminate beds also, along with small climacograptid graptolites.

This outcrop lies within a complex N-S trending geomagnetic anomaly which extends some 20 km northwards and continues south into the Cootamundra sheet area.

We will visit the nearby Troy farm to view a collection of Ordovician fossils, mostly nautiloids, collected from the property. No surface outcrops are present to verify the source rocks for these fossils which are assumed to have originated in limestones from a near-shore environment.

En Route to Stop 3.9

We backtrack to the north, then pass over colluvial slopes southwest of Wirrinya.

STOP 3.9 Road cutting, 2 km west of Wirrinya, Back Marsden Road.
GR 573000mE 6273000mN

Pullabooka Formation (Trundle Group) - Early Devonian

The Pullabooka Formation lies at the base of the Trundle Group and is conformably overlain by the Carawandool Volcanics. The Pullabooka Formation is comprised mainly of mature, thick-bedded, well sorted quartz sandstones to quartzites, interbedded with lesser siltstone and minor shale. The sandstones commonly contain trace detrital tourmaline. The Pullabooka Formation sediments are rarely cross bedded, and may become tuffaceous at the top of the formation where they are overlain by the Carawandool Volcanics. A lens of quartz rich sandstone within the Carawandool Volcanics suggests the fluvial influence of the Pullabooka Formation persisted somewhat into the later volcanic environment. Much of the northern part of the Pullabooka Formation occurs within the contact aureole of the Dalrida Granite. Finely disseminated biotite and coarser biotite spotting is commonly developed in these metamorphosed sediments.

The Pullabooka Formation exposed in the road cutting at Stop 3.8 is steeply east dipping and overturned. Minor small scale cross bedding and graded beds provide the evidence of facing. The sediments become markedly tuffaceous and purple towards the western end of the road cutting (up section), and suggest a transition from the mature fluvial environment of the Pullabooka Formation to the volcanic environment of the overlying Carawandool Volcanics. Fossil fish fragments have been reported from this site and preliminary inspection suggested a Middle to Late Devonian age (G.C. Young, pers. comm.). However, this conflicts with SHRIMP U-Pb zircon dating (L. Black, AGSO, pers. comm.) of the Early Devonian Dalrida Granite which intruded the Pullabooka Formation, and the Early Devonian Carawandool Volcanics, which overlie the Pullabooka Formation.

En route to Stop 3.10

Over erosional rises and low hills for 2 km northeast of Wirrinya, and then onto alluvial plains with extensive gilgai. After about 5 km of alluvium, we pass onto and skirt bedrock dominated rises at Stop 3.10.

STOP 3.10 Road cutting and quarry, Sandy Creek Road
GR 585200mE 6279400mN

Pinnacles-Ironbarks quartz vein gold district, Kirribilli Formation (Late Ordovician)

Stop 3.10 is in a road cutting exposing the Late Ordovician Kirribilli Formation, in the Pinnacles-Ironbarks quartz vein hosted gold district. The quarry is adjacent to the sites of the Young Australia and Kirkpatricks Reef mines (deposit numbers 151 and 153 on the Forbes 1:250 000 metallogenic map), which were worked intermittently between 1895 and 1938.

The host rock at Stop 3.10 is a strongly foliated, grey-green to buff phyllite, and is fairly typical of strongly deformed Kirribilli Formation. The foliation is steep to vertical, and strikes 020° (with kink bands developed at a high angle to the foliation). Massive quartz veins, up to 10 cm wide, are subparallel to the foliation (Fig. 8.6) at this locality. Some notably graphitic phyllite units occur at the northern end of the quarry, and at other locations in the Pinnacles-Ironbarks district. It is possible that these units provided chemical trap-sites for gold deposition in quartz veins cutting the reduced host rocks. Some small intrusive bodies (d[illegible]ite to syenite) have been reported in workings of the Pinnacles-Ironbarks district, and may have had a bearing on the genesis of the gold mineralisation. However, the poor outcrop in the region inhibits a better understanding of the distribution of these small bodies. The bedrock is typically covered by a thick red loam soil with abundant quartz vein float .

The Pinnacles-Ironbarks deposits are similar in style to, and occur along strike from, the Parkes-Forbes line of gold deposits. While no discrete faults are mappable in the Pinnacles district, the intense foliation of the host rocks suggests that the district forms the southerly extension of the Parkes Thrust Zone. The fault zone can be delineated south-east of Ironbarks by the apparently faulted margins of the Wirrinya and Caragabal granites, interpreted from regional magnetic data. The potential for similar style gold deposits in the structural corridor between Forbes and Pinnacles must be regarded as fairly high. However, there is virtually no outcrop in the 25 km between Forbes and Pinnacles; it being covered by deep alluvium of the Lachlan River and Ooma Creek.

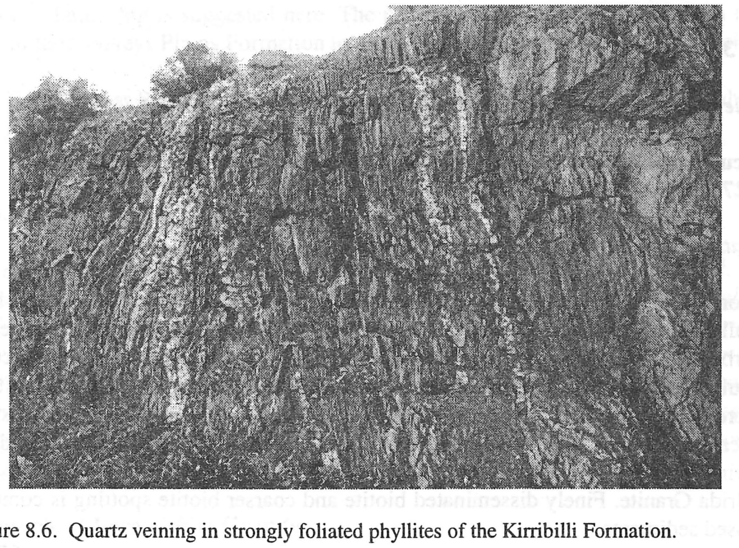


Figure 8.6. Quartz veining in strongly foliated phyllites of the Kirribilli Formation.

En Route to Forbes

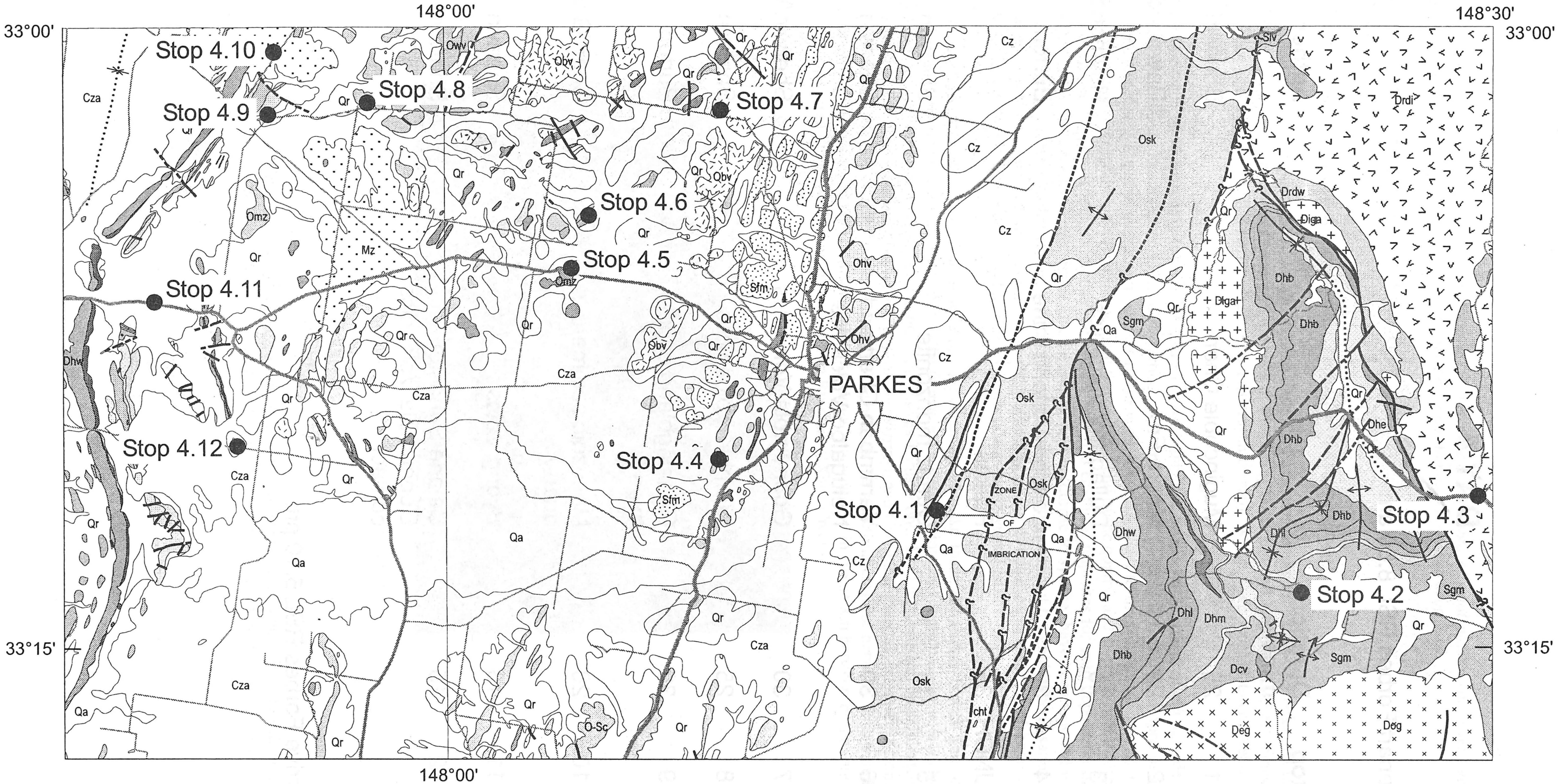
We pass from the erosional landscape just north of Stop 9, and back onto alluvium. At Garema silos and rail head we cross Ooma Creek, which drains from the ranges north and west of Grenfell, to Bundaburrah Cowal swamp which we crossed earlier today.

DAY 4

Depart Forbes RSL 8:00 am

Stop	Duration mins		Author
4.1	25	Mugincoble Chert	Sherwin
4.2	20	Moura Fm	Raymond
4.3	20	Dulladerry Volcanics	Raymond
4.4	30	London-Victoria mine	Burton
LUNCH	35	Parkes	
4.5	15	Quartz monzonite	Sherwin
4.6	30	Yarrimbah Chert and Nelugaloo Volcanics	Sherwin
4.7	30	Goonumbla Volcanics	Sherwin/Wallace
4.8	25	Wombin Volcanicss	Sherwin
4.9	30	Gunningbland copper mine	Burton
4.10	20	Mesozoic sediments, quarry	Chan/Gibson
4.11	15	Byong Volcs	Sherwin
4.12	15	Calarie Sandstone-Goonumbla Volcanics contact	Sherwin

Arrive Forbes RSL 5.10 pm



DAY 4 EXCURSION STOPS

Day 4 15 April 1999

En Route to Stop 4.1

We straddle the boundary between the Lachlan alluvial plain to the east and erosional plains and rises to the west for the first few kilometres, then cross erosional areas before coming onto the alluvial plains associated with Goobang Creek, which are about 2 km wide at this point. We then come back onto an erosional area with higher relief (rises to low hills) around Parkes. We cross alluvial plains associated with Goobang Creek for about 5 km after leaving Parkes and heading southeast, then into an erosional area of low hills interspersed with colluvial slopes. A ridge of Ordovician Mugincoble Chert north of Stop 4.1 has magnetically defined palaeochannels on its northwest side.

Stop 4.1 Mugincoble Chert

Railway cutting 1 km E of Mugincoble level crossing
GR 615180mE 6326280mN

WARNING ***Watch out for trains if entering the cutting***

The Mugincoble Chert is essentially a siliceous unit within a much thicker sedimentary "package", probably the Kirribilli Formation. Although the chert beds within the Mugincoble Chert are mostly measured in thicknesses of several centimetres the combined result is a prominent ridge in an area of little or no relief. Although the ridge as a whole is a distinctive topographic feature, there is little actual outcrop other than scattered cherty float. The cherts are interbedded with siltstones, the colour ranging from off-white to reddish purple, the more intense colours being more typical of the chert beds. Conodonts within the chert beds indicate a mid Ordovician age (Darriwilian - Gisbornian), typical of cherts within the Girilambone Group (I. Stewart and R. Glen, pers. comm.), a probable correlative of the Kirribilli Formation.

This unit has a very strong aeromagnetic signature that is closely coincident with known outcrops. However, very little of the outcrop has any measurable magnetic susceptibility at all. Towards the eastern end of the rail cutting there are some thin ferruginous beds, conspicuous by their very dark brown to black colour, which have a magnetic susceptibility as high as 20 000 x 10^{-5} SI.

En Route to Stop 4.2

Back track to near Parkes, turning north, then east, crossing more of the Goobang Creek alluvial plain. Near Parkes airport we come onto low angle colluvial slopes. Further east, we come into a westward-draining funnel-shaped area of rises and low hills with surrounding colluvial slopes, surrounded by higher landforms. We then cross slightly weathered Hervey Group sediments in hills and mountains of the Crokers Range. Stop 4.2 is in an easterly draining area of rises and low hills with colluvial slopes.

STOP 4.2 Road cutting, Cookamidgera - Mandagery road
GR 631700mE 6322400mN

Moura Formation

The road cutting at Stop 4.2 exposes intercalated, thin to thick-bedded greywackes and shales of the Moura Formation dipping at 60° towards the west. A pervasive sub-vertical foliation is developed only in the shaley beds (Fig 8.7). The Moura Formation occurs within the structural wedge between the Coolac-Narromine fault zone and the Bumberry Fault. The formation consists of well bedded, lithic to quartzose sandstones with lesser intercalated shales, siltstones, and minor conglomerate. The sandstones are commonly fine-grained, grey to green, variably thinly to very thickly bedded, with massive to rarely graded internal stratification. The sandstones are predominantly feldspar-lithic, containing volcanic detritus of intermediate composition. One coarse-grained sedimentary breccia also contains small limestone clasts. A concordant, quartz-phyric, flow banded rhyolite occurs in the Moura Formation. However, it is unclear whether this rock is a thin lava flow, or a sill derived from the nearby, younger Dulladerry Volcanics. Several other rhyolite dykes also intrude the Moura Formation.

The age of the Moura Formation is not well constrained. No fossils have been found in the sediments, and there are no exposed conformable stratigraphic contacts. Although, the base of the Moura Formation is not exposed, it is unconformably overlain by the Late Devonian Hervey Group in the Parkes and Bumberry Synclines. Folded sediments of the Moura Formation are intruded by the Early Devonian Lords and Eugowra Granites, and the formation is faulted against the Middle Devonian Dulladerry Volcanics by the Bumberry Fault. An originally unconformable relationship most probably existed with the Dulladerry Volcanics at a position close to the present faulted contact, and only a small amount of reverse movement is inferred on the fault. The Moura Formation is tentatively correlated with the Late Silurian Goonigal Group which occurs about 20 km to the east, in the Bathurst 1:250 000 sheet area.

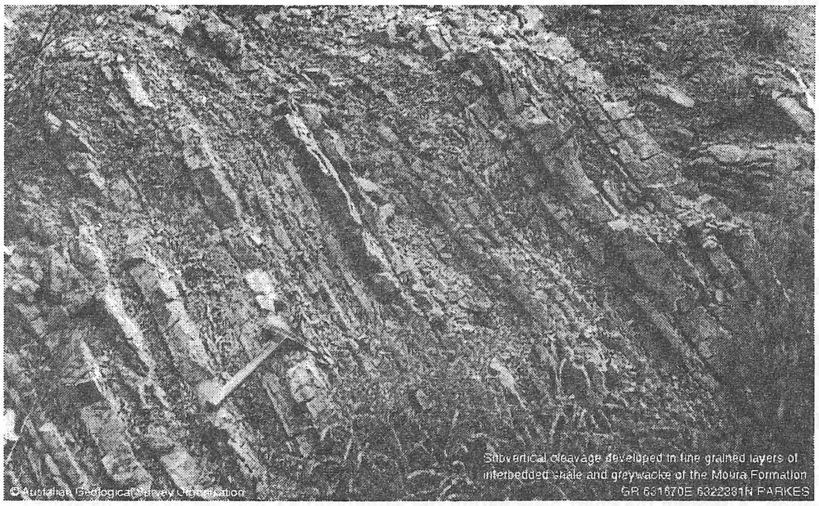


Figure 8.7. Subvertical foliation developed in fine-grained layers of interbedded shale and greywacke of the Moura Formation.

En Route to Stop 4.3

We climb onto hills and mountains of Dulladerry Volcanics

STOP 4.3 Road cutting on the Orange – Parkes road, Bumberry
GR 637000mE 6326700mN

Curumbenya Ignimbrite Member - Dulladerry Volcanics (Middle Devonian)

The Dulladerry Volcanics are a complex of A-type rhyolitic lavas, ignimbrites and breccias, with intercalated basalt, andesite, and epiclastic sediments. The volcanics were deposited in a sub-aerial rift during the Middle Devonian. The Dulladerry Volcanics are similar in age, composition and depositional environment to the Warrumba Volcanics, which occur some 80 km to the south. These two volcanic units have been included in a new group, the Rocky Ponds Group.

The age of the Dulladerry Volcanics is constrained by SHRIMP zircon U-Pb dating of the Curumbenya Ignimbrite Member in the Bathurst 1:250 000 sheet area (376 ± 4 Ma, Raymond in Pogson and Watkins (eds.), 1998); by the occurrence of Givetian-Frasnian phyllolepid fossils at Tomingley in the Narromine 1:250 000 sheet area (Young, 1994); and by Middle Devonian lepidodendrons described by Pickett (1993), also from Tomingley. The Dulladerry Volcanics unconformably overlie Silurian to Devonian rocks of the Cowra Trough and Early Devonian granites of the Eugowra and Yeoval batholiths. The volcanics are overlain by the Late Devonian Hervey Group, with a low angle unconformable to disconformable contact. In the Forbes 1:250 000 sheet area, the volcanics are faulted against the Hervey Group by the Bumberry Fault, which truncates the eastern limb of the Bumberry Syncline.

On a regional scale, the volcanics appear to be generally horizontal to shallowly dipping. The exceptions to this rule occur where they are folded around Hervey Group synclines (e.g., Bumberry, Mandagery, and Hervey Synclines) at the margins of the exposed volcanics. Evidence of volcanic layering, or bedding, at outcrop scale is very poor. Where visible, layering commonly displays irregular dips, reflecting flow folding or flow around local palaeotopography. The basal rocks of the volcanics, primarily the Warraberry Member, consist of complexly intercalated flow banded rhyolite lavas, polymict breccias, epiclastic sandstones and siltstones, amygdaloidal basalt lavas, and minor andesite. These rocks were covered by an extensive welded ignimbrite sheet, the Curumbenya Ignimbrite. The ignimbrite is the predominant exposed unit of the Dulladerry Volcanics, comprising over 60% of outcrop. This explosive phase of volcanism was followed by less violent extrusion of rhyolite flows and domes, with some basalt lavas and minor ignimbrite. A large rhyolite-dacite lava dome, the Yahoo Peaks composite dome, occurs just to the northeast of the Forbes 1:250 000 sheet about 40 km northeast of Parkes, and probably represents an eruptive centre for the volcanics.

The Curumbenya Ignimbrite is well exposed in road cuttings along the highway between Parkes and Orange. Stop 4.3 shows a typical example of this very widespread ignimbrite containing small basalt clasts. In outcrop, the ignimbrite is a massive quartz-K-feldspar phyric (1-2 mm) rhyolite containing minor lithic fragments. Eutaxitic layering is rarely seen in outcrop, and then only on appropriately weathered surfaces. In thin section (Fig. 8.8), igneous textures are often masked by devitrification and low grade metamorphic recrystallisation (commonly with pumpellyite and chlorite). However, fresher samples contain glass shards and abundant tubular pumice fragments (4 mm) showing strong welding. Basalt and rare granite rock fragments commonly comprise less than 1% of the rock. The ignimbrite is generally poorly magnetic, but more strongly magnetic parts may reflect higher concentrations of basaltic lithics.

Figure 8.8. Photomicrograph of ignimbrite from the Dulladerry Volcanics showing fractured and embayed quartz (qz) and K-feldspar (kf) crystals, and basalt (bs) lithics. Width of field of view is 2.5 mm.

En route to Stop 4.4

We descend into a valley eroded in less resistant lithologies of the Hervey Group (Eurow Formation), then across a steep ridge of more resistant rocks before rejoining our outwards route, and back tracking to Parkes. From Parkes to Stop 4.4, we cross rises and low hills with surrounding colluvial slopes. Numerous deep leads in the Parkes area (some within the urban area) attest to incision, then alluviation in Goobang Creek and its tributaries. Leads were mined for gold to depths of 60 m, with production of about 200 000 ounces. Several leads originate on the hill at the London-Victoria mine (Stop4. 4).

Stop 4.4 London-Victoria Mine - haulage road into the Victoria open pit
GR 604600mE 6328900mN

WARNING For safety reasons it is advised that you do not proceed any further than half way down the ramp. Likewise, do not go too close to the edge of the pit to the east, and the steep wall to the west.

The London-Victoria mine is developed on vein-style mineralisation at, and east of, the London-Victoria Fault. The fault separates Ordovician andesitic to trachytic tuffs (Bushmans Formation) to the east and Silurian sandstones, mudstones and conglomerates (Mumbidgle Formation and Bocobidgle Conglomerate) to the west. For more detail refer to the mineral occurrence section.

The Victoria open cut is the most southerly working of the London-Victoria mine. At this locality examples of vein mineralisation and alteration can be examined and sampled; mainly massive to strongly foliated, kinked and crenulated, fine-grained quartz and sericite, possibly with minor chlorite and carbonate. This is probably an andesite, however, it is difficult to be sure. Veins, from less than 1 mm to several centimetres wide, are common in the altered rock and comprise various combinations of milky quartz, calcite, albite, K-feldspar, ankerite and pyrite. The veins are zoned with quartz in the centres and carbonate or albite on the selvedges. Fine- to coarse-grained pyrite occurs, both pervasively disseminated through the wall rock and in thin veinlets, which cross-cut the foliation. Commonly, there is only a minor amount of pyrite within the veins but abundant pyrite within the wallrock for several centimetres away from the vein wall.

In places it is possible to see several generations of veining. For example, quartz-calcite-pyrite veins are cut and displaced by obliquely trending quartz-ankerite veins. Massive milky quartz veins with no mineralisation post-date the mineralised veins.

En Route to Stop 4.5

Back track, and then turn west, on rises and low hills, then erosional plains and rises, both with extensive colluvial slopes. Two kilometres of alluvium is crossed to the east of Ridgey Creek before Stop 4.5

Stop 4 5 quartz monzonite intrusion

Outcrop on Condobolin road at Currajong trig., 12 km W of Parkes
GR 599000mE 6337300mN

WARNING Beware of fast moving traffic if crossing road

This intrusive quartz monzonite is typical of several which intrude the Late Ordovician Goonumbla Volcanics between Nelungaloo and Goonumbla. In the latter area they are associated with copper - gold mineralisation at the Northparkes mine. Stratigraphic evidence (pebbles of these intrusives are present in the Bocobidgle Conglomerate) suggests an age between the end of the Ordovician and mid Silurian (Wenlock).

Krynen *et al.* (1990a) described the intrusives as containing "...phenocrysts of ubiquitous plagioclase, with biotite and/or hornblende or pyroxene, in a groundmass of alkali feldspar, plagioclase, oxides, quartz, titanite and apatite."

En Route to Stop 4.6

Mostly on alluvium associated with Ridgey Creek

Stop 4 6 Yarrimbah Chert and Nelungaloo Volcanics

Yarrimbah gravel pit, 12 km NW of Parkes
GR 599800mE 6339750mN

This stop is a low hill formed by the Yarrimbah Chert on the SE slope and the Nelungaloo Volcanics to the NW. Outcrop is generally poor except in the shallow gravel pit on top of the hill.

The Yarrimbah Chert was formerly regarded as a member *within* the Nelungaloo Volcanics, although at this locality there are only obvious volcanics *below* the chert. Elsewhere, outcrops are too poor to determine the exact relationship of the Yarrimbah Chert with younger units. About 14 km to the southwest, on Nelungaloo station, the base of the Late Ordovician Goonumbla Volcanics is marked by a thin limestone with angular chips of probable Yarrimbah Chert. Current thinking is that the Yarrimbah Chert overlies the Nelungaloo Volcanics and is overlain by the Goonumbla Volcanics, thus being a discrete formation.

The Yarrimbah Chert is well bedded but tends to be very blocky in outcrop. Note the very shallow dip to the southeast. Most of the formation consists of dark greyish brown cherty shales and siltstones with some thin (mostly < 2-3 mm) feldspathic bands. Near the base it is conglomeratic to lithic sandy, the lithic debris being derived from the underlying volcanics. Please be careful with the very limited outcrop of the conglomerate.

The Yarrimbah Chert has a well dated graptolite fauna of Early Ordovician age (Lancefieldian-Bendigonian) and is the oldest fossil dated unit in the central west. The duration of the erosional break between the underlying Nelungaloo Volcanics and the chert, implied by the volcanolithic conglomerate, is uncertain.

The Nelungaloo Volcanics produce some scattered boulders and very poor outcrop of purplish brown feldspar porphyry down the northwest slope. Krynen *et al.* (1990a) described the Nelungaloo Volcanics at this locality as lavas, "...sparsely to strongly plagioclase-phyric with minor pyroxene and oxide phenocrysts set in a trachytic alkali feldspar rich groundmass...highly weathered (?altered) and epidotised".

West of the gravel pit, amid a small clump of trees at the boundary fence, is a small intrusion of quartz monzonite.

En Route to Stop 4.7

We cross erosional plains and rises, with extensive colluvial slopes. Slightly higher and more rugged terrain (erosional rises and low hills) is present to the east of Stop 4.7.

Stop 4-7 Goonumbla Volcanics - latite extrusives

Crushed aggregate quarry N of road, 12 km NW of Parkes
GR 605750mE 6344200mN

The Goonumbla Volcanics consist of interbedded sediments and mafic-intermediate volcanics (Krynen *et al.*, 1990), with cognate intrusives such as the quartz monzonite at stop 4-5, and show a close association with copper gold mineralisation at several localities between Forbes and Goonumbla (Clarke, 1990b; Jones, 1985; Muller and Groves, 1995). North of the Forbes 1:250 000 sheet area this association applies at Peak Hill and Tomingley. The volcanic members are strongly magnetic and are distinctive on radiometric maps because of their high K content. Successive members in the Goonumbla Volcanics show variations in thickness and distribution. Probable volcanic centres include Goonumbla, north of Parkes, and Daroobalgie (the former Daroobalgie Volcanics) just northeast of Forbes. Fossils in the interbedded limestones suggest a shallow marine environment and an interbedded cobble conglomerate indicates near contemporary erosion. With the exception of the limestone members, the interbedded sediments have very poor outcrops. The very thick Gunningbland Shale Member is known from extensive float and a few small gravel pits.

The Wombin Volcanics, which overlie the Goonumbla Volcanics northwest of Parkes, are readily distinguished from the volcanic members of the Goonumbla Volcanics by the deep red colour, obvious in outcrops. However, Clarke (1990b) noted that in some areas it was difficult to distinguish the Wombin Volcanics from the slightly less felsic Goonumbla Volcanics.

This phase of mafic-intermediate alkaline volcanism began in the Middle Ordovician time (about Darriwilian-Gisbornian) and continued until at least the late Ordovician (Bolindian), when deposition of the Cotton Formation became widespread. The Goonumbla Volcanics were extensively eroded by mid Silurian time to form the coarse Bocobidgle Conglomerate.

The rock is a leucocratic gabbro with a composition bordering between high - K calcalkaline and shoshonitic (SiO_2 49.4%; K_2O 2.12%,). The rock is dominated by slightly zoned andesine plagioclase phenocrysts and has low content of clinopyroxene altered to actinolite. Groundmass K-felspar is commonly micrographically intergrown with quartz.

En Route to Stop 4.8

Again, we cross erosional plains and rises with extensive colluvial slopes.

Stop 4.8 Wombin Volcanics

Outcrop on roadside, 22 km NW of Parkes
GR 594940mE 6346500mN

The red colour of the Wombin Volcanics is obvious in outcrop, the main reason they are differentiated from the underlying dark greyish green Goonumbla Volcanics. Clarke (1990a) regarded the Wombin Volcanics as having a composition very like the Goonumbla Volcanics. The red colour results from the abundant fine-grained haematite disseminated in alkali feldspar. Krynen *et al.* (1990a) described these volcanics as "... strongly porphyritic in plagioclase and porphyritic to a lesser degree in hornblende, biotite, and oxides, with microphenocrysts of apatite and rare titanite, in a groundmass of alkali feldspar, oxides, and in some cases minor quartz". Muller and Groves (1995) described the Wombin Volcanics as trachytes, in contrast with the andesites and latites of the Goonumbla Volcanics.

En Route to Stop 4.9

More erosional plains and rises.

Stop 4.9 Gunningbland Copper Mine (Endeavour 6)
GR 585529mE 6344458mN

The Gunningbland Copper mine, or the Endeavour 6 occurrence, represents part of a skarn system. The area was worked for copper in 1898 but there is no recorded production (Bowman, 1977b). Similar mineralisation occurs further northeast at the Endeavour 7 and Endeavour 44 occurrences (Fig. 8.9). A limestone unit has been contact metamorphosed by monzonitic intrusions, but the timing of mineralisation is controversial. Sherwin (1975) interpreted the limestone unit to be part of the Siluro-Devonian Milpose Volcanics, based on its fossil assemblage.

However, Perkins *et al.* (1995) dated alteration sericite from the skarn assemblage at Endeavour 44 at 440.0 ± 1.1 Ma (Late Ordovician). Refer to the section on mineral occurrences for more information.

This locality comprises three main areas. To the west there is an infilled shaft with surrounding mullock of silicified limestone with chalcocite, disseminated pyrite, secondary iron oxide after sulphide, malachite, and azurite. In the middle there are infilled pits with mullock comprising massive magnetite with malachite, azurite, and chrysocolla. Thirdly, to the east there is a filled-in pit with some adjacent outcrop comprising silicified and ferruginised limestone. Unaltered limestone, containing Silurian corals and conodonts, crops out just east of the easternmost pit.

Assay results from dump material, by North Limited, included 0.5% Cu, 2% Zn and 1.28 ppm Au (in quartz vein float), and 12.2% Cu, 5.2% Zn, 51 ppm Ag and 1.25 ppm Au (in a haematite and malachite-bearing altered volcanic sandstone) (Arundell *et al.*, 1997).

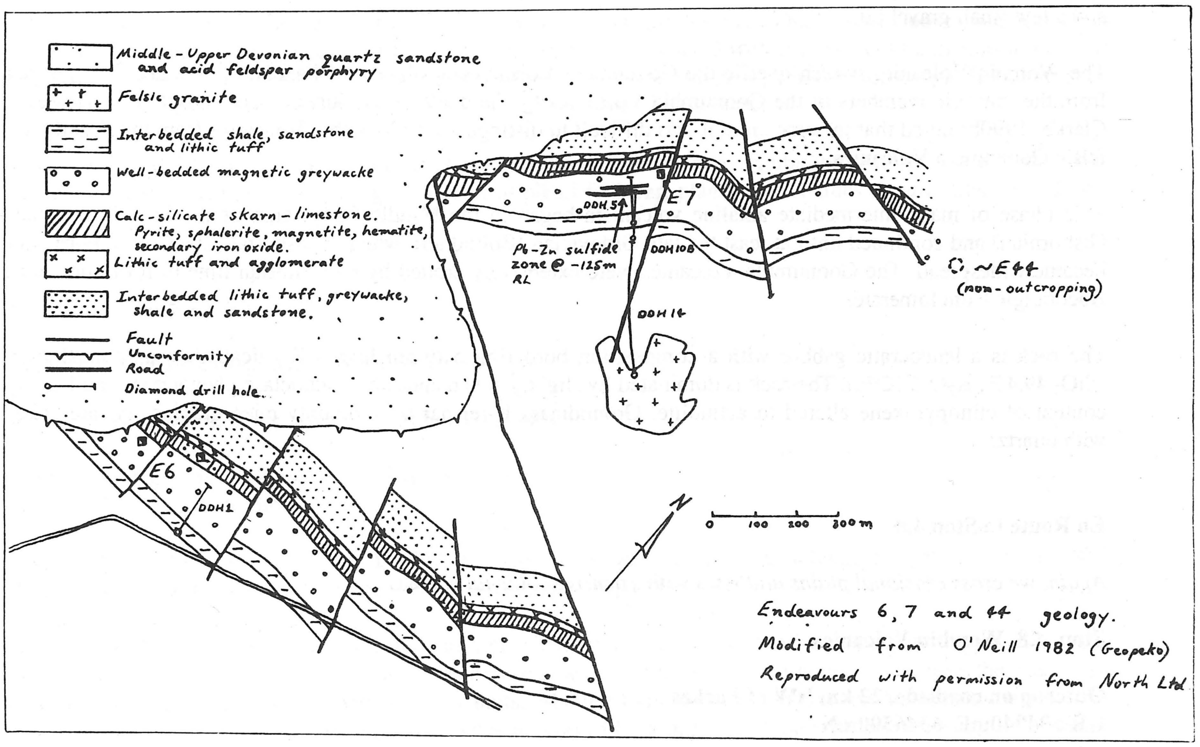


Figure 8.9. Simplified plan of geology of Endeavour 6, 7, and 44 deposits.

En Route to Stop 4.10

We pass into a shallow northeast oriented valley between low ridges of Palaeozoic rocks. The valley is floored by Mesozoic sediments. The ridges are most probably exhumed by removal of the Mesozoic sediment, and are thus Mesozoic or older landforms.

Stop 4.10 Quarry in Mesozoic sediments
GR 0585917mE 6346979mN

This is a gravel pit, with extensive exposure of Mesozoic sediments. Most of the sediment is moderately well cemented conglomerate, with subordinate sandstone, mostly white, but in places slightly ferruginised. The clasts are mostly pebbles to cobbles, rounded to subrounded, mostly resistant rock types, but there are rare clasts of slate. Loose boulders of subrounded, well-cemented sandstone are large clasts from the sediment (as shown by adhering matrix in some places) up to 120 × 60 × 30 cm. Other exposures and dam spoil in the area are of ferruginised sandstone and siltstone, and bleached mudstone.

The age of the sediments is given by plant fragments too broken for reliable identification, but they are consistent with Jurassic genera (Krynen *et al.*, 1990a). The Parkes Special 1:100 000 geological sheet (Krynen *et al.*, 1990b) shows Jurassic sediments continue to the north-northwest for about 40 km in a meandering belt about 5 km wide at 300-320 m elevation. Cross bedding exposed in a gravel pit about 10 km S of this site on the Parkes-Bogan Gate road indicates a northward current direction. The Narromine 1:250 000 geological sheet (Sherwin, 1997) shows the extent of the Jurassic sediments to be much wider than that shown on the 1:100 000 map, with the sediments forming a 15 km wide swath in a valley in the axis of the Tullamore Syncline. Hence it is uncertain whether the sediments are the remnant of a discrete, topographically inverted Jurassic palaeochannel, or whether they are an erosional remnant of a broad sheet of sediment deposited in a wide Jurassic valley, draining northward to the Surat Basin, or even an erosional remnant of the Surat Basin itself. Apatite fission track thermoluminescence may help determine the original thickness of the sediments. Specimens of the nearby Devonian sandstones have so far proved to be barren of apatite, but more sampling is planned.

Similar sediments have been identified near Molong, east of Parkes, and dated by palynology from drill cuttings samples as Late Jurassic, of similar age to the Pilliga Sandstone (Gibson and Chan, 1999). There the sediments were deposited in a landscape with relief up to 100 m, which has been exhumed to form the basis of the modern local landscape.

The large boulders in the sediments at Stop 4.10 indicate very high energy fluvial transport from a distal source, local derivation from precipitous slopes, or the involvement of ice. The palaeogradient on the unconformity surface appears to be low (the outcrops of the sediment in the area are all at the same elevation), thus transport from a distant source by high energy flow appear to be doubtful.

We have already shown that ridges of Devonian sandstone in the area have been either exhumed from beneath the sediment or continuously exposed as ridges since the Jurassic. Hence we could expect that they were much higher and steeper then, possibly being the source of colluvial boulders which made their way down steep slopes into the fluvial systems, and were rounded by abrasion by sand and smaller clasts being carried by the fluvial system. The boulders would not necessarily have been transported far.

A third possibility, which is considered likely to have occurred in the Cobar area to the northwest (Gibson, 1999; Gibson and Chan, 1999), is that ice rafting of large clasts may have occurred. Evidence for sea ice, and palaeopole positions (Frakes and Francis, 1988; Frakes *et al.*, 1992; Frakes *et al.*, 1995) indicate that winter freezing of rivers may have occurred in the Late Jurassic to Early Cretaceous. During winter, river ice would enclose bedload clasts. During spring thaw, the clasts would be rafted downstream in blocks of ice. After the ice melted, the transported boulders might not be moved till the spring thaw.

The presence of preserved Mesozoic sediments close to the Lachlan River gives a possible scenario for how the river developed its course across strike of the underlying bedrock (Chan, 1999; Gibson and Chan, 1999). If the sediments formed a near-continuous veneer over the pre-sedimentation landscape, which may have had considerable relief, the local post-sedimentation landscape at the close of the Early Cretaceous would have been a low relief, depositional plain, perhaps like the depositional surface of the Murray Basin, possibly punctuated by hills of older bedrock. Uplift, along what is now the Great Divide, at the onset of rifting of the Tasman Sea at about 95 Ma would induce a northwesterly to westerly palaeoslope across the area, and drainage would reorganise itself and migrate across the, now inclined, plain until it flowed generally downslope. As the Mesozoic sediments were eroded, the major watercourses (the palaeo-Lachlan in this area) would superimpose onto the underlying rocks, oblique to the structural grain, and in places eroding narrow gaps through resistant ridges.

En Route to Stop 4.11

We cross more erosional plains and rises with extensive colluvial slopes before coming onto the upstream part of the broad alluvial plain of Gunningbland Creek. Stop 4.11 is on a small area of bedrock outcrop within the plain.

Stop 4.11 Byong Volcanics

Tank on south side of Parkes-Condobolin road, 30 km W of Parkes
GR 580500mE 6335000mN

Although this area is quite flat and looks like an alluvial plain, there is very little actual cover. Large blocks of volcanics were unearthed within a few metres of the surface during excavation of the tank, the largest being near the southwest corner. The blocks have clean planar joints. These volcanics overlie the Calarie Sandstone, the low ridge about 2 km to the east, which marks the base of the Derriwong Group.

These outcrops of microlitic alkali rhyolite were formerly called the Milpose Volcanics, the type area being about 14 km to the northeast of this stop. However, the composition and age of the Milpose Volcanics suggests that they an eastern extension of the Byong Volcanics west of Bogan Gate. Krynen *et al.* (1990a) described these volcanics as "...compositionally rhyolitic or granitic, with plagioclase phenocrysts set in a groundmass of quartz and alkali feldspar in about equal amounts". The groundmass at this stop is devitrified, in places vesicular, with small scattered pink feldspar phenocrysts. In thin section these are identifiable as An40 and sanidine. Geochemistry indicates a high-K rhyolitic composition.

North of this stop the volcanics are interbedded with shallow water fossiliferous sediments indicating an age range (late Ludlow to Lochkovian) straddling the Siluro-Devonian boundary. Some of the more massive outcrops, as at Amys Lookout (the prominent hill to the south) or the Byong Hills northwest of Bogan Gate, possibly represent laccolithic intrusions into partly consolidated sediments (Krynen *et al.*, 1990a).

North of the road, and 500 metres west of this stop, there is some exposure of the associated fine grained sediments of the Cookeys Plains Formation on the walls of a dam.

En Route to Stop 4.12

We backtrack, and then cross erosional plains and rises with extensive colluvial slopes. A trench at the Gunningbland tip is excavated in a low angle colluvial slope similar to what we have been passing over. Deep red and yellow clay soils are present, but fragments of highly weathered shale are present in the trench spoil, indicating weathered bedrock at fairly shallow depth. Extensive alluvial plains associated with Goobang Creek are present immediately south of Stop 4.12.

Stop 4.12 Calarie Sandstone-Goonumbla Volcanics contact

Roadside outcrop on Monumea Gap road at South Gunningbland
GR 584042mE 6329643mN

The Calarie Sandstone at this locality dips westerly and forms a distinct low ridge. Whereas, just east of Stop 3.2 this unit overlies the mid Silurian Mumbidgle Formation (upper Forbes Group), and 5 km north of Stop 3.1 it rests on the Bocobidgle Conglomerate (lower Forbes Group), here it overlies the Late Ordovician Goonumbla Volcanics. Volcanic boulders and outcrop occur near the foot of the eastern slope of the escarpment but volcanic pebbles are very rare in the overlying sandstone and deeply weathered.

The brown to reddish brown sandstone is medium to coarse grained with isolated milky quartz pebbles and lithic fragments. Bedding is as much as 2 metres thick and commonly massive. There are some cross bedded units to 50 cm. The cross bedding is low angle, concave upwards, with opposing dips in successive sets.

About 4 km north of this stop there is an exposure of thinly bedded fine grained laminate sandstone overlying this basal coarse sandstone, overlain in turn by a repeat of the coarse sandstone. The laminate sandstone contains a poorly preserved marine fauna of brachiopods and lamellibranchs.

Stop 4.12 to Forbes

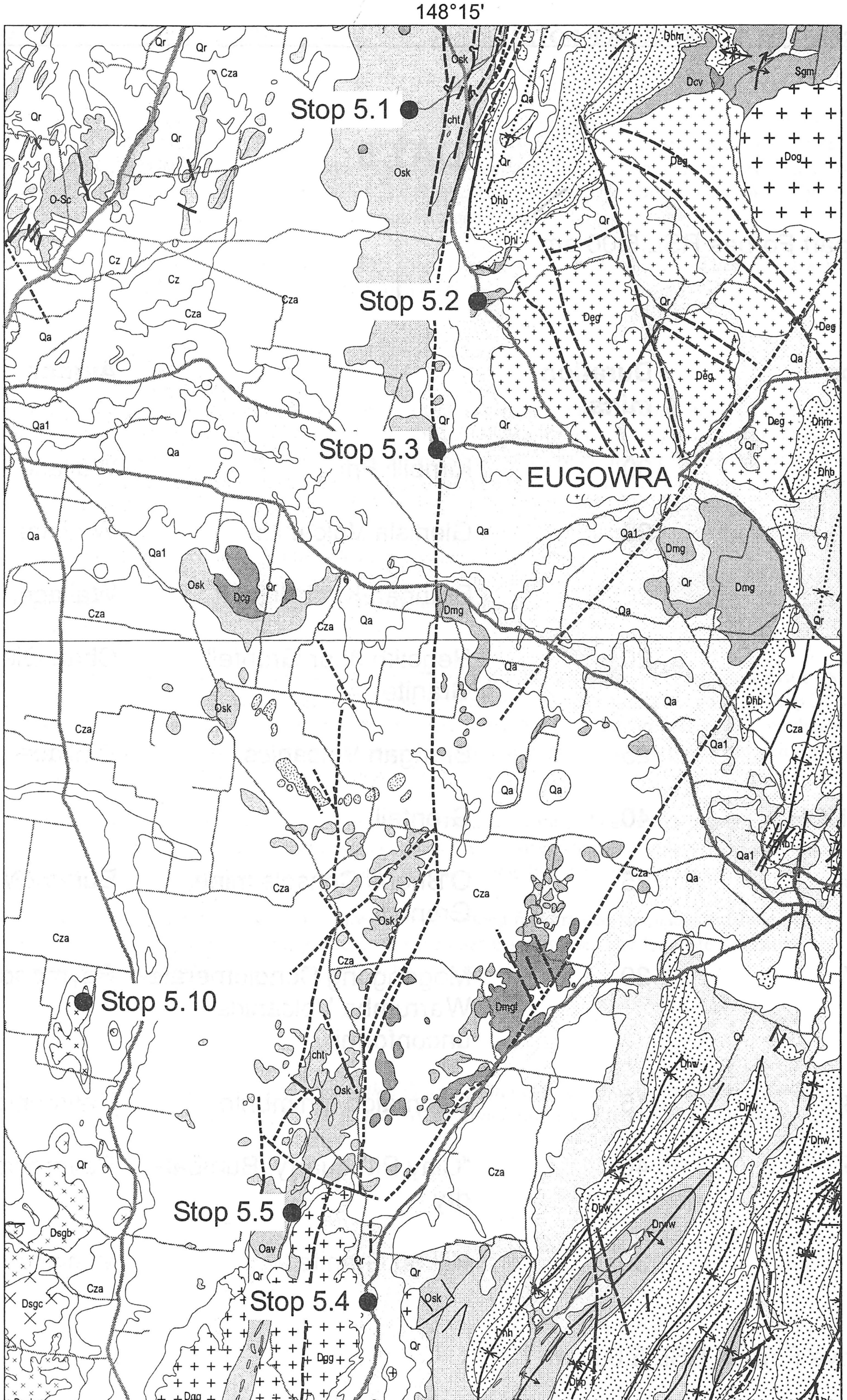
We backtrack across erosional plains and rises with colluvial slopes before crossing about 9 km of alluvial plain, almost entirely to the south of Goobang Creek, then cross erosional plains and rises closer to Forbes.

DAY 5

Depart Forbes RSL 8:00 am

Stop	Duration mins		Author
5.1	30	Kirribilli Fm	Wallace
5.2	20	Glenisla Volcanics	Wallace
5.3	20	Brangan/Kirribilli fault	Wallace
5.4	20	Regolith near Grenfell Granite	Chan/Gibson
5.5	25	Brangan Volcanics	Wallace
LUNCH	40	Grenfell	
5.6	25	O'Briens Consols mine, Grenfell	Burton/Wallace
5.7	30	Mogongong Conglomerate-Warrumba Volcanics unconformity	Raymond
5.8	15	Coomaloo Ignimbrite	Raymond
5.9	40	"Clay Pit" quarry, Bumbaldry	Raymond/Burton
5.10	30	Hill 60 Granite	Wallace

Arrive Forbes RSL 5.00 pm



DAY 5 EXCURSION STOPS

Day 5 16 April 1999

En Route to Stop 5.1

We travel northeast towards Parkes on the Newel Highway. The road runs roughly along the depositional-erosional landscape boundary for the first 6 km from Forbes, then entirely over a landscape of erosional plains and rises. About 6 km after turning east off the highway, we come onto the narrow proximal part of a triangular-shaped northward extension of the Lachlan alluvial plain. We then pass into an area of low hills.

Stop 5.1 Kirribilli Formation

GR 613090mE 6318064mN

The Kirribilli Formation is a thick monotonous shale, siltstone and sandstone sequence which forms a northerly trending belt extending northwards into the Peak Hill sheet area and southwards into the Grenfell sheet area (Krynen *et al.*, 1990a). Typically, the Kirribilli Formation is poorly exposed, cropping out as a series of low-lying, scrubby, undulating hills. The unit is finely banded and tightly to isoclinally folded, with chevron folding and intense crenulation in places. The age of the unit is uncertain primarily due to deformation, which was not favourable for the preservation of fossils. The Kirribilli Formation is similar to and invites comparison with the Ordovician Girilambone Group in the western part of the 1:250 000 sheet area, to the north of Wyalong Conodonts and radiolaria from the Girilambone Group rocks near Cobar suggest a Darriwillian-Gisbornian depositional age (~460 Ma).

This exposure is a rare example of a comparatively less deformed section of the Kirribilli Formation which has been interpreted as occupying the core of a broad syncline. The siltstone-sandstone, sequence exposed in the creek bed is an antiform plunging shallowly to the south. Sandstones are relatively uncommon in the predominantly finer grained sedimentary succession of the Kirribilli Formation. This creek bed sequence is identifiable by its higher radiometric response in airborne geophysical data .

En Route to Stop 5.2

After turning south a few kilometres east of Stop 5.1, we skirt to the west of hills and mountains of Hervey Group, crossing rises and low hills, and colluvial slopes. Although there are plenty of rock exposures in these high relief areas, regolith is still present in the form of stony soils in colluvial and residual material, alluvium along watercourses, and slightly weathered bedrock.

Stop 5.2 Glenisla Volcanics

GR 617989mE 6308665mN

This road section shows an outcrop of the Glenisla Volcanics intruded by the fine-grained western margin of the Eugowra Granite. Along its contact with the microgranite the porphyry is strongly altered to a depth of about 2 m. The Glenisla Volcanics are a massive garnetiferous quartz-feldspar rhyolitic porphyry compositionally identical to the Canowindra Volcanics. Outcrops of the Glenisla Volcanics have been identified elsewhere in the Parkes sheet area and at two localities in, and to the east of, Grenfell and at the join with the Grenfell, Cowra and Young 1:100 000 sheet areas. The Canowindra Volcanics have been interpreted as an ignimbrite deposited in a shallow marine to subaerial environment. Recent Ar-Ar data obtained by AGSO on a sample from Grenfell yield an age which is closely comparable to a SHRIMP U-Pb age of 432±7 Ma from the Canowindra Volcanics (Pogson and Watkins, 1998). The identification of the Glenisla Volcanics in the Forbes sheet area extends the known limits of this major ignimbrite unit by some 30 km westwards from its previously known boundaries. This limit is a minimum, as the unit is truncated by the Coolac-Narromine Fault east of Eugowra, where it out crops intermittently along the eastern margin of the fault zone.

The Eugowra Granite is a large elliptical pluton extending westwards from the margin of the sheet area over an estimated area of about 250 km^2. It is a composite fractionated I-type granite, geochemically similar to felsic plutons within the Yeoval Batholith, which is included in the Boggy Plain Supersuite of Wyborn *et al.* (1987).

En Route to Stop 5.3

We continue southeast, skirting to the west of hills (they are, technically speaking, not high enough to be considered as mountains, which we define as having more than 300 m relief) of Eugowra Granite, characterised by numerous tors and corestones, with little weathering. We cross areas of low hills and colluvial slopes developed on *granite. Nearing Eugowra, we turn west, still on very low angle colluvial slopes that are probably mostly developed on granite. Stop 5.3 is on the southern edge of an area of erosional rises, west of the wide colluvial slope.*

Stop5.3 Fault between Brangan Volcanics and Kirribilli Formation

GR 616185mE 6301502mN

This is a road section in which strata are intersected by a subsidary of the Coolac-Narromine Fault. In the eastern part of the section Glenisla Volcanics are faulted against a wedge of Kirribilli Formation sediments which are faulted against a 200 m-thick section of the mafic Brangan Volcanics. Further west the volcanics, in turn, overlie poorly exposed sediments of the Kirribilli Formation. These sediments are finely laminated sandy siltstones which show pervasive andalusite spotting. The metamorphism of these sediments could be attributed either to contact metamorphism by the Brangan Volcanics or to a subsurface non-magnetic granite body, possibly an extension of the Cumbijowa Granite, the southern margin of which is exposed 7 km to the southwest. On the basis of previous work, the Brangan Volcanics have been correlated with the Cambro-Ordovician Jindalee Group, which was formally defined in the Cootamundra sheet area. Recognition of the conodont ?*Walliserodus* sp in chert associated with the Brangan Volcanics in the Grenfell area (Stop 5.5) established that the volcanics are Ordovician in age and therefore were erupted either contemporaneously with the Kirribilli Formation or represent a later period of oceanic basalt volcanism possibly extending into the Silurian. Geochemically the Brangan Volcanics are relatively primitive (MgO ~7%) olivine tholeiites, characterised by high field strength elements (TiO_2 ~ 1.8%), low K/Na_2O and flat to slightly depleted light rare earth which distinguish them from the Goonumbla Volcanics further west in the Parkes-Forbes area.

En Route to Stop 5.4

We back track, and then continue east, crossing Mandagery Creek at Eugowra. The palaeo-Mandagery Creek was considerably incised prior to alluviation. A line of bores 1.5 km upstream of Eugowra intersected a maximum of 86 m of valley fill, with a layer of basalt above a basal alluvial layer up to 9 m thick (Williamson, 1986). Petrography and XRD examination suggests that the basalt is a distal part of the 12 Ma Toogong flow, which flowed down the palaeo Bourimbla and then Mandagery Creeks from Mount Canobolas, 70 km distant. Since the time of eruption, the stream profile has changed considerably, with alluviation in the downstream reaches, but considerable incision upstream. Downstream of Eugowra, sediments in the main Lachlan palaeovalley are tapped to augment the Parkes-Forbes water supplies.

We continue south from Eugowra across the Lachlan alluvial plain, crossing the deepest part of the palaeovalley, a little way north of the modern river. Upstream of the Eugowra area, the Lachlan alluvial plain is much narrower than near Forbes, narrowing to less than 5 km in places. Terraces, not recognised downstream, are present, and further upstream near Cowra, reach 41 m above modern river level. It appears that the floodplain is still aggrading downstream of the Eugowra area, but is being incised upstream. The 'balance point' between aggradation and erosion corresponds roughly with the abrupt transition from relatively narrow floodplain bordered by steep hill and mountains, to wide floodplain mostly bordered by much lower relief erosional landforms.

After leaving the floodplain, we cross a variety of generally low relief erosional and colluvial landforms and part of a southern lobe of the Lachlan alluvial plain, then enter a valley between hills of Grenfell Granite as we near Stop 5.4.

Stop 5.4

A low road cutting exposes poorly to moderately cemented, coarse, angular sandstone, with some clay beds, and granule and pebble conglomerate with clasts of granite rock fragments. The exposure displays surface hardening. The top of the exposed sediment is at least 6 m above the local creek. The sandstone is interpreted as part of a blanket of colluvial to alluvial, granite-derived sediment deposited within the valley, and now being eroded by modern drainage. In effect, the sediment is being stored away from the creek. Environmental geomorphologists have found that erosion of such sediment stores on slopes may be triggered by changed environmental factors, resulting in large scale transport of sediment to watercourses, and subsequent rapid choking and alluviation of the streams. The total thickness and extent of the sediment in this area is not known. We have encountered similar granitic-derived partly cemented sediments around granite hills north of Temora.

En Route to Stop 5.5

We backtrack 4 km before turning west. Just before the turn off, a creek has incised to a depth of about 5 m into its alluvium on the downstream (east) side of the road, but not upstream. The road is preventing gullying from proceeding upstream. Experience from elsewhere in Australia shows that severe gullying like this can occur very *rapidly, with one reported case from near Adelaide occurring overnight along a creek section several kilometres long during heavy rain; another case of devastating change after a threshold is reached.*

We skirt round the north side of the hills of the Warraderry Range to Stop 5.5

Stop 5.5 Brangan Volcanics

GR 608096mE 6265627mN

Exposure of intercalated ferruginised microcrystalline quartzite and metabasalt of the Brangan Volcanics. This is the northern margin of a 1.5 km-wide outcrop of the Brangan Volcanics which extends continuously a further 10 km south to the Mid-Western Highway and is enclosed by the Grenfell Granite. This basalt enclave within the granite is distinguished by airborne geophysics by its strong magnetic signature and a very low radiometric response when compared to the granite. Resolution of the airborne magnetic data suggests that the basalt is a shallow detached slab of basement which has been incorporated within the Grenfell Granite. Cherts peripheral to the volcanics are thinly bedded and pale coloured, sometimes banded. At this stop the chert has been subsumed by, and reacted with the volcanics, resulting in intense ferruginisation which caused recrystallisation of the chert to dark coloured microcrystalline quartzite with sinuous veins of haematite. Localised concentrations of manganese (predominantly rhodonite) produced by these reactions were sufficiently high to be commercially exploited up to the 1940's at several localities within the Brangan Volcanics in the Grenfell area also near Cookamidgera. The best known of these deposits is the Hoskins Manganese Deposit 3 km west of Grenfell, which produced 25 700 Mt of MnO_2 during the years 1915-41. The composite basalt-chert complex is presumed to have been emplaced during a relatively short-lived period of submarine volcanism. Previous work (Ryall, 1974; Bowman, 1977a) has suggested that this unit is a correlative of the Cambro-Ordovician Jindalee Group in the Cootamundra area (Basden, 1982). Poorly exposed, sparse enclaves of altered Kirribilli Formation sediments associated with the basalts are inconclusive regarding the relative ages or these two units, however recognition of conodont *? Walliserodus* sp in chert at this locality by I Percival, NSWGS (pers. comm.) excludes a Cambrian age and supports emplacement during the Ordovician, where they erupted either contemporaneously with deposition of the Kirribilli Formation sediments, or during a later period of oceanic basalt volcanism possibly extending into the Silurian..

En Route to Stop 5.6

We traverse broad, low angle, colluvial slopes to the east of the Warraderry Range, then south along a narrow alluvial valley floor along the upper reaches of Ooma Creek, which we encountered on Day 3, draining into Bundaburrah Cowal Swamp, then mostly over colluvial slopes and low hills closer to Grenfell. Gold was mined from both hard rock mines and deep leads before the turn of the century. The deep leads are in alluviated valleys. Cassiterite is also present in the deep leads. Depth of working was generally up to 60 m, with one lead being reported as worked to 150 m depth (Bowman, 1977b). Modern valley floors in the area are generally flat in cross section, indicating alluviation by sediment transported down the watercourses. Longitudinal profile gradients are much steeper than for the Lachlan and Bland alluvial plains, and the elevation (about 340 – 400 m) of the alluviated valleys is well above these plains. This indicates that the valleys have alluviated not by backfilling of the valleys by rising base levels in the main palaeovalleys, but inability of the watercourses to transport all the sediment supplied by minor tributaries and slopewash on valley sides.

Stop 5.6 Grenfell Gold Field, O'Briens Consols mine

GR 608100mE 6248450mN

The following description of the O'Briens Consols mine is based on information provided from Bowman (1977b) and the NSW Department of Mineral Resources Mine Record MR02383.

The orebody comprises quartz (+minor calcite) veins and stockworks, containing disseminated pyrite and gold. The veins strike northeasterly, dip 55° to 70° northwest, and are hosted by green quartz-feldspar porphyry. Some veins are more than 3 m wide. The workings extend to a depth of 219 m and 43 kg of gold was won. The claim was originally pegged in 1866. No mining was done from 1888 to 1930, nor from 1932 to about 1970. From 1971 to 1980 the mine was cleaned out, dewatered, and retimbered. A ten-head battery was erected and had been given a trial run but there is no record of production from this period.

Further information on the Grenfell gold field is given in the mineral occurrence section.

En Route to Stop 5.7

We cross low hills formed on Ordovician Kirribilli Formation, with flat-floored alluviated valley floors up to several kilometres wide in the headwaters of the south-flowing Brundah Ck, which flows around the southern side of the Weddin Mountains, then north to join Bland Creek. The moderately steep longitudinal gradient of the valleys is apparent.

STOP 5.7 Road base quarry, Mid Western Highway
GR 620800mE 6246900mN

PARK THE BUSES AT THE GATE AND WALK INTO THE QUARRY

Unconformable contact between the Walloy Member - Warrumba Volcanics (Middle Devonian) and Peaks Formation - Hervey Group (Late Devonian)

The Warrumba Volcanics are A-type, predominantly felsic volcanics of similar age and geochemistry to the Dulladerry Volcanics, which occur about 80 km to the north. These two volcanic units comprise the Rocky Ponds Group, and represent intraplate subaerial rift volcanism during the Middle Devonian. The Rocky Ponds Group was covered by the Late Devonian fluvial sediments of the Hervey Group with minor to no angular unconformity. The Warrumba Volcanics are dominated by flow banded rhyolite lavas in the west (Walloy Member), and by crystal-lithic welded ignimbrite in the east (Coomaloo Ignimbrite Member). A thin unit of basalts to trachytes (Adelargo Member) overlies the Walloy Member rhyolites. Minor epiclastic conglomerate and finer-grained sedimentary lenses are intercalated with the Walloy Member. The volcanics are well exposed in the cores of the shallowly north-plunging Gooloogong and Broula Anticlines. Smaller outliers of the volcanics are also exposed in doubly-plunging cores of other anticlines surrounded by Hervey Group sediments.

The Warrumba Volcanics are typically overlain by a red to maroon mudstone or siltstone of the Peaks Formation, which forms the basal unit of the Hervey Group. However, in the southern part of the Sugarloaf (or Yambira) Syncline the basal sediments of the Peaks Formation are comprised of a massive conglomerate unit, the Mogongong Conglomerate Member (Fig. 8.10). The conglomerate reaches a maximum thickness of 120 m, but has a very limited lateral extent.

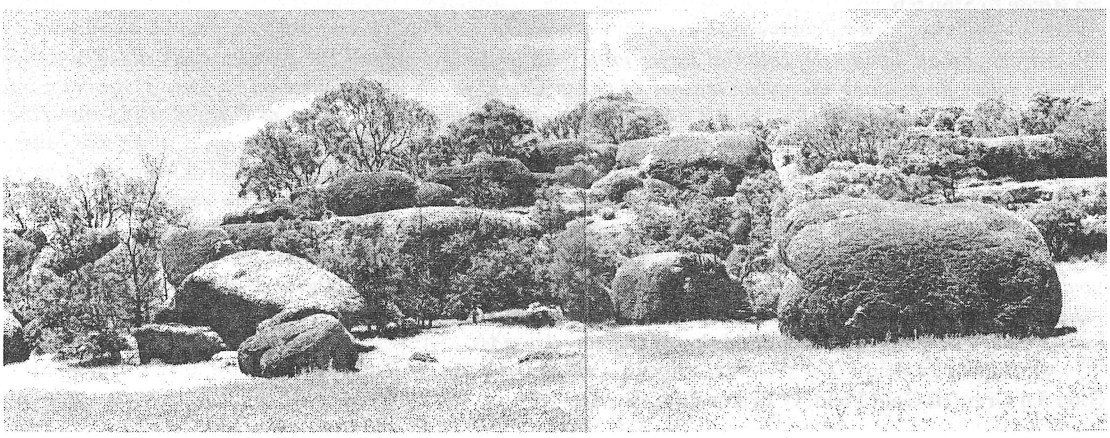


Figure 8.10. Large outcrops of massive polymict conglomerate of the Mogongong Conglomerate Member of the Peaks Formation, on the western flank of the Sugarloaf Syncline.

The northern end of the quarry at Stop 5.7 exposes sericitised, maroon, flow banded rhyolite lavas of the Walloy Member, overlain by polymict, rounded-cobble conglomerate of the Mogongong Conglomerate Member. Clasts in the conglomerate are locally derived, being mainly felsic volcanics from the Warrumba Volcanics and quarztose metasediments of the Ordovician Kirribilli Formation.

En Route to Stops 5.8, 5.9

We continue over low hills of Young Granodiorite, passing across the narrow alluvial plain of Bungalong Creek, where there is at least one erosional terrace. Steep hills and mountains of the Hervey and Rocky Ponds Groups are present to the north.

STOP 5.8 2 km west of Bumbaldry, north of the Mid Western Highway
GR 630600mE 6247400mN

STOPS 5.8 AND 5.9 MAY BE INACCESSIBLE AFTER RAIN

Coomaloo Ignimbrite Member - Warrumba Volcanics (Middle Devonian)

A weakly sericitic, quartz-K-feldspar phyric ignimbrite of the Coomaloo Ignimbrite Member crops out at Stop 5.8. The small quartz and K-feldspar phenocrysts (< 1-3 mm) are diagnostic of the ignimbrite and are very similar to the Curumbenya Ignimbrite of the Dulladerry Volcanics. An intensely altered version of the Coomaloo Ignimbrite occurs at the next stop, and can be identified by its phenocryst characteristics despite the strong alteration.

About 3 km to the southwest of this stop, the ignimbrite contains abundant limestone xenoliths up to several metres in diameter. These xenoliths were incorporated in the ignimbrite during eruption through or flow over the underlying Early Silurian Illunie Volcanics, which contain *in situ* limestone lenses. Inheritance of basement material in the Warrumba Volcanics also extends to the rock's zircon population, which is dominated by inherited Early Silurian zircons with only a small percentage of primary igneous Middle Devonian zircons (L. Black, AGSO, pers. comm.).

STOP 5.9 "The Claypit" quarry, 300 m south-east of Stop 8
GR 631100mE 62467000mN

PARK THE BUSES AT THE GATE AND WALK INTO THE QUARRY

Illunie Volcanics - Douro Group (mid Silurian) - Coomaloo Ignimbrite Member - Warrumba Volcanics (Middle Devonian)

Alteration is widespread in the Illunie and Warrumba Volcanics. The Illunie Volcanics are generally so altered and highly weathered that finding any fresh outcrop at all is difficult. Primary igneous textures apart from phenocrysts are often not preserved. The current level of erosion of the Illunie Volcanics is close to the Late Devonian erosion surface on which the Hervey Group was deposited and it is probable that the high degree of weathering is partly due to Devonian weathering.

The area surrounding the Broula King gold mine and The Claypit in the Bumbaldry mining district is the most severely altered area of the Illunie and Warrumba Volcanics. The volcanics are variably silicified, sericitised, argillised, and less commonly quartz veined and chloritised. Disseminated limonite after pyrite is not uncommon in the altered volcanics. The Bumbaldry district contains more than ten mineral occurrences, mostly hosted in the Illunie Volcanics. These include the Broula King and Cowfell mines, as well as the smaller Boori, Woods Prospect, Balston and Tyagong Creek occurrences. At the Broula King mine, six quartz reefs up to 1.5 m thick were mined in altered porphyritic rhyodacite between 1901 and 1930. They produced over 87 kg of gold at an average grade of 15 g/t Au. The shallowly dipping (~40°) reefs, comprised of braided quartz veins up to 30 cm thick, were stoped to depths between 6 and 50 metres. Recent exploration has indicated a remaining resource of 226,000 t at 3.15 g/t Au. Wall rock alteration at Broula King is dominated by pervasive silicification with variable development of sericite, chlorite, kaolinite, minor epidote and widely disseminated pyrite, galena and arsenopyrite. Smith (1985) considered much of the chlorite and epidote to be related to regional metamorphism rather than hydrothermal alteration.

Patchy argillic and sericitic alteration is developed in the Coomaloo Ignimbrite Member of the Warrumba Volcanics (Fig 8.11). The Claypit is the most extensive example of argillic epithermal alteration. It is developed at the unconformable contact of the Coomaloo Ignimbrite and the Illunie Volcanics. Some banded quartz veining occurs, but generally the alteration is massive to brecciated clay, silica and sericite. Quartz phenocrysts are commonly the only relict igneous textures visible, but the two volcanic units can generally be distinguished on the morphology of their phenocrysts. The Illunie Volcanics contain larger (commonly >3 mm), and often fractured, quartz phenocrysts, compared to the finer-grained (commonly 1-2 mm) phenocrysts of the Coomaloo Ignimbrite. Some relict breccia textures may also be seen in the ignimbrite. No economic gold grades have been reported from The Claypit. The development of epithermal alteration in the Warrumba Volcanics indicates that the alteration in the Silurian Illunie Volcanics is of Middle Devonian age. It is also possible that the mineralisation at Broula King, which is entirely hosted by the Illunie Volcanics, is hosted in the deeper parts of a Middle Devonian epithermal system related to the overlying Warrumba Volcanics.

Sericite-silica ± clay alteration in the Walloy Member of the Warrumba Volcanics is developed in several areas, including at the southern end of the Gooloogong Anticline near "Red Hill" and at the northern end of the anticline near "Billeroy". Both of these alteration zones have a strong foliation developed in the sericitic alteration. Quartz veining occurs in some rocks and disseminated limonite, after pyrite, occurs west of "Billeroy". The combination of alteration and foliation in the fine-grained rhyolites at the southern end of the Gooloogong Anticline makes it difficult to distinguish the volcanics from foliated phyllites of the Ordovician Kirribilli Formation. Rare fine-grained relict quartz phenocrysts are, commonly, the only evidence of an igneous origin for the volcanics.

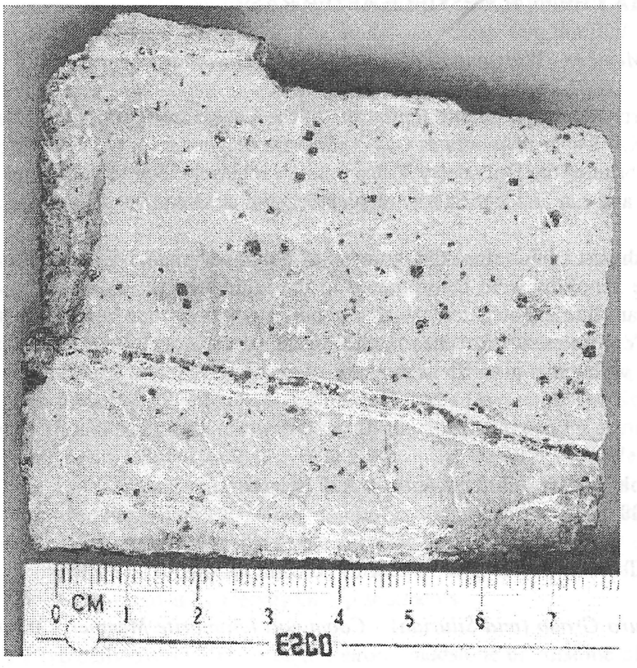


Figure 8.11. Intensely altered ignimbrite of the Warrumba Volcanics. Quartz phenocrysts and feldspars replaced by clay lie in a strongly sericitic matrix cut by quartz-kaolinite veinlets.

En Route to Stop 5.10

We retrace our route, passing onto the flanks of the buried Lachlan palaeovalley about 20 km northwest of Grenfell, and then to Hill 60, an inlier of granite forming a low hill.

Stop 5.10 Hill 60 Granite

GR 597850mE 6273341mN

Quarry within the Hill 60 Granite. This is the northernmost exposure of a north-south elongate granite complex extending southwards to the Grenfell -West Wyalong road. Interpretation of airborne magnetic suggests that the granite extends northwards up to about Ooma Creek and also extends at shallow depth further westwards, where it is overlain by Ordovician basement sediments.

The granite is an S-type (ASI > 1.1), is heavily tourmalinised, and has been explored further to the south for Sn.

Return to Forbes

We back track before crossing the Grawlin Plain, characterised by brown, grey, and red clay soils, with low radiometric response, before crossing the Lachlan River.

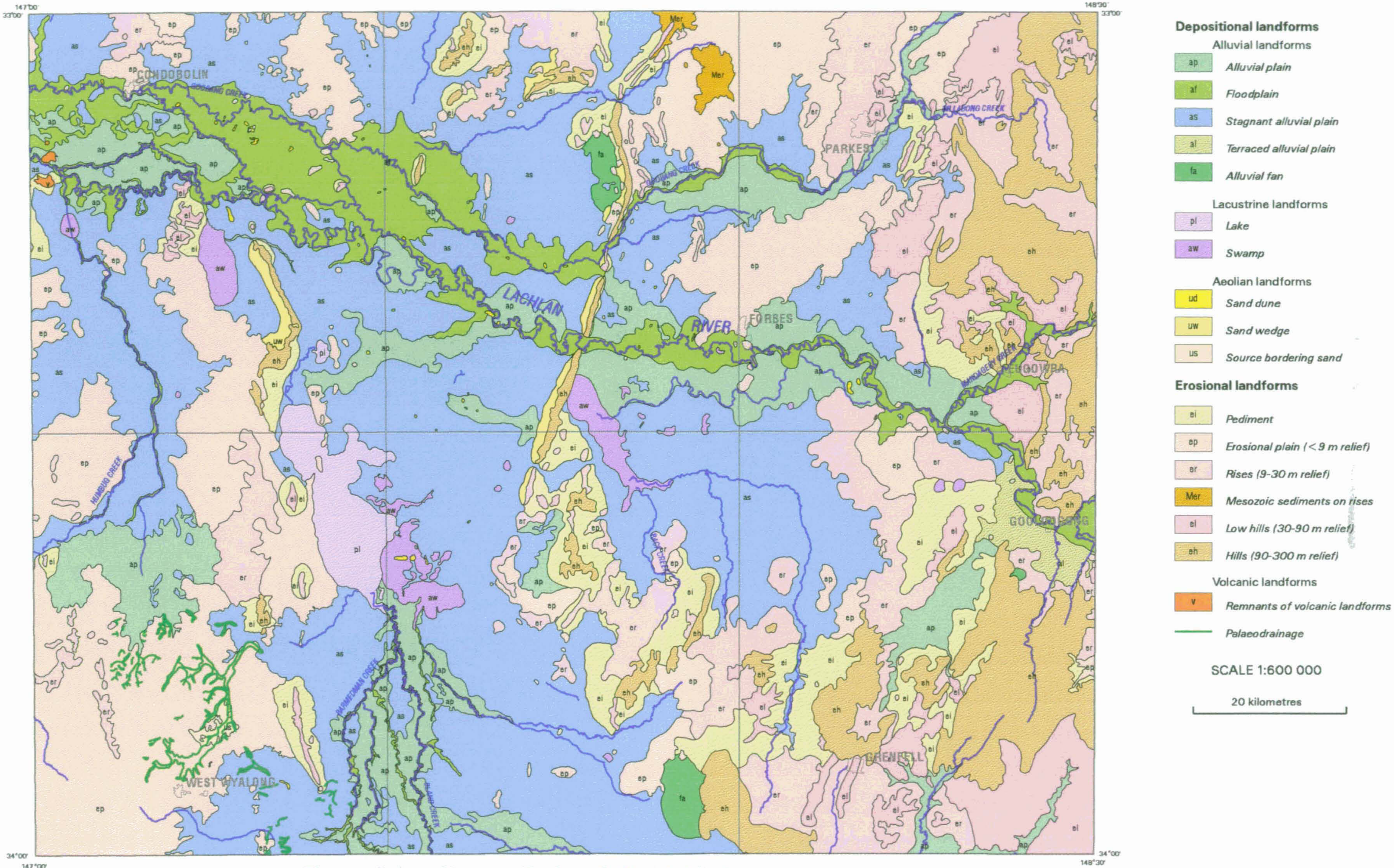


Figure 1: Landforms: Forbes 1:250 000 sheet

APPENDIX

REFERENCES

ANDERSON, J., GATES, G. & MOUNT, G.J. 1993. Hydrogeology of the Jemalong and Wyldes Plains irrigation districts. *New South Wales Department of Water Resources, Technical Services Report* 93.045.

ANDREWS, E.C. 1910. The Forbes-Parkes Gold Field. *New South Wales Geological Survey, Mineral Resources* **13**, 109 pp.

ARUNDELL, M., MORRIS, L., COLLINS, G., ROBERTSON, B., DAVIS, D., MÜLLER, D. & HANNINGTON, M. 1997. North Limited 6th Annual combined exploration report, ELs 3275, 3276, 3277, 3278, 3279, 3543, 4074, 4075, 4447, 4980 and 4981, 6th April 1996 to 5th April 1997. *Geological Survey of New South Wales,* Report GS1998/095 (unpublished).

BACCHIN, M., DUGGAN, M., GLEN, R., GUNN, P., LAWRIE, K., LYONS, P., MACKEY, T., RAPHAEL, N., RAYMOND, O., ROBSON, D. & SHERWIN, L. 1999. Cootamundra, Interpreted Geology Based on geophysics and previous geological mapping, (1:250 000 scale map). Australian Geological Survey Organisation, Canberra and Geological Survey of New South Wales, Department of Mineral Resources.

BARRON, L.M. 1998a. Metamorphism. In: DJ Pogson & JJ Watkins (eds) *Bathurst 1:250 000 Geological Sheet SI/55-8. Explanatory Notes*, Geological Survey of New South Wales, Sydney, 284-286.

BARRON, L.M. 1998b. A suite of rocks from the Condobolin 1:100 000 map 8331. *Petrological report 98/8, Geological Survey of New South Wales, Report* GS 1998/380 (unpublished).

BARRON, L.M. in press. Metamorphic Map. In E Morgan & SN Meakin (eds) *Dubbo 1:250 000 Geological Sheet SI/55-4. Explanatory Notes*, Geological Survey of New South Wales, Sydney.

BASDEN, H. 1982. Preliminary report on the geology of the Tumut 1:100 000 sheet area, southern New South Wales, *Geological Survey of New South Wales, Report* GS1986/106 (unpublished).

BHP Gold Mines Ltd 1989. Exploration reports for EL3211, Tallabung, Wirrinya area. *Geological Survey of New South Wales, Report* GS1989/397 (unpublished).

BLEVIN, P.L. & CHAPPELL, B.W. 1996. Controls on the distribution and character of the intrusive-metallogenic provinces of eastern Australia. *Geological Society of Australia Abstracts* **41**, 42.

BOWMAN, H.N. 1976. *Forbes 1:250 000 metallogenic map SI/55-7* Geological Survey of New South Wales, Sydney.

BOWMAN, H.N. 1977a. *A Metallogenic Study of the Forbes 1:250,000 Sheet SI 55-7.* 97 pp. Geological Survey of New South Wales, Sydney.

BOWMAN, H.N. 1977b. *Mine data sheets to accompany Metallogenic Map Forbes 1:250,000 Sheet SI 55-7.* 296 pp. Geological Survey of New South Wales, Sydney.

BRUNKER, R.L. 1972. *Forbes 1:250 000 geological map SI55-7.* Geological Survey of New South Wales, Sydney.

BURRELL, P.S. 1994. First annual report for the period ending 28th July 1994 on Exploration Licence 4565 (SI55-7). North Exploration. *Geological Survey of New South Wales, Report* GS1995/002 (unpublished).

BURRELL, P.S. 1996. North Limited, 2nd Annual Report for the period ending 23 November 1996 on Exploration Licence 4982 South Caragabal. *Geological Survey of New South Wales, Report* GS1997/093 (unpublished).

CAMPI, D., McGAIN, A. & ELLEM, C. 1975. Gibsonvale alluvial tin deposit, N.S.W. In: Knight, C.L. (Editor), *Economic Geology of Australia and Papua New Guinea, 1. Metals.* The Australasian Institute of Mining ad Metallurgy, Melbourne. 1049-1053.

CARR, G.R., DEAN, J.A., GULSON, B.L., ASHLEY, P.M. & KORSCH M.J. 1996. Mineral Exploration in the Tasmanides: Pb Isotope Models as a Guide to Prospectivity. *Geological Society of Australia, Abstracts* **41**, 76.

CARR G.R., DEAN J.A., SUPPEL D.W. & HEITHERSAY P.S. 1995. Precise lead isotope fingerprinting of hydrothermal activity associated with Ordovician to Carboniferous metallogenic events in the Lachlan Fold Belt of New South Wales. *Economic Geology* **90**, 1467-1505.

CHAMPION, D.C. & HEINEMANN, M.A. 1994. Igneous rocks of northern Queensland: 1:500 000 map and explanatory notes. *Australian Geological Survey Organisation Record* 1994/11, 82p.

CHAN, R.A. 1999. Palaeodrainage and its significance to mineral exploration in the Bathurst region, NSW. *Proceedings of Regolith 98 Conference, Kalgoorlie, WA, May 1998.* CRC LEME, Perth.

CHAPPELL, B.W. & WHITE, A.J.R. 1992. I- and S-type granites in the Lachlan Fold Belt. *Geological Society of America Special Paper* **272**, 1-26.

CLARKE, I. 1990a. Igneous petrology. *In* Clarke I & Sherwin L (Eds), Geological Setting of Gold and Copper Deposits in the Parkes Area, New South Wales, *Records of the Geological Survey of New South Wales* **23**, 137-185.

CLARKE, I. 1990b. Primary deposits in the Forbes-Parkes-Peak Hill-Tomingley gold belt. *In* Clarke I & Sherwin L (Eds), Geological Setting of Gold and Copper Deposits in the Parkes Area, New South Wales, *Records of the Geological Survey of New South Wales* **23**, 137-185.

COENRAADS, R.R. 1996. Copper, gold, silver and manganese exploration in the Parkes-Forbes-Eugowra area, NSW, Exploration Licence 4826. *Geological Survey of New South Wales, Report* GS1996/220 (unpublished).

COLLINS, W.J., BEAMS, S.D., WHITE A.J., & CHAPPELL, B.W. 1982. Nature and origin of A-type granites with particular reference to southeastern Australia. *Contributions to Mineralogy and Petrology* **80**, 189-200.

CONOLLY, J.R. 1965. The stratigraphy of the Hervey Group in central New South Wales. *Royal Society of New South Wales, Journal and Proceedings* **98**, 37-83.

CUNDARI, A. 1973. Petrology of the leucite-bearing lavas in New South Wales. *Journal of the Geological Society of Australia* 20, 465-492.

DEAN, J.A. 1995. The Pb isotopic composition of alteration zones in sediments at the Five Mile Hill Prospect, west of Condobolin, NSW. CSIRO Division of Exploration and Mining, Exploration and Mining report 118c, Sirotope Report SR 304. *Geological Survey of New South Wales, Report* GS1995/273 (unpublished).

DEGELING, P.R. 1974. Wagga Anticlinorial Zone. In Markham N.L. & Basden H. (eds), *The Mineral Deposits of New South Wales.* Geological Survey of New South Wales, Department of Mines, Sydney.

DIEMAR, V. 1986. Devex Limited, Exploration Licence 2393 Grenfell, Report for the Period 20.4.85 to 19.10.85. *Geological Survey of New South Wales, Report* GS1986/108 (unpublished).

DOWNES, P.M. 1997. METMIN-97 Data Package, NSW Metallic Mineral Occurrence Database and accompanying ArcView/Mapinfo Coverages. *Geological Survey of New South Wales, Report* GS1997/291.

EDGAR, W. 1990. *Acid alteration styles within the volcanic hosted, precious metal epithermal prospects - Peak Hill and Wirrinya; N.S.W.* Unpublished B.Sc (Hons) thesis, Monash University, Melbourne, 141p.

ELLIOTT, S.J. & MARTIN, A.R. 1991. Alaskan-type intrusive complexes of the Fifield Belt, central New South Wales, in *Geology and mineralisation of the Fifield Platinum Province, New South Wales, Sixth International Platinum Symposium, Excursion Guidebook*, 4-11. Geological Society of Australia, Sydney.

ENGLAND, R.N. 1995. Appendix 111 Petrological Report. In Pietsch G Project 262 EL2291 Bumbaldry Joint Venture Annual Report for period ending 13 November 1995, Lachlan Resources NL. *Geological Survey of New South Wales, Report* GS1996/521 unpublished.

FERGUSSON, C.L. & Coney, P.J. 1992. Convergence and intraplate deformation in the Lachlan Fold Belt of southeastern Australia. *Tectonophysics* **214**,417-439.

FERRIS, B. & HARLEY, R. 1993. Dominion Mining Limited, First Annual and Final Report for Currawong EL 4111, 12 Months to 30 October 1992. *Geological Survey of New South Wales, Report* GS1993/128 (unpublished).

FERRIS, B. 1996. Delta Gold Exploration Pty Ltd, Toad Joint Venture, Exploration Licence 4732/4991 Warregal, Second Annual Report to 27 November 1996. *Geological Survey of New South Wales, Report* GS1997/327 (unpublished).

FOSTER, D.A. & GRAY, D.R. Chronology and deformation within the turbidite-dominated Lachlan Orogen: implications for the tectonic evolution of eastern Australia and Gondwana. *Tectonics* (in press).

FRAKES, L.A. & FRANCIS, J.E. 1988. *Early Cretaceous Ice*. Geological Society of Australia, Abstracts *21, 144-145*.

FRAKES, L.A., ALLEY, N.F. & DEYNOUX, M. 1995. Early Cretaceous ice rafting and climate zonation in Australia. *International Geology Review* **37**, 567-583.

FRAKES, L.A., FRANCIS, J.E. & SYKTUS, J.I. 1992. *Climatic Modes of the Phanerozoic*. Cambridge University Press, Cambridge.

FRANKLIN, R. 1993. Forbes: Airborne Geophysical Survey - Operations Report, *AGSO Record* 1993/80.

GIBSON, D.L. & CHAN, R.A. 1999. Aspects of palaeodrainage in the north Lachlan Fold Belt. *Proceedings of Regolith 98 Conference, Kalgoorlie, WA, May 1998*. CRC LEME, Perth.

GIBSON, D.L. 1999. Notes to accompany the 1:500 000 Cobar regolith landforms map. *CRC LEME Report*, in press. CRC LEME, Perth.

GLASER, L. 1988. Consultants Report Claypit Prospect N.S.W. In Rangott M. & Kennedy G. 1989. Quotidian No 101/Cluff Minerals (Australia) Pty Ltd, Exploration licence No 3196 "Bumbaldry South" exploration progress report for the six months period ending 15th March, 1989. *Geological Survey of New South Wales, Report* GS1989/212 (unpublished).

GLEN, R.A. 1992. Thrust, extensional and strike-slip tectonics in an evolving Palaeozoic orogen- a structural synthesis of the Lachlan Orogen of southeastern Australia. *Tectonophysics* **214**, 341-380.

GLEN, R.A. 1998. *Lachlan Fold Belt '98 Extended Abstracts*. Australian Institute of Geoscientists, Bulletin *23*.

GOVETT, G.J.S., DOBOS, V.J. & SMITH, S. 1984. Exploration rock geochemistry for gold, Parkes, New South Wales. *Journal of Geochemical Exploration* **21**, 175-191.

GREENHALGH, A.N. 1997. Climax Mining Ltd, Final report on exploration, EL5192, Wirrinya NSW. *Geological Survey of New South Wales, Report* GS1997/421 (unpublished).

HEALD, P. FOLEY, N.K. & HAYBA, D.O. 1987. Comparative anatomy of volcanic-hosted epithermal deposits: acid-sulphate and adularia-sericite types. *Economic Geology* **82**, 1-26.

HEITHERSAY, P.S. & REN, S.K. 1992. Peko Wallsend Operations Ltd, First six monthly report on ELs 3275, 3276, 3277, 3278, 3279. *Geological Survey of New South Wales, Report* GS1992/185 (unpublished).

HEITHERSAY, P.S. & WALSHE, J.L. 1995. Endeavour 26 North: a Porphyry copper-gold deposit in the Late Ordovician shoshonitic Goonumbla Volcanic Complex, New South Wales, Australia. *Economic Geology* **90**, 1506-1532.

HEITHERSAY, P.S. 1986. Endeavour 26 North copper-gold deposit, Goonumbla, N.S.W. - paragenesis and alteration zonation. *Council of Mining and Metallurgical Institutions and Australasian Institute of Mining and Metallurgy Congress, 13th, Publications* **2**, 181-189.

HEITHERSAY, P.S., O'NEILL, W.J., VAN DER HELDER, P., MOORE, C.R. & HARBON, P.G. 1990 Goonumbla Porphyry Copper District -Endeavour 26 North, Endeavour 22 and Endeavour 27 Copper-Gold Deposits. In Hughes F.E. (ed), *Geology of the Mineral Deposits of Australia and Papua New Guinea*,.1385-1398.

HOOPER, B., HEITHERSAY, P.S., MILLS, M.B., LINDHORST, J.W. & FREYBERG, J. 1996. Shoshonite-hosted Endeavour 48 porphyry copper-gold deposit, Northparkes, central New South Wales. *Australian Journal of Earth Sciences* **43**, 279-288.

INGPEN, I.A. 1995. *Geological, structural and tectonic history of the Temora, West Wyalong, Grenfell and Forbes area, New South Wales: Implications for the structural controls on gold and copper mineralisation*. MSc thesis (unpublished), Monash University, Melbourne.

IWATA, K., SCHMIDT, B.L., LEITCH, E.C., ALLAN, A.D. & WATANABE, T. 1995. Ordovician microfossils from the Ballast Formation (Girilambone Group) of New South Wales. *Australian Journal of Earth Sciences* **42**, 371-376.

JONES, B.M. 1991. *Geological setting and genesis of the Endeavour 44 Au, Pb, Zn skarn, Parkes, NSW*. BSc thesis, Australian National University, (unpublished).

JONES, G.J. 1973. Geopeko Limited, Endeavour 6 - Gunningbland Creek, Report to support application for drilling aid from the prospecting vote. *Geological Survey of New South Wales, Report* GS1973/451, (unpublished).

JONES. G.J. 1985. The Goonumbla Porphyry Copper Deposits, New South Wales. *Economic Geology* **80**, 591-613.

KEMEZYS, K.J. 1976. Geology and mineralisation between West Wyalong and Condoblin, New South Wales. *Bulletin of the Australian Society of Exploration Geophysicists* **7**, 34-36.

KRYNEN, J.P., SHERWIN, L. & CLARKE, I. 1990a. Stratigraphy and structure. *In* Geological setting of gold and copper mineralisation in the Parkes area, New South Wales. *Geological Survey of New South Wales, Records* **23**, 1-76.

KRYNEN, J.P., SHERWIN, L. & CLARKE, I. 1990b. *Parkes Special 1:100 000 geological sheet*. Geological Survey of New South Wales, Sydney.

Lachlan Resources NL & Platinum Search NL 1995. Final Report for EL 2653, Derriwong area. Geological Survey of New South Wales, Report *GS1995/144 (unpublished).*

LAWRIE, K.C., CHAN, R.A., GIBSON, D.L. & DE SOUZA KOVACS, N. in press. Alluvial gold potential in buried palaeochannels in the Wyalong district, Lachlan Fold Belt, New South Wales. *AGSO Research Newsletter* in press.

LE BAS, M.J., LE MAITRE, R.W., STRECKEISEN, A. & ZANETTIN, B. 1986. A chemical classification of volcanics rocks based on the total alkali-silica diagram. *Journal of Petrology* **27**, 745-750.

LEVEN,J.H., STUART-SMITH, P.G., MUSGRAVE, R.J., RICKARD, M.J. & CROOK, K.A.W. 1992. Ageophysical transect across the Tumut Synclioria1 Zone, N.S.W. *Tectonophysics* **214**, 239-248.

LINDSAY-PARK, K. 1985. *The geology, ground magnetics and alteration mineral assemblage of Nibbler's Hill, Parkes, New South Wales.* BSc thesis, University of New South Wales (unpublished).

LOVE, M.C. 1985a. Ninth progress report on ELs 1498, 1504, 1547, and 1548. *Geological Survey of New South Wales, Report* GS1984/380 (unpublished).

LOVE, M.C. 1985b. Tenth progress report on ELs 1498, 1504, 1547, and 1548. *Geological Survey of New South Wales, Report* GS1984/380 (unpublished).

MARLOW, A. 1996. Report on Geological Mapping at West Wyalong E.L. 4615. In Dawe, J, 1996 (Appendix 6), unpublished.

MARTIN, H.E. 1991. *Tertiary stratigraphic palynology and palaeoclimate of the inland river system in New South Wales. In Williams, M.A.J. et al. (eds), The Cainozoic in Australia: a reappraisal of the evidence.* Geological Society of Australia, Special Publication *18, 181-194.*

McINNES, P., MILES, I., & BROOKER, M. 1998. Endeavour 42 (E42) gold deposit, Lake Cowal. In Geology of Australian and Papua New Guinean Mineral Deposits (Eds Berkman D.A. & Mackenzie D.H.), *Australasian Institute of Mining and Metallurgy; Melbourne, Monograph* **22**, 581-586.

McINTOSH, C. & MacCORQUODALE, F. 1997. Newcrest Mining Limited Fourth Annual Report for ELs 4502, 4503, 4515 and 4936, Fairholme Project, NSW. *Geological Survey of New South Wales, Report* GS1998/001 (unpublished).

McINTOSH, C. 1996. Newcrest Mining Limited, combined third annual report for ELs 4502, 4503 and 4515, Fairholme Project NSW . *Geological Survey of New South Wales, Report* GS1996/460 (unpublished).

McLEAN, G. 1997. Golden Cross Operations Pty Ltd, Third annual exploration report, EL 4975 "Warraderry", Grenfell, Canowindra area. *Geological Survey of New South Wales, Report* GS1997/231 (unpublished).

MILES, I.N. & BROOKER, M.R. 1998. Endeavour 42 deposit, Lake Cowal, New South Wales: a structurally controlled gold deposit. *Australian Journal of Earth Sciences* **45**, 837-847.

MILES, I.N. 1993. *The palaeoenvironment of the Late Ordovician Lake Cowal volcanics, Central New South Wales,* BSc (Honours) thesis, Monash University, Melbourne, (unpublished).

Mineral Management & Securities Pty Ltd 1986. Exploration reports for EL 2269, Parkes area. *Geological Survey of New South Wales, Report* GS1986/074 (unpublished).

Minfo 1988b. Broula King Gold Mine, Bumbaldry. *Minfo* **22**, 7-10.

MULHOLLAND, C. ST J. 1935. Geological Survey of the Grenfell district. *Geological Survey of New South Wales, Report* GS1935/002 (unpublished).

MÜLLER, D. & GROVES, D.I. 1995. *Potassic igneous rocks and associated gold - copper mineralisation.* Lecture Notes in Earth Sciences *56, xiii + 210. Springer - Verlag, Heidelberg.*

MÜLLER, D., HEITHERSAY, P.S. & GROVES, D.I. 1994. The shoshonite porphyry Cu-Au association in the Goonumbla District, N.S.W., Australia. *Mineralogy and Petrology* **51**, 299-321.

MÜLLER, D., ROCK, N.M.S. & GROVES, D.I. 1992. *Geochemical Discrimination between shoshonitic and potassic volcanic rocks from different volcanic settings: a pilot study.* Mineralogy and Petrology *46, 259-289*

Newcrest Mining Ltd 1992. Final exploration report for ELs 2269 and 3705, Parkes area. *Geological Survey of New South Wales, Report* GS1995/291 (unpublished).

NOTT, J., YOUNG, R. & McDOUGALL, I. 1996. Wearing down, wearing back, and gorge extension in the long-term denudation of a highland mass: quantitative evidence from the Shoalhaven catchment, southeast Australia. *Journal of Geology* **104**, 224-232.

O'NEILL, W. 1982. Annual progress report on MLs 691 and 692, Milpose Creek, Bogan Gate area (Geopeko Ltd). *Geological Survey of New South Wales, Report* GS1982/110 (unpublished).

O'SULLIVAN, P.B., KOHN, B.P., FOSTER, D.A. & GLEADOW, A.J.W. 1995. Fission track data from the Bathurst Batholith: evidence for rapid mid-Cretaceous uplift and erosion within the eastern highlands of Australia. *Australian Journal of Earth Sciences* **42**, 597-607.

O'SULLIVAN, P.B., KOHN, B.P., PILLANS, B. & PAIN, C.F. 1998. Late Paleozoic to Cainozoic landscape evolution of the North Parkes Mine area, New South Wales; constraints from fission track and paleomagnetic data. *Eighth Biennial Conference of the Australian and New Zealand Geomorphology Group, Goolwa, SA, Abstract Booklet,* 42.

PAIN, C., CHAN, R., CRAIG, M., HAZELL, M., KAMPRAD, J. & WILFORD, J. 1991. RTMAP: BMR regolith database field handbook. *Bureau of Mineral Resources, Australia, Record,* 1991/29.

PECCERILLO, A. & TAYLOR, S.R. 1976. Geochemistry of Eocene calc-alkaline volcanic rocks from the Kastomonu area, northern Turkey. *Contributions to Mineralogy and Petrology* **58**, 63-81.

PERKINS, C. 1990. $^{40}Ar/^{39}Ar$ and U-Pb dating of the Goonumbla porphyry copper-gold deposits, NSW Australia. *Geochronology Cosmochronology and Isotope Geology, Geological Society of Australia Abstracts* **27**, p 78.

PERKINS, C. WALSHE, J.L. & MORRISON, G. 1995. Metallogenic episodes of the Tasman Fold Belt System, eastern Australia. *Economic Geology* **90**, 1443-1466.

PERKINS, C., McDOUGALL, I. & CLAOUÉ LONG, J. 1990. *Dating of ore deposits with high precision: examples from the Lachlan Fold Belt, NSW, Australia.* Proceedings of the Pacific Rim 90 Congress, *105-112.*

PICKETT, J.W. & INGPEN, I.A. 1990. Ordovician and Silurian strata south of Trundle, New South Wales. *Geological Survey of New South Wales, Quarterly Notes* **78**, 1-14.

PICKETT, J.W. 1992. Review of selected Silurian and Devonian conodont assemblages from the Mineral Hill - Trundle area, Palaeontological Report 1992/01. *Geological Survey of New South Wales, Report* GS1992/024 (unpublished).

PICKETT, J.W. 1993. *Plant fossils from the Dulladerry Rhyolite.* Geological Survey of New South Wales Palæontological Report 93/04 (unpublished).

PILLANS, B., TONUI, E. & IDNURM, M. 1998. Paleomagnetic dating of weathered regolith at Northparkes Mine, NSW. *Regolith 98 Conference, Program and Abstracts,* **9**. CRC LEME, Perth.

POGSON, D.J. 1991. *Geology of the Bobadah 1:100 000 Sheet 8233.* 130 pp. Geological Survey of New South Wales, Sydney.

POGSON D.J. & FELTON E.A. 1978. Reappraisal of Geology, Cobar-Canbelego-Mineral Hill Region, Central Western New South Wales. *Geological Survey of New South Wales, Quarterly Notes* **33**, 1-14.

POGSON, D.J. & WATKINS, J.J. 1998. *Bathurst 1:250 000 geological sheet SI/55-8: Explanatory notes.* Geological Survey of New South Wales, Sydney, xiv + 430 pp.

RAFTY, D.J. & HEMMING, G.R. 1997. Conquest Mining NL Report No P475/2, 1st Annual Report for the period of 20th May 1996-19th May 1997 on Exploration Licence 5016. *Geological Survey of New South Wales, Report* GS1997/519 (unpublished).

RAFTY, D.J. & HEMMING, G.R. 1997. Conquest mining, first annual report for the period ending 19th May 1997 on exploration licence 5015. *Geological Survey of New South Wales, Report* GS1998/212 (unpublished).

RAFTY, D.J. & HEMMING, G.R. 1998. Conquest Mining NL, Second annual report for the period ending 19th May 1998 on EL5016. *Geological Survey of New South Wales, Report* GS1998/433, (unpublished).

RAMPE, M. 1992a. Harvest Exploration Pty Limited, Final Report exploration (prospecting) licence 1109, prepared for Telberth NL. *Geological Survey of New South Wales, Report* GS1989/320, (unpublished).

RAMPE, M. 1992b. Harvest Exploration Pty Limited, The Pinnacle Goldfield, Exploration Licence 3795, Final and Relinquishment report, prepared for Telberth NL. *Geological Survey of New South Wales, Report* GS1992/346 (unpublished).

RANGOTT, M. & KENNEDY, G. 1989. Quotidian No 101/Cluff Minerals (Australia) Pty Ltd, Exploration licence no 3196 "Bumbaldry South" exploration progress report for the six months period ending 15th March, 1989. *Geological Survey of New South Wales, Report* GS1989/212 (unpublished).

RAYMOND, O.L. & SUN, S-S, 1998. A comparison of Ordovician and Devonian magmatism in the eastern Lachlan Fold Belt: re-evaluating exploration targets. *AGSO Research Newsletter* **28**, 8-10.

RAZA, A., HILL, K.C. & KORSCH, R.J., in press. Mid-Cretaceous uplift of the Bowen-Surat Basins, Eastern Australia; its relation to Tasman Sea rifting, from apatite fission track and vitrinite reflectance data. *AGSO Bulletin*, in press.

RICHARDSON, R. 1994. Platinum Search NL, EL 2653 Derriwong, Annual report for the period 8th September 1992 to 8th September 1994. *Geological Survey of New South Wales, Report* GS1989/335 (unpublished).

ROLLAN, L.A. 1984. *A petrographic and geochemical study of wallrock alteration around gold mineralisation at Parkes, New South Wales*. MAppSc thesis, University of New South Wales (unpublished).

ROWE, B.A. 1998. Tri Origin Australia NL, Toad Joint venture (Tri Origin Australia NL and Delta Gold NL), Annual report for EL 3425 and ML 739, to 25th February 1998. *Geological Survey of New South Wales, Report* GS1998/243 (unpublished).

RYALL, A.W. 1974. *Geology of the Grenfell area, NSW*. BA Honours thesis (unpublished) Macquarie University.

Samedan Oil Corporation of Australia 1982. Exploration report ELs 1486, 1538, 1624 and 1634, Wirrinya - Pullabooka - Bedgerebong area, Forbes district. *Geological Survey of New South Wales, Report* GS1982/315 (unpublished).

SCHWEBEL, P.J. 1982. John F Gilfillan & Associates Pty Limited, report on exploration of EL 1658, West Wyalong, New South Wales for period January-June 1982., *Geological Survey of New South Wales, Report* GS1981/544 (unpublished).

SCOTT, M.M. 1999. Structure and mineralisation at Condobolin, Lachlan Fold Belt, New South Wales. *Geological Society of Australia Abstracts* **53**, 239-240.

SHERWIN, L. 1973. Stratigraphy of the Forbes - Bogan Gate district. *Geological Survey of New South Wales, Records* **15**, 47-101.

SHERWIN, L. 1974. Llandovery graptolites from the Forbes district, New South Wales. *In* Graptolite studies in honour of O.M.B. Bulman. *Special Papers in Palaeontology* **3**, 149-175.

SHERWIN, L. 1975. Early Devonian fossils from Endeavour 6, 7 (Milpose Creek) and 10 Prospects, near Gunningbland. *Geological Survey of New South Wales, Report* GS1975/180 (unpublished)

SHERWIN, L. 1976. The Secrets section through the Cotton Beds north of Parkes. *Geological Survey of New South Wales, Quarterly Notes* **24**, 6-10.

SHERWIN, L. 1984. Fossils from the Morangarell 1:50 000 Sheet. *Geological Survey of New South Wales, Palaeontological Report 1984/1, Report* GS 1984/002 (unpublished).

SHERWIN, L. 1985. Fossils from the Marsden and Bogan Gate 1:100 000 Sheets. *Geological Survey of New South Wales, Palaeontological Report 1985/08, Report* GS 1985/187 (unpublished).

SHERWIN, L. 1986. Fossils from the Cootamundra 1:250 000 sheet area. *Geological Survey of New South Wales, Palaeontological Report 1986/5, Report* GS 1986/030. (unpublished).

SHERWIN, L. 1996. *Narromine 1:250 000 Geological Sheet SI/55-3: Explanatory Notes*. viii+104 pp. Geological Survey of New South Wales, Sydney.

SHERWIN, L. 1997. *Narromine 1:250 000 geological sheet, SI/55-3, Second Edition*. Geological Survey of New South Wales, Sydney.

SMITH, J.V. 1985. *Bumbaldry gold-silver-copper district, Central New South Wales: origin and evolution of the mineralisation*. BAppSc (Honours) Thesis, New South Wales Institute of Technology, (unpublished).

SMITH, R.E. 1969. Zones of progressive regional burial metamorphism in part of the Tasman Geosyncline, eastern Australia. *Journal of Petrology* **10**, 144-163.

STEVENS, B.P.J. 1975. A Metallogenic study of the Bathurst 1:250,000 sheet. *Geological Survey of New South Wales, Sydney*.

STEWART, J.R. & GLEN, R.A. 1986. An Ordovician age for part of the Girilambone Group at Yanda Creek, east of Cobar. *Geological Survey of New South Wales, Quarterly Notes* **64**, 23-25.

STRUSZ, D.L. 1984. Brachiopods from the Silurian of Fyshwick, Canberra, Australia. *BMR Journal of Australian Geology and Geophysics*. **9**, 107-119.

SUN, S.-S. & McDONOUGH, W.F. 1988. Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. In: Saunders, A.D. & Norry, M.J. (Editors), Magmatism in the Ocean Basins. *Journal of the Geological Society of London – Special Publication* **42**, 313-345

SUPPEL D.W. & POGSON D.J. 1993. *Nymagee Metallogenic Map*. Geological Survey of New South Wales, Department of Mineral Resources.

SUPPEL, D.W., WARREN, A.Y.E., WATKINS, J.J., CHAPMAN, J., TENISON WOODS, K. & BARRON, L. 1986. A reconnaissance of the geology and gold deposits of the West Wyalong-Temora-Adelong district. *Geological Survey of New South Wales Quarterly Notes* **64**, 1-23.

Swingler N. & K. & Associates Pty. Ltd. 1984. Assessment of Exploration Licence 2077 Condobolin, New South Wales. Nationwide Resources Pty. Ltd. *Geological Survey of New South Wales, Report* GS1984/081 (unpublished).

TIMMS, P.D. 1993. Final report, West Wyalong Project, West Wyalong, NSW, Exploration Licence 3971, St Joe Australia Pty Ltd. *Geological Survey of New South Wales, Report* GS1993/313 (unpublished).

WALLACE, D.A., & WYBORN, D. 1997. *Precious Metal Abundances in Ordovician Magmas of the Bathurst 1:250K Sheet Area - Guides to Mineralisation Potential.* Geological Society of Australia, Abstracts *44, 71.*

WARD, L.J. 1985. *The geology and geochemistry of the Cookeys Plains prospect.* BAppSc (Honours) Thesis, New South Wales Institute of Technology, (unpublished).

WARREN, A.Y.E., GILLIGAN, L.B. & RAPHAEL, N.M. 1995. *Geology of the Cootamundra 1:250 000 map sheet.* viii+160 pp. Geological Survey of New South Wales, Sydney.

WATT, J.A. 1899. Report on the Wyalong Goldfield. *Geological Survey of New South Wales, Mineral Resources* **5**, 40 pp.

WELLMAN, P.W., CUNDARI, A. & McDOUGALL, I. 1970. Potassium-argon ages for leucite-bearing rocks from New South Wales, Australia. Journal and Proceedings of the Royal Society of New South Wales **103**, 103-107.

WHALEN, J.B., CURRIE, K.L. & CHAPPELL, B.W. 1987. A-type granites: geochemical characteristics, discrimination and petrogenesis. *Contributions to Mineralogy and Petrology* **95**, 407-419.

WHITE, N.C. and HEDENQUIST, J.W. 1990. Epithermal environments and styles of mineralisation: variations and their causes, and guidelines for exploration. *Journal of Geochemical Exploration* **35**, 445-474.

WILLIAMSON, W.H. 1969. Cainozoic rocks outside the Murray basin - 3. The Lachlan Valley. In Packham, G.H. (Ed), The Geology of New South Wales. *Journal of the Geological Society of Australia*, **16**, 545-549.

WILLIAMSON, W.H. 1986. Investigation of the groundwater resources of the Lachlan Valley alluvium. Part 1: Cowra to Jemalong Weir. Water Resources Commission of New South Wales, Hydrogeological Report *1986/12.*

WILSON, I.R. & McNALLY, G.H. 1996. A geological appraisal of Tertiary deep leads in the Parkes-Forbes area. *The Geological Evolution of Eastern Australia. Sydney Universities Consortium of Geology and Geophysics, Abstracts* 71-73

WORMALD, R.J. & PRICE, R.C. 1988. Peralkaline granites near Temora, southern New South Wales: Tectonic and petrological implications. *Australian Journal of Earth Sciences* **35**, 209-221.

WYBORN, D. & SUN, S.-S. 1993. Nd-isotope "fingerprinting" of Cu/Au mineralisation in the Lachlan Fold Belt. *AGSO Research Newsletter* **19**, 13-14.

WYBORN, D., TURNER, B.S. & CHAPPELL, B.W. 1987. The Boggy Plain Supersuite: A distinctive belt of I-type igneous rocks of potential economic significance in the Lachlan Fold Belt. *Australian Journal of Earth Sciences*, **34**, 21-43.

YOUNG, G.C. 1993. Middle Palaeozoic macrovertebrate biostratigraphy of eastern Gondwana. Chapter 9, 208-251, In: Long, J.A. (Editor) *Palaeozoic Vertebrate Biostratiography and Biogeography.* Belhaven Press, London.

YOUNG, G.C. 1994. Palæontological evidence on the age of volcanics ('Dulladerry Rhyolite') underlying the late Devonian Hervey Group in central New South Wales, *Professional Opinion*, 1994/007, Australian Geological Survey Organisation, Canberra.