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GOLD METALLOGENY OF AUSTRALIA

by

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ABSTRACT

The gold metallogeny of Australia is predominantly confined to the Archaean and Palaeozoic Provinces. The Archaean gold occurrences are predominantly hosted in ultramafic-mafic dominated greenstone belts, with less associated to felsic-volcanic and sedimentary sequences. Most gold occurrences are confined to shear zones or faults, and adjacent host rocks. Recent discoveries of economic laterite-hosted deposits, are presently under investigation and will supply a significant proportion of production in the future.

The Proterozoic gold deposits of Australia, are confined to geosynclinal sequences, commonly turbidites (eg : Telfer), with other hydrothermal deposits associated directly to granites. An important feature of the North Australian Craton deposits, is the spatial association of most deposits to granite bodies, although a genetic link has not been established conclusively. The Roxby Downs deposit in South Australia is a unique occurrence of gold in association to copper, uranium and R.E.E. This deposit is tentatively related to intraplate alkaline-magmatism, with further work necessary.

The most significant recent discovery of gold mineralization in Australia is in the Drummond Basin in Queensland. This epithermal mineralization, associated to acid-volcanic centres, is tentatively related to mineralization within the Georgetown Inlier. The latter mineralization is Permo-Carboniferous, in a Proterozoic (and possibly Archaean) sequence of schists. It is tentatively suggested that all the gold mineralization in northern Queensland may be related to single tectonic event, a feature which requires further study. Other mineralization in the Phanerozoic includes the turbidite-hosted metamorphogenic deposits of Victoria, the rift related deposits in New South Wales and magmatic related deposits in Queensland.

The gold deposits in Australia may in the future be classified in a tectono-geological framework, similiar to the layout of this dissertation, particularly once further data becomes available on recent discoveries.

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1. INTRODUCTION

The history of gold mining in Australia extends back to 1823, with the first discovery of the precious metal near Bathurst in New South Wales (Blainey, 1963 in King, 1975). Since this time, the gold industry in Australia has fluctuated quite dramatically, particularly around the 1850's during the gold rush days. Currently there is a resurgence of interest in all aspects of the metal from exploration to mining. With this in mind the choice of **Gold Metallogeny of Australia** as a topic for this dissertation was a timely one.

It would be presumptuous to think that this dissertation has adequately described the many tens of thousands of gold occurrences in Australia in detail. The main objectives are rather, to describe the major occurrences of gold, the geological and tectonic framework of these occurrences, and to present a more or less standardized format in which further discoveries of importance may be included. Previous workers in this field have to a large extent confined descriptions to individual deposits or provinces, without taking note of the grander scale of features. A number of obvious constraints are applied (or inevitable) in a study such as this, including availability of data (eg. lack of 1:250 000 Geology Sheets and descriptions), and a lack of personal experience in the areas described. Where possible, the latest available information is used, including non-scientific publications such as the Gold Gazette and the Mining Journal.

The broad frames of reference in this dissertation are time boundaries, the Archaean, Proterozoic and Phanerozoic, which also reflect fundamentally different tectonic regimes. Within this framework the most important gold-rich geological provinces are described in terms of general geology, tectonic environment (and in some instances evolution), and gold mineralization. The latter concentrates on the different styles of mineralization in each area, and in some instances, the different deposits of an area.

The availability of information within the framework presented, is reflected in the detail (or lack thereof), in which each domain is described. With recent developments in the industry being so rapid, little information is available on the newer deposits, particularly in Western Australia and Queensland. It is suggested, that format of the dissertation as presented, is suitable for the inclusion of new information, and the future classification of all the gold deposits in a broad tectonic and geological framework.

The final section of this dissertation is a synthesis of the important gold-provinces, identifying areas of potential, and various features occurring consistently throughout a single area or including adjacent areas. The conclusions drawn in this section, are based on the research undertaken during the writing of this dissertation. It is hoped that this dissertation supplies a general background to the geological and tectonic framework of the many different types of gold occurrences in Australia, for those unfamiliar with the **Gold Metallogeny of Australia.**

2. GEOLOGICAL AND TECTONIC FRAMEWORK OF AUSTRALIA - General Review and Nomenclature

The Australian continent can be subdivided into three broad geological provinces, the Western, Central and Eastern Cratons (Figure 2.1 a). The tectonic provinces of the continent have been described in many publications including Brown et al., (1968), Compston and Arriens (1968), Warren (1972), Rutland (1973, 1976, 1981), Denmead et al., (1974), Fisher and Warren (1975), Plumb (1979 a,b), Gee (1979), Hunter (1981), and Harrington and Korsch (1985 a,b) amongst others. Some of the above publications specifically refer to a selected tectonic province while others concentrate on the Australia-wide concepts. The tectonic framework adopted for this dissertation is modified after Plumb (1979 a, Figure 2.1 b), with the geological framework after Palfreyman (1984, Figure 2.2). Within the individual tectonic provinces (Figure 2.1 b), detailed descriptions of the geology and tectonics include those by Gee (1979; Western Australian Shield), Plumb (1979 b, Northern Australian Precambrian), Groves and Batt

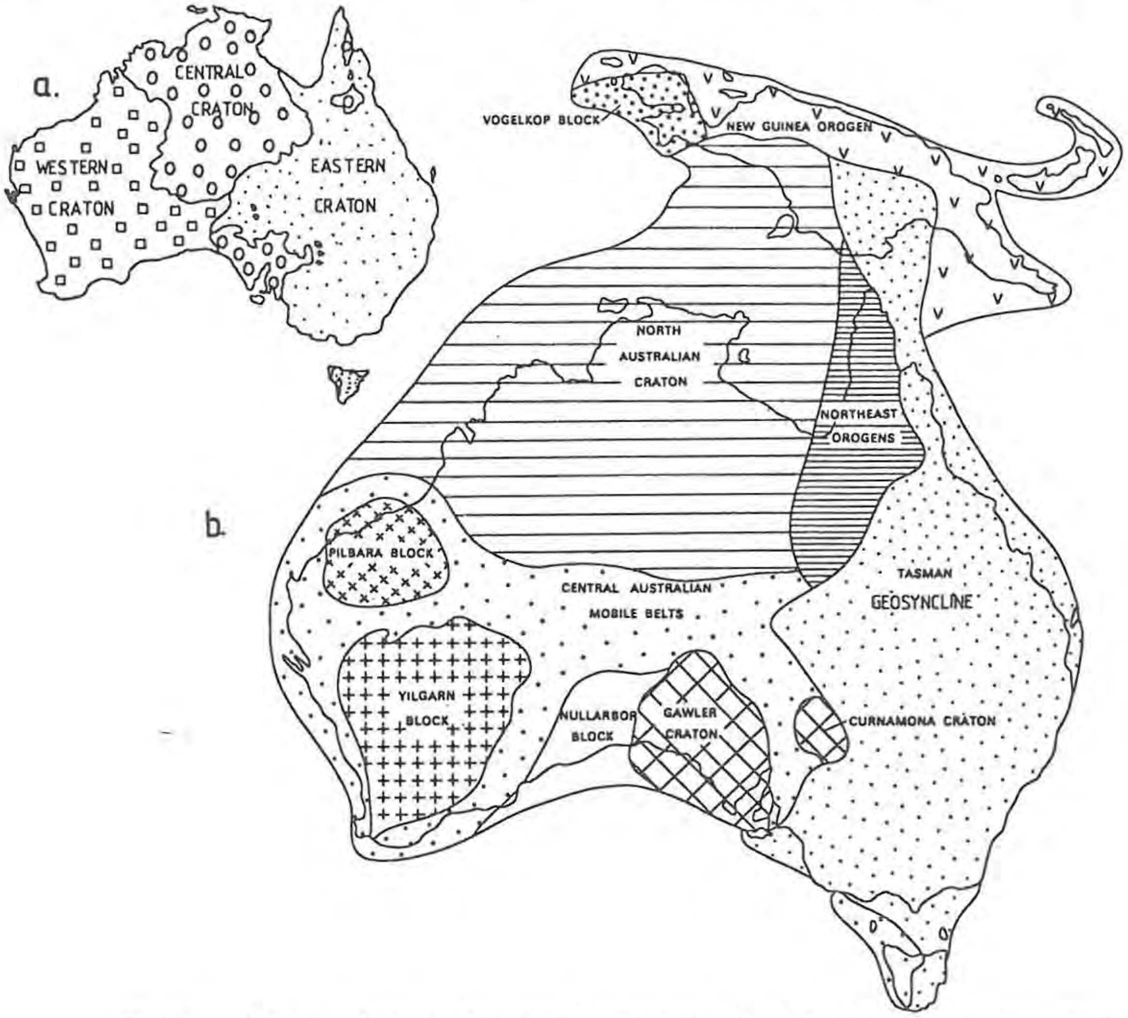

Figure 2.1 : (a) Geological framework of the Australian continent (Palfreyman, 1984); (b) Tectonic framework of Australia, used in this dissertation (slightly modified after Plumb, 1979 a).

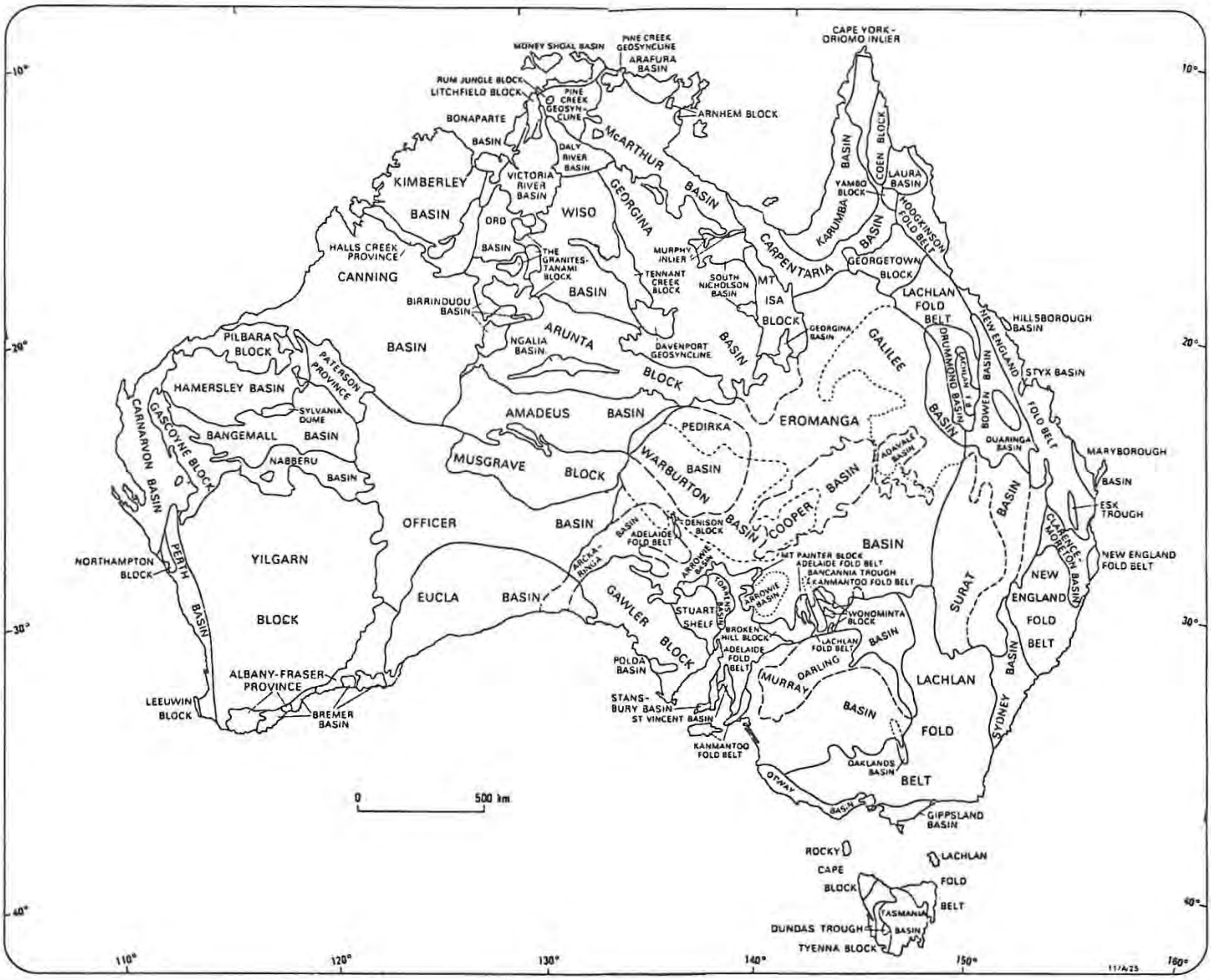

Figure 2.2 : Geological sub-divisions of the Australian continent (Palfreyman, 1984).

(1984; Western Australian Shield), Glickson (1976; Western Australian Greensone Belts), Harrington and Korsch, (1985 a,b; Palaeozoic in New South Wales) and, Solomon and Griffiths (1972; Tasman Orogenic Zone).

The nomenclature used in describing the tectonic history of Australia is as varied, as the publications available. For the purposes of this dissertation the following terminology is used (after Bates and Jackson, 1980; Warren, 1972; Plumb 1979 a).

Tectonic Province: this refers to a large area with a characteristic group of features which serve to distinguish it from adjacent areas. The features are tectonic such as lithologies and strucutre. A tectonic province may contain cratons, fold belts, basement inliers, sedimentary basins and mobile belts.

Craton: is a part of the Earth's crust which has attained stability following a number of orogenic cycles, and is usually in areas that have been subsequently covered by Platform Cover sequences. A craton may consist of a number of different tectonic units (eg. Yilgarn Craton).

Orogenic Cycle: is an evolutionary cycle involving intitial deposition of sediments and or volcanics (Geosynclines), followed by deformation (Orogeny), and plutonism/metamorphism (Metamorphic Belts).

Orogeny: is the process by which geosynclinal sequences form mountain belts by deformation (thrusting, folding and faulting in the outer and upper layers, and plastic folding in the inner and deeper layers), metamorphism and plutonism (in the inner and deeper layers).

Orogenic Belt: is a mobile belt which has been subjected to post-orogenic tectonism.

Mobile Belt: is a geosyncline which has been subjected to the early phases of an orogeny.

Transitional Domain: an area of late- to post- orogenic tectonism associated with the last stages of cratonisation and is transitional between orogenic and cratonic domains.

Orogenic Domain: is in part equivalent to an Orogenic Belt and a Mobile Belt. The domains were belts of intense tectonism involving the filling and deformation of ortho-geosynclines or the development of metamorphic and igneous complexes prior to cratonization.

Fold Belt: is a synonym for Orogenic Belt.

Platform Cover: is a group of sedimentary basins which developed more or less at the same time and in the same way, and overlie the immediately preceeding Orogenic Domain and Transitional Domain, and spread across older Cratons and Platform Covers.

The above terminology is necessarily simplified to allow flexibility in interpretation of different tectonic units. A geochronological order simplifies the discussion of geological and tectonic units, and their evolution. The Archaean consists of the Pilbara and Yilgarn Cratons, the Proterozoic consists of the North Australian Craton, the Gawler Craton, the Curamona Craton, the North-east Orogens and the Central Australian Mobile Belts, and the Phanerozoic is dominantly the Tasman Geosyncline* (Figure 2.1).

This chronological framework reflects the complete history of Australia and hence the evolution from Archaean tectonics to modern plate tectonics (see Windley, 1984). The Archaean in Australia is an area of stability from 2300 Ma, which influenced the emplacement and deposition of Proterozoic rocks, in a dominantly geosynclinal (basinal) environment. The Phanerozoic rocks in Australia show the characteristics of active plate margin tectonics, a feature not readily observed in earlier terrains. In preference to presenting an all encompassing tectonic model of evolution for the Australian continent, the individual provinces descriptions in the following sections consist of a review of tectonic processes affecting those areas, and the geological characteristics.

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* The term Geosyncline is adopted in preference to Orogen or Fold Belt to avoid confusion with sub-divisions within the Tasman tectonic province.

3. ARCHAEAN

The Archaean of Australia consists of the Yilgarn and Pilbara Cratons in the Western Australian Shield, (Figure 3.1) and possibly some minor Archaean basement fragments in the North Australian Craton (Plumb, 1979 a,b). The geological and tectonic evolution of Archaean rocks in general, has been discussed previously by numerous authors including Glickson (1976), Condie (1975,1981), Goodwin and Smith (1980) and Windley (1984). With particular reference to the evolution and geology of the Western Australian Archaean cratons, key papers include; Compston and Arriens (1968), Glickson (1976), Gee (1979), Gee et al., (1981), Hickman (1981), Groves and Batt (1984) and Hallberg (1986). In this dissertation the geology of the two cratons is predominatly taken from Gee (1975), and the interpretative geology and tectonics is taken from Gee et al., (1981) and Groves and Batt (1984).

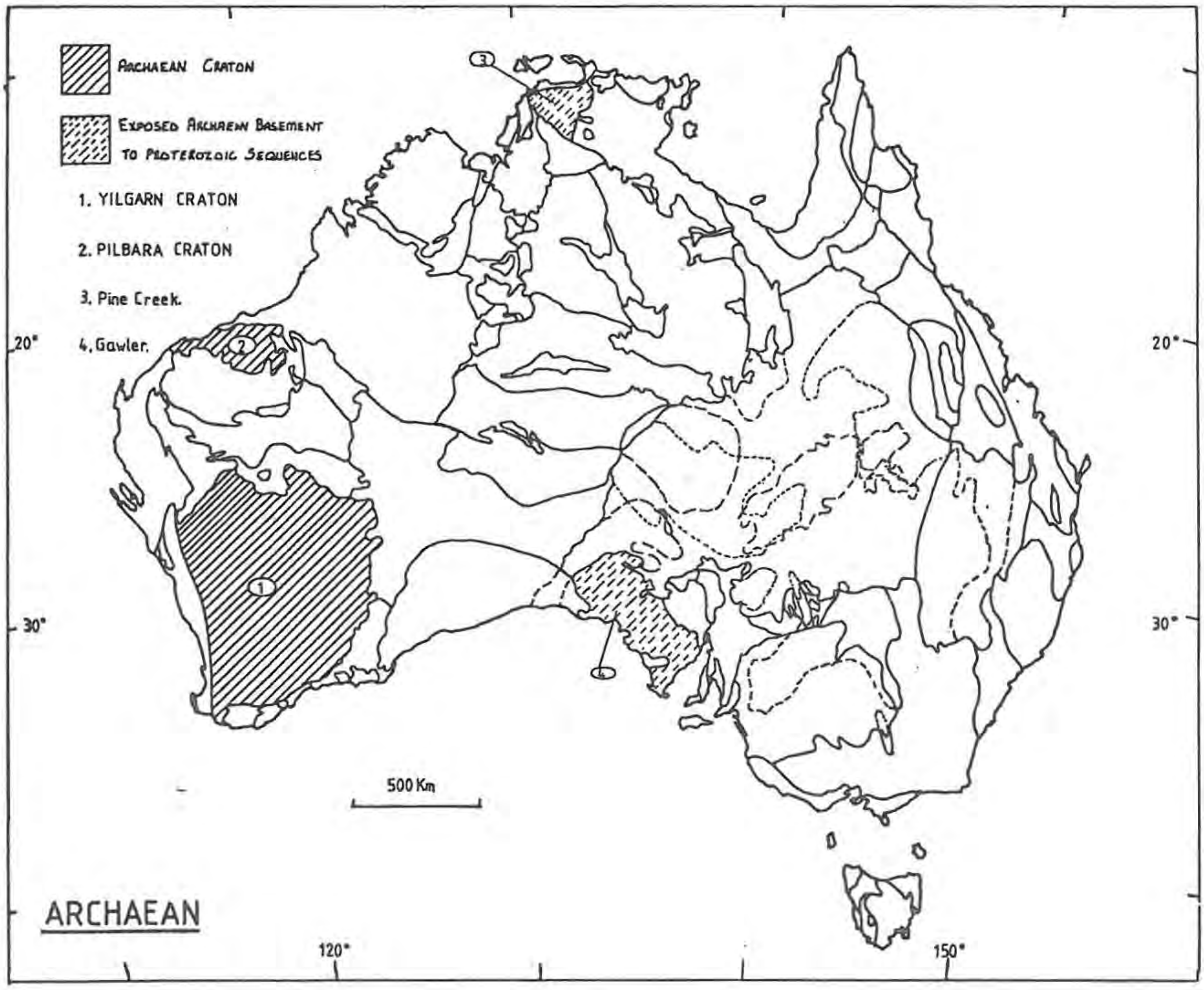


Figure 3.1 : Distribution of Archaean rocks in Australia (Modified after Palfreyman, 1984 and Plumb, 1979 a).

3.1 Yilgarn Craton

3.1.1 Geology

The Yilgarn Craton consists of three major structurally and geologically distinct provinces (Figure 3.2), the Southwestern, Murchison and Eastern Goldfields Provinces (Gee, 1975). The Southwestern Province consists of shallow water sediments which have been deformed and metamorphosed repeatedly, and intruded by mafic and ultramafic rocks, which formed the Western Gneiss terrain. The granite-greenstone terrains are the Murchison and Eastern Goldfields Provinces, consisting of pre-, syn- and post-tectonic granitoids (70%) and greenstone belts (±30%). The pre-tectonic types are gneisses, that occur predominantly in the Southwest Province, with minor occurrences in the other provinces. The syn-tectonic (± 2.6 Ga) granites are discrete domal and/or coalesing plutons with indistinct intrusive contacts and a strong tectonic fabric. The post-tectonic granitoids have distinct contacts with, and are discordant to the syn-tectonic granitoids (Gee et al., 1981), and greenstone belts.

The main deformational and metamorphic event in the Yilgarn Craton occurred at 2.2 Ga, represented by a zonation from a lower-amphibolite facies (high-grade regime) in the southwest, gradational to a greenschist facies (low-grade regime) in the northwest.

Groves and Batt (1984), subdivide the Yilgarn Craton, on an interpretative and metallogenic basis, with further subdivision of greenstone belts on the basis of types of depositories, interpreted from lithological associations. The level of erosion in greenstone belts is predominantly higher in the north and lower in the south (Gee et al., 1981). The main lithological associations in the greenstone belts are the mafic-ultramafic volcanic, felsic volcanic and sedimentary associations. The mafic-ultramafic association comprises tholeiites, komatitic basalts and peridotites. The komatitic lavas do not have a specific association to lower levels of the stratigraphy (Gee et al., 1981), a feature that has been regarded as characteristic to greenstone belts (eg. Barberton Greenstone Belt, Belt, Anhaeusser, 1976). There is however a close spatial and temporal relationship between tholeiites and komatiites in the stratigraphic

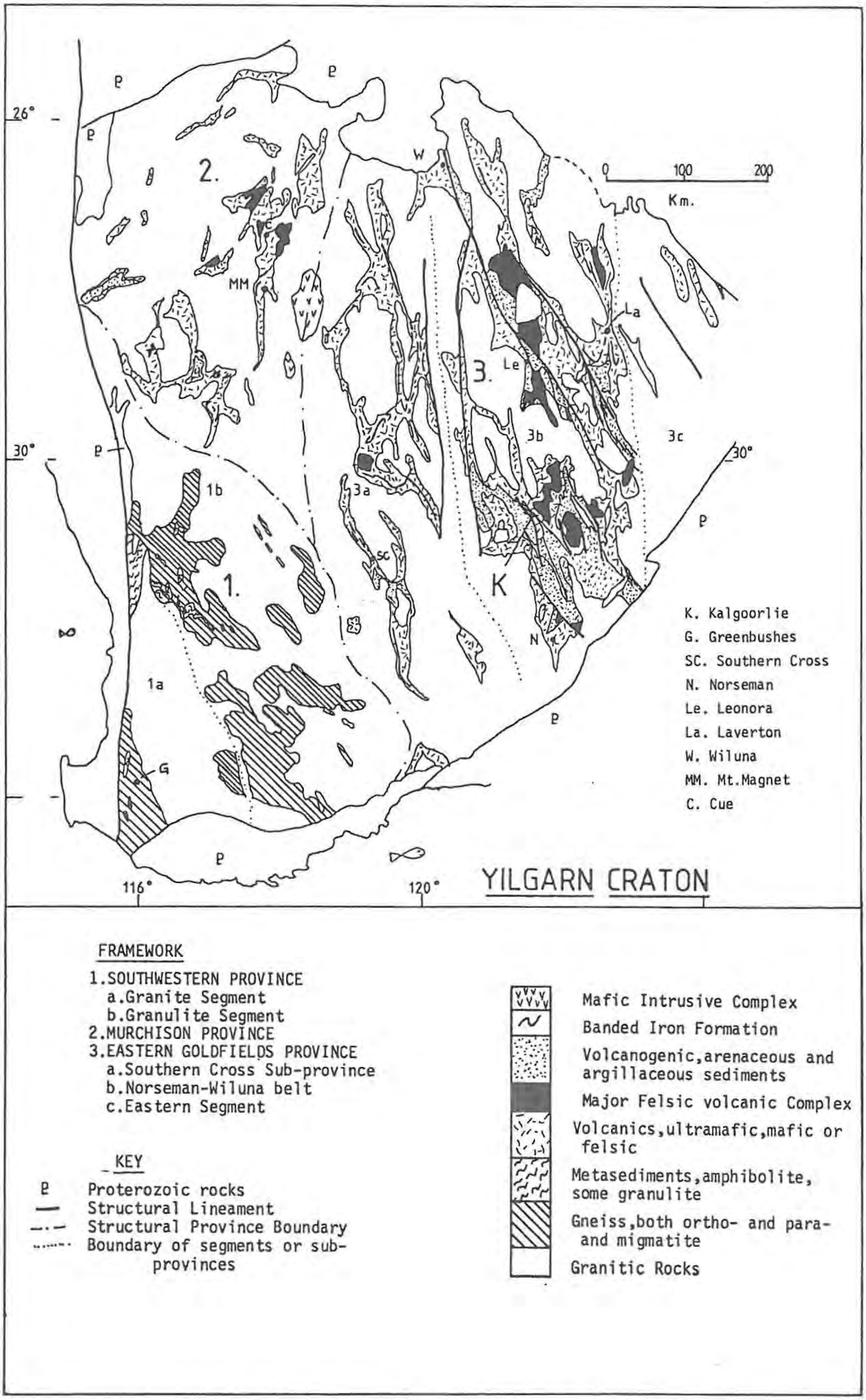


Figure 3.2 : Geology of the Yilgarn Craton (after Gee, 1975).

successions of the Yilgarn Greenstone Belts, and peridotites may occur in the felsic volcanic or sedimentary associations.

The felsic volcanic association consists of complexes containing agglomerates, tuffs, minor lavas and subvolcanic intrusives (Gee et al., 1981), and in some instances ignimbrites and ash fall tuffs. The ignimbrites and ash fall tuffs indicate a change from submarine to subaerial volcanism which occurred on a local scale. A further suggestion by Gee et al., (1981), is that beds of graded ash-tuff and cherts in the generally coarse agglomerate sequences, could possibly represent caldera deposits. The tectonic environment for the felsic volcanism (prior to becoming subaerial) is a quiet sea floor, with individual volcanic centres (Gee et al., 1981), and associated chemical sedimentation. As mentioned above the volcanism may have become subaerial at a later stage.

The sedimentary association commonly occurs at higher levels in the stratigraphy and consists of conglomerates, sandstones and shales, indicating a shallow marine basin depository. Chemical sediments (cherts) occur within the sedimentary successions, usually in association with felsic volcanics, indicating a possible deeper water reducing environment, relative to the clastic sediments (the latter containing evidence of cross-bedding and mud cracks, Gee et al., 1981).

The interpretative review of Groves and Batt (1984) of the West Australian Archaean, defined four major tectonic terrains on the basis of lithologies, structure and mineralization. This subdivision is in essence similiar to that proposed by Lowe (1982), which defined older (3.55 - 3.3 Ga) greenstone belt volcanic sequences accumulated in a shallow water depository as anorogenic volcanic platforms, and younger (2.8-2.6 Ga) greenstone belts with volcanic sequences deposited in deeper water depositories. The Groves and Batt (1984) subdivisions are high grade gneiss terrains, granite-greenstone terrains, intracratonic basins and late-Archaean complexes (Table 3.1), of -which the granite-greenstone terrains are further divided into older and younger greenstone belts, and rift-phase or platform phase greenstone belts. The charactersitics of the Groves and Batt (op cit) subdivisions are shown in Tables 3.1 and 3.2.

Major features	High grade gneiss belts	Granitoid-greenstone terrains	Intracratonic basins	Late Archaean complexes
1. Age	ca. 3.8 Ga and younger	Largely ca. 3.5 – 2.7 Ga	ca. 3.0 – 2.4 Ga	ca. 2.6 – 2.4 Ga
2. Lithofacies	Mainly granitic orthogneiss. Supracrustals dominated by shelf and lesser trough sediments intruded by ultramafic, mafic and/or anorthositic bodies. Volcanics rare	Mainly intrusive granitoids and derived gneisses. Supracrustals dominated by early mafic-ultramafic and lesser felsic volcanics and later clastic sediments	Shallow marine to fluvial clastic sediments including significant conglomerate sequences. Subaerial basalt sequences may be developed	Mainly granitic orthogneiss and variable paragneisses derived from sedimentary and volcanic precursors
3. Structure	Widespread early subhorizontal deformation including major recumbent folding and thrusting. Subsequent upright folding. Major dyking between deformation stages. Generally high strain	Local evidence for subhorizontal deformation and transition to gneiss belts. Structural trends dominated by upright folding and diapiric uprise of granitoids. Generally low strain	Relatively mild deformation. Normal faulting common, but folding and reverse faulting also present in parts of the basins. Low strain	Complex deformation involving both subhorizontal structures and upright folding. Generally high strain
4. Metamorphism	Complex polymetamorphic history. Generally granulite facies or amphibolite-granulite transition	Single-stage prograde metamorphism with local retrogression. Generally greenschist facies or below, with zones of amphibolite facies commonly developed adjacent to granitoids	Generally sub-greenschist facies metamorphism	Variable metamorphic grade, generally amphibolite facies
5. Subsequent history	Commonly site of later Proterozoic tectono-thermal mobile belts	Commonly site of late Archaean or early Proterozoic sedimentary basins	Commonly site of Proterozoic or younger sedimentary basins	Commonly basement to early Proterozoic shelf to trough sedimentary basins
6. Metallogenic associations (with major review articles where appropriate)	Terrains poorly mineralized. Generally subeconomic associations include anorthosite-chromite, volcanic- or sedimentary-hosted disseminated Cu, ultramafic-mafic intrusive Ni-Cu, stratiform Au, and pegmatite Sn-Ta (largely related to younger granitoids)	Terrains heterogeneously but extensively mineralized. Major associations include: i) komatiite Ni-Cu ± PGE (Marston et al. 1981). ii) volcanogenic Fe-Cu-Zn massive sulphide association (Franklin et al. 1981) iii) Volcanic- and BIF-hosted Au (Boyle 1979); probably largely metamorphogenic deposits (Kerrich and Fryer 1979) iv) pegmatite Sn-Ta-Li v) layered intrusion chromite-asbestos-talc-magnetite (Anhaeusser 1976b) vi) Algoma-type BIF iron	Terrains contain some of the major sedimentary ore deposits of the world, including: i) quartz-pebble conglomerate Au-U (Pretorius 1981) ii) Superior-type BIF enriched Fe (Bayley and James 1973) Other deposit types include stratiform Mn, disseminated Cu in altered basalts, shale-hosted Au and small Pb-Zn-F deposits	Terrains, themselves, are generally poorly mineralized, although they may host small base-metal deposits and pegmatite Sn-Ta associations. However, they exert an important control on U deposits located at or adjacent to the unconformity with overlying Lower Proterozoic sedimentary sequences – the so-called unconformity-type U deposits (Nash et al. 1981)

Table 3.1 : Features of different Archaean terrains including metallogenesis (Groves and Batt, 1984).

Older terrains (3.5 – 3.0 Ga)	Younger terrains (3.0 – 2.7 Ga)
Platform-phase greenstones	
1. Maximum exposure of terrain is ca. 50000 km^2 (east Pilbara)	1. Maximum exposure of terrain is ca. 300000 km^2 (Murchison and Southern Cross Provinces)
2. No unequivocal basement exposed; sialic basement inferred from indirect evidence	2. Earlier sialic crust exposed in some terrains; sialic crust inferred in others
3. Gross tectonic pattern of more or less equi-spaced granitoid domes with intervening greenstones	3. Gross tectonic pattern of more or less equi-spaced granitoid domes with intervening greenstones
4. Formation interval 300 – 500 Ma; metamorphism at least 300 Ma after earliest volcanics	4. Formation interval 100 – 300 Ma; metamorphism at least 200 Ma after earliest volcanics
5. Coherent volcanic stratigraphy; indirect evidence of more or less constant thickness of greenstone pile	5. Coherent volcanic stratigraphy; indirect evidence of more of less constant thickness of greenstone pile
6. Basalts dominate volcanic sequences; komatiites and felsic volcanics rare	6. Basalts dominate volcanic sequences; komatiites and felsic volcanics rare
7. Very shallow-water depositional environments; sediments include subaerial to shallow-water volcaniclastic sediments, evaporites and accretionary lapilli	7. Variable depositional environments, but very shallow-water basins rare or absent; sediments include shallow-water clastics, turbidites and BIF
8. Anomalous metallogenic associations include evaporative barite, small Pb- and sulphate-rich volcanogenic massive sulphides and porphyry-style Mo-Cu. Fe-sulphides rare. Gold deposits small and dispersed. Komatiite-associated Ni-Cu deposits absent. Mineralization potential low	8. Widespread volcanic-hosted and BIF-hosted gold deposits. Generally relatively small volcanogenic massive Cu-Zn sulphides and komatiite-associated Ni-Cu deposits are widely dispersed. Fe-sulphides common. Mineralization potential higher than older counterparts, but lower than rift-phase greenstones
Older terrains (3.5 – 3.0 Ga)	Younger terrains (3.0 – 2.7 Ga)
Rift-phase greenstones	
1. Maximum exposure of terrain is ca. 10000 km^2 (West Pilbara)	1. Maximum exposure is ca. 150000 km^2 (Norseman-Wiluna Belt)
2. Developed on earlier greenstone belts of platform phase	2. Probably partly developed on earlier platform-phase greenstones and partly on thinned sialic crust
3. Gross tectonic pattern is linear	3. Gross tectonic pattern markedly linear with elongate granitoid domes and strike-slip faults
4. Formation interval unknown	4. Formation interval probably less than 100 Ma.
5. Thick turbidite sequences; complex stratigraphy where volcanics present	5. Complex volcanic stratigraphy; may have elongate zones dominated by felsic volcanics
6. Felsic volcanics and/or komatiites present where volcanics occur	6. Komatiites and/or felsic volcanics widespread; thick volcanic sequences developed
7. Variable sedimentary environments, but dominant deposition in deep troughs; sediments dominated by turbidites	7. Variable depositional environments ranging from subaerial to deep water troughs in axial zones of rift; sediments include turbidites and sulphidic shales/cherts
8. Variable metallogenic associations include Sb- or Bi-rich gold deposits, small volcanogenic massive Cu-Zn sulphides and small gabbroid-associated Ni-Cu deposits. Mineralization potential greater than adjacent platform-phase greenstones, but much lower than younger counterparts	8. Major metallogenic associations; commonly spatial overlap of two or more major mineralization types. Important deposits include volcanogenic massive Cu-Zn sulphides, komatiite-associated Ni-Cu deposits and volcanic-hosted gold deposits. Greatest mineralization potential of all greenstone terrains

Table 3.2 : Characteristic features of platform-phase and rift-phase greenstone belts, within older - and younger terrains (Groves and Batt, 1984).

The Yilgarn and Pilbara Cratons of Western Australia, contain some of the largest gold deposits currently being exploited. Recent studies of mineralization and the cratons include those by Woodall (1979), Groves and Batt (1984), Phillips (1985 a,b), Groves et al., (1985), Phillips (1986), and Groves et al., (1986). The studies of styles of mineralization in the Archaean (in addition to those above) include; Groves et al., (1984), Hodgson (1985) and (in part) Rossiter (1984).

3.1.2 Gold Mineralization

The distribution of gold deposits in the Archaean of Western Australia is shown in Figure 3.3. The most obvious feature of the West Australian Cratons is the abundance of gold deposits in the Kalgoorlie region, "the Golden Mile", and the apparent lack of deposits, in the western portions of the Yilgarn Craton, and in the Pilbara Craton. The majority of deposits occur within greenstone belts in these cratons. Important Western Australian Archaean gold deposits have been classified according to host rock composition and style of mineralization by Groves et al., (1985), and this classification is given on Table 3.3. The characteristics of the gold deposits in the Western Australian Shield can be summarized as follows : (from Phillips, 1985 a; Groves et al., 1985).

i. most deposits occur in B.I.F.'s (banded iron formations) or tholeiitic basalts or dolerites,

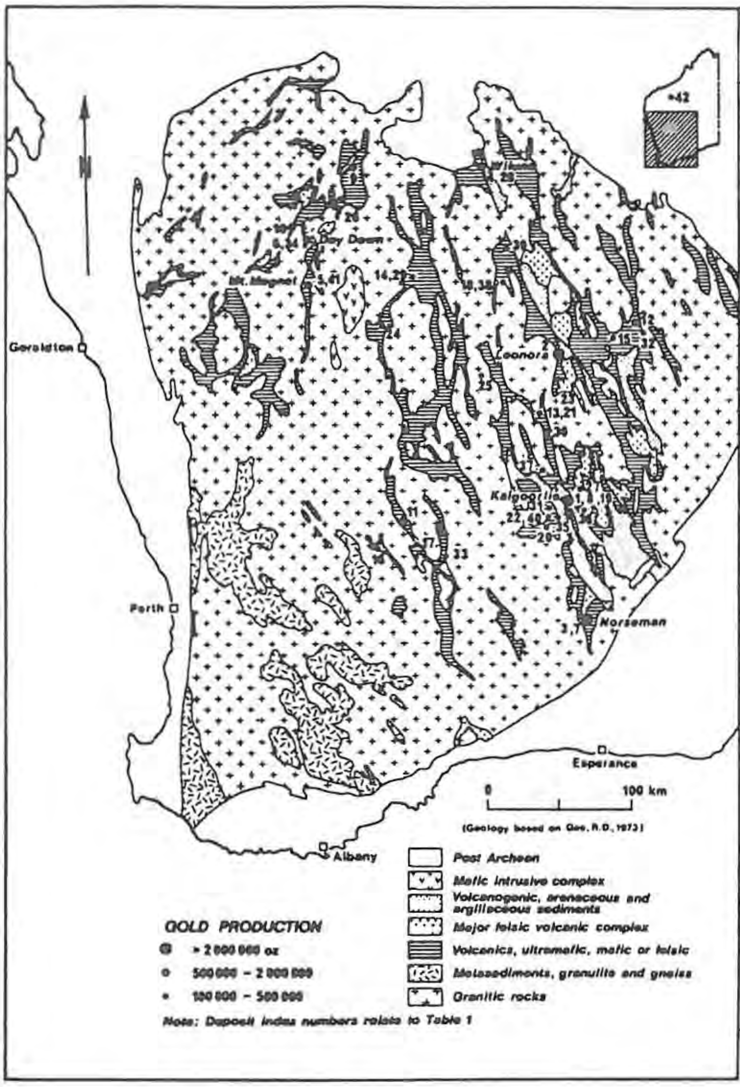
ii. most deposits have a strong structural control in the form of faults, shear zones or stockworks,

iii. most deposits have a larger down dip extension than surface width or length dimension,

iv. most deposits in sub-amphibolite metamorphic facies rocks have distinct alteration haloes (K-mica, ankerite-siderite and iron sulphide alteration surrounded by carbonation),

v. within the deposits gold occurs as sub-microscopic grains associated to sulphides in the alteration assemblage or B.I.F. types, rather than the quartz veins (with exceptions),

vi. distinctive metal associations with gold, usually one of; silver, arsenic, boron and tungsten, with generally low levels of base-metal concentrations, and no apparent zonation of metals, laterally or vertically.



Reference Fig. 9	Deposit	Mining Centre	Tonnes of ore	Gold Production		Grade g/tonne
				Kg	Oz. $(x10^3)$	
1	Golden Mile	Kalgoorlie	94,514,178	1,120,947	36,039	11.9
2	Sons of Gwalia	Leonora	7,254,395	82,025	2,637	11.3
3	Mararoa-Crown	Norseman	5,434,775	65,996	2,122	12.1
4	Wiluna	Wiluna	7,810,552	45,657	1,468	5.8
5	Hill 50	Mt Magnet	3,219,720	42,208	1,357	13.1
6	Great Fingall	Day Dawn	1,927,219	38,550	1,239	20.0
7	Princess Royal	Norseman	1,605,618	37,008	1,190	23.0
8	Mt Charlotte	Kalgoorlie	7,795,340	33,201	1,067	4.3
9	Paddy's Flat	Meekatharra	1,726,214	27,890	897	16.2
10	Big Bell	Big Bell	5,694,357	23,077	742	4.1
11	Copperhead	Bullfinch	3,935,524	20,552	661	5.2
12	Lancefield	Laverton	1,587,706	16,464	529	10.4
13	Lady Shenton-Crusoe Line	Menzies	440,559	14,383	462	32.6
14	Oroya Black Rge	Sandstone	754,214	12,097	389	16.0
15	Westralia	Mt Morgans	815,793	11,705	376	14.3
16	Edna May	Westonia	575,104	11,191	360	19.5
17	Fraser's	Southern Cross	851,631	9,392	302	11.0
18	Emu	Lawlers	1,107,025	8,677	279	7.8
19	Hannan's North	Kalgoorlie	591,339	8,553	275	14.5
20	Brubanks-Main Reef	Burbanks	386,684	8,544	275	22.1
21	Princess May	Menzies	526,242	8,515	274	16.2
22	Bayley's	Coolgardie	508,540	8,490	273	16.7
23	Cosmopolitan	Kookynie	558,881	8,360	269	15.0
24	Youanmi	Youanmi	715,330	8,265	265	11.6
25	Timoni	Mt Ida	477,933	7,486	241	15.7
26	Triton	Reedys	730,471	7,116	229	9.7
27	White Feather	Kanowna	429,954	7,078	228	16.5
28	Moonlight Wiluna	Wiluna	899,332	6,775	218	7.5
29	Black Range	Sandstone	264,628	6,447	207	24.4
30	Gladsome-Sand Queen	Comet Vale	249,017	5,662	182	22.7
31	Bonnievale	Bonnievale	343,098	5,482	176	16.0
32	Ida H.	Laverton	235,214	5,347	172	22.7
33	Palmer's Find	Mt Palmer	310,728	4,928	158	15.9
34	Main Line-Light of Asia-Cue #1	Cue	194,131	4,593	148	23.7
35	Barbara-Surprise	Hampton Plains	284,640	4,485	144	15.8
36	Golden Ridge	Golden Ridge	254,847	4,368	140	17.1
37	Gimlet-Slippery Gimlet-Victorious	Ora Banda	409,967	4,328	139	10.6
38	Gt Eastern	Lawlers	222,083	4,151	122	18.7
39	Bellevue	Sir Samuel	252,340	4,033	130	16.0
40	Tindals	Coolgardie	547,065	4,023	129	7.4
41	St George	Mt Magnet	477,190	3,663	118	7.7
42	Comet	Marble Bar	125,281	3,513	113	28.0
	TOTAL PRODUCTION			2,174,000		

Statistics are to December 1977 and based on records of the W.A. Mines Department except for Mararoa-Crown and Princess Royal which are to June 1978 based on mine records.

Figure 3.3 : Distribution of important gold deposits in the Yilgarn Craton (Woodall, 1979).

Mineralization Style	Important Deposits	Maximum Size	Host Rocks in Order of Importance	Size of Ore Shoots			Ore Mineralogy	Alteration
				length	width	depth		
Alteration haloes ± quartz vein systems in shear zones (low metamorphic grade)	Golden Mile Oroya Sons of Gwalia Harbour Lights	1 000+ t Au	Tholeiitic dolerite, tholeiitic basalt, ultramafic rocks, granitoids	10s m to ~2 km	1 m to 50 m	10s m to 1,5 km	quartz-pyrite (±pyrrhotite) ±carbonate ±K–V–Cr–mica ±chlorite ±arsenopyrite	Restricted K-mica, Fe-sulphides, more extensive carbonation
Persistent laminated quartz veins (low metamorphic grade)	Mararoa–Crown Princess Royal Great Fingall	70+ t Au	Tholeiitic basalt, tholeiitic dolerite, ultramafic rocks	100s m to 1,2 km	0,5 m to 10 m	10s m to 300 m	Quartz with very minor Fe-sulphides	Restricted K, Cr-mica, chlorite, amphibole, carbonate
Quartz stockworks (low metamorphic grade)	Mt Charlotte Paddington	50+ t Au	Granophyric units in differentiated tholeiitic dolerite, felsic porphyries	10s m to 500 m	25 m to 50 m	10s m to 1,5 km	Quartz, K-mica carbonate, Fe-sulphides ±arsenopyrite	Restricted K-mica, Fe-sulphide, more extensive carbonation, arsenopyrite
Disseminated stratabound deposits (high metamorphic grade)	Big Bell (Spargoville)	120 t Au	Altered basalt/ dolerite (greywacke)	10s m to 500 m	5 m to 40 m	10s m to 1,5 km	Muscovite, K-feldspar, Fe-sulphides, quartz	Biotite-rich envelope around lode schist
BIF replacement deposits (low to high metamorphic grade)	Hill 50 Lancefield Copperhead Westralia Nevoria Water Tank Hill	45 t Au	Oxide facies BIF, ferruginous chert, shale, carbonate facies BIF	10s m to 450 m	1 m to 45 m	10s m to 850 m	Quartz, chert, Fe-sulphides ± carbonate carbonaceous material	Some carbonation and chlorite, rare micas

Table 3.3 : Classification of Archaean gold deposits, giving characteristic features and examples of different styles of mineralization (Groves et al., 1985).

Of importance when considering the Western Australian Shield, is the identification of different types of mineralized and tectonic terrains. Groves and Batt (1984) proposed a model of the tectonic framework of Yilgarn and Pilbara Craton which is a modification on a theme previously proposed by Gee et al., (1981) and Lowe (1982). This interpretative model of Groves and Batt (op. cit.) distinguishes two main phases of greenstone belts developments, (Table 3.2) the Platform-phase and Rift-phase (Figure 3.4).

The Platform-phase greenstone belts occur in older terrains (3.5-3.0 Ga) and younger terrains (3.0-2.7 Ga), and have characteristically shallow water lithologies (eg. vesiculated pillow lavas). The older platform phase greenstones are poorly mineralized due to the restricted komatiitic magmatism which has previously been interpreted as a source rock for gold mineralization (Keays, 1984; Groves and Batt, 1984). This lack of komatiitic magmatism has been related to a lack of, or poor rate of extension. The younger platform phase greenstones have a more extensive volcanic record, and developed in a tectonically-active platform environment (Lowe, 1982; Groves and Batt, 1984).

The Rift-phase greenstone belts have also been identified as younger and older belts, with the older belts being poorly mineralized, which is also related to the relatively small amount of extension and hence, low amount of subsidence and magmatism (Groves and Batt, 1984). The younger rift-phase greenstone belts host the best gold mineralization due to the relatively large amount of subsidence and magmatism, which resulted in extensive komatiitic volcanism.

A schematic section through an evolving younger terrain greenstone belt is shown on Figure 3.5, whereas a section through older and younger rift-phase greenstones with associated mineralization is shown on Figure 3.6.

The different types of gold-deposits (see above) can be related to the type of tectonic setting, for example the deposits hosted in B.I.F.s can be related to the initial stages of rifting (Figure 3.5), while those hosted in shear zones are related to post-depositional deformation and metamorphism in younger rift-phase greenstones (predominantly).

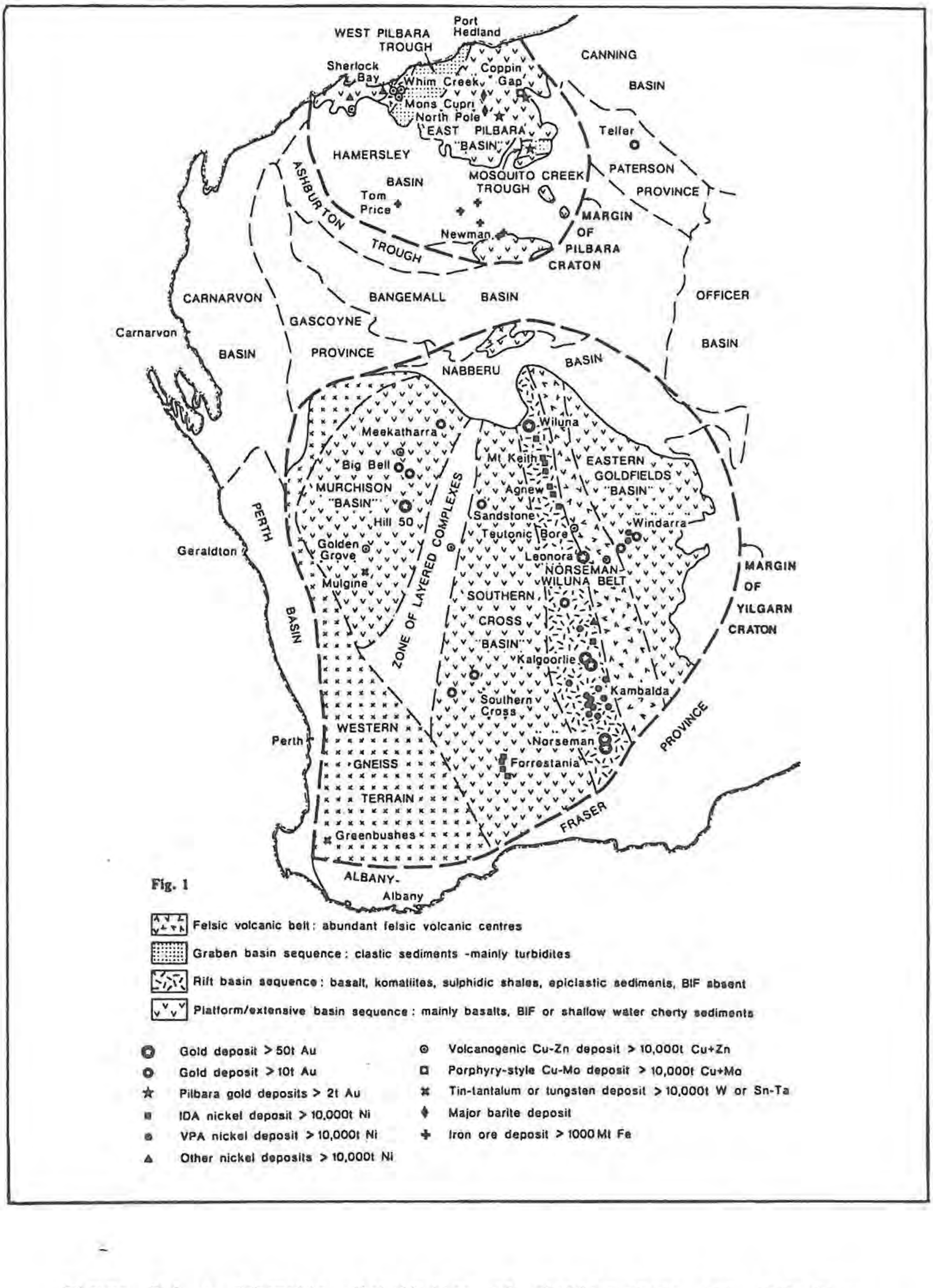


Figure 3.4 : Schematic distribution of platform-phase and rift-phase greenstone belts of the Yilgarn and Pilbara Cratons, and related tectonic units (Distribution of felsic volcanics is generalized). Metallogenic associations as shown (Groves and Batt, 1984).

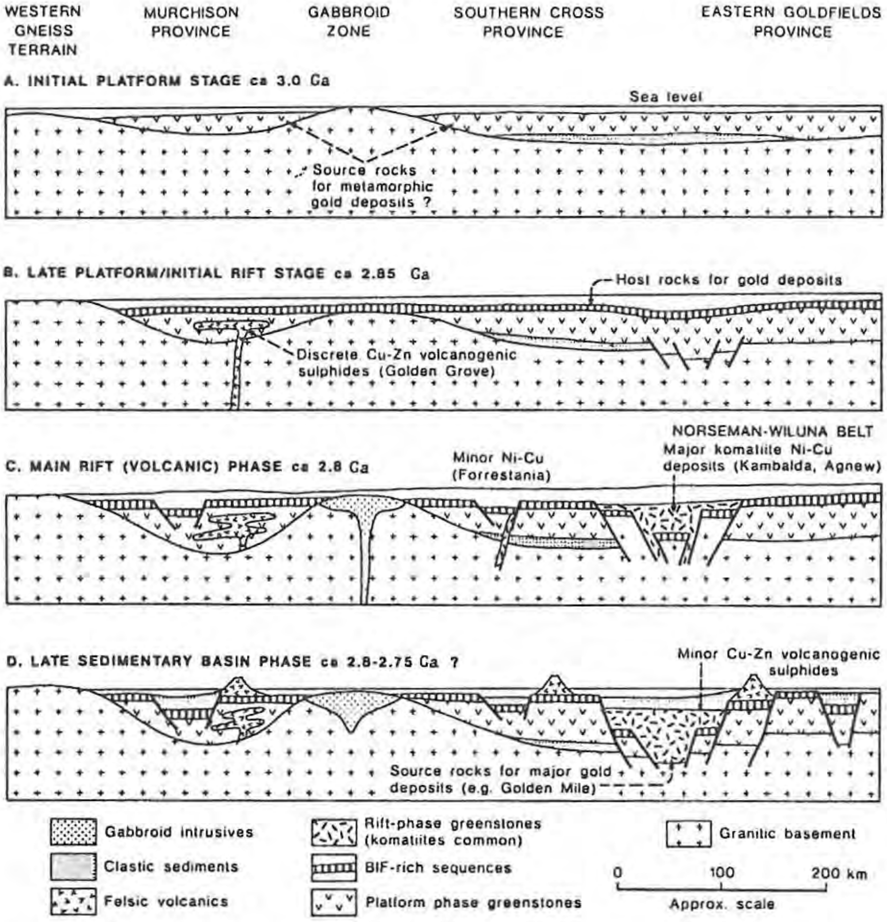


Figure 3.5 : Tentative model for the evolution of greenstone terrains through platform- and rift-phases based on the Yilgarn Craton (Groves and Batt, 1984). Vertical scale exaggerated.

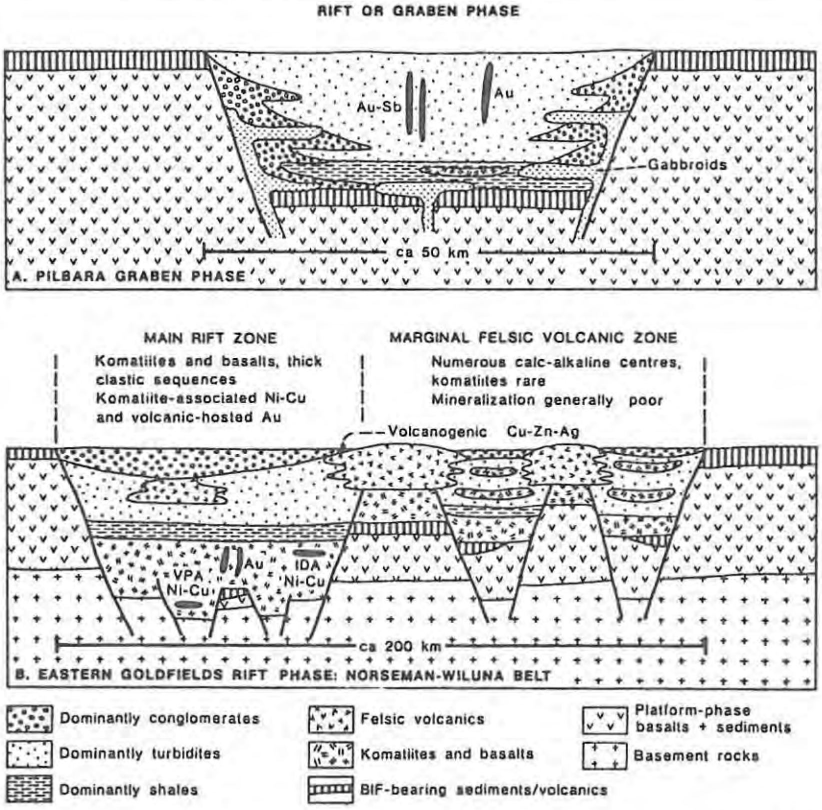
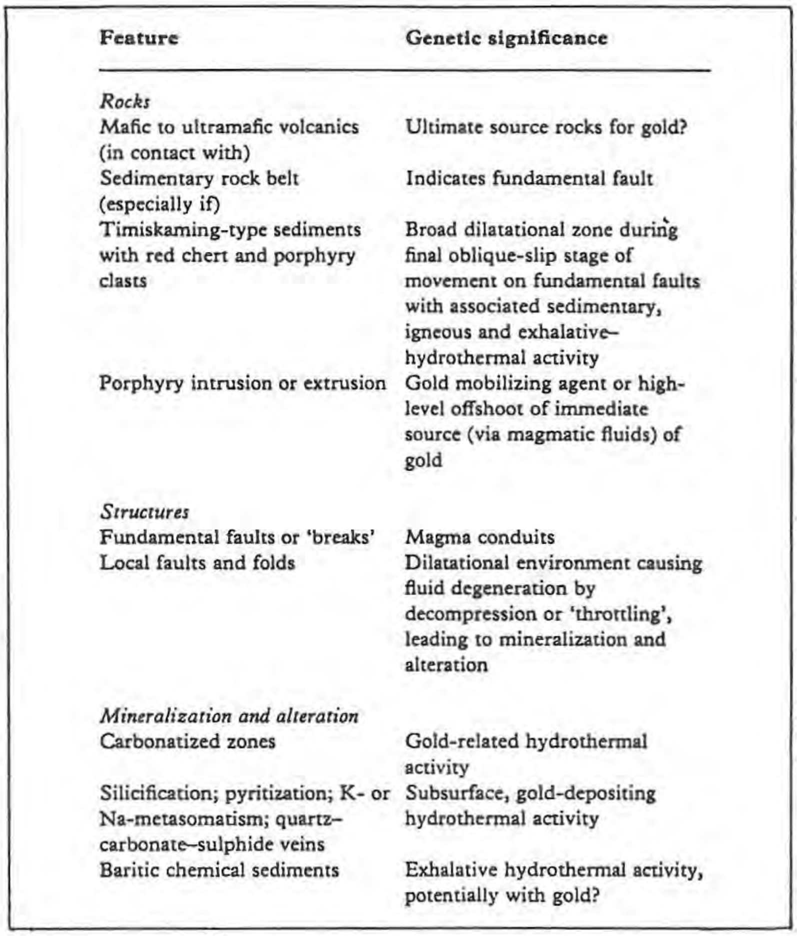


Figure 3.6 : Schematic sections through rift-phase greenstones in older and younger granite-greenstone terrains (Groves and Batt, 1984). Vertical scale exaggerated.

The genesis of gold deposits in the Archaean has been researched in detail in the past (eg. Fripp, 1976; Kerrich and Fryer, 1979), and presently the metamorphic replacement model of Phillips et al., (1984) is gaining support. Hodgson (1985, 1986) reviewed various genetic aspects of Archaean gold-deposits and these are summarized on Table 3.4. The epigenetic model of Phillips et al., (op cit) (Figure 3.7) involves the generation of H_2O-CO_2 rich fluids of low salinity from metamorphism, which carried gold as sulphide complexes. The deposition of gold (particularly in the Western Australian greenstone belts), was due to either structurally favourable traps or to a high iron content in the host rocks. The high iron content (either FeO in silicates or Fe_3O_4 in B.I.F.s), is oxidized and complexed with the sulphides in solution, to precipitate (by reduction) pyrite and gold-metal. The syngenetic B.I.F. deposition of gold also occurs in the Archaean environment, for example at Vubachikwe in Zimbabwe (Fripp, 1976), although this is still contentious (Phillips et al., 1984).



Feature	**Genetic significance**
Rocks	
Mafic to ultramafic volcanics (in contact with)	Ultimate source rocks for gold?
Sedimentary rock belt (especially if)	Indicates fundamental fault
Timiskaming-type sediments with red chert and porphyry clasts	Broad dilatational zone during final oblique-slip stage of movement on fundamental faults with associated sedimentary, igneous and exhalative–hydrothermal activity
Porphyry intrusion or extrusion	Gold mobilizing agent or high-level offshoot of immediate source (via magmatic fluids) of gold
Structures	
Fundamental faults or 'breaks'	Magma conduits
Local faults and folds	Dilatational environment causing fluid degeneration by decompression or 'throttling', leading to mineralization and alteration
Mineralization and alteration	
Carbonatized zones	Gold-related hydrothermal activity
Silicification; pyritization; K- or Na-metasomatism; quartz–carbonate–sulphide veins	Subsurface, gold-depositing hydrothermal activity
Baritic chemical sediments	Exhalative hydrothermal activity, potentially with gold?

Table 3.4 : Genetic features of Archaean gold deposits, with significance in terms of exploration (Hodgson, 1986).

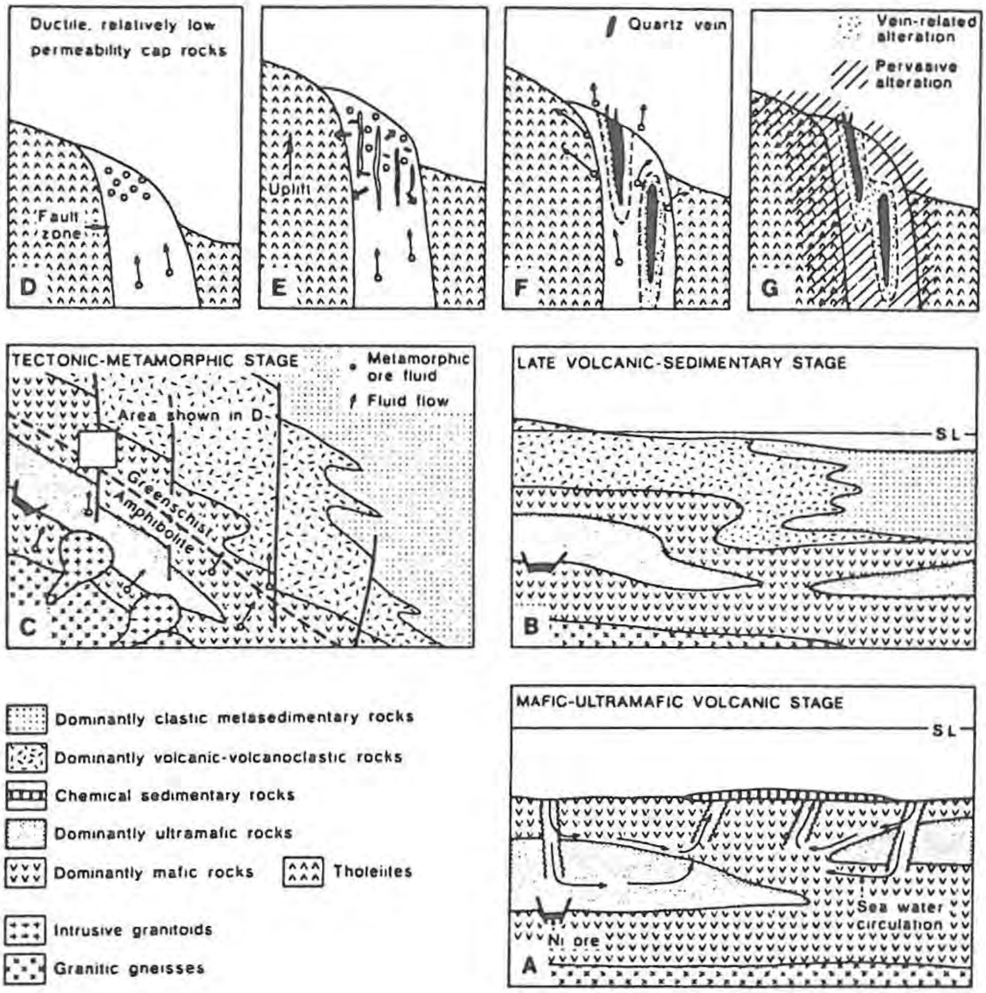


Figure 3.7 : Metamorphic replacement model for the genesis of Archaean gold deposits (Groves et al., 1984; Phillips et al., 1984; Phillips, 1985 a). (A) Seawater alteration of volcanic-rich pile, addition of H_2O, CO_2 and Sulphur, (B) emplacement of sediments and felsic-volcanics, (C) burial metamorphism/deformation causing devolatilization, releasing H_2O-CO_2 rich, auriferous fluid into channelways, (D) (E) (F) (G) deposition of gold in response to fluid-wallrock interaction.

One important type of gold-deposit in the Archaean which has only recently received attention, is the 'Hemlo type', named after the Hemlo deposits in the Marathon Greenstone Belt, Superior Province, Canada. The gold within these deposits occurs as disseminations in felsic volcanics, usually adjacent to a sedimentary/volcanic rocks contact (Robinson and McMillan, 1985). No significant mafic or ultramafic component occurs in the stratigraphy nearby and the deposits have an absence of quartz veins, and an absence of the common element association in adjacent sedimentary host rocks. Of importance is the occurrence of these deposits in a high grade metamorphic terrain, which was previously regarded as unprospective. The Big Bell deposit in Western Australia is regarded as being of the same type as the Hemlo deposit (Phillips, 1985 b) (see below). The genesis of the disseminated Hemlo type of deposit is still questionable, with syngenetic and epigenetic models being proposed. The syngenetic model is based on the occurrence of these deposits near the basin margins (defined by sedimentary facies), and the epigenetic model is based on the close association of these deposits to granite plutons marginal to greenstone terrains (Key features from Phillips 1985 b). More deposits of this type must be studied prior to presentation of a complete genetic model.

The majority of gold-deposits in the Western Australian Archaean occur in the younger rift-phase greenstone sequences of the Norseman-Wiluna belt in the Yilgarn Craton. In excess of 2 000 deposits are known, of which the Kalgoorlie Golden Mile deposits are the most important (Table 3.5; Figure 3.4). In the context of this dissertation four main types of deposits are recognized (after Phillips, 1985 a, and Woodall, 1979).

i. Kalgoorlie type : hosted by mafic or ultramafic sequences and some felsic and sedimentary sequences, with extensive carbonate and chloritic alteration, and greenschist metamorphism. The distribution of gold is related to shear zones and/or quartz veining. This type of deposit includes the Golden Mile, Oroya and Charlotte styles of mineralization, in the Golden Mile and at other Mines such as at Norseman and Great Fingall Mine.

ii. B.I.F. type; hosted in banded iron formations (B.I.F.s), and includes deposits such as Hill 50, Bullfinch, Watertank Hill and Lancefield deposits.

iii. Hemlo type; disseminated gold mineralization, lack of carbonate alteration, generally low grade high tonnage in a high grade metamorphic terrain (amphibolite facies) and includes the Big Bell deposit.

iv. other types ; including laterite hosted deposits such as Boddington, and alluvial deposits associated to most of the above types of deposits.

Location	Deposit/Type	Tonnes	Host Rock	Mineralization
EASTERN GOLDFIELDS PROVINCE				
Kalgoorlie	Golden Mile	1000	dolerite	vein (shear zone related)
	Oroya	200	basalt/sediments	breccia vein near contact
	Mt Charlotte	50	granophyre	quartz vein
Leonora	Sons of Gwalia	90	amphibolite	quartz vein
Norseman	Mararoa-Crown	69	basalt	quartz vein
	Princess Royal	46	basalt	quartz vein
Wiluna	Wiluna	46	basalt	quartz vein
Laverton	Lancefield	18	banded iron-formation	disseminated
Kanowna	White Feather	7	conglomerate	quartz vein (Kanowna Main Reef)
	Red Hill	1	felsic	quartz vein
Kambalda	Hunt	1	basalt	quartz vein
	Victory	1	basalt/sediments	quartz vein
SOUTHERN CROSS PROVINCE				
Bullfinch	Copperhead	21	banded iron-formation	disseminated
Marvel Loch	Marvel Loch	1	basalt	quartz vein
	Nevoria	2	banded iron-formation	disseminated, quartz veins
Southern Cross	Frasers	9	basalt	quartz vein
MURCHISON PROVINCE				
Big Bell	Big Bell*	110	schist	disseminated in altered mafic
Cue	Great Fingall	39	dolerite	quartz vein
	Golden Crown	1	dolerite	quartz vein
Mt Magnet	Hill 50	42	banded iron-formation	disseminated
	Hill 60	2	banded iron-formation	disseminated, quartz veins
	St George	4	banded iron-formation	disseminated
	Water Tank Hill	1	banded iron-formation	disseminated, quartz veins
	Morning Star	3	basalt	quartz vein
Meekatharra	Paddys Flat	28	? schist	quartz vein, porphyry
PILBARA BLOCK				
Marble Bar	Comet	4	ultramafic	vein

* includes published reserves

Table 3.5 : Major gold producers in the Yilgarn and Pilbara Cratons, Western Australia (Phillips, 1985 a).

The Kalgoorlie types account for most of the gold production (± 80%), with the B.I.F. type contributing ± 10%, and the remaining past-production mostly from Hemlo type.

Kalgoorlie Type Deposits

Previous work specifically on the Kalgoorlie deposits includes that by Phillips (1985 a), Woodall (1975, 1979) and Phillips (1986). The deposits of the Golden Mile (Figure 3.8) are predominantly hosted in the Golden Mile Dolerite, with some in the adjacent Paringa Basalts, and the Black Flag Beds (minor). Three styles of mineralization are recognized, the Golden Mile style, the Oroya style and the Charlotte style. The characteristics are summarized on Table 3.6.

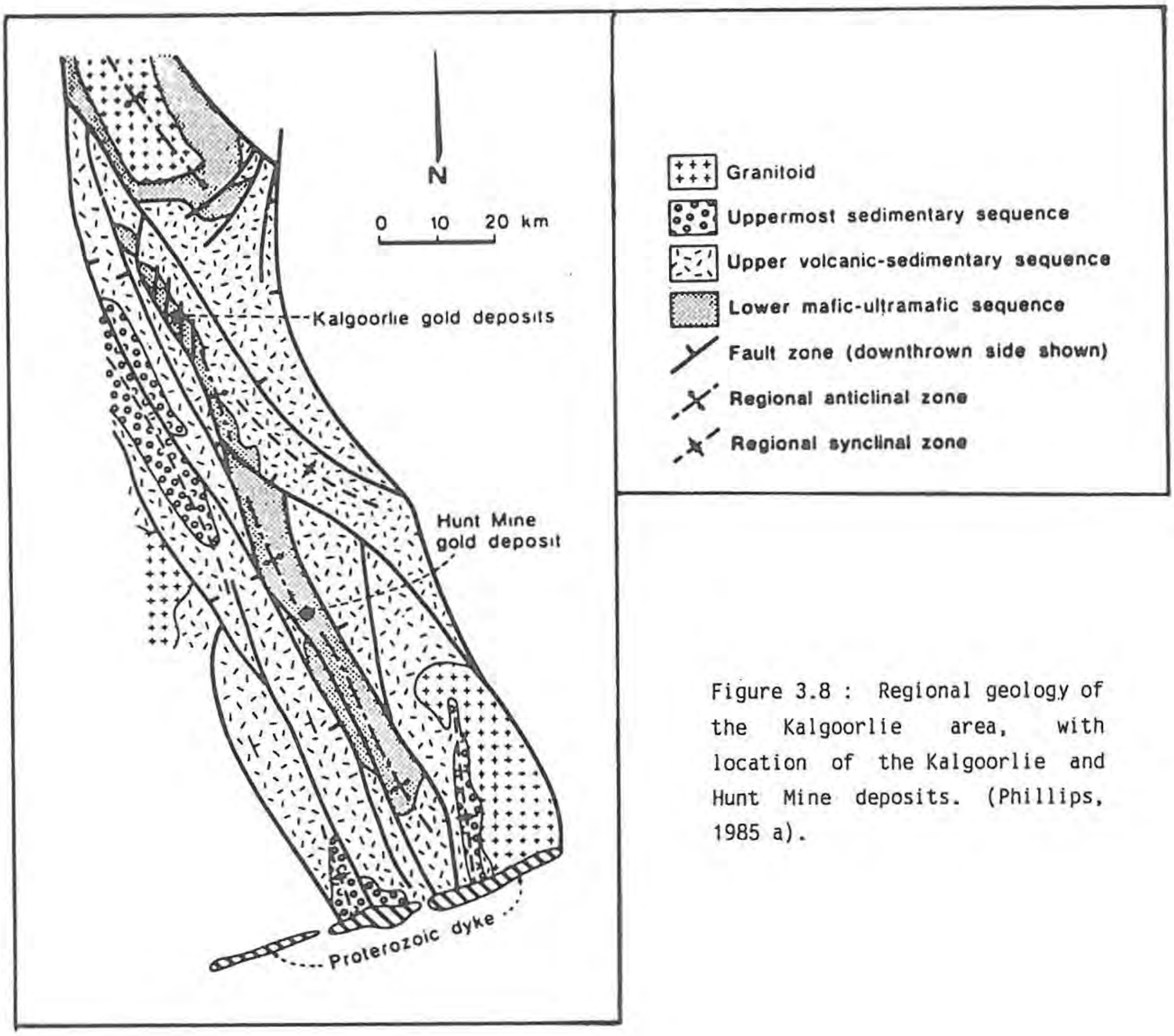


Figure 3.8 : Regional geology of the Kalgoorlie area, with location of the Kalgoorlie and Hunt Mine deposits. (Phillips, 1985 a).

The **Golden Mile style** of mineralization is concentrated around the Kalgoorlie Syncline (Figure 3.8), in lode structures which are generally parallel to the axis of the syncline, in the Eastern Lode system. The Western Lode system has well developed lode structures dipping east or west and extending to a depth of 1 km (Phillips 1985 a) within the Golden Mile Dolerite, Paringa Basalt and Black Flag Beds. Metamorphism of the dolerite is upper greenschist facies (Phillips, 1986), with original magmatic textures and structures preserved. The dolerite is tentatively identified as a single magmatic event (sill intrusion) with chilled margins and a differentiated central portion, with 10 units defined (Travis et al., 1971, and Clark, 1980; in Phillips, 1986). The Paringa Basalt is the footwall

Style	Gold	Host Rock	Structural Setting	Mineralogy/Alteration
Golden Mile	1000t	Golden Mile Dolerite, occasionally Paringa Basalt and porphyry dykes	a) Steeply dipping veins that follow shear zone system. With or without quartz b) Commonly near sediments	a) Pyrite, rare arsenopyrite, tourmaline, free gold very rare. 0,1 to 10+m zones of carbonate alteration. Gold mostly in alteration zone b) Rich; tellurides, free gold, base metal sulphides
Oroya	200-300t	Paringa Basalt, rarely inferflow sediments	1. Shallow plunging ore pipes near top of Basalt and shear zones (e.g. Oroya Shoot) 2. Breccia zones in Basalt near interflow sediments (e.g. Lewis Lode). 3. Immediate footwall of interflow sediments and sediments themselves (e.g. OHW Shoot)	Complex, very rich. Pyrite, numerous tellurides, vanadium mica, free gold, tourmaline, galena, sphalerite, and chalcopyrite
Charlotte	50t	Golden Mile Dolerite, nearly all in granophyre	Two quartz vein sets localized between steep oblique shear zones, within the granophyre	Quartz veins with ankerite/siderite, scheelite and albite: pyrite (nearer surface) or pyrrhotite (deeper). Muscovite, carbonate, pyrite alteration with pyrrhotite at depth. Rare tellurides. Gold in alteration zone
Other	minor	Black Flag Beds, other rock types	Stratabound, but near shear zones	Pyrite, pyrrhotite, arsenopyrite

Table 3.6 : Most important styles of mineralization in the Kalgoorlie Gold field. (Phillips, 1985 a), with a summary of main characteristics.

sequence to the dolerite sill intrusive (Figure 3.9 a), varying from a pillowed high- magnesian flow, upward to a tholeiitic flow. Gold mineralization occurs preferentially in the upper portions of the basalt toward the dolerite contact.

The Black Flag Beds consist predominantly of carbonaceous black shales, greywackes and thin cherts in the lower portions, and siltstones, shales, and felsic breccias and tuffs higher in the sequence. Some shale units are intercalated with the Paringa Basalts.

The dolerite is the main host to mineralization of the Golden Mile style, with a marked association of alteration to mineralization. The alteration type and distribution, is intimately associated to the iron content of the host rocks (see above), as summarized in Table 3.7 (Phillips, 1986). The broad zonation is from an outer extensive chloritic alteration zone to a carbonate zone, to an inner pyrite (gold) zone. The pyrite alteration zone is used as a visual cutoff during mining operations. The alteration is

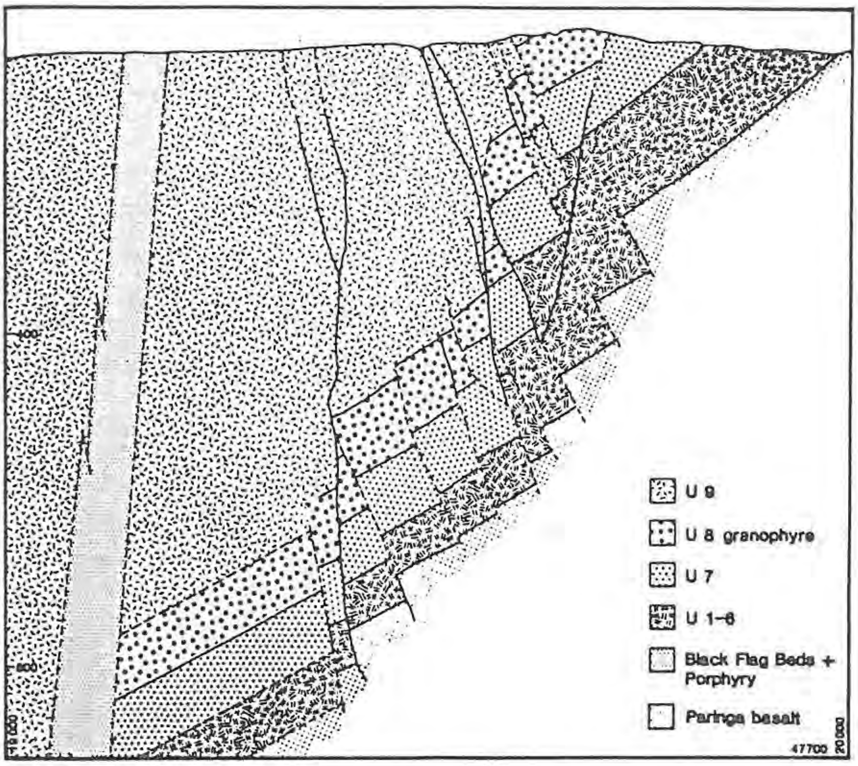


Figure 3.9 : a. Stratigraphy of the Eastern Lode system through the Lake View Shaft, Kalgoorlie. Mineralization is confined to fractures, predominantly in the upper U9 and U8 units of the Golden Mile dolerite. (Phillips, 1986).

caused by the introduction of CO_2, potassium, sulphur and gold to the system by a fluid generated by metamorphism at depth (Phillips, 1986).

The second important style of mineralization in the Kalgoorlie-type deposits is the **Oroya style** (Table 3.6). This mineralization occurs sub-parallel to and near the contact between the Golden Mile Dolerite and the Paringa Basalt, (Figure 3.9 b). Mineralization also occurs in lodes with restricted zones of alteration (predominantly carbonation). The mineralization is free gold, pyrite, tellurides and vanadiferous micas (Table 3.6). The best known example of this mineralization is the Oroya Shoot.

The **Charlotte Style** of mineralization is confined to a granophyric host in the Golden Mile Dolerite, as quartz stockworks and minor veins in zones of tensional deformation (Phillips, 1985 a). The orebodies are terminated by fault dislocations (Figure 3.9 c). Alteration around the stockworks and individual veins is generally very minor 1-5 cm, but may be extensive where

Zone	Distribution	Origin	Assemblage
Actinolite	Outside Golden Mile, regional extent, not in mine environment	Regional metamorphic	*Actinolite*-albite-chlorite-quartz
Chlorite	Throughout Golden Mile, dominant zone in mine environment	Mild carbonation of Golden Mile Dolerite during gold mineralization	*Chlorite-calcite*–ankerite-albite–paragonite-quartz-magnetite, siderite, pyrite
Carbonate	100-m-thick zones through eastern and western lode systems, narrower zones around pyrite alteration	Intense carbonation of Golden Mile Dolerite during gold mineralization	*Ankerite*-quartz-muscovite-albite-*siderite*, pyrite
Pyrite	1- to 5-m-thick zones within shear zones, synonymous with economic and subeconomic gold "lodes"	Intense sulfide, carbonate, and muscovite alteration during gold mineralization	*Pyrite*-quartz-*ankerite*-albite-*muscovite*-siderite, dolomite, tourmaline

Table 3.7 : Alteration zones within the Golden Mile Dolerite associated to mineralization (Phillips, 1986).

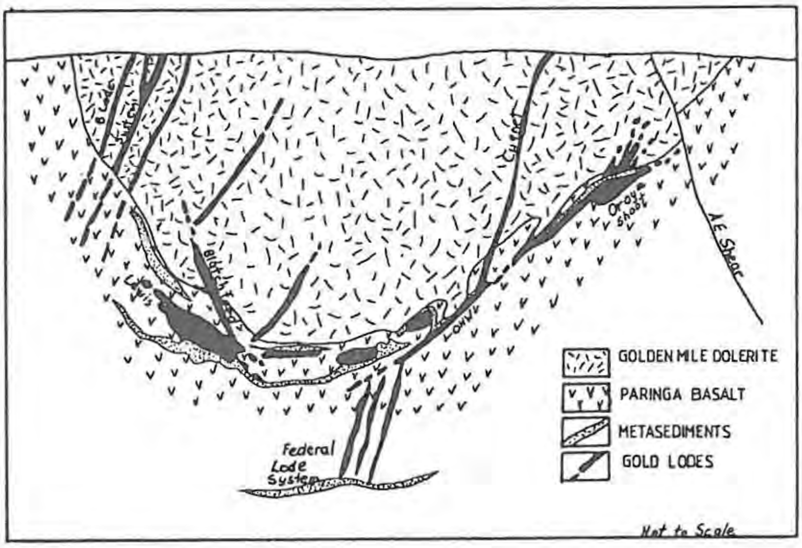


Figure 3.9 : b. Oroya Style mineralization, in the Oroya Shoot and other lodes, in the Brownhill syncline (Phillips, 1985 a). The 'B Lode System' and Cygnet ore bodies are examples of Golden Mile Style mineralization.

there is a coalescing of veins. The dominant alteration is carbonation. The granophyre has acted as preferential host rock due to the variation in tensile competency relative to adjacent rock types (Phillips, 1986). Fluid access of mineralizing solutions is via faults in the footwall.

The gold deposits in the Great Fingall Mine area (ie. Great Fingall and Golden Crown) are examples of Charlotte style of mineralization, where mineralization is hosted in the granophyric phase of a differentiated mafic sill (Figure 3.10). Recent work in the area (Gold Gazette, Nov. 10 1986), involving the re-evaluation of reserves previously abandoned as uneconomic, has delineated 230 000 t at 4.5 g/t. The mineralization is 1.5 to 2.0 % sulphides consisting of pyrrhotite, galena, arsenopyrite, pyrite and sphalerite in gold-rich quartz veins (Woodall, 1975, 1979).

The Norseman Goldfield deposits, are tentatively included as Kalgoorlie type deposits, hosted in upper greenschist facies tholeiites and high-magnesium lavas, and minor metasediments (Phillips, 1985 a). The gold bearing sequence has a higher average iron-oxide content (in the order of +12 wt%) relative to adjacent rock types. The alteration hosted Princess Royal gold-mineralization, differs from the folded and laminated quartz veins of the Crown and Mararoa mineralization. The latter consists of free gold, pyrite galena, sulphides (minor) and tellurides (minor). Alteration of wallrocks is biotite-carbonate and chlorite-carbonate. These deposits, although occurring in the tholeiites, have yet to be genetically modelled, and hence are tentatively included in the Kalgoorlie type deposits, most likely of the Oroya style or a variation of the Golden Mile style (similiar to those deposits occurring within the upper portion of the Paringa Basalt).

Other deposits which are included in the Kalgoorlie type of deposit, are (after Phillips, 1985 a) Kanowna Main Reef (vein hosted in turbidite flow conglomerate), Red Hill (quartz veins in a dacitic porphyry stock) and numerous deposits in the Norseman Wiluna Belt (Figure 3.3).

B.I.F. Type Deposits

The B.I.F. type deposits are characterized by a general restriction to iron formations (including jasper/chert horizons) with quartz veining and an apparent strong structural control (Phillips, 1985 a). Approximately 10% of the Yilgarn gold production comes from B.I.F. hosted deposits in the Murchison Southern Cross and Eastern Goldfields Provinces. Deposits include Hill 50, Bullfinch, Lancefield, Water Tank Hill, Nevoria, Westralia (?) and St George (?) (Phillips, 1985 a, Woodall, 1979) (Figure 3.3).

The deposits are hosted in rocks consisting of laminated quartz-magnetite iron formations, with interspersed chert or jasperlite horizons. The origin of these types of deposits is controversial, with syngenetic and epigenetic models being proposed. Based on studies of the Water Tank Hill deposit, Phillips et al., (1984) and Phillips (1985 a) proposed an epigentic origin within the metamorphic replacement model. Features of the deposits include laminations and/or banding (iron-rich bands hosting gold mineralization), and an association of zones of gold-enrichment to quartz veins normal to the bedding of the B.I.F.. These features are observed also at the Nevoria Mine (Phillips et al., 1984).

Hemlo Type Deposits

The Hemlo type deposit is characterized by a lack of quartz veining and carbonate alteration, and occurrence in a high grade (upper amphibolite) metamorphic terrain. The Big Bell deposit (Figure 3.3) is an example of this type of deposit and it has been studied in some detail by Chown et al., (1984) and Phillips (1985 a,b). The greenstone sequence in the mine area has been divided up into five units (Chown et al., 1984) : Unit I, 100m thick unit of quartz-plagioclase-biotite gneisses; Unit II, 600m thick unit of mafic and ultramafic rocks; Unit III, 200 m thick unit of felsic and mafic rocks; Unit IV, porphyritic felsic rocks intruded into Unit III, and Unit V, 300m mafic rocks (Figure 3.11). The complete sequence has been metamorphosed to upper-amphibolite facies, and the host sequence is Unit IV. The metamorphism of the sequence appears to be spatially associated to the intrusion of granitoids on the margin of the greenstone belt (Phillips, 1985 b), which overprinted earlier low grade metamorphism (greenschist) which is characteristic of other greenstone sequences in the Yilgarn (Phillips, 1985 a; Chown et al., 1984).

The gold-mineralization at Big Bell is interpreted (based on rock chemistry and limited fluid inclusion work) as being emplaced prior to, and remobilized during the peak metamorphic event (Phillips, 1985 b). Current information on the Big Bell deposit is insufficient to allow a complete understanding of the timing involved in the genesis of the deposit. Phillips (1985 b) suggests the deposit has features of a metamorphic replacement genesis.

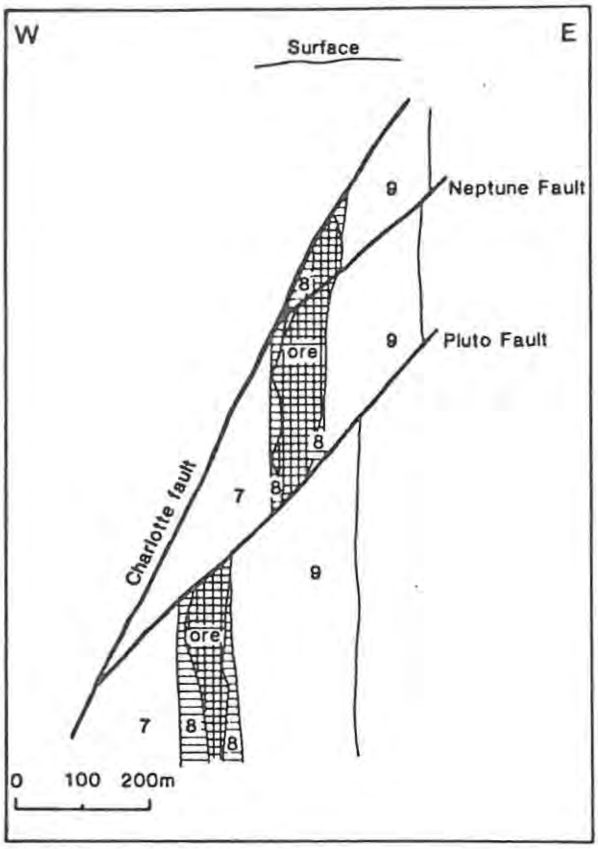


Figure 3.9 : c. Charlotte Style mineralization in the Charlotte ore body (Phillips, 1985 a). Mineralization is restricted to the U8 - granophyric unit of the Golden Mile Dolerite.

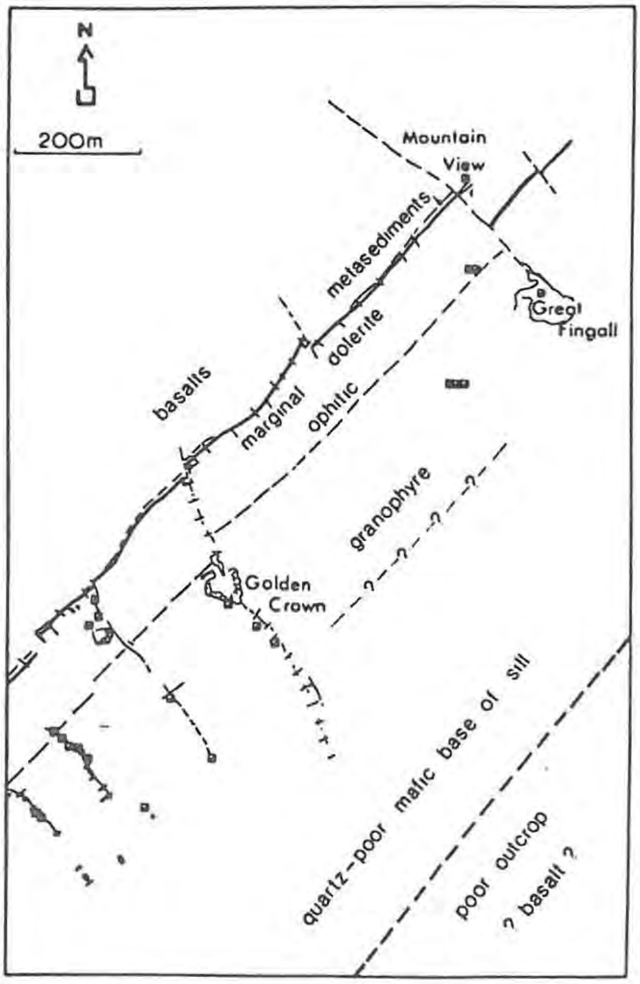


Figure 3.10 : Regional geology of the Great Fingall Area, and the distribution of ore bodies within the granophyric phase of a dolerite sill (Phillips, 1985 a).

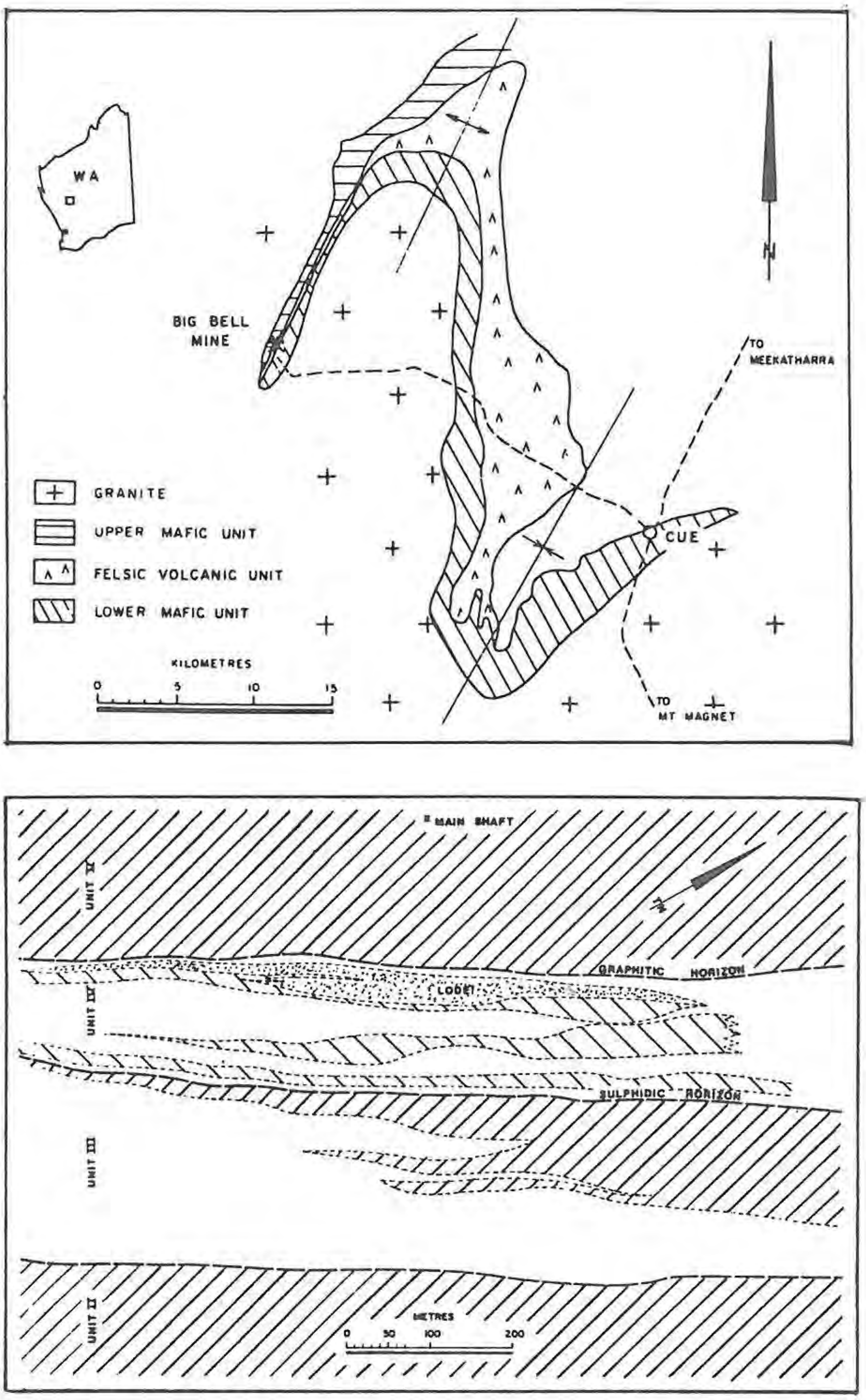


Figure 3.11 : a. Regional geological setting of the Big Bell gold deposit, (Chown et al., 1984).

b. Local geology of the Big Bell gold deposit (Chown et al., 1984).

3.2 Pilbara Craton

3.2.1 Geology

The Pilbara Craton (Figure 3.12 a) consists of domal granitoids and elongate belts of volcanic and sedimentary greenstone belts. The granitoids are preferentially associated to, and intruded into the volcanic sequences, with the sedimentary sequences dominantly consisting of deformed deep water turbidite successions. The evolution of the Pilbara Craton has been discussed by Gee (1979), Hickman (1981), Groves and Batt (1984), Blake and McNaughton (1984), and Muhling et al., (1984, and references therein). The geochronology of the Pilbara Craton has not yet been fully resolved, due to the wide dispersion of granitoid and sedimentary/volcanic ages. There are two distinct age groups of granites/gneisses at 3500-3300 Ma and 3050-2850 Ma (Blake and McNaughton, 1984), which are synchronous with known ages of sedimentary and volcanic sequences (eg. Warrawoona Group, 3500-3300 Ma). A detailed study of the Warrawoona Group, in eastern Pilbara Craton, by Barley (1984), located areas of intense hydrothermal alteration and indications of shallow water volcanism similiar to that known in the Barberton Greenstone Belt in South Africa. This indicates that the older granite-greenstone terrains (Pilbara and Barberton) had a distinctive volcanic evolution differing to that for the younger terrains (eg. Yilgarn or Zimbabwe Belts).

3.2.2 Gold Mineralization

The Pilbara Craton as previously mentioned, is dominantly an older platform-phase greenstone belt terrain which has a low potential for gold-mineralization and preservation. The overall lack of komatiite sequences which are potential source rocks (Keays, 1984), and the intense silicification and carbonation of the volcanic sequences, reduce the iron content of the rocks, thus reducing the potential for concentrating gold (Barley and Groves, 1984; Barley, 1984; see earlier section discussion of ore genesis). The most notable occurrence of gold mineralization is the Comet deposit at Marble Bar a quartz-carbonate-pyrite replacement lode hosted in basic volcanics. Other deposits include the Blue Spec Goldmine, the Bamboo Gold Mine and the North Pole deposit (Figure 3.12 b). The Blue Spec deposit occurs near Nullagine (Figure 3.12 a).

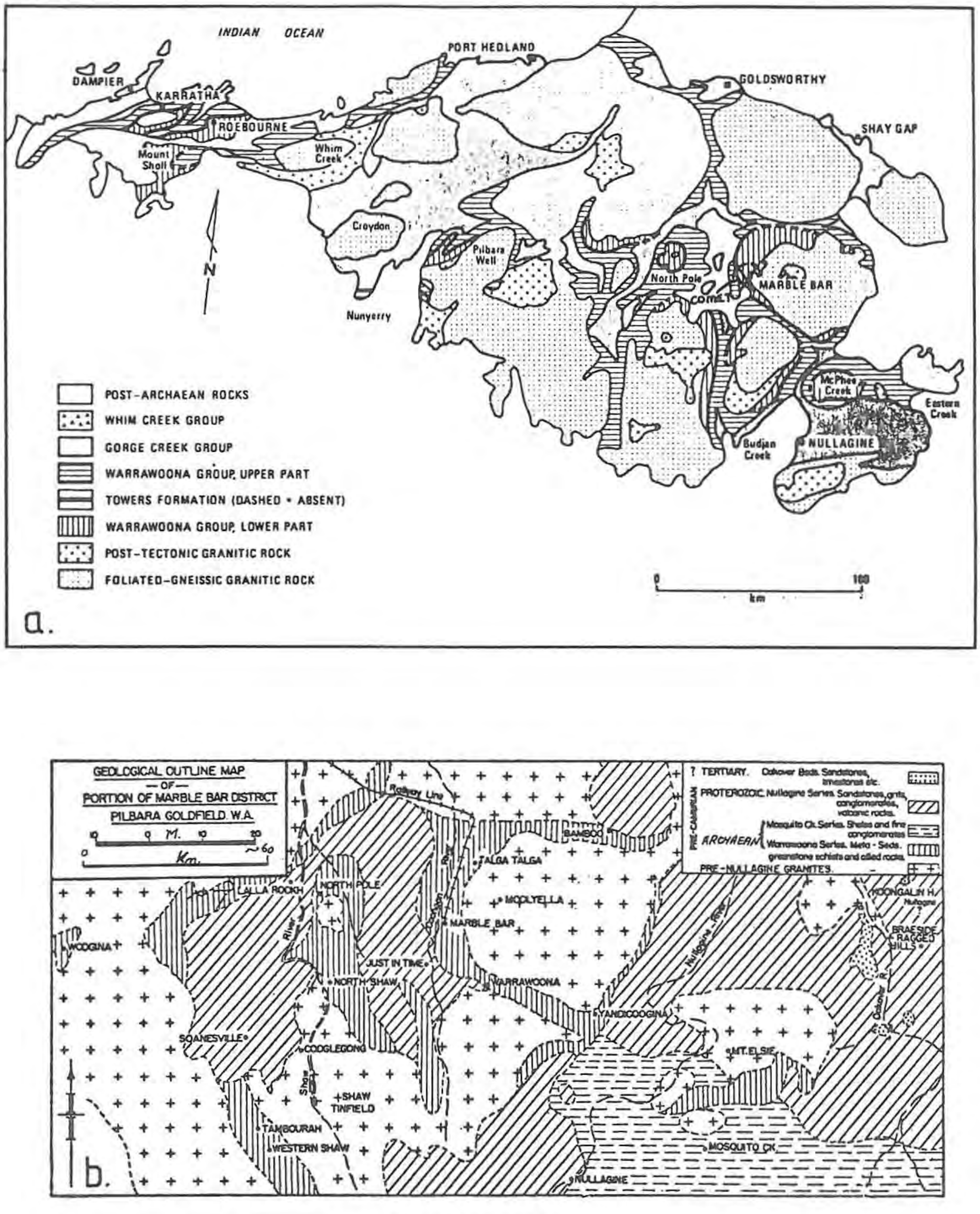


Figure 3.12 : a. Regional geology of the Pilbara Craton (Hickman, 1981).
b. Local geology and distribution of gold deposits in the Pilbara goldfield (McMath, 1953).

The older terrain of the Pilbara Craton contains insignificant mineralization compared with the deposits of the Yilgarn Craton, in particular the Eastern Goldfields Province and the Murchison Province. Potential however exists for deposits along the margin and beneath the margin of the Hammersley Basin, where better preservation may have occurred. An interesting deposit in the Pilbara Craton, known as the 'Nullagine Group' of deposits, occurs in the basal 30 metres of conglomerate of the 'Nullagine Series' (McMath, 1953). These deposits appear, from limited available information, to be similiar in nature to the Witwatersrand deposits in South Africa, having a close association to lenticular pyritic horizons. The pyrite is nodular, similiar to the Witwatersrand pyrite, up to 5 cm in diameter (David, 1950). Grade on these deposits (after David, op. cit.), based on 5000 t mined, was approximately 19 g/t (.63 oz/t) with lower grades to 3.7 g/t (2.4 dwt/t). Reserves of these deposits are unknown. Original genetic models suggest gold deposition from solution, but the presence of water-worn gold particles (Just in Time Mine NW of Nullagine) suggest a detrital origin (David, 1950 p222).

Numerous other small mines/deposits occur in the Pilbara Craton, but geological data is sparce. The most important features of the Pilbara deposits, are the small sizes and generally low tonnages and the majority can be regarded as Kalgoorlie type. Due to a high degree of hydrothermal alteration in the eastern portion of the Pilbara Goldfield (see above), potential may exist for Hemlo type deposits, with the alteration leaching out a large component of the gold content prior to metamorphism and deformation.

4. PROTEROZOIC

The Proterozoic rocks of Australia are confined to the North Australian Craton, the Central Australian Mobile Belts, the Northeast Orogens, the Curamona Craton and the Gawler Craton (Figures 2.1 and 4.1). In addition to the main tectonic units of the above provinces, a large number of platform cover sequences are identified within the Proterozoic (Figure 4.1). The charactersitic of the tectonic units in the Proterozoic, is that they were all subjected to a number of orogenies. Detailed descriptions of different tectonic units include those by Compston and Arriens (1968), Fisher and Warren (1975) and Plumb (1979 a,b). The major tectonic province descriptions are taken from Plumb (1979 a,b), and geological framework from Palfreyman (1984). Only the orogenic provinces of Proterozoic rocks, are considered in this dissertation.

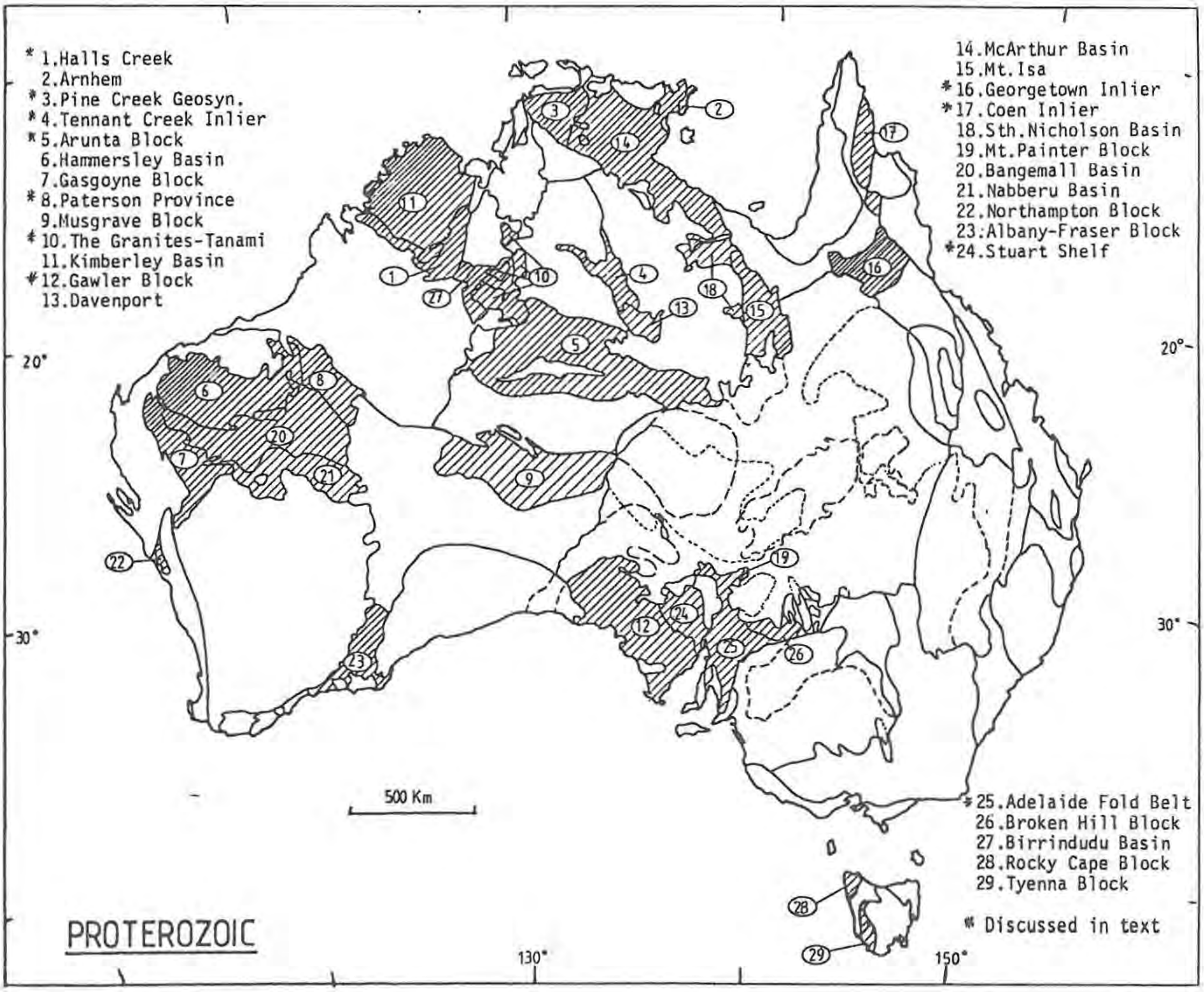


Figure 4.1 : Distribution of Proterozoic rocks in the Australian continent (after Palfreyman, 1984 and Plumb, 1979 a).

4.1 North Australian Craton

4.1.1 Geology

The North Australian Craton (Figure 4.2) is an orogenic province which was finally cratonized at 900 Ma, as evidenced by the deposition of the North Australian Platform Cover. The Halls Creek Inlier is a typical example of an area which underwent an orogenic cycle during its evolution. The initial history of the area was the deposition of geosynclinal sediments and volcanics (2200 Ma) on an inferred Archaean basement (Plumb, 1979 b). These deposits were metamorphosed at 1960 Ma during the Tinkalara metamorphic event, a generally low grade event with interpreted high grade belts beneath North Australian Platform cover. Until 1850 Ma, the Halls Creek Inlier was cratonized through a period of transitional tectonism.

The Halls Creek Province contains turbidites and basic volcanics (minor and volcanics) of the Halls Creek Group which have been intruded by early Lamboo

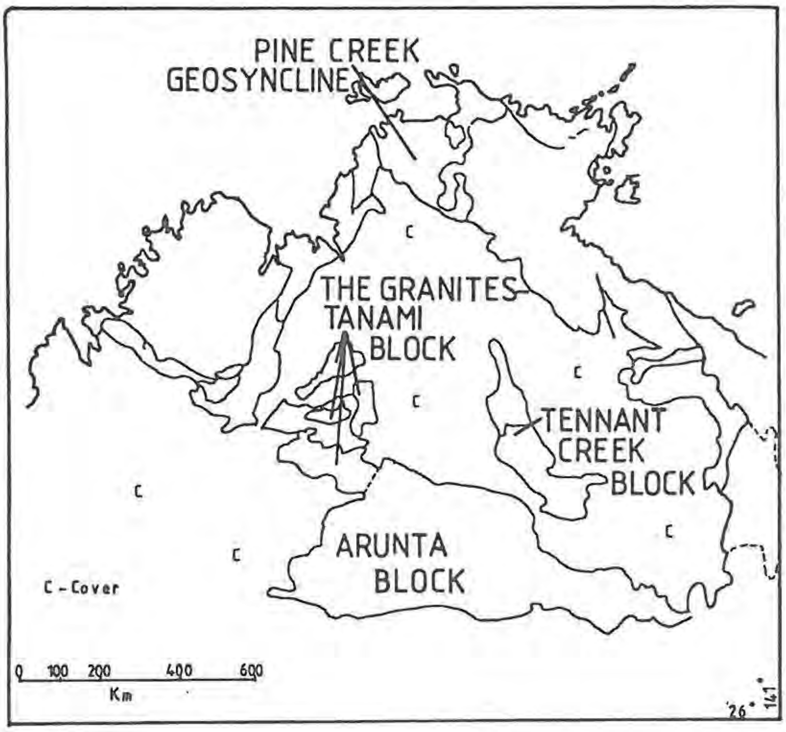
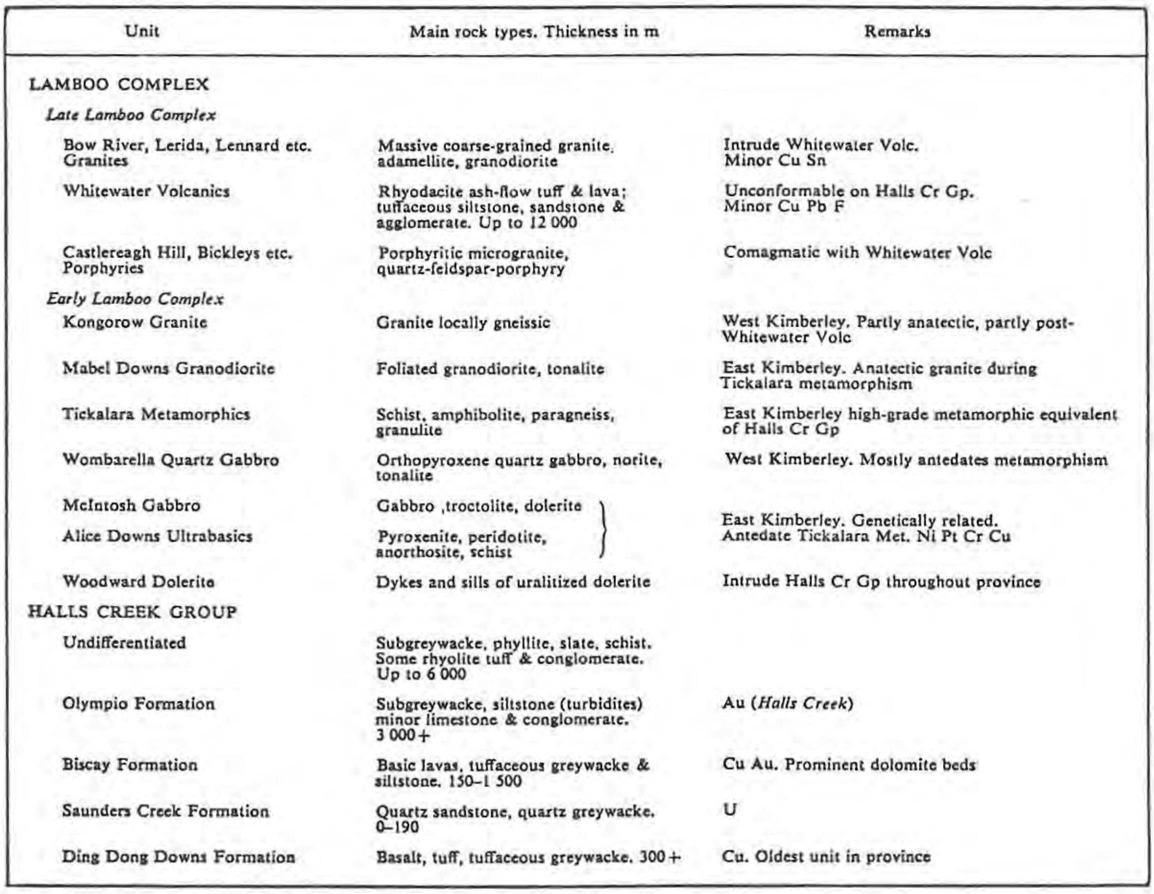


Figure 4.2 : Major tectonic units of the North Australian Craton (after Plumb, 1979 and Palfreyman, 1984).

Complex basic rocks (Plumb, 1979 b). Deformation and greenschist to lower-granulite facies metamorphism, formed the Tinkalara Metamorphics and related Mabel Granodiorite. The transitional tectonism that followed involved the late-Lamboo Complex rocks, the Whitewater Volcanics, and high level granites (eg. Bow River Granite) (Plumb, 1979 b). The stratigraphic succession in the Halls Creek Province is summarized in Table 4.1.



Unit	Main rock types. Thickness in m	Remarks
LAMBOO COMPLEX		
Late Lamboo Complex		
Bow River, Lerida, Lennard etc. Granites	Massive coarse-grained granite, adamellite, granodiorite	Intrude Whitewater Volc. Minor Cu Sn
Whitewater Volcanics	Rhyodacite ash-flow tuff & lava; tuffaceous siltstone, sandstone & agglomerate. Up to 12 000	Unconformable on Halls Cr Gp. Minor Cu Pb F
Castlereagh Hill, Bickleys etc. Porphyries	Porphyritic microgranite, quartz-feldspar-porphyry	Comagmatic with Whitewater Volc
Early Lamboo Complex		
Kongorow Granite	Granite locally gneissic	West Kimberley. Partly anatectic, partly post-Whitewater Volc
Mabel Downs Granodiorite	Foliated granodiorite, tonalite	East Kimberley. Anatectic granite during Tickalara metamorphism
Tickalara Metamorphics	Schist, amphibolite, paragneiss, granulite	East Kimberley high-grade metamorphic equivalent of Halls Cr Gp
Wombarella Quartz Gabbro	Orthopyroxene quartz gabbro, norite, tonalite	West Kimberley. Mostly antedates metamorphism
McIntosh Gabbro	Gabbro ,troctolite, dolerite	East Kimberley. Genetically related. Antedate Tickalara Met. Ni Pt Cr Cu
Alice Downs Ultrabasics	Pyroxenite, peridotite, anorthosite, schist	
Woodward Dolerite	Dykes and sills of uralitized dolerite	Intrude Halls Cr Gp throughout province
HALLS CREEK GROUP		
Undifferentiated	Subgreywacke, phyllite, slate, schist. Some rhyolite tuff & conglomerate. Up to 6 000	
Olympio Formation	Subgreywacke, siltstone (turbidites) minor limestone & conglomerate. 3 000+	Au (*Halls Creek*)
Biscay Formation	Basic lavas, tuffaceous greywacke & siltstone. 150–1 500	Cu Au. Prominent dolomite beds
Saunders Creek Formation	Quartz sandstone, quartz greywacke. 0–190	U
Ding Dong Downs Formation	Basalt, tuff, tuffaceous greywacke. 300+	Cu. Oldest unit in province

Table 4.1 : Stratigraphy of the Halls Creek Province (Plumb and Derrick, 1975).

The Pine Creek Geosyncline consists of early Proterozoic sediments with interlayered tuffs overlying Archaean basement granite complexes (Needham et al, 1980). Deformation and metamorphism of the sediments occurred at 1800 Ma, resulting in tightly folded greenschist facies metamorphic strata in the central areas, and isoclinally folded amphibolite facies metamorphic strata in the west and north-east areas. Post-orogenic granites intruded the early-Proterozoic strata, and are of Carpentarian age (Figure 4.3).

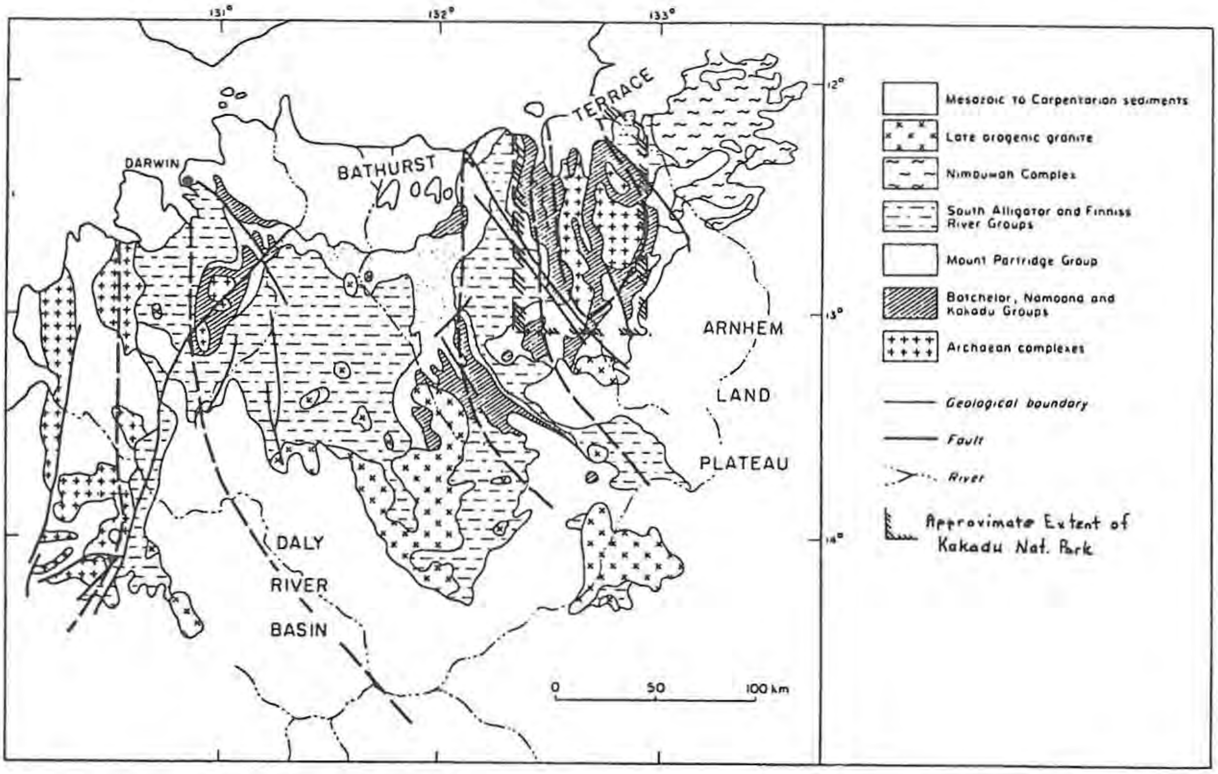


Figure 4.3 : Simplified geology of the Pine Creek Geosyncline (Stuart-Smith et al., 1980).

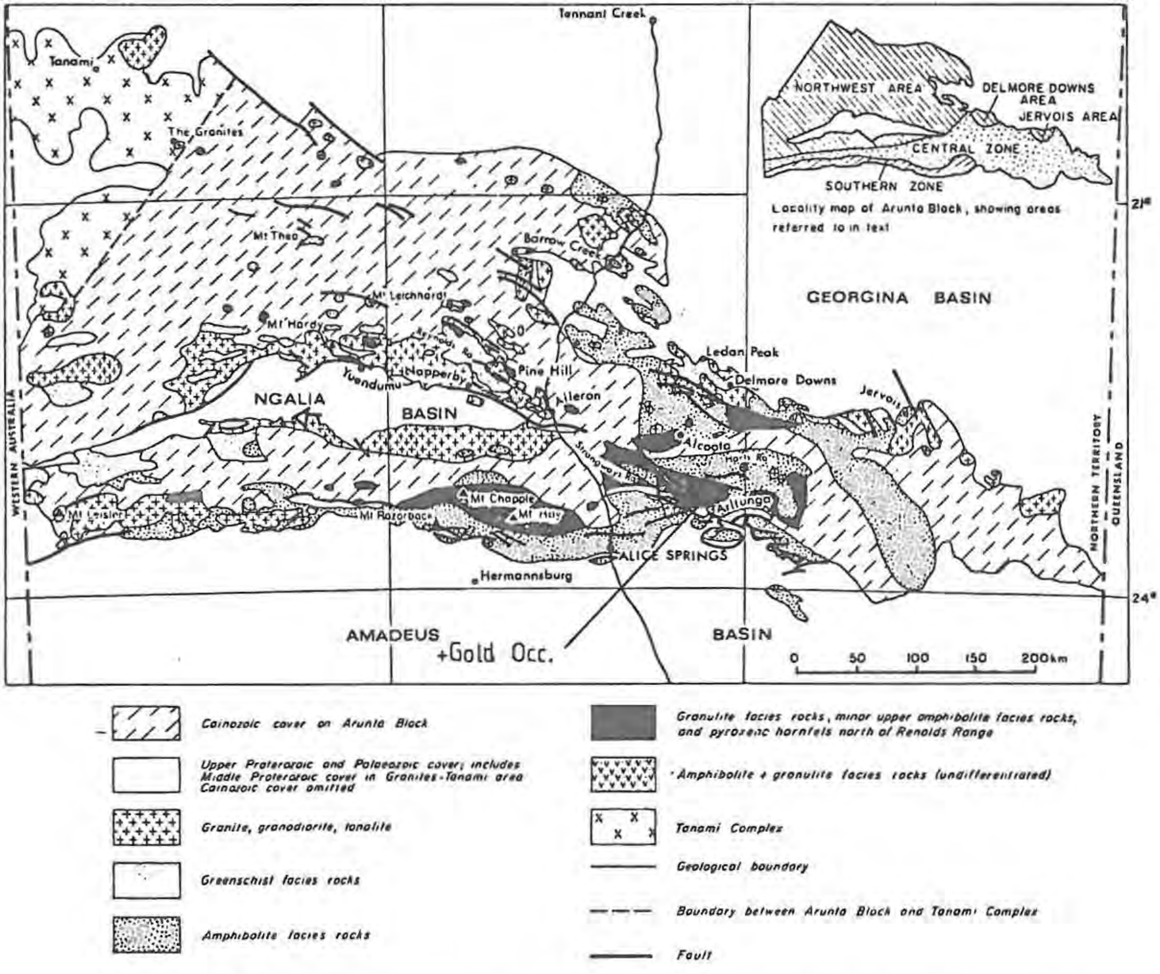
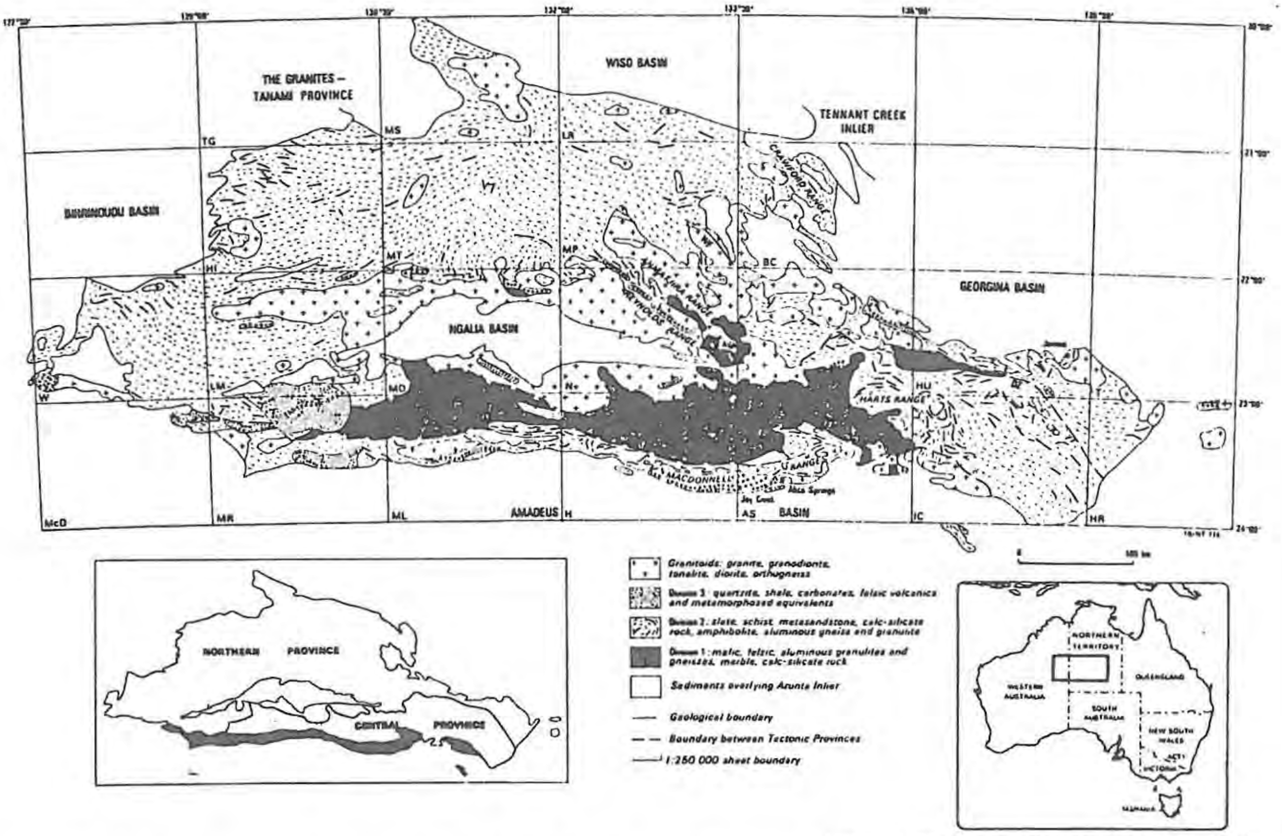


Figure 4.4 : Regional geology of the Arunta Block, showing known gold occurrences (after Shaw and Stewart, 1975).

A similar history is evident in the Arunta Block (Figure 4.4). This block has been interpreted as a possible equivalent of the Halls Creek Inlier, with similar ages of lithologies, periods of metamorphism (1800 and 1700 Ma) and plutonism (1700 and 1600 Ma). Additional features of the Arunta Block are the occurrence of a major thermal event at 1470 Ma and migmatization at 1050 Ma (Plumb, 1979 b). The tectonic evolution of the Arunta Block has been described by Shaw and Stewart (1975), Plumb et al (1981), Stewart et al (1984) and Shaw et al (1984). The Arunta Block contains three tectonic divisions, the Northern, Central and Southern Provinces, with distinct structural, lithological and metamorphic histories (Shaw et al, 1984). The lithologies in the area are divided into three divisions (Stewart et al, 1984); Division 1 consisting of mafic, felsic and aluminous qualities with lesser amounts of calc-silicate rock and marble. Division 2 consists of flysh-like sequences, and Division 3 contains rocks of dominantly platform facies, such as orthoquartzites (Figure 4.5).



Large and small dots or dashes indicate known and inferred trends of lithologic layering, respectively. RZ = Redbank Deformed Zone, HZ = Harry Creek Deformed Zone, DZ = Delny-Mount Sainthill Fault Zone, WF = Walabanba Fault Zone. Initials in bottom left corners of sheet areas denote names as follows: A, *Alcoota*; AS, *Alice Springs*; BC, *Barrow Creek*; H, *Hermannsburg*; HI, *Highland Rocks*; HR, *Hay River*; HU, *Huckitta*; IC, *Illogwa Creek*; LM, *Lake Mackay*; LR, *Lander River*; McD, *MacDonald*; MD, *Mount Doreen*; ML, *Mount Liebig*; MP, *Mount Peake*; MR, *Mount Rennie*; MS, *Mount Solitaire*; MT, *Mount Theo*; N, *Napperby*; T, *Tobermory*; TG, *The Granites*; W, *Webb*.

Figure 4.5 : Geological and tectonic sub-divisions of the Arunta Block (Stewart et al., 1984).

The tectonic evolution of the Arunta Block, involves several cycles of extension and compression (Shaw et al, 1984) with the Division 1 lithologies being deposited during the initial stages of rifting. The deposition of sediments (although interrupted by deformation, metamorphism and plutonism)

Event and approximate age	Northern Province	Central Province	Southern Province
Alice Springs Orogeny 400-300 Ma	Overthrusting, local retrogression	Faulting; local metamorphism up to greenschist	Overthrusting, greenschist metamorphism, zones of intense deformation
Platform cover deposition 900-300 Ma	Georgina Basin	Ngalia Basin	Amadeus Basin
Late igneous rocks			
730 Ma		Mud Tank Carbonatite	
900 Ma	Rare dolerite and troctolite	Rare dolerite	Abundant dolerite; gabbro, dacite
Ormiston Event 1050-900 Ma	Local zones of deformation, local granite	Local zones intense deformation, local granite	Amphibolite metamorphism, migmatite, local granite, acid volcanics
Intrusion of Mordor Complex 1185 Ma			Potassic-ultramafic intrusives; unmetamorphosed
Anmatjira Event 1500-1400 Ma	Greenschist metamorphism; 'S-type' granites	Possible migmatite and local granulite metamorphism	Possible granite intrusion
Aileron Event (includes Chewings phase) 1750-1600 Ma	Granulite metamorphism, many granites, minor pegmatite	Local amphibolite metamorphism at southern margin	Amphibolite metamorphism, 'I-type' granites, local diorite, dolerite, ultramafic rocks
Strangways Event 1800-1750 Ma	Possible local granulite metamorphism, granites in NW and NE	Granulite metamorphism, migmatite, anatectic granite	Not evident
Deposition of Division 3; Early Proterozoic	Quartzite, shale, carbonate, and metamorphosed equivalents, e.g. Reynolds Range Group	Quartzite, rare pelitic gneiss, schist, and calc-silicate rocks, e.g. Mendip Metamorphics	Metamorphosed quartz arenite, shale, conglomerate, e.g. Iwupataka Metamorphic Complex
Contact relationship	Unconformity	Inferred unconformity	Probable unconformity
Deposition of Division 2A; Early Proterozoic	Aluminous and siliceous metasediments, calcareous rocks, amphibolite, e.g. Lander Rock beds	Pelitic and calcareous rocks, amphibolite, e.g. upper Harts Range Group	Metasediments, calc-silicate rocks, orthogneiss, e.g. Hayes Metamorphic Complex
Deposition of Division 2B; Early Proterozoic	Not evident	Layered granitic gneiss, e.g. Entia Gneiss, lower Harts Range Group	Layered granitic or granodioritic gneiss; amphibolite
Contact relationship	Faulted; disrupted by granite	Div. 2B locally unconformable on Div. 1A; elsewhere faulted	Div. 1 thrust over Div. 2B at northern margin
Deposition of Division 1A; Early Proterozoic or earlier	Not evident	Calcareous and pelitic rocks; quartzofeldspathic gneiss, e.g. Cadney Metamorphics	Not evident
Deposition of Division 1B; Early Proterozoic or earlier	Felsic and mafic granulites, overlain by metasediments, Anmatjira Range	Felsic and mafic granulites, subordinate metasediments, e.g. Strangways Metamorphic Complex	Not evident

Table 4.2 : Summary of the stratigraphic and tectonic evolution of the Arunta Block (Shaw et al., 1984).

reflects the increasing stability of the block (as shown in Division 3 carbonate sequences). A summary of the tectonic evolution of the Arunta Block is given in Table 4.2. Other areas which have a similiar history are the Granites-Tanami Block and the Tennant Creek Inlier (Figure 4.2).

The Granites-Tanami Block (Figure 4.6) consists of a series of steeply dipping tightly folded sedimentary and volcanic rocks, (the Tanami Complex), which have been tentatively correlated to the Halls Creek Group in the Halls Creek Province (Dow and Gemuts 1969, in Blake and Hodgson, 1975). The complex has been intruded by post-orogenic granites and is overlain by lithics and tuffaceous sandstone, acid lavas and pyroclastics of the Mount Winnecke Formation. This formation is intruded by the Winnecke Granophyre which is inferred to be co-magmatic with the acid volcanics (Dow and Gemuts op ct.). The stratigraphy of the block is shown in Table 4.3.

The Tennant Creek Block (Figure 4.7) contains the most significant occurrences of gold mineralization in the North Australian Craton, associated with the early-Proterozoic Warramunga Group. The Warramunga Group (Table 4.4) consists of greywackes, lithic sediments (including turbidites, Elliston, 1963 in Large, 1975 a) and volcanics. This sequence is overlain unconformably by the arenaceous Tomkinson Creek Beds and Hatches Creek Group, the latter containing interbedded acid and basic lavas (Crohn, 1965; Crohn, 1975; Large, 1975 a).

Cainozoic	Quaternary: aeolian, alluvial and lacustrine deposits Tertiary: laterite, calcrete, silcrete
Mesozoic	Cretaceous?: Larranganni Beds, Hazlett Beds
	——— unconformity ———
Palaeozoic	Post Cambrian?: Lucas Formation, Pedestal Sandstone Lower Cambrian: Antrim Plateau Volcanics
	——— unconformity ———
Adelaidean?	Redcliff Pound Group: includes Erica Sandstone and Kearney Beds
	——— unconformity ———
Carpentarian	Birrindudu Group: includes Gardiner Sandstone, Talbot Well Formation, Coomarie[2] Sandstone
	——— unconformity ———
L. Proterozoic	Winnecke Granophyre, Lewis Granite, unnamed granite, Pargee Sandstone, Mount Winnecke Formation, Supplejack Downs Sandstone
	——— unconformity ———
Archaean or L. Proterozoic	Tanami complex: Killi Killi, Mount Charles, Nanny Goat Creek, Nongra and Helena Creek Beds

Table 4.3 : Summary of the stratigraphy of the Granites-Tanami area (Blake and Hodgson, 1975).

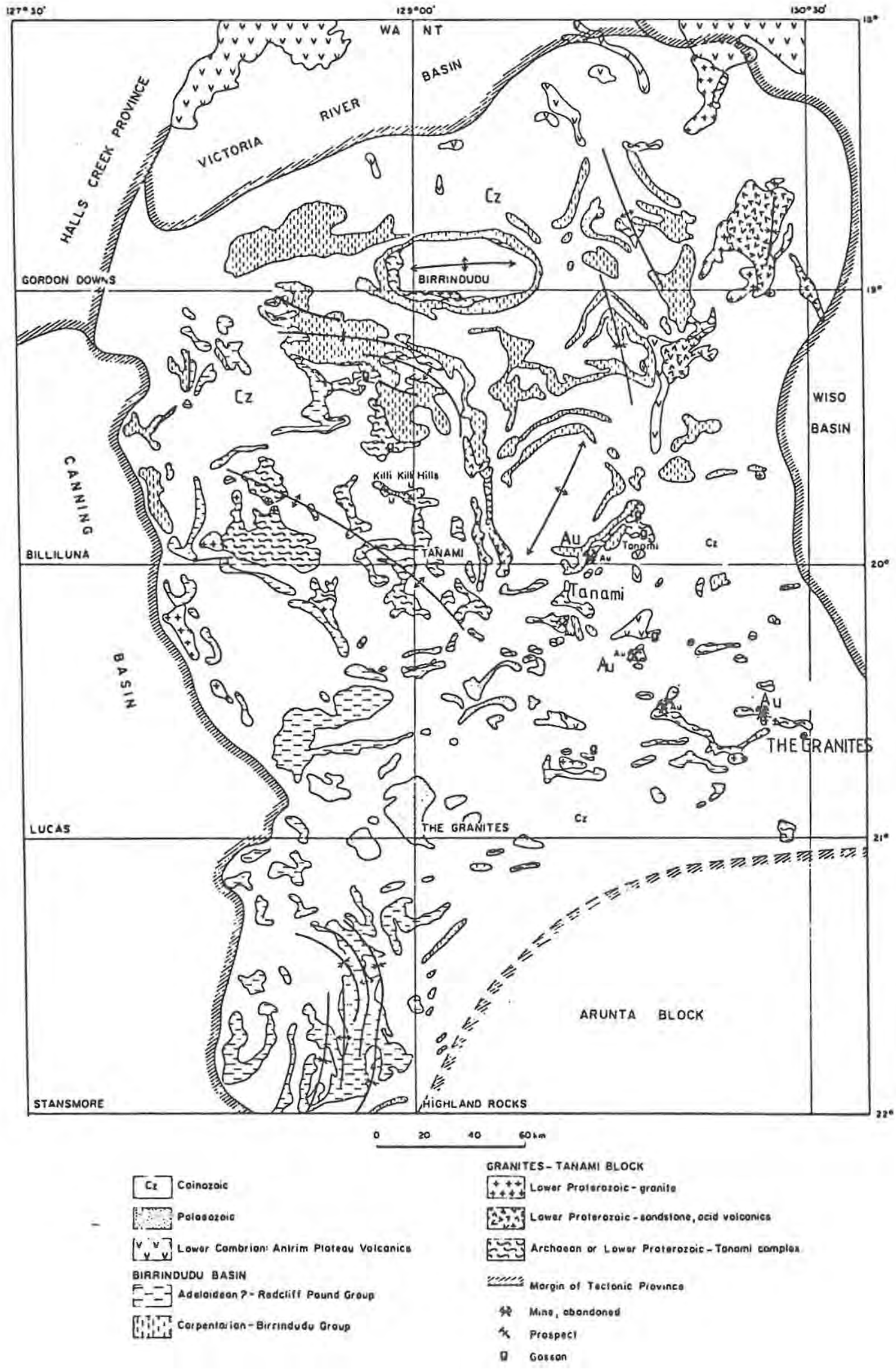


Figure 4.6 : Outcrop geology and mineralization of The Granites-Tanami Block (Blake and Hodgson, 1975).

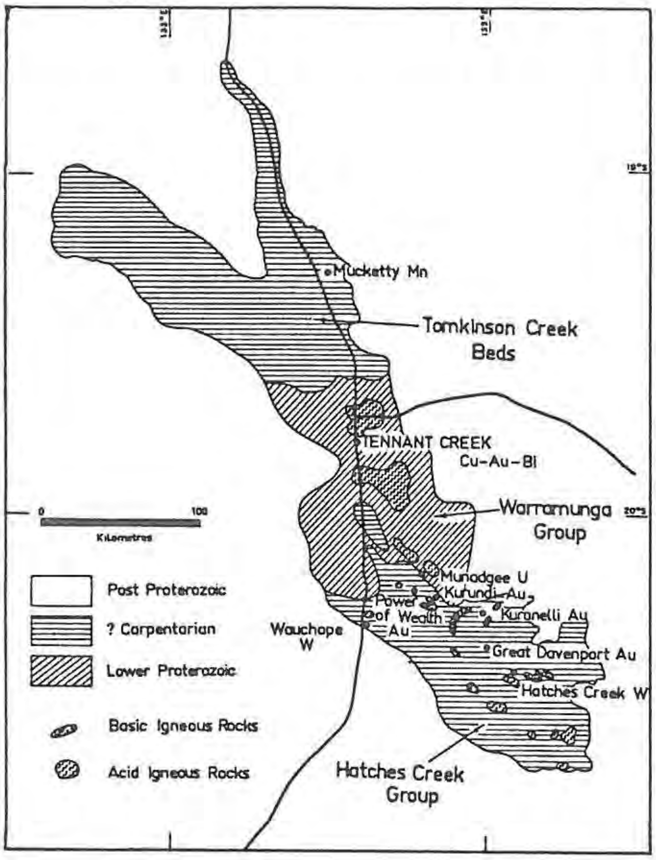


Figure 4.7 : Simplified geology of the Tennant Creek Block (Crohn, 1975).

Formation name		Lithology	Approx. thickness
			(meters)
Carraman	Iron-free facies	graywackes, lithic graywackes, and minor shales	500
	Hematite facies	felsic turbidites, tuffaceous graywackes, argillaceous iron-formations, rhyolitic pyroclastics, and ash-flow tuffs	500–1,500
	Magnetite facies	felsic turbidites, chloritic siltstones, argillaceous iron-formations	500
Bernborough		Rhyolitic lavas, pyroclastics, tuffs, and shales	0–700
Whippet		Massive sandstones, minor graywackes, and shales	300

Table 4.4 : Stratigraphy of the Warramunga Group, Tennant Creek Block (Large, 1975 a).

4.1.2 Gold Mineralization

The gold mineralization of the Tanami deposits (Figure 4.6) is confined to the Mount Charles Beds within the Tanami Complex, within a NE trending fracture zone. Lodes are lenticular quartz bodies and quartz-jasper-hematite bodies in siliceous sediments, with minor greywackes. In The Granites deposit, mineralization occurs in discontinuous thin quartz veinlets, and wide quartz-calcite veins, as well as in the host rocks of schists and thin-banded quartzites (Tanami Complex). The veins are steeply dipping, concordant lodes, restricted to one stratigraphic horizon, and may be genetically related to the intrusion of late stage (post-orogenic) granites or to the regional deformation and low grade metamorphism (Blake and Hodgson, 1975). Recent re-evaluation and development in The Granites-Tanami Block, includes the re-establishment of milling operations at The Granites mine (reserves 1.08Mt at a grade of 10.2 g/t) (Gold Gazette, November 10, 1986).

The gold mineralization in the Tennant Creek Block, is mostly confined to the Carraman Formation of the Warramunga Group in the Tennant Creek Goldfield (eg. Juno, Peko and Warrego Mines), with minor occurrences in the Hatches Creek Group (eg : Great Davenpoort Mine)(Figure 4.7).

Regional control on mineralization, in addition to lithology, is structural with folding and ENE trending shear zones. The folding is second order, and may be associated to first order anticlinal (or domal) folds, or synclinal folds. The lithological control is dominantly sedimentary (eg magnetite facies) and a close association to B.I.F. horizons. In all mines, a magnetite-chlorite core-zone carries the highest grade of gold and bismuth mineralization with copper occurring associated to an outer talc-magnetite zone (eg. Juno Mine, No. 2. Orebody, Figure 4.8 and Table 4.5). The orebodies are magnetite and/or hematite rich. The shape is lenticular or pipe-like, transgressive to the strata, with the economic concentrations of gold, having a close spatial association to the hematite facies of the Carraman Formation. The Juno Mine, No. 2 Orebody is associated to second order anticlinal folds (Large, 1975 a,b), with a clear alteration zonation (Figure 4.8), the core of which has a preferential enrichment of gold and bismuth mineralization. The footwall of the orebody is chloritized, in places bleached, and contains magnetite-quartz-pyrite veins, which are interpreted as the hydrothermal fluid channelways. The Warrego and Peko Mines contain similiar gold-copper(-bismuth) mineralization alteration patterns, and preference for second order structures as the Juno Mine. The B.I.F. horizons, which are spatially associated to the orebodies, have acted as geochemically favourable sites for mineral deposition (in part due to a high carbonate content)(Large, 1975 b).

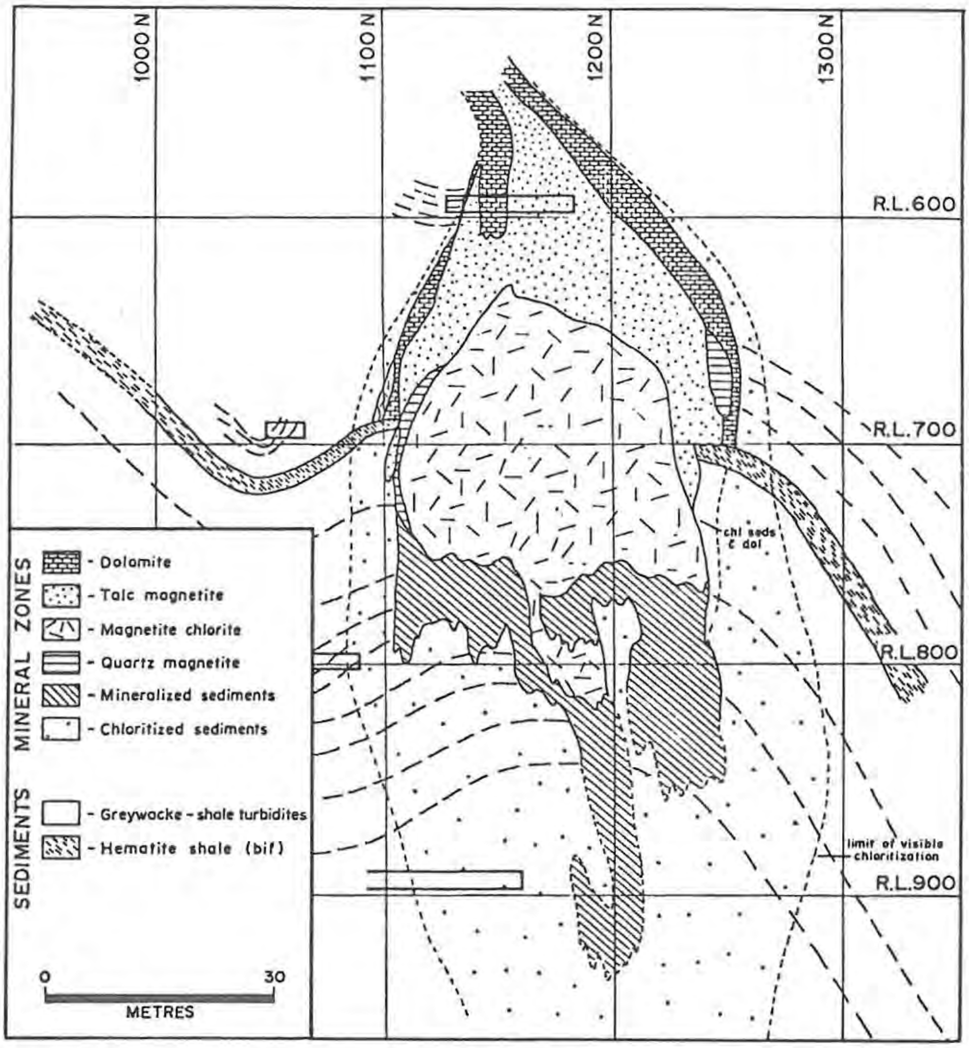


Figure 4.8 : Geological cross-section of the Juno No. 2 Orebody, Juno Mine Tennant Creek Block (Large, 1975 b).

SILICATE - OXIDE ZONE	METAL ZONE	ORE MINERAL	S/Se * Min.	S/Se * Max.	Wt%S * Min.	Wt%S * Max.
	Au	Native gold	–	–	0	0
MAGNETITE CHLORITE		$Bi_{10}(Pb(Cu_2))_8(S,Se)_{23}$ Wittite ?	0·5	0·8	8·2	11·1
	Bi	$Bi_8Pb_3Cu_2(S,Se)_{16}$ Junite	1·1	3·5	12·0	15·2
		$Bi_2(S,Se)_3$ -- $Bi_6Pb_2Cu_2(S,Se)_{12}$ Bismuthinite-Aikinite series	2·1	38	14·6	18·6
		Emplectite $CuBiS_2$	56	193	17·8	19·3
TALC MAGNETITE	Cu	Chalcopyrite $CuFeS_2$	∞		34·9	
		Pyrite FeS_2	∞		50·2	

Table 4.5 : Zonation and ore mineralogy relationships, Juno Mine Tennant Creek Block (Large 1975 b).

The Warrego Mine mineralization is dominantly pyrite, chalcopyrite, bismuthinite and gold, while the Peko mine contains chalcopyrite, gold and other metal sulphides (eg sphalerite and pyrhotite). The majority of orebodies which crop out in the Tennant Creek Goldfield have a deep level of oxidation, in places containing supergene gold and copper enrichment.

The minor gold deposits of the Hatches Creek Group (eg. Great Davenpoort), occur in faults and shear zones in quartzites, and in sandstone-shale sequences (Crohn, 1975), as auriferous quartz veins. The Great Davenport deposit is significant as it occurs within the Hatches Creek Tungsten Field which contains wolframite, scheelite, chalcopyrite and bismuthinite mineralization. Some of the tungsten lodes carry minor gold concentrations which suggests a possible genetic link to the deposits of the Warramunga Group. The lodes have distinct alteration haloes in the dominantly arenaceous sandstone, and acid to intermediate volcanic sequence wall rocks. The dominant gangue minerals are quartz and muscovite (greisen?). An outcropping granite 5km to the south of the mine may be genetically related to these tungsten (-gold) deposits (Crohn, 1975). Recent developments in the area include the Explorer 46 mine which contains resources of 200 000t at a grade of 1.8g/t (Gold Mining Magazine, September, 1986).

The gold mineralization of the Tennant Creek Goldfield, has the characteristics of "magmatic-related" type gold occurrences. Large (1975 a), envisages a basinal deposition of the Warragunga Group (geosynclinal) interspersed with off-shore volcanics including rhyolites tuffs and ash flow units. The sedimentary facies which occur are related to the depositional environment, with the last stages of volcanism associated with a period of east-west folding, during which granites re-intruded the sedimentary pile. This last period of volcanism and deformation, generated hydrothermal cells (adjacent to the granitic intrusions), in which fluids, when moved in response to lithostatic pressure and temperature, began leaching elements and metals from the enclosing sedimentary pile. Localization of mineralization was structurally and lithologically controlled by shearing and second order folds and BIF horizons respectively. The mineralization in the Hatches Creek Group appears to be related to a magmatic source (?) which may have remobilized metals and elements from the Warramunga Group rocks at depth (as indicated by the presence of gold and bismuth), in addition to deriving elements (tungsten) from sediments adjacent to the granite intrusions (which may also lie at depth). The origin of gold-bearing fluids in the Tennant Creek Goldfield is at present speculative.

The mineralization in the Pine Creek Geosyncline is dominantly uranium with minor associated gold. Needham and Roarty (1980) define a number of different types of mineral deposits, based on geological associations and deposit type. The gold mineralization within this classification, occurs in three main types :

(a) stratabound deposits in the Masson and Cahill Formation close to areas of basement rocks, associated to uranium mineralization.

(b) stratiform deposits in the Koolpin Formation, Garowie Tuff and Kapalga Formation, either singularly or in association to uranium or base metals and

(c) vein type deposits associated with Carpentarian granites, and is related to tin, silver, lead, tungsten, tantalum, copper and bismuth mineralization.

The distribution of the above types of deposit is shown on Figure 4.9 a, and a generalized section (Figure 4.9 b), shows the distribution of mineralization.

The stratabound deposits (type a) are located in breccia zones in carbonaceous pelitic rocks adjacent to crystalline carbonate rocks, and are the dominant source of uranium in the province. The Jabiluka Two deposit is the only uranium deposit which contains economically recoverable gold (529 000 tonnes at 15.3gm/t). All the deposits have an alteration halo of chloritization which occurred at about 1610 Ma.

The stratiform (type b) gold deposits are of two types, gold in tuffs and ashstone of the Gerowie Tuff, and gold-uranium in the carbonaceous shale of the Koolpin Formation. The Howley Anticline to the west of the post-Orogenic Cullen granite, contains gold mineralization in the cores of folds and where there is a change in the pitch or deformation of folds. The favourable_ horizons for mineralization are chloritized carbonaceous schists (with quartz and carbonate), tuff beds and chert-banded siltstones. The Cosmopolitan Howley mine which contains fold mineralization occurs at the contact between graphitic shale and underlying chlorite schists (Needham and Roarty, 1980). In two areas in the geosyncline, the Margret Syncline and

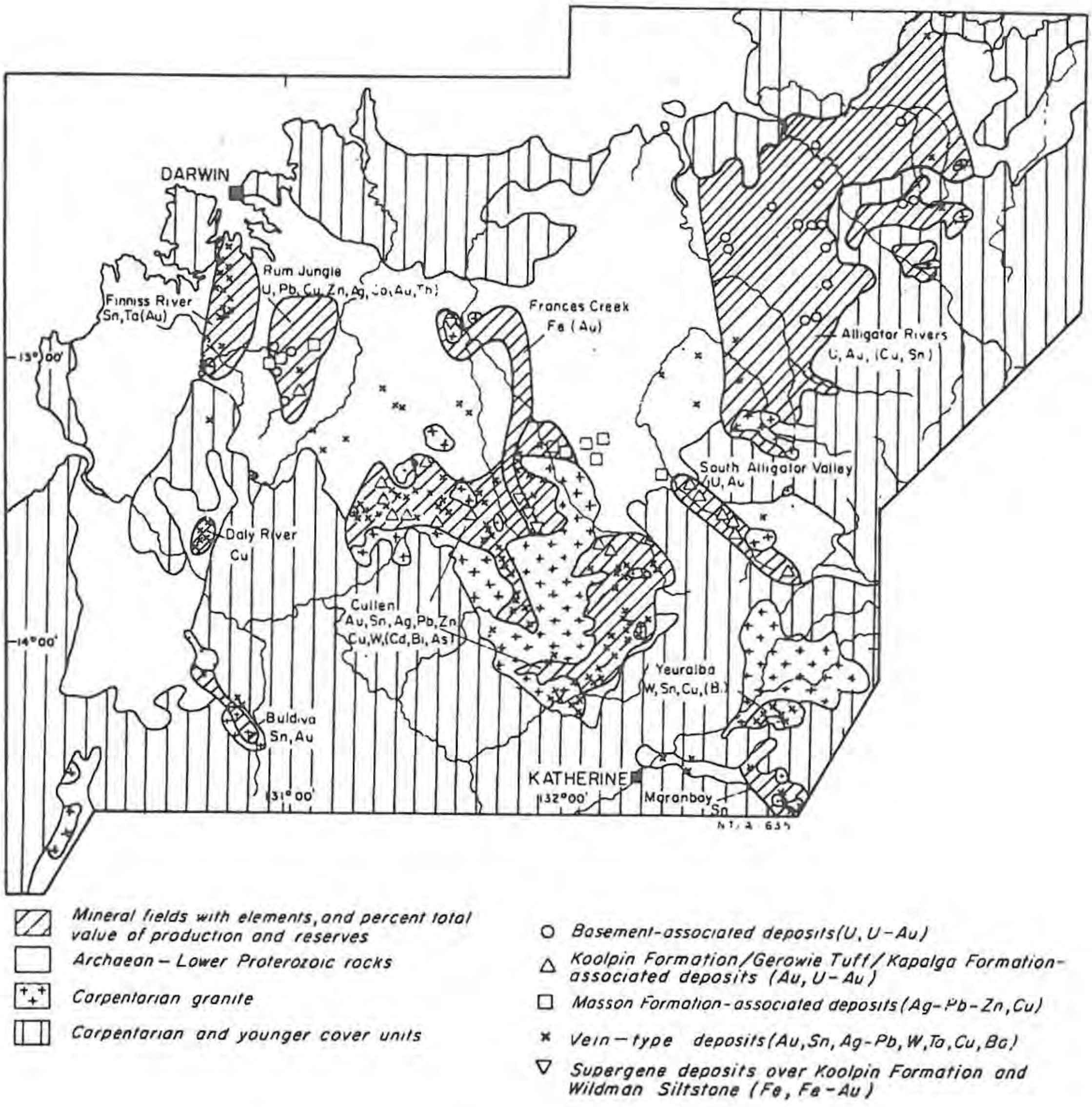


Figure 4.9 a : Distribution of Mineral Fields in the Pine Creek Geosyncline (after Needham and Roarty, 1980).

Howley Anticline, the gold deposits are adjacent to granites and associated with tourmalinites. Nicholson (1980), suggests that these tourmalinites were deposited by submarine exhalative volcanism, and the metals in the system were preferentially leached from tuffs in the sequence. The leaching of the tuffs was a result of the late post-orogenic granitic intrusions into the system generating a convection cell of sea-water, through the sedimentary/volcanic pile.

The gold mineralization is dominantly associated to banded ferruginous sediments, indicating a lithological control on mineralization which may be

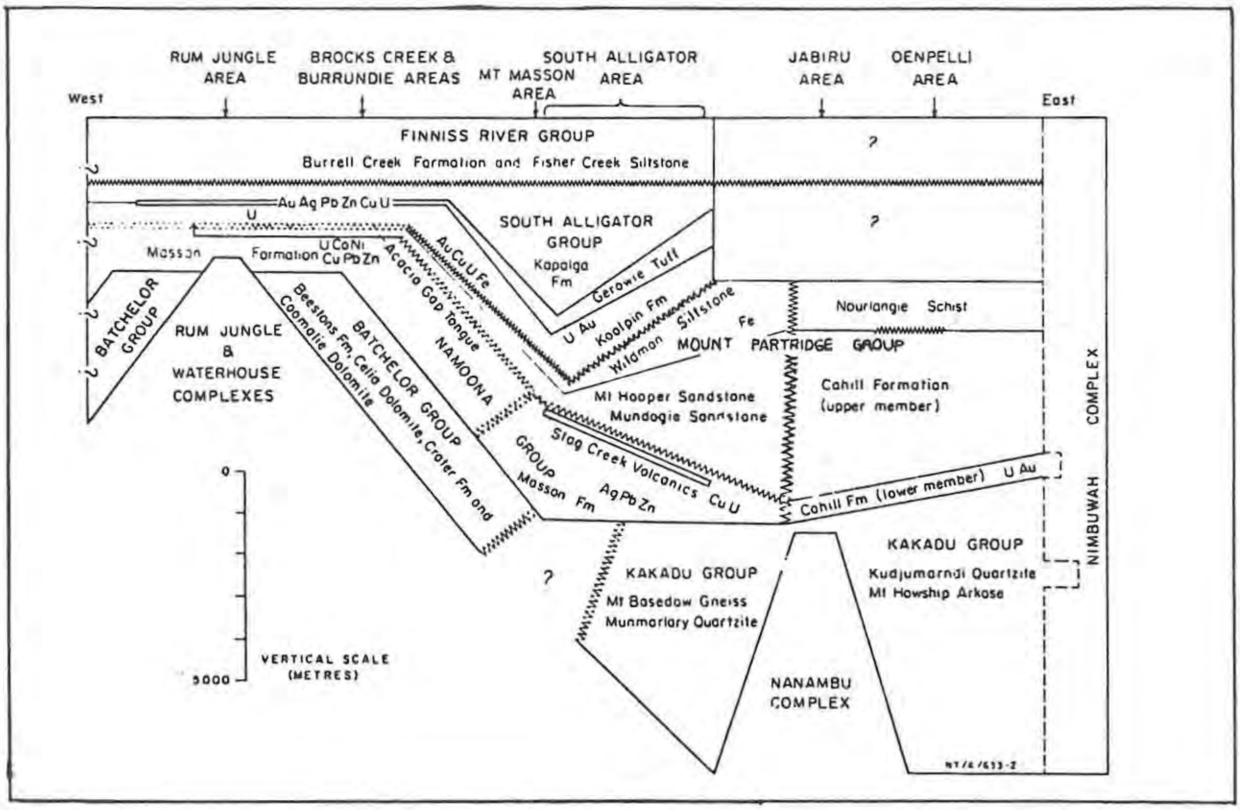


Figure 4.9 b : The position of stratabound mineralization in an idealized stratigraphic cross-section of the Pine Creek Geosyncline (Needham and Roarty, 1980).

related to a change in brine chemistry (Nicholson, 1980), or alternatively some of the fluids may have been magmatic and related to the granites (Needham and Roarty, 1980)

The vein type (type c) gold deposits, are dominantly hosted in the Burrell Creek Formation, and controlled by emplacement in shear zones. The Union Reef mines are an example of this type of mineralization, which occur in close spatial association to the Cullen granite, in a NNE-trending shear zone (Needham and Roarty, 1980). The host rocks are tuffaceous greywacke, slate and siltstone, with some metamorphics. This mineralization is interpreted as having a partial magmatic origin, with fluids being related to the post-orogenic granites (ie. Cullen granite).

The recent discovery of the Coronation Hill, gold and platinum deposit, within the confines of the Kakadu National Park, extends the gold potential of the area significantly. Preliminary work has indicated enough potential reserves to make Australia self-sufficient in platinum.

The gold mineralization in the Arunta Block is minor, with the Claraville goldfield being the most important (Warren et al, 1975). These deposits occur in an area tectonised by the 400-300 Ma Alice Springs Orogeny (Warren et al, 1975 , in the Central and Southern tectonic zones, about 100km NE of Alice Springs (Figure 4.4). The host rocks are granulite and amphibolite facies metamorphics of dominantly Division 1 lithologies (Stewart et al, 1984). The gold mineralization occurs in tensional joints, consisting of quartz-pyrite-calcite-siderite (gold in pyrite, undeformed terrain). The mineralization in the deformed terrain is quartz-pyrite-chalcopyrite. The age of emplacement of mineralization is unclear, with a genesis synchronous to deformation, and remobilization of older deposits due to the deformation being proposed (Warren et al, 1975). Burlinson and Mackie (1986), suggest that the mineralization was leached from volcanic assemblages in the basement complex, by fluid generated during retrograde greenschist metamorphism at 335-310 Ma (ie: the Alice Springs Orogeny), and deposited in structurally favourable sites.

4.2 Gawler Craton

4.2.1 Geology

The Gawler Craton basement is of possible Archaean age (Plumb, 1979 a), with the main rock units of the craton (*sensu stricto*) related to the Kimban Orogeny from 1855 Ma (a high grade metamorphic event). From 1700 to 1650 Ma syn-orogenic granites were emplaced, and the cratonization occurring after a period of transitional tectonism from 1550 to 1450 Ma. The products of this transitional tectonism are the Mundi Mundi granite and the Gawler Range volcanics and granites (Figure 4.10). Deposition of the Central Australian Platform Cover at 1400 Ma was the final stage of cratonization. The Gawler Range Volcanics have recently been dated (Cooper et al., 1985) at 1631 Ma and the granites at 1514 Ma, thus extending the period of transitional tectonism back 100 Ma, to immediately after the emplacement of the syn-orogenic granites, suggesting a more or less continuous cycle of magmatism.

The occurrences of rifts and interpreted occurrences of calderas, lineaments and grabens tending predominantly to the north-west were first identified by Crawford (1963), and re-defined by Branch (1978). These structures are

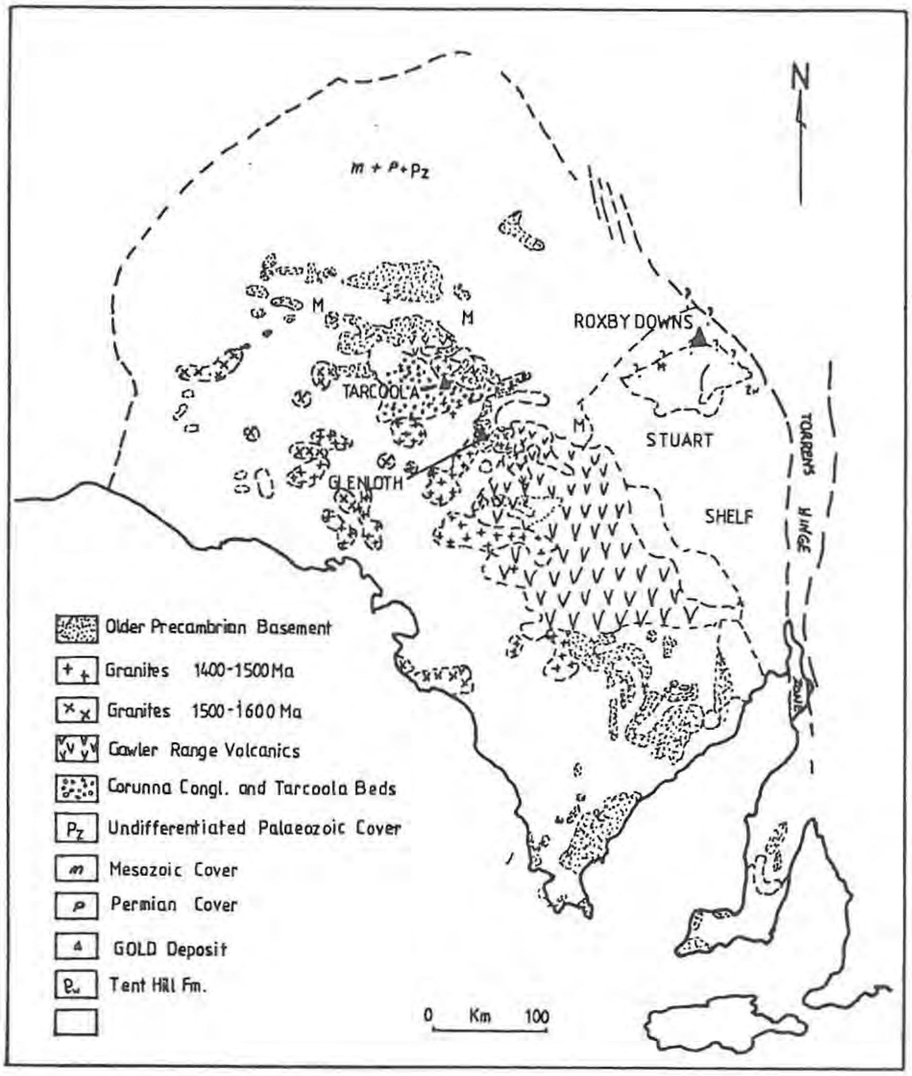


Figure 4.10 : Simplified geology of the Gawler Craton (after Thomson, 1975).

probably related to the graben structure tentatively identified as hosting the copper-uranium-gold-silver Roxby Downs deposit (Section 4.2.2). Further data (Webb et al, 1986) indicates the development of these structures is related to the second and third stages of the Kimban Orogeny.

The Stuart Shelf is a succession of shallow marine sediments deposited on the eastern margin of the Gawler Craton, adjacent to the Adelaide Fold Belt. These shallow water sediments were deposited on a stable shelf marginal to the Adelaide Fold Belt rifting, which continued into the Cambrian. Deformation of these rift-related sediments (Adelaide Fold Belt) occurred in the late Cambrian, during the Delemarian Orogeny which lasted until 450 Ma, but did not affect the Stuart Shelf sediments (Thomson et al., 1975).

The main geological units of the Gawler Craton are shown on Figure 4.10, with the stratigraphic succession of the area given in Table 4.6.

4.2.2 Gold Mineralization

Within the tectonic and structural boundaries of the Gawler Craton, gold deposits include the Roxby Downs, Tarcoola, Glenoth and Earea Dam deposits. The Roxby Downs deposit occurs in the northern part of the Stuart Shelf basement sequence, and the in-situ content of gold (and other metals) makes it one of the largest resources of gold, outside South Africa. The deposit contains an estimated 2000 million tonnes of ore with a grade 0.6g/t gold (Roberts and Hudson, 1983).

Two types of mineralization are recognized in Roxby Downs deposit, stratabound and transgressive, consisting of uranium, rare earths, gold and silver mineralization. The stratabound mineralization occurs within the Olympic

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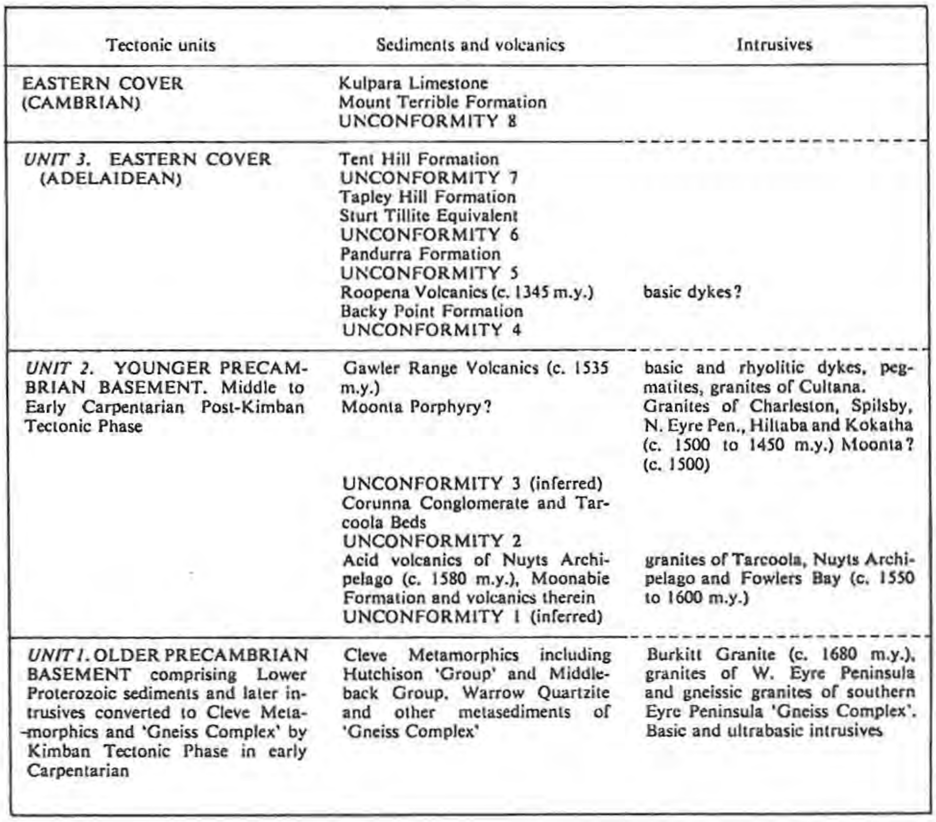


Tectonic units	Sediments and volcanics	Intrusives
EASTERN COVER (CAMBRIAN)	Kulpara Limestone Mount Terrible Formation UNCONFORMITY 8	
UNIT 3. EASTERN COVER (ADELAIDEAN)	Tent Hill Formation UNCONFORMITY 7 Tapley Hill Formation Sturt Tillite Equivalent UNCONFORMITY 6 Pandurra Formation UNCONFORMITY 5 Roopena Volcanics (c. 1345 m.y.) Backy Point Formation UNCONFORMITY 4	basic dykes?
UNIT 2. YOUNGER PRECAMBRIAN BASEMENT. Middle to Early Carpentarian Post-Kimban Tectonic Phase	Gawler Range Volcanics (c. 1535 m.y.) Moonta Porphyry?	basic and rhyolitic dykes, pegmatites, granites of Cultana. Granites of Charleston, Spilsby, N. Eyre Pen., Hiltaba and Kokatha (c. 1500 to 1450 m.y.) Moonta? (c. 1500)
	UNCONFORMITY 3 (inferred) Corunna Conglomerate and Tarcoola Beds UNCONFORMITY 2 Acid volcanics of Nuyts Archipelago (c. 1580 m.y.), Moonabie Formation and volcanics therein UNCONFORMITY 1 (inferred)	granites of Tarcoola, Nuyts Archipelago and Fowlers Bay (c. 1550 to 1600 m.y.)
UNIT 1. OLDER PRECAMBRIAN BASEMENT comprising Lower Proterozoic sediments and later intrusives converted to Cleve Metamorphics and 'Gneiss Complex' by Kimban Tectonic Phase in early Carpentarian	Cleve Metamorphics including Hutchison 'Group' and Middleback Group. Warrow Quartzite and other metasediments of 'Gneiss Complex'	Burkitt Granite (c. 1680 m.y.), granites of W. Eyre Peninsula and gneissic granites of southern Eyre Peninsula 'Gneiss Complex'. Basic and ultrabasic intrusives

Table 4.6 : Stratigraphic units of the Gawler Craton (Thomson, 1975).

Dam Formation (Figure 4.11), and consists of a bornite (minor chalcocite) - chalcopyrite-pyrite assemblage. The transgressive mineralization occurs above the stratabound mineralization zone and consists of a chalcocite-bornite assembly (Roberts and Hudson, 1983). Gold mineralization appears to be spatially related to zones of quartz-sericite alteration. (Roberts, 1986). The mineralization is confined to a north west trending graben zone buried below the sediments of the Stuart Shelf (Roberts and Hudson, 1983).

A tentative genetic model for the deposit has been presented by Roberts (1986). The mineralization is confined to a graben structure, and the transgressive deposits may have been deposited by a large hydrothermal cell generated by the intrusion of alkaline granites (Roberts, 1986). The age of the mineralization is constrained by the age of the host rocks (1580Ma, Roberts and Hudson, 1983) which is synchronous with Gawler Range volcanism (1631 Ma - 1400 Ma; Cooper et al, 1985; Webb et al, 1986). The host rocks are derived from the erosion of the Hiltaba Suite of granitoids (1550 Ma) and the Gawler Range volcanics (± 1700-1300 Ma)(Webb et al, 1986).

Fluid inclusion studies (Roberts, 1986) indicate a common source for mineralizing fluids, which deposited the two types of mineralization at different temperatures. This may indicate a potential association of

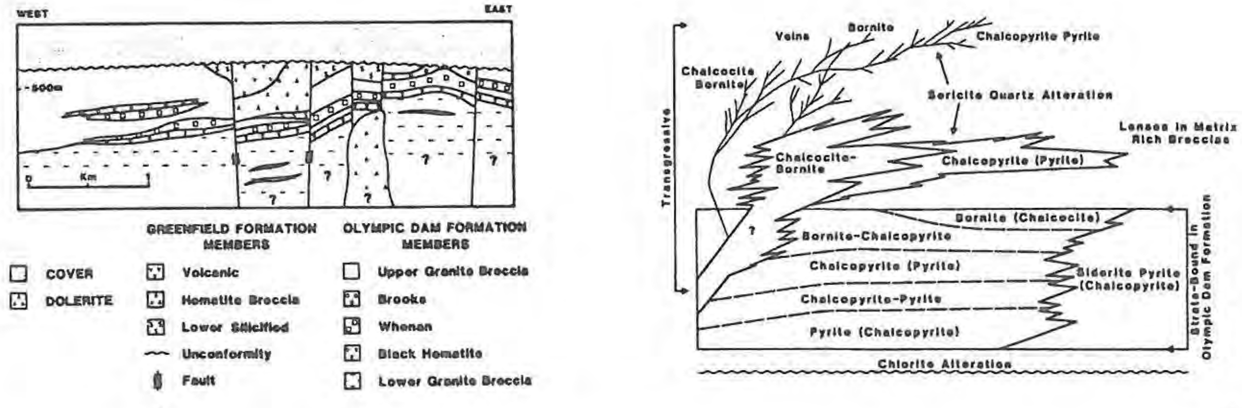


Figure 4.11 : (a) Generalized east-west cross-section of Olympic Dam/Roxby Downs deposit. (b) Diagrammatic representation of the transgressive and stratabound mineralization, of the Olympic Dam/Roxby Downs deposit (Roberts and Hudson, 1983).

stratabound mineralization to marginal faults on the graben structure, (an early mineralizing event related to an ascending granite magma), with the transgressive mineralization being a later event, in part derived from originally deposited stratabound mineralization. The possible association of mineralization to an intra-plate setting and alkaline granitoids is at present speculative (Roberts, 1986).

The Tarcoola deposit consists of a vein swarm of narrow steeply-dipping gold-quartz veins, hosted in the Taracoola Beds. The mineralized veins/veinlets are adjacent to, and in some places transgressive into basement granites (Johns, 1975). The Earea Dam deposit occurs in quartz-ironstone in association to basic dykes, within granites exhibiting evidence of hydrothermal alteration (Johns, 1975).

4.3 Central Australian Mobile Belts

4.3.1 Geology

The Central Australian Mobile Belts developed between the stabilized North Australian Craton and the Gawler Craton. The majority of this area is covered by platform cover with the exception of the Bangemall Basin, the Paterson Province and the Adelaide Fold Belt (Figure 4.12). The Paterson Province may be a remnant of a Proterozoic mobile belt marginal to the Pilbara Craton, active from 1700 Ma to 1400 Ma (Gee, 1979 b). Plumb (1979 a) correlates the Rundal Metamorphic complex of the Paterson Province with the Hammersley Basin (2300-1950 Ma), and the basement of the Paterson Province to the basement of the Musgrave Block (high grade metamorphics).

The Paterson Province occurs on the eastern margin of the Bangemall Basin (Figure 4.13) and has previously been interpreted as a part of this basin (eg Gee, 1975; Goode and Hall, 1981). Goode and Hall (1981) recognised a close association of the province to a regional NE trending gravity high, interpreted as a fold belt extending into the Central Australian Musgrave Block. A tentative correlation is suggested with the Petermann Orogenic Belt (Plumb, 1979 a, Preiss and Forbes, 1981). Within the Paterson Province inliers of basement, such as the Rundall Inlier of middle-Proterozoic age, overlie the sediments of the late Proterozoic (Goode and Hall, 1981), as a

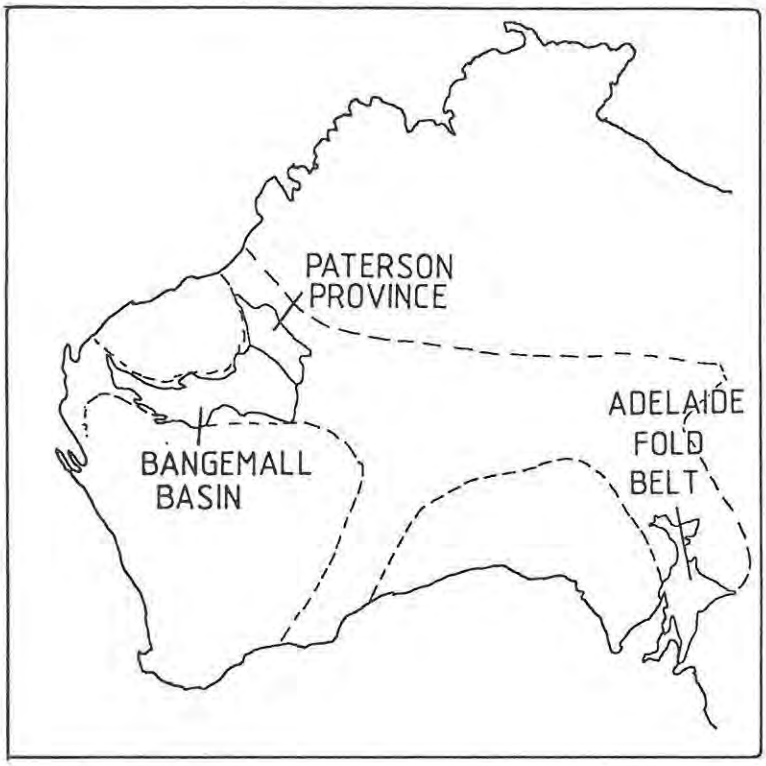


Figure 4.12 : Main Orogenic units of the Central Australian Mobile Belts (After Palfreyman, 1984).

result of folding and some faulting.

The Adelaide Fold Belt is predominantly a deformed geosynclinal sequence, developed in a continental rift setting with the Gawler Craton to the west and the Willyama and Mount Painter Inliers to the east, being original basement material (Thomson et al, 1975) (Figure 4.14). A review of the develoment of Adelaidean Basins in Australia by Preiss and Forbes (1981), identified the earliest sedimentation in the trough associated with rifting and basic volcanism (1100Ma), with coarse clastics on the Stuart Shelf, and mixed clastic-carbonate sequences in the geosyncline. From 1000-800 Ma the sedimentation was a mixed clastic-carbonate sequence, followed by (800-570 Ma) glacial and clastic sediments (Preiss and Forbes, 1981). Deformation of the Adelaide Geosyncline occurred during the Delamerian Orogeny which occurred up until 450 Ma.

4.3.2. Gold Mineralization

The Telfer Gold deposit is the best known deposit within the Paterson Province. It is hosted in the turbidite facies Telfer Formation, of the Yeneema Group (Figure 4.12).

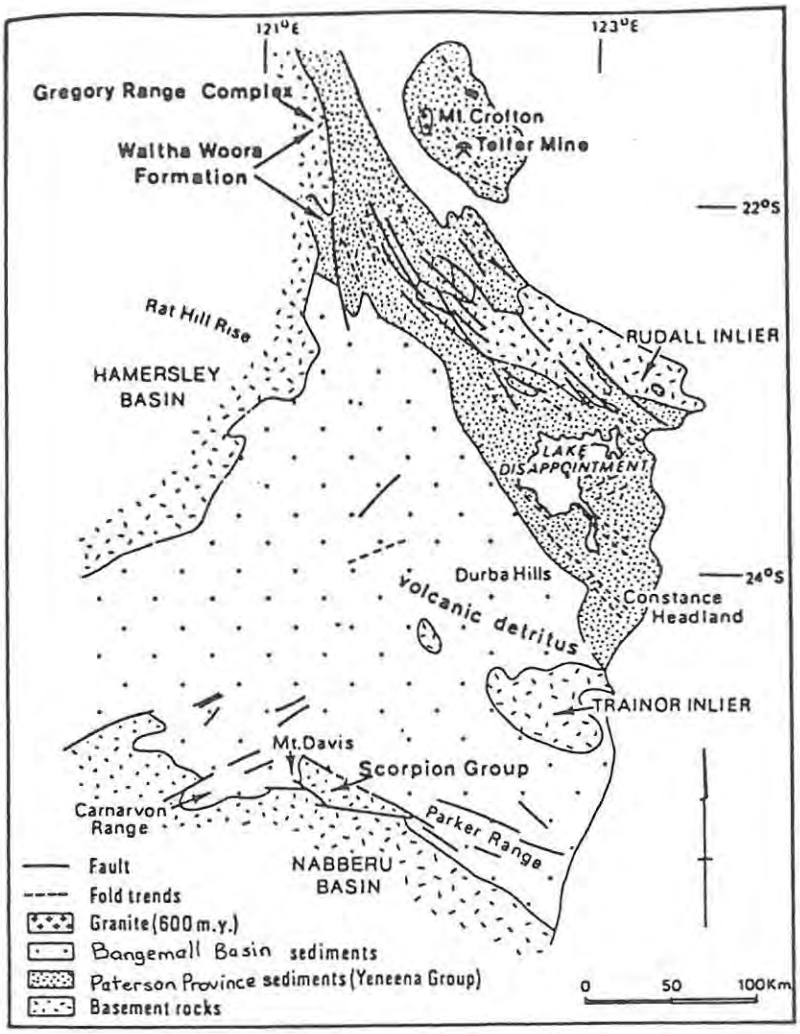


Figure 4.13 : Generalized geology of the eastern Bangemall Basin and the Paterson Province, Western Australia (after Goode and Hall, 1981).

The mineralization is strata-bound, in two carbonate-bearing siltstone members, in a thick sequence of arenites siltstones, mudstones and carbonates (Yeneena Group). The Middle Vale Reef (MVR) contains the best mineralization (10g/t) and is separated from overlying E1 and E2 ore horizons in typical Bouma sequences (Leeming, 1985). The major structure in the area is the Main Dome, an elliptical pericline, which has localized mineralization around it. The gold occurs in the lower siltstone member, as quartz limonite beds and may be either a syngenetic or an epigenetic replacement deposit. (Turner, 1980 in Leeming, 1985). The epigenetic model involves the intrusion of a 600 Ma granite, 25km west of the deposit, acting as the heat source for the generation of hydrothermal solutions.

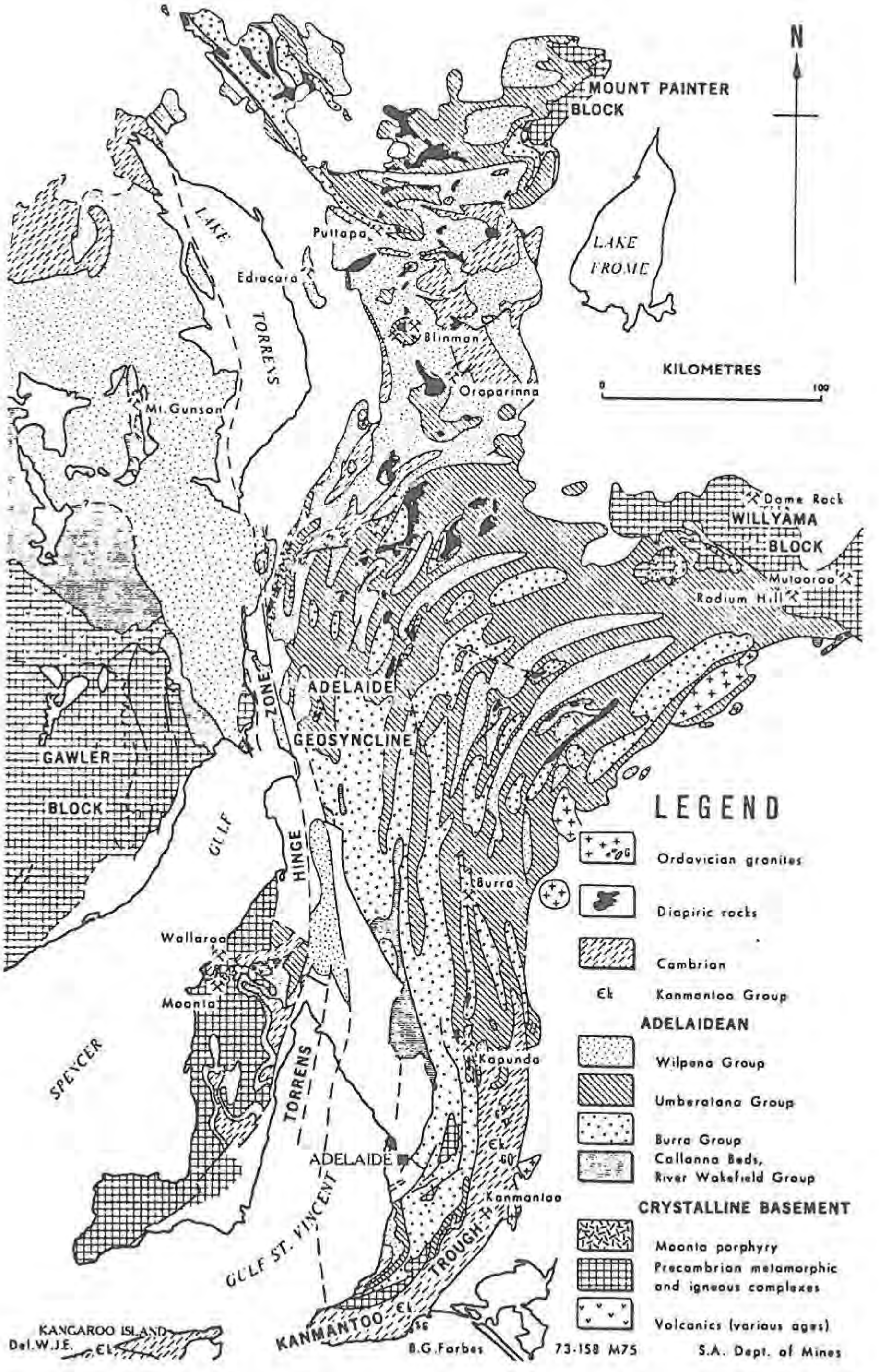


Figure 4.14 : Geology of the Adelaide Fold Belt (Geosyncline), South Australia (Thomson et al., 1975).

An interesting aspect which was overlooked by Leeming (1985), when considering the genesis of the deposit, is that the circulating hydrothermal fluids may have been generated in the classic metamorphogenic style associated to the deformation and metamorphism of the sequence. The domal structure formed at this time and acted as a localizing feature for the migrating fluids.

The gold-mineralization in the Adelaide Geosyncline is dominantly alluvial with some minor vein-hosted deposits. These latter deposits include stockworks and veins which become numerous in the southern part of the geosyncline. The origin of these minor gold deposits hosted in Adelaidean sediments, is possibly the remobilization of basement deposits during deformation, metamorphism and granitic plutonism (Dalamerian Orogeny) (Johns, 1975).

4.4 Northeast Orogens

4.4.1 Geology

The Northeast Orogens including the Mt.Isa Block, the Georgetown, Coen and Yambo Inliers, developed marginally to the North Australian Craton (Figure 4.15). The Mt. Isa Block is an area of orogeny, with an initial stage of sediment and volcanic deposition, followed by deformation and metamorphism, and the intrusion of granites from 1700 Ma. From 1670-1620 Ma, a regional unconformity developed, related to a metamorphic and granite intrusion event, and from 1490-1460 Ma the final deformation of the block occurred. The Coen, Yambo and Georgetown Inliers shared a common evolution with deformation, high grade metamorphism and plutonism at 1575 Ma and 1470 Ma. At 970 Ma the Georgetown Inlier underwent a period of retrograde metamorphism, one of the final events of stabilization.

The geology and structure of the Georgetown Inlier have been discussed by Branch (1966) and Oversby et al., (1975). The tectonic evolution of the Georgetown Inlier is synchronous to the Mt. Isa Block, marginal to the Northern Australian Craton with periods of high grade metamorphism,

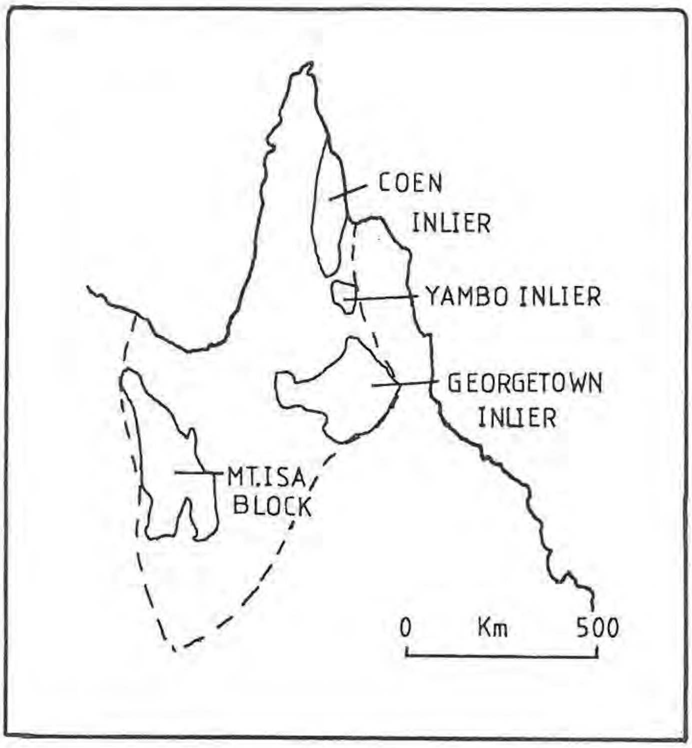


Figure 4.15 : Distribution of important tectonic domains in the Northeast Orogens (after Palfreyman, 1984 and Plumb, 1979 a).

deformation and plutonism at 1575 Ma and 1470 Ma, followed at 970 Ma by retrograde metamorphism during the final stabilization of the Precambrian basement. Subsequent to this stabilization, the area was intruded by granitic rocks during the Palaeozoic (Silurian-Devonian) (Oversby et al, 1975), such as the Forsayth Granite, the Dunbano Granite (both part of the Forsayth Batholith), the McKimons Creek Granite and the Dido Granodiorite. The Precambrian Basement rocks are amphibolite and granulite facies rocks (originally mudstones, siltstones, sandstones and some mafic lavas), and some granitic rocks such as the Esmeralda and Robin Hood granites (Oversby et al, 1975). Recent dating in the Georgetown Inlier (Black and McCulloch, 1984) suggests that the basement sequences (Candlower Formation and Einasleigh metamorphics, both part of the Ethridge Group) may be up to 2500 Ma old (Archaean), which is older that the Mt. Isa Block and may be a provenance area for sediments in the Mt. Isa sequence (Black and McCulloch, 1984). Available maps of the Georgetown Inlier do not define the individual rock units mentioned above, and the general geology of the area is shown on Figure 4.16. a.

The Georgetown Inlier was affected by two tectonothermal events at 400 Ma and 300 Ma (Black and McCulloch, 1984) which resulted in the intrusion of Permo-Carboniferous granitoids. Cover on the inlier includes sediments and volcanics of Proterozoic to Cainozoic age. The area is characterized by numerous ring complexes and areas of cauldron subsidence (Branch, 1966) (Figure 4.16 b).

The Coen Inlier (including the Yambo Inlier) is a northward extension of the Georgetown Inlier, consisting of a Precambrian basement of metamorphic and granitic rocks, and of middle Palaeozoic granitic (adamellite) rocks (Figure 4.17) (Oversby et al, 1975). These middle-Palaezoic rocks are the possible source of gold mineralization in the area, as are the Permian, high level granites which intruded the inlier. With the close similarity of geology between the Coen and Georgetown Inliers, it is expected that a similar volcanic province (as outlined by Branch, 1966) could exist.

4.4.2 Gold Mineralization

The gold mineralization in the Georgetown Inlier is dominated by the recently commissioned Kidston Mine (Figure 4.15) on the northern side of the Lochaber Ring Complex (Branch, 1966). The mineralization at Kidston is in a well developed breccia pipe, (Mining Magazine, January 1986), which appears to be spatially associated to the Permo-Carboniferous Lochaber Granite (Branch, 1966). The breccia pipe is near vertical with the mineralized zone on the southern side (Wise's Hill), dipping slightly shallower toward the north (Mining Magazine, January 1986). This indicates that mineralizing fluids slightly post-date the breccia pipe and were confined to zones of higher permeability in the pipe. The gold occurs dominantly as free gold (90%) with the remainder contained in pyrite and arsenopyrite. The late stage veining is a quartz-carbonate assemblage with sphalerite, galena arsenopyrite and pyrite. The alteration is dominantly sericite and carbonates.

The Georgetown Inlier contains numerous gold deposits including those of the Croydon Goldfield which occur in the Croydon volcanics as either narrow steeply dipping (near vertical) as thicker shallower dipping (15-45 E) quartz filled fractures (Wall and Withnall, 1975). Further gold mineralization occurs in the Esmeralda Granite at Croydon, where shear zones

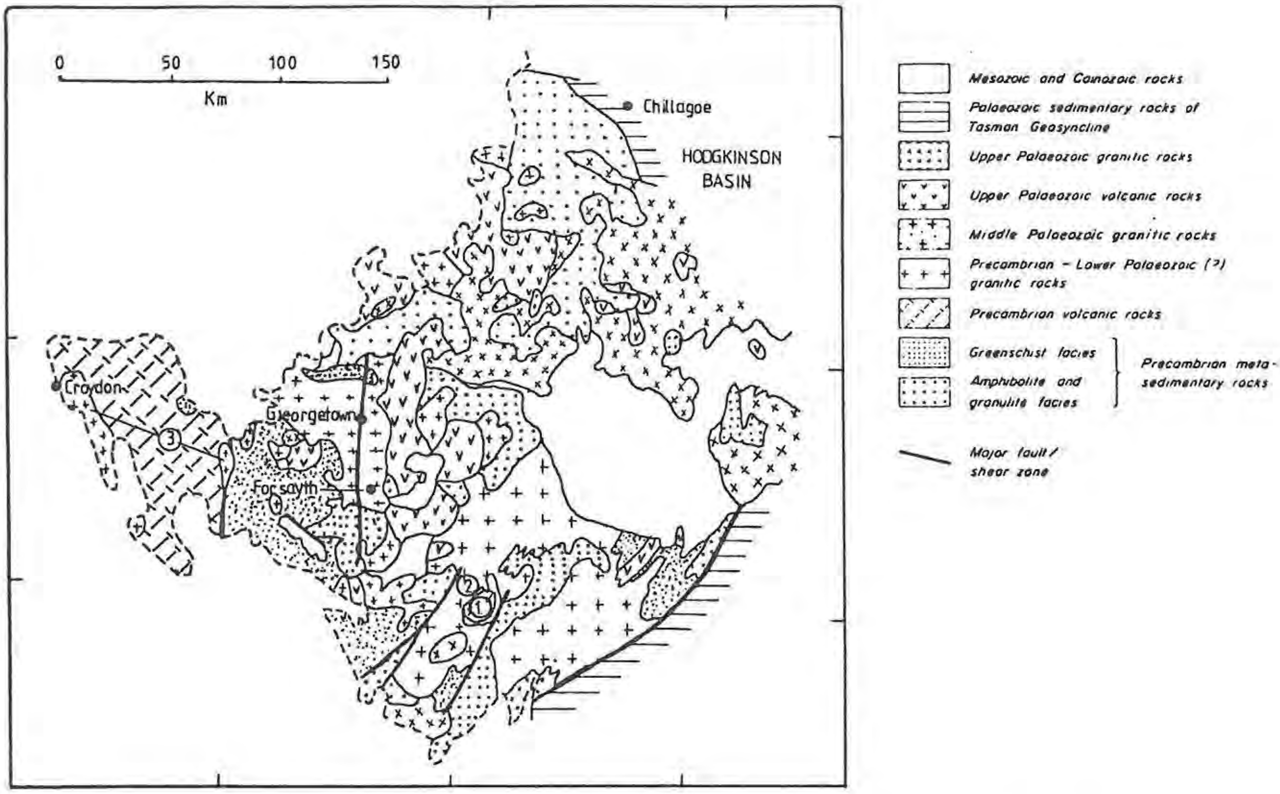
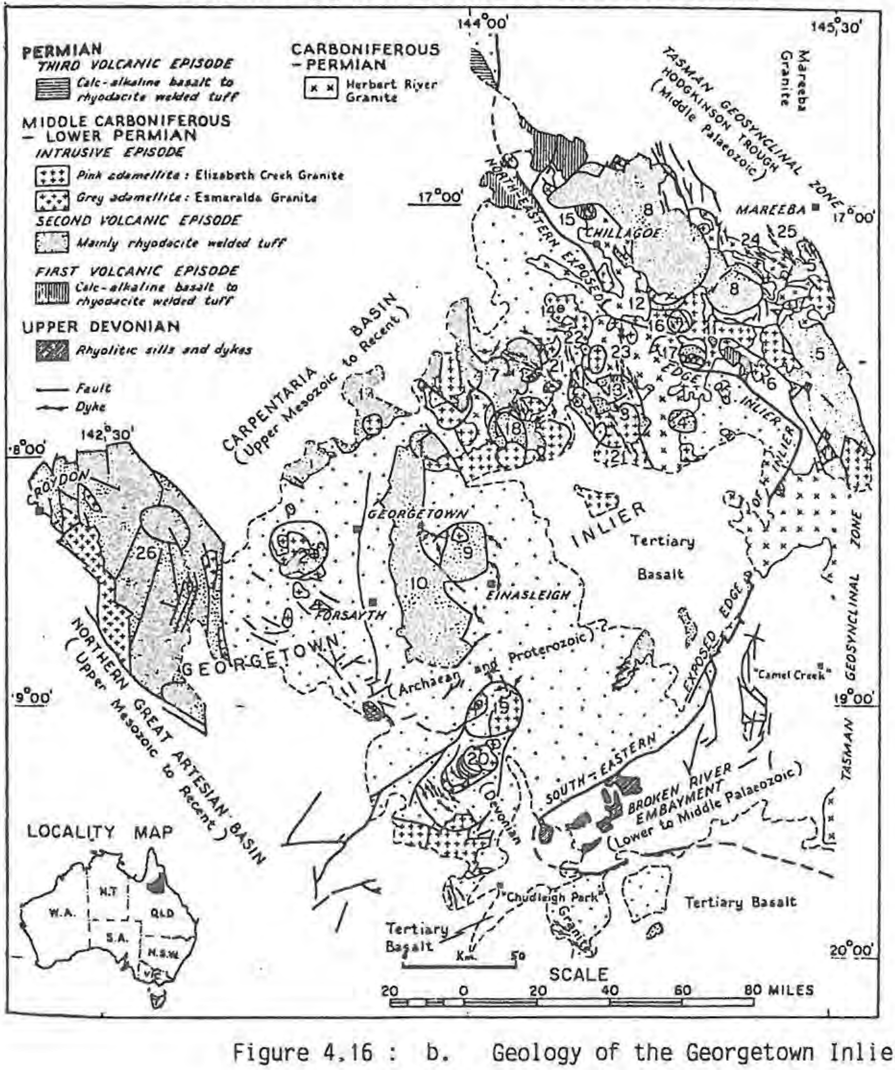


Figure 4.16 : a. Regional geology of the Georgetown Inlier (after Oversby et al., 1975). Numbers represent the Lochaber Ring Complex (1), Kidston Gold Mine (2) and Elizabeth Creek Granite (3).



ELIZABETH CREEK SUBPROVINCE

1. Galloway Cauldron Subsidence Area
2. Cumberland Range Cauldron Subsidence Area
3. Gingerella Cauldron Subsidence Area
4. Kallon Cauldron Subsidence Area
5. Glen Gordon Cauldron Subsidence Area
6. Nanyeta Cauldron Subsidence Area
7. Scardons Cauldron Subsidence Area
8. Featherbed Cauldron Subsidence Area
9. Eastern Newcastle Range Cauldron Subsidence Area
10. Newcastle Range Cauldron Subsidence Area
11. Gurrumba Volcanic Neck
12. Tennyson Volcanic Fissure
13. Barwidgi Volcanic Fissure
14. Crystal Brook Volcanic Neck
15. Doolan Creek Ring Complex
16. Boxwood Ring Complex
17. Claret Creek Ring Complex
18. Warby Ring Complex
19. Lochaber Ring Complex
20. Bagstowe Ring Dyke Complex
21. Wireyard Dyke Swarm
22. Emu Dyke Swarm
23. Graves Dyke Swarm
24. Collins Weir Dyke Swarm
25. Parada Dyke Swarm

ESMERALDA SUBPROVINCE

26. Croydon Cauldron Subsidence Area

Figure 4.16 : b. Geology of the Georgetown Inlier showing distribution of ring complexes, cauldrons, and major structural elements (Branch, 1966).

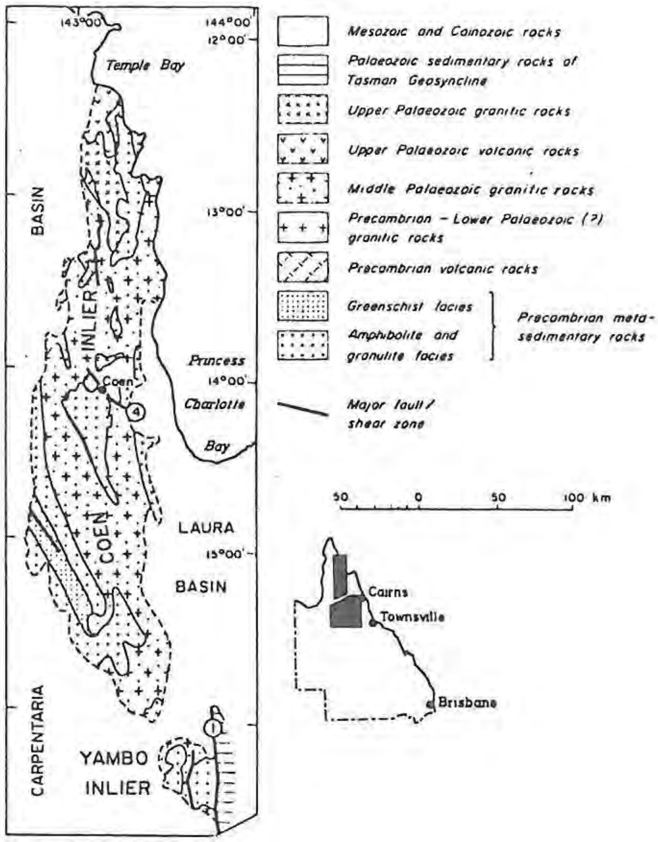


Figure 4.17 : Simplified geology of the Coen and Yambo Inliers (Oversby et al., 1975).

intersect zones of graphitic granite. The gold occurs with silver in a quartz gangue with arsenopyrite. Between Georgetown and Forsayth (Precambrian) granite mineralization is gold with galena and pyrite and minor amounts of chalcopyrite and sphalerite. The host rock is brecciated and altered granite.

The basement Etheridge Formation, west of Forsayth, contains coarse gold in quartz reefs, and the Einasleigh Metamorphics at Percyville contain gold bearing quartz veins (with traces of bismuth, tungsten, lead, copper, zinc sulphides), narrow rhyolite and pegmatite dykes. The host in these latter deposits is greisenized schists.

The gold mineralization in the Coen Inlier occurs (predominantly) within the Devonian granitic rocks of the Cape York Peninsular Batholith, and in adjacent Proterozoic metasediment contact rocks. The main fields of past production include the Alice River field (14kg alluvial, 94kg/2845 tonnes ore, accessory stibnite) and the Hamilton field (682 kg alluvial, 1372kg/34194 tonnes ore). The Hamilton deposits are predominantly in joints and fractures with some veining within granodiorite. Whitaker (1975) indicates that mining in the Hamilton field was not profitable below 45g/t, a grade which currently would be regarded as economic.

The Coen field contained the largest deposit of the area, the Great Northern mine (2180kg/26200t ore), and the mineralization is dominantly shear zone hosted (Coen Shear Zone). Other gold fields include the dominantly alluvial Wenlock Field, derived from quartz veins in the Kintore adamellite (mid-Proterozoic), and the Claudie River Field of quartz veins in schists, associated to faulting.

4.5 Curnamona Craton

The Curnamona Craton contains the Broken Hill Block and the Mt. Painter Block (in addition to platform cover sequences). The Broken Hill Block (cf. Willyama Inlier) is in part equivalent to the Gawler Craton, and is the basement to the eastern part of the Adelaide Fold Belt (Plumb, 1979 a). The main metamorphic event in the area was 1700-1650 and the final stabilization was synchronous with the Gawler Craton from 1550 Ma-1450 Ma. Only very minor gold occurrences are recorded in the Curnamona Craton (Blissett, 1975; Johnson and Gow, 1975), and are not discussed further in this dissertation.

5. PHANEROZOIC

The geological and tectonic evolution of the Phanerozoic Terrains in eastern Australia (Figure 5.1), is at present poorly understood with numerous proposed models. The Tasman Geosyncline* is the tectonic province of eastern Australia which is subdivided into four main fold belts, the Lachlan Fold Belt, the New England Fold Belt, the Hodgkinson Fold Belt, the Kanmantoo Belt (Figure 5.2) (Plumb, 1979 a; Palfreyman, 1984) and basinal terrains such as the Drummond Basin. General descriptions of the tectonic units, history and evolution of the Tasman Geosyncline include those by Solomon and Griffiths (1972), Scheibner (1973), Packham and Leitch (1974), Williams et al., (1975) Fisher and Warren (1975), Rutland (1976), Day et al (1978), Plumb (1979 a), Crook (1980) Pelham,(1983), Adams et al., (1985),

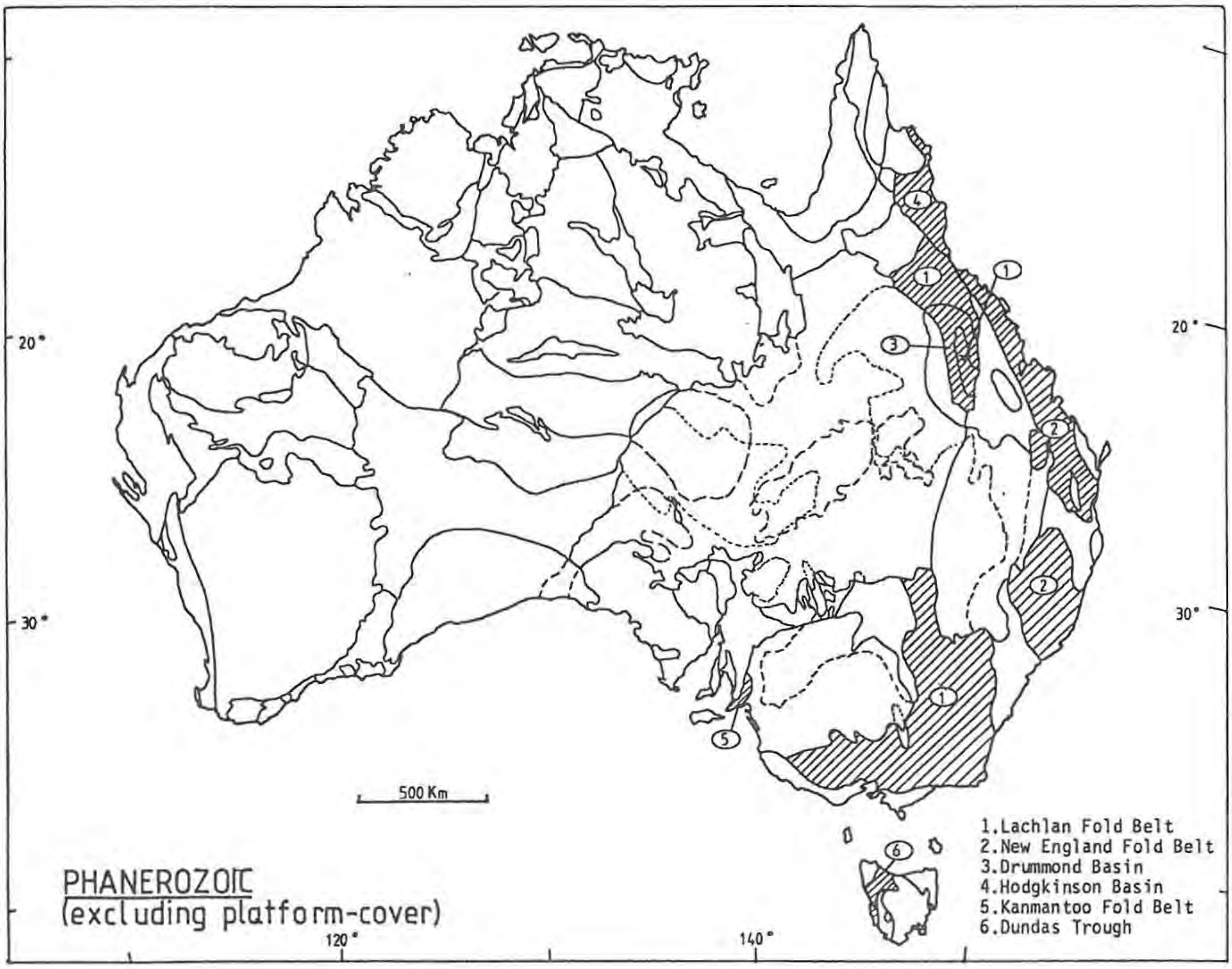


Figure 5.1 : Distribution of Phanerozoic rock units of Australia, excluding Mesozoic and Cainozoic cover sequences. (modified after Palfreyman, 1984, and Plumb, 1979 a).

* The term Geosyncline is adopted in preference to Orogen or Fold Belt to avoid confusion with sub-divisions within the Tasman tectonic province.

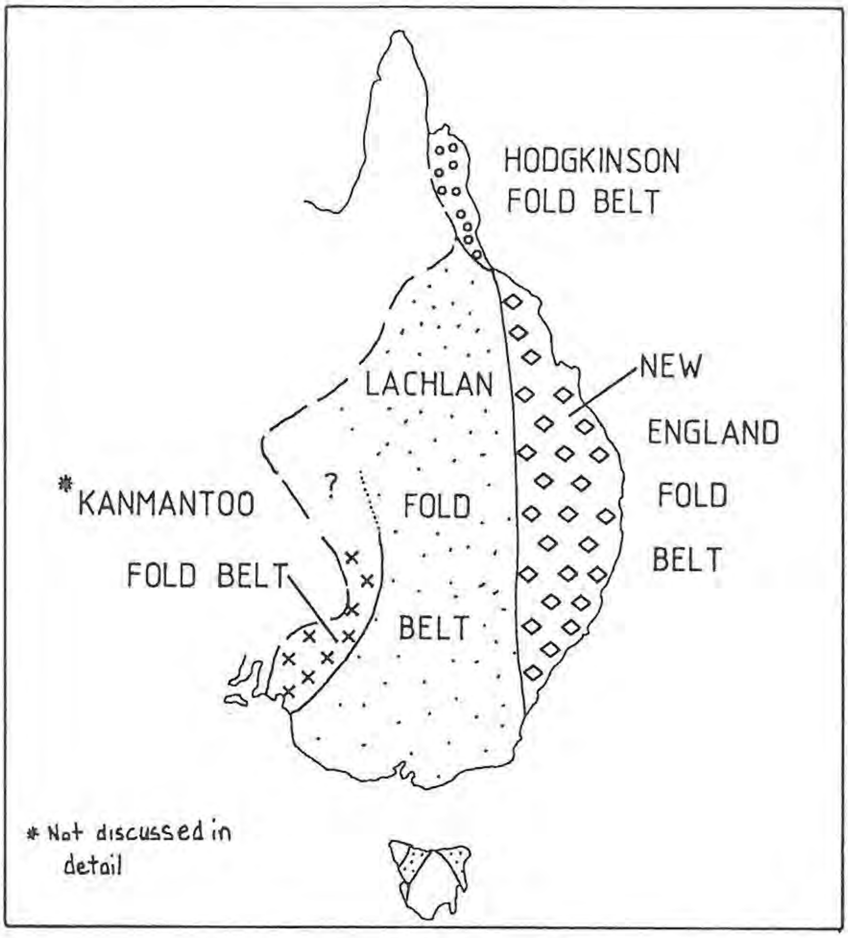


Figure 5.2 : Schematic distribution of the major tectonic subdivisions of Tasman Geosyncline.

and Harrington and Korsch (1985 a,b). No single description of the tectonic framework of the Tasman Geosyncline accounts for all the observed features (see Packham and Leitch, 1974), although some of the more localized descriptions are independently complete (eg. Crawford and Keays, 1978). The Kanmantoo Fold Belt is discussed within the framework of the Lachlan Fold Belt (Central Area) due to the relatively insignificant gold mineralization.

The geological and tectonic evolution of the Tasman Fold Belt can be simply summmarized as follows :

i. development of a marginal sea on oceanic crustal material, adjacent to the stabilized Australian Precambrian Craton. (Kanmantoo Belt)

ii. deposition of predominantly deep water sediments and formation of an island arc to the east, (Lachlan Fold Belt)

iii. deformation of complete sequence due to an arc-continent collision, and development of ophiolite sequences.

iv. granite plutonism in the eastern part (predominantly) related to subduction and possibly crustal thickening.

v. development of multiple volcanic arcs and shallow basinal sequences east of the Tasman Geosyncline (New England Fold Belt).

vi. deposition of Hodgkinson Fold Belt in part synchronous with the New England Fold.

vii. deposition of Drummond Basin synchronous with the early development of the New England Fold Belt.

After the Archaean Yilgarn Craton, the Lachlan Fold Belt is Australia's richest gold province, having produced in excess of 770 tonnes of gold up until 1977 (Woodall, 1979). Other gold-rich Phanerozoic provinces are the New England Fold Belt and Hodgkinson Fold Belt, in addition to the Drummond Basin. The Drummond Basin historically was one of the so-called gold 'barren' provinces in eastern Australia, until the recent discoveries of high-grade epithermal-type gold mineralization in 1985 (Australian Business, September 4, 1985). The full extent of these new discoveries is yet to be ascertained, but in the relevant section below, a preliminary evaluation of the potential in the area, and associated areas in terms of tectonic environment, geological framework and mineralization style is presented from the available information.

5.1 Lachlan Fold Belt

The Lachlan Fold Belt (Figure 5.1), is the largest tectonic province within the Phanerozoic Tasman Geosyncline and consists of three related areas, the Southern (Tasmania), the Central (New South Wales and Victoria), and the Northern (Queensland) areas.

5.1.1 Geology

Southern Area - Tasmania

The Southern Area of the Lachlan Fold Belt in Tasmania is confined to the northeast corner and the Dundas Trough in the west. The Dundas Trough is a

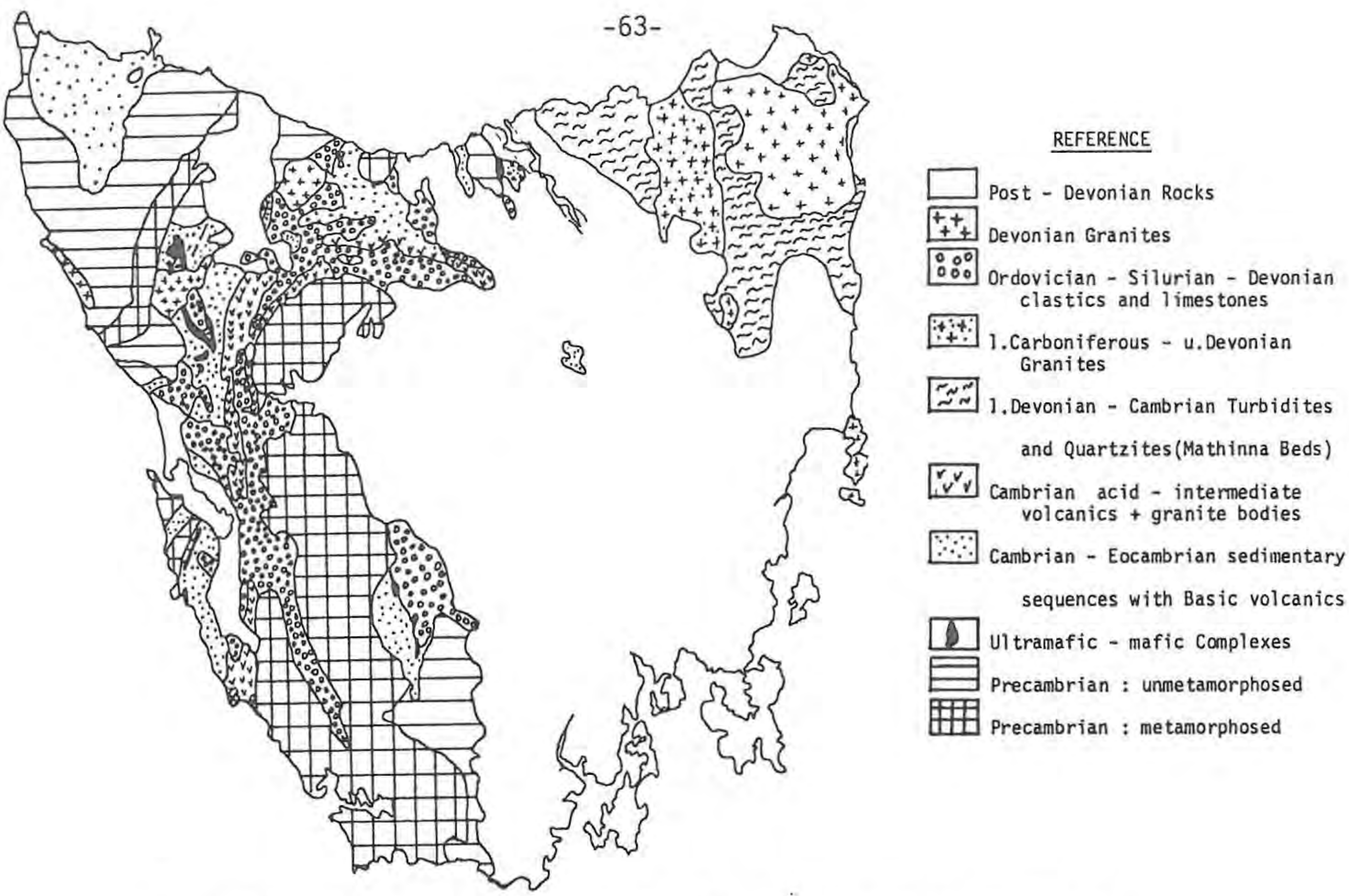


Figure 5.3 : Geology of Tasmania (modified after Williams et al., 1975 and Adams et al, 1985).

volcano-tectonic depression containing acid volcanics, basic volcanics, clastics, sedimentary sequences, ultramafic-mafic complexes and minor Devonian granitoids, while the northeast corner is predominantly quartzites and turbidites of the Mathinna Beds, with widespread Devonian granites (Figure 5.3). The Dundas Trough occurs between two Proterozoic basement blocks, the Rocky Cape Region and the Tyennan Nucleus (Figure 5.4). Deposition of sediments, volcanics and serpentinites in the Dundas Trough was initiated following deformation during the Pengiun Orogeny (700-750 Ma, Adams et al., 1985). The presence of ultramafic-mafic complexes within the Dundas Trough may indicate (in part) an oceanic crust as basement to the sequences, similar to the postulated marginal basin environment in Victoria (Solomon and Griffiths, 1972; Crawford and Keays, 1978; Crawford et al., 1984; Adams et al., 1985).

The main stratigraphic units in the Dundas Trough region (Figure 5.5) are the Success Creek Group (shallow to moderate depth sediments), the Crimson Creek Formation (volcanics, cherts and mudstones), and the Dundas Group (quartz flysch with felsic volcanics)(Adams et al., 1985). Inliers of

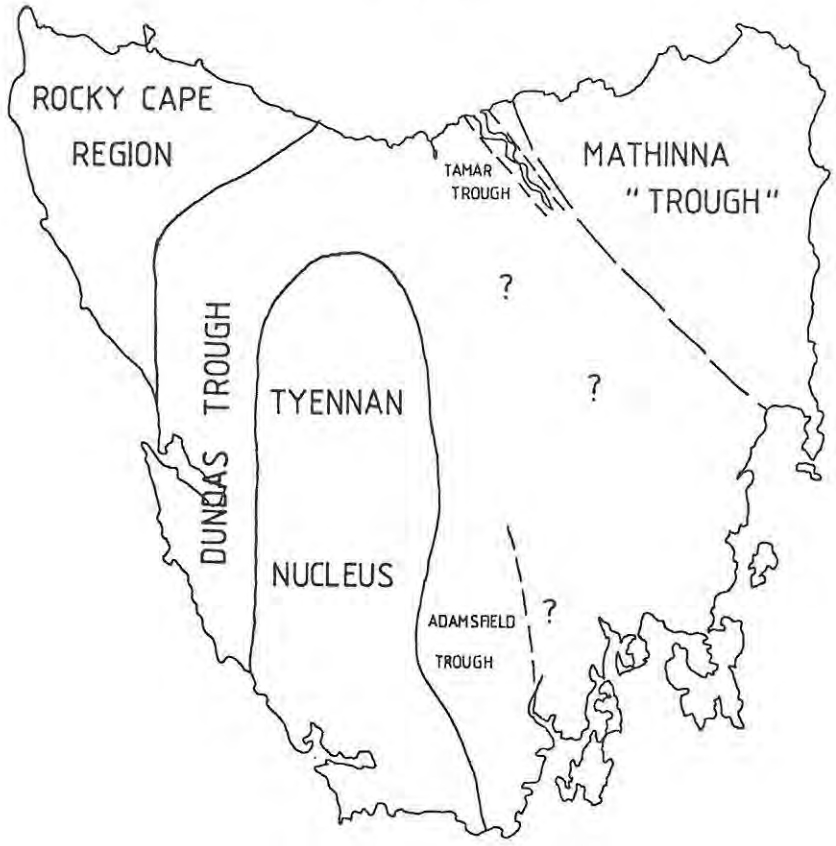


Figure 5.4 : Tectonic elements of Tasmania (modified after Williams et al, 1975, and Adams et al, 1985 and others).

Proterozoic Oonah formation rocks in the Dundas Trough, indicate (inpart) a continental crustal basement to the Cambrian sediments (Figure 5.5). Local geology of the Dundas Trough in the vicinity of Rosebery and Queenstown is shown on Figure 5.6. Deformation of the Dundas Trough was during the Tabberabberan Orogeny (± 390 Ma, Adams et al., 1985), with relatively minor deformation during the mid-to-late Cambrian, due to uplift of the basement Tyennan Nucleus (Adams et al., 1985). The uplift in the Tyennan Nucleus, initiated the deposition of the Owen conglomerate.

Corbett (1981), tentatively identifies the presence of poorly preserved caldera structures in the Dundas Trough, from the occurrence and distribution of lavas, ash flows and pyroclastics of rhyolite to andesite-basalt composition. These caldera structures may be the concentrating mechanisms of mineral deposits in the trough (Corbett, 1981; Cox 1981; Woodall, 1979).

The northeast corner of Tasmania consists of the Marthinna Beds and Devonian

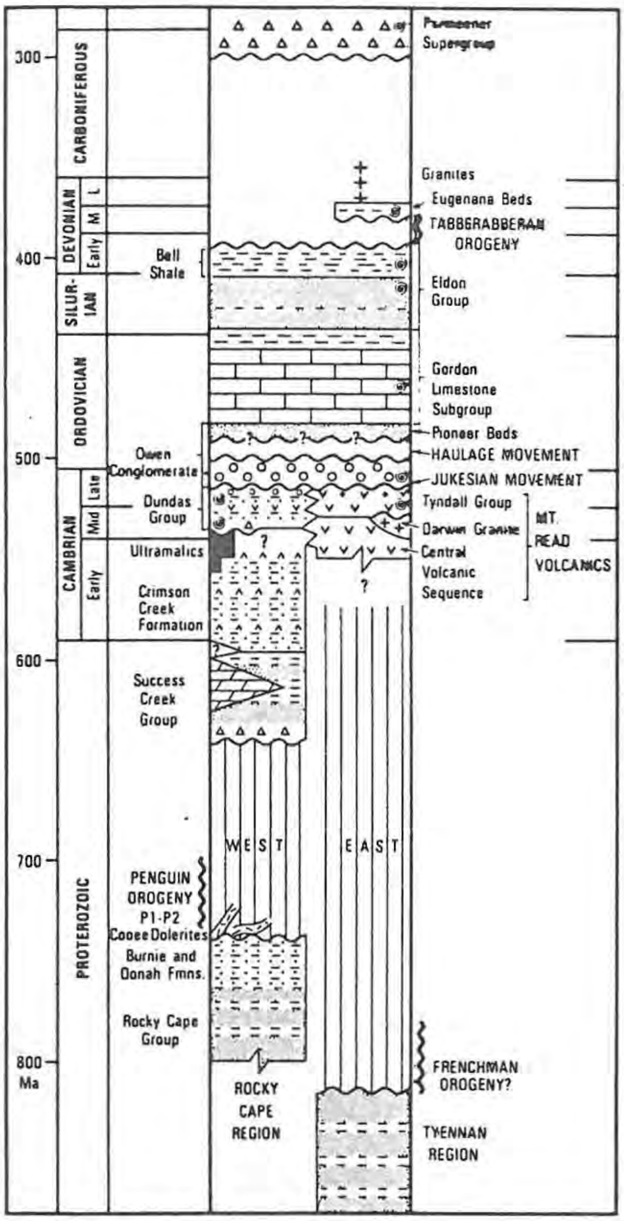


Figure 5.5 : Stratigraphy of the Dundas Trough Region in Western Tasmania (Adams et al, 1985).

Granitoids in roughly equal proportions (Figure 5.3). The sediments of the Marthinna Beds (turbidites etc.) are interpreted as a marginal basin fill, with the granites (ie Scottsdale and Blue Tier Batholiths) emplaced from 375-335 Ma post-orogenically.

Central Area - New South Wales and Victoria

The Cambrian Kanmantoo Fold Belt is the oldest and most westerly unit of the Tasman Geosyncline (Figure 5.7). The deposition of sediments and volcanics in this area was terminated by the Cambro-Ordovician Delmerian Orogeny,

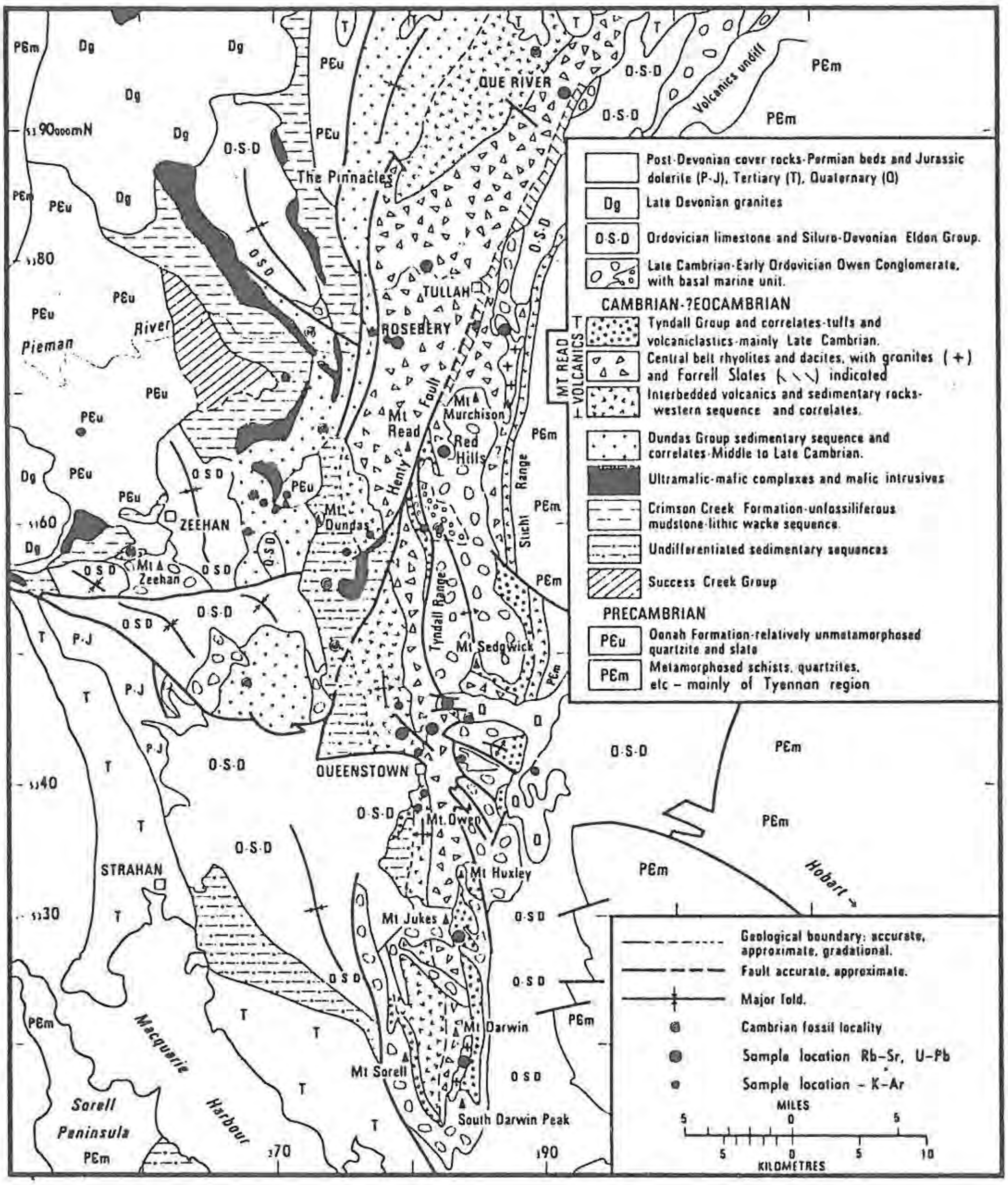


Figure 5.6 : Geology of the Mt.Lyell/Rosebery district, Tasmania (Adams et al, 1985).

which affected the Adelaide Fold Belt to the West. The Lachlan Fold Belt to the east, is a complex series of troughs, basins and ophiolite sequences, which were emplaced during and after the Delmerian Orogeny. Deformation in the Lachlan Fold Belt occurred in late - Ordovician to middle- Devonian, after a period of transitional tectonism which stabilized the Kanmantoo Fold Belt (Plumb, 1979 a). The oldest rocks of the Lachlan Fold Belt in Victoria, are a series of 'greenstones (Figure 5.8 a) (Crawford and Keays,1978), which have been interpreted as remnants of crustal material (ophiolites), from a marginal sea developed by rifting of a thin continental crust, on the margin of the Australian Plate (Crawford and Keays, 1978; Crawford et al., 1984). Crawford et al (1984), further interprets the setting as being similar to the Western Pacific-type settings, with island arcs and back-arc basins. These linear 'greenstone' belts (Stavely, Heathcote and Mt. Wellington Belts, Figure 5.8 a) separate basinal sequences of greywacke-shale, of the Ballarat and Melbourne Troughs. The chemistry of the three 'greenstone' belt lithologies varies, and at present only the Heathcote Belt has been studied in detail (Crawford et al., 1984).

Powell (1983), also supports a back-arc basinal model for the western part of southern Tasman Geosyncline. The major difference between the Powell (op. cit) and Crawford et al., (1984) models, is the former has an Ordovician oceanic crust, mid-Silurian ensialic setting and dominant control on tectonic evolution by regional dextral shearing, while the latter is oceanic setting with an arc-continent collision. A detailed analysis of the sedimentary successions by Powell (1983), and an interpretation of the

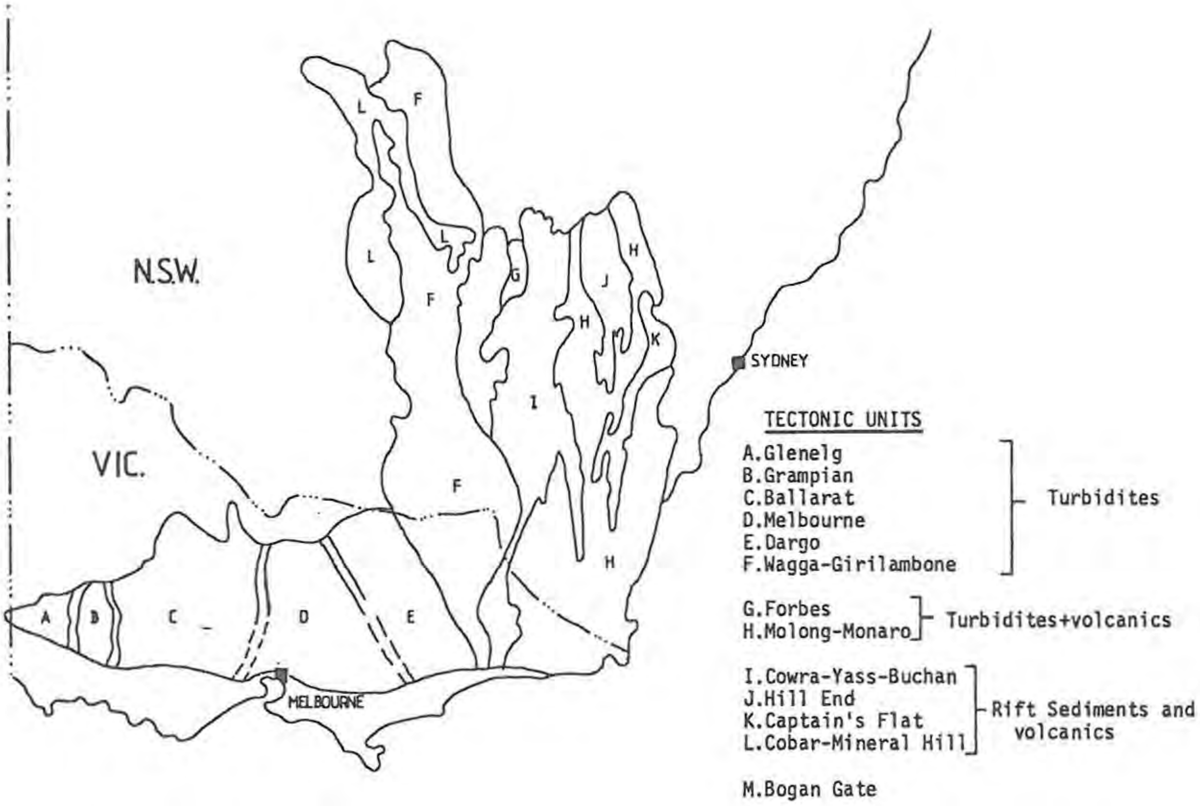


Figure 5.7 : Main tectonic units of the Southern Area of the Lachlan Fold Belt (after Woodall, 1979).

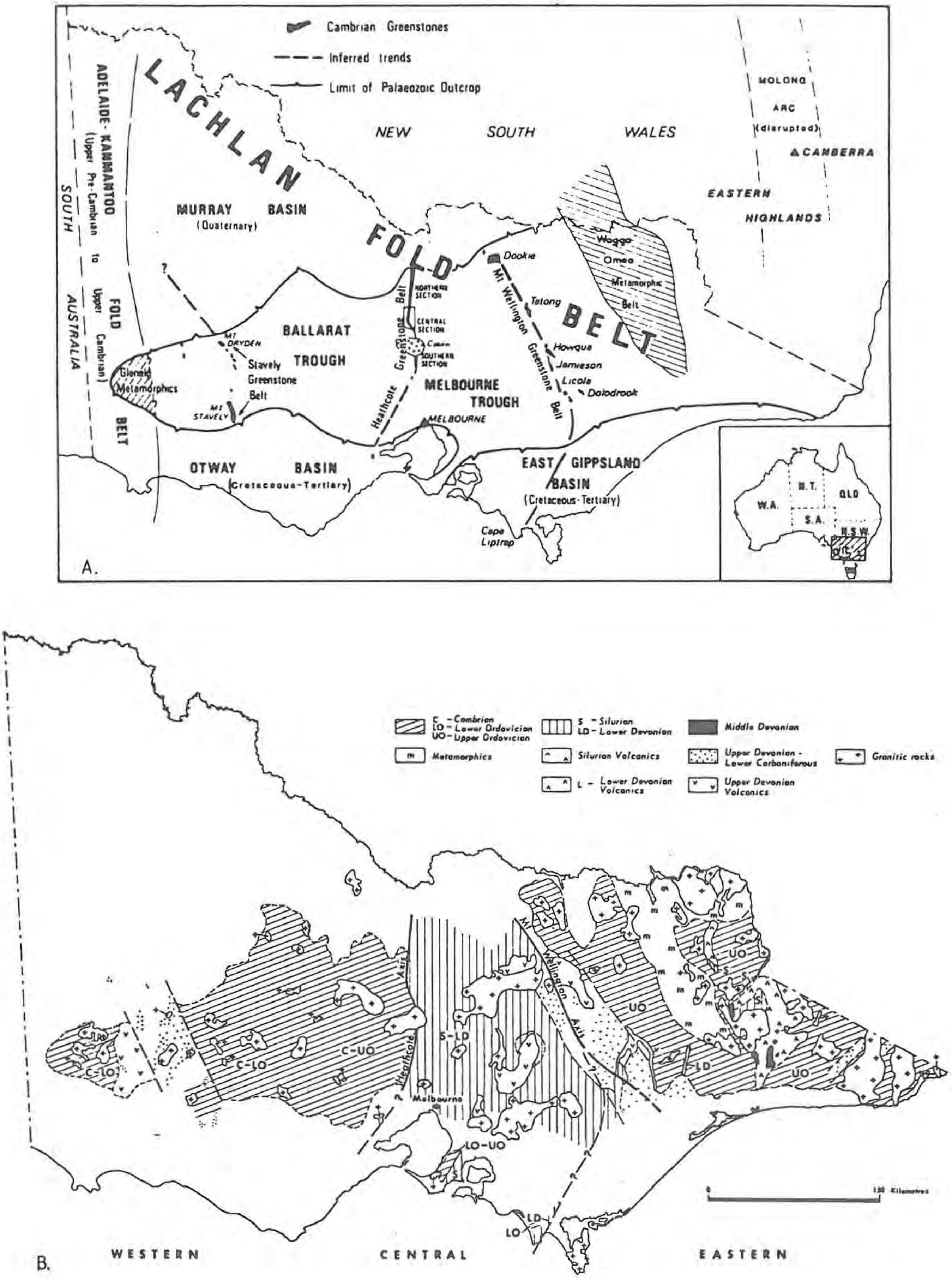


Figure 5.8. a : Distribution of greenstone belts in Victoria, in relation to important tectonic elements (Crawford and Keays, 1978).
b : Palaeozoic geology of Victoria (Spencer-Jones and Vandenberg, 1975).

tectonic evolution (Figure 5.9), outlined a paleogeographic reconstruction as shown in Figure 5.10. An alternative to the above models is presented by Crook (1980), who interprets the evolution as being a fore-arc basinal setting, which to a large extent is obviated by the data presented by Crawford et al., (1984).

The eastern part of the Lachlan Fold Belt in Victoria is dominated by the Wagga Metamorphic Belt (WMB) and syn-to post-Silurian granitoids. The Wagga Metamorphic Belt, is a zone of high-temperature low-pressure metamorphism (Powell, 1983), previously interpreted as a trench zone (Solomon and Griffiths, 1972), a marginal basin (Scheibner, 1973), a marginal sea (Cas et al., 1980) and a back arc basin (Powell 1983). Further to the east a complex series of granites younging to the east (Powell, 1983) of S- and I-type affinities have been identified (Chappell, 1984). Sources for these granites are dominantly crustal, and crustal + mantle derived material respectively, indicating supra-crustal and under-plating origins (Chappell, 1984). The emplacement of granites in this eastern zone required a thick crust, and is generally related to a major melting event at 400 ± 20 Ma (Chappell, 1984). The greywacke shale sequences in this eastern area have been derived from the Adelaide Fold Belt and/or the Trans Antarctic Mountains (Wyborn and Chappell, 1983).

The late Devonian to late Carboniferous history of the Lachlan Fold Belt, is generally related to stabilization of the belt, with basin deposition in Queensland (eg. Drummond, Adavale and Burdekin Basins) and New South Wales (Lambie Group). These basins contain deformed molasse-type sediments, acid volcanics, high level granites and some development of cauldron structures in Victoria (Plumb, 1979 a).

In New South Wales, the Central Area of the Lachlan Fold Belt is sub-divided into a number of different tectono-stratigraphic units (Scheibner, 1974) (Figure 5.11). All of these different units have been described as synclinorial or anticlinorial zones. Only those zones defined as synclinorial will be discussed, because they contain the most significant occurrences of gold. The main synclinorial zones are the Cobar - Mineral Hill Zones, the Bogan Gate Zone, the Cowra-Yass Zone, the Hill End Zone and the Captains Flat Zone (after Scheibner, 1974 and Markham, 1975).

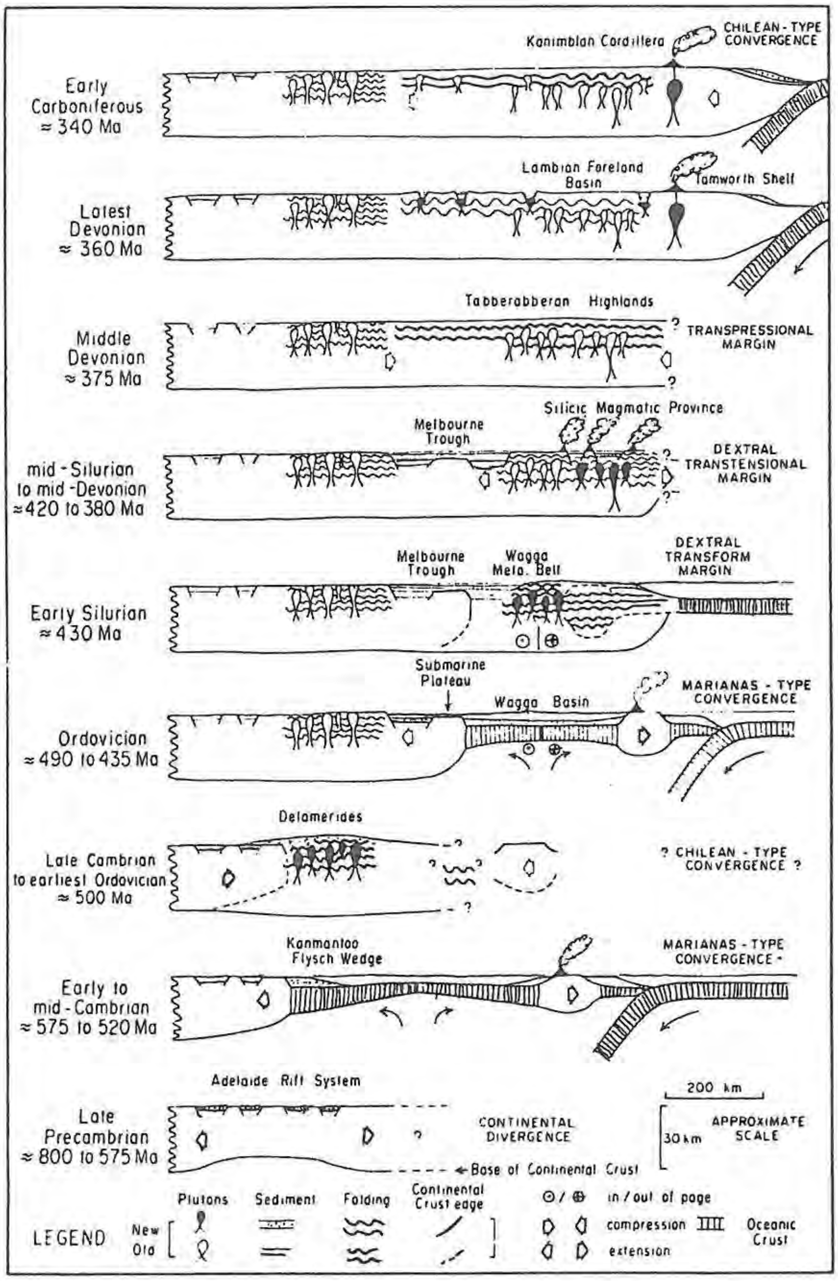
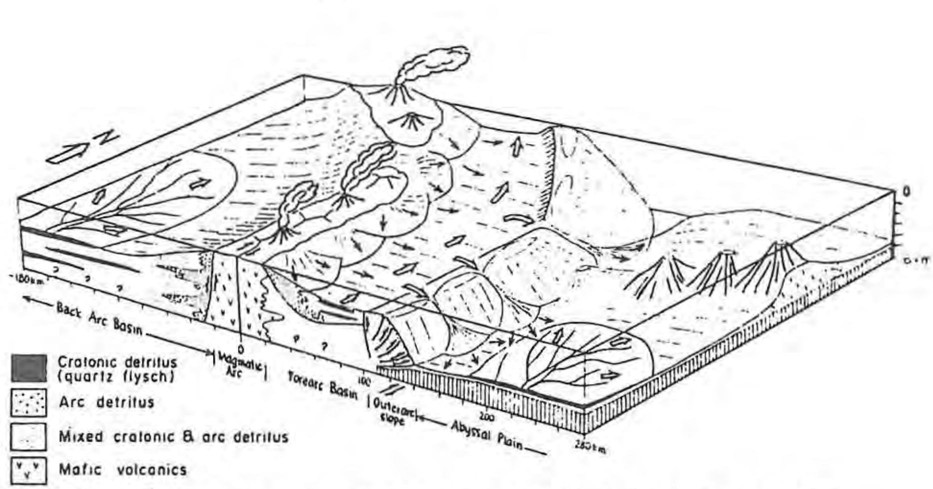
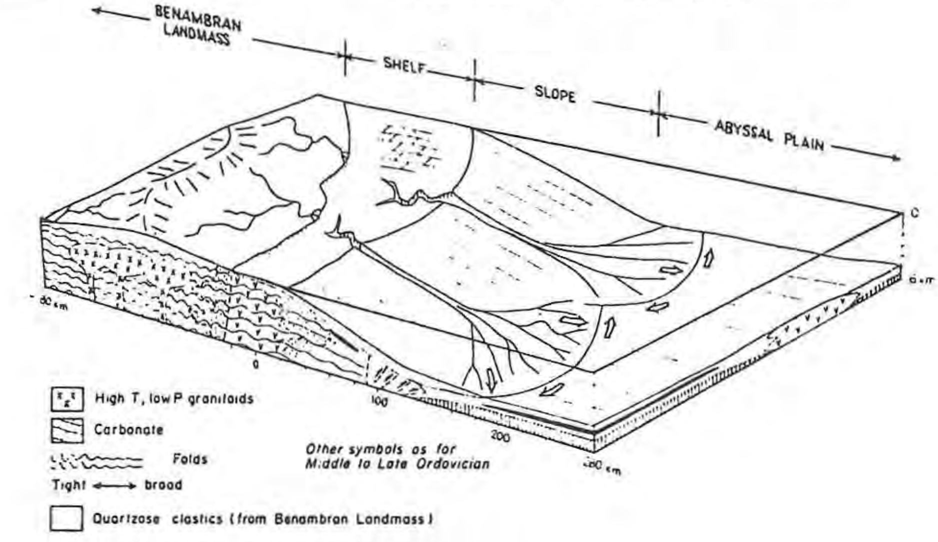


Figure 5.9 : Model of tectonic evolution of the Lachlan Fold Belt (Powell, 1983).

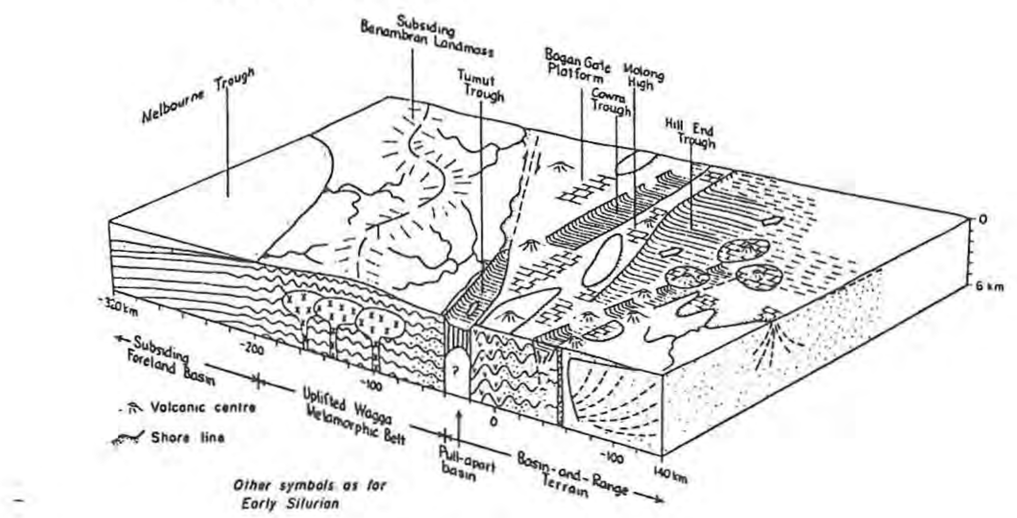
The Cobar-Mineral Hill Zones consist of two distinct zones of sediments, the older early-Silarian Ballast Beds (various sandstone units, quartzites slates and phyllites, minor mafic lavas) of the Mineral Hill Zone in the east, and the late-Siurian Cobar Group consisting of conglomerates, greywacke sandstones of the Chesney Greywacke Suite, the Great Cobar Slate and the CSA Siltstone (Gilligan 1974 a). The late-Silurian rocks of the



MIDDLE to LATE ORDOVICIAN GEOGRAPHY
(Darriwilian & Gisbornian) ≈ 460 Ma



EARLY SILURIAN GEOGRAPHY
(Late Llandoverian) ≈ 430 Ma



LATE SILURIAN GEOGRAPHY
(Ludlovian ≈ 415 Ma)

Figure 5.10 : Palaeogeographic reconstructions of the Lachlan Fold Belt (Powell, 1983).

Cobar Zone also includes the Ootha Beds, which have also been recognized as fragments in the New England Fold Belt. Other important lithologies of the Zone are shown on Figure 5.12. The volcanics and granites in the area (eg. Mt. Hope Volcanics) are of late-Silurian or Devonian age. The formation of the zone is inferred to be as a result of tensional rifting and subsequent sedimentation and volcanism during this period.

The Bogan Gate Zone consists of Ordovician sediments (including greywackes, sandstones, limestones, slates etc) and a Silurian volcano-sedimentary sequence, with Siluro-Devonian and Devonian intrusives (Figure 5.13). The ages and distribution of various units in the Bogan Gate Zone are at present poorly understood with a variety of different boundaries proposed (Fitzpatrick 1974, Gilligan and Scheibner, 1978, and B.P. Minerals Australia, unpublished data). The preferred geological distribution of units is that proposed by Fitzpatrick (1974), as shown in Figure 5.13.

Structural deformation in the sequence of volcanics and sediments gives an overall fabric trending northerly (Fitzpatrick, 1974). Basic dykes occur toward the western margin of the zone near Tremora and Reefton, and may be spatially associated to granite intrusives (Fitzpatrick, op. cit.). A

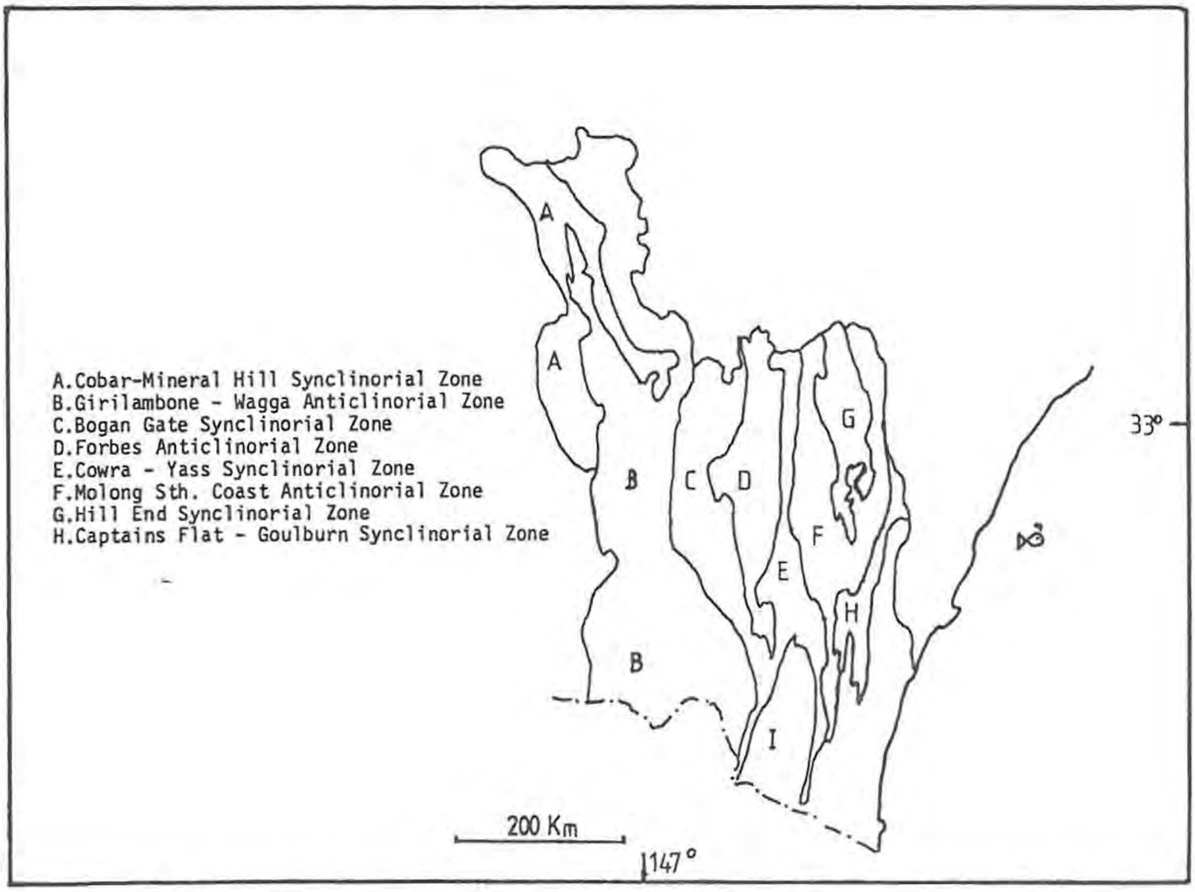
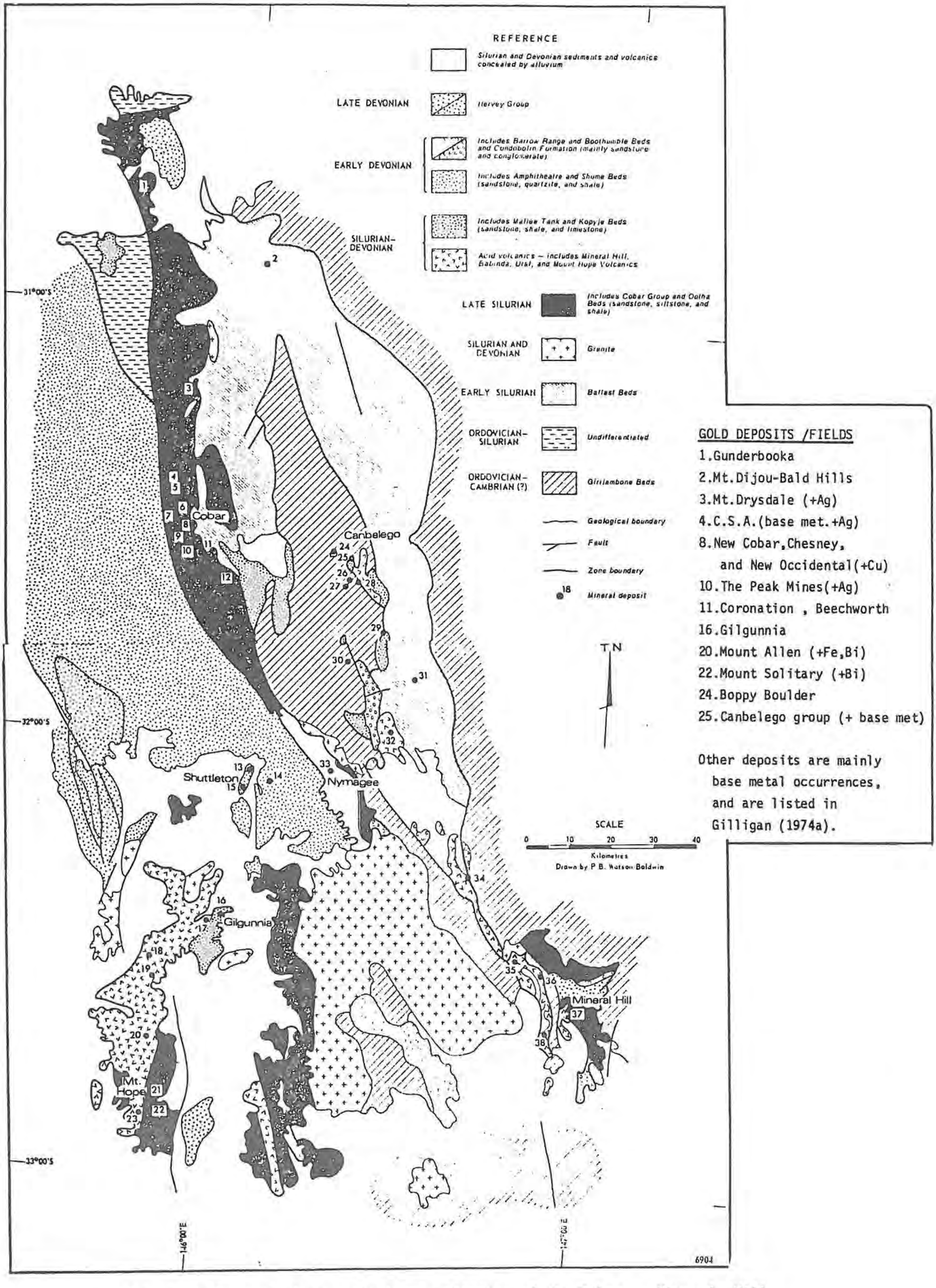


Figure 5.11 : Major tectonic elements of New South Wales, defined as synclinorial and anticlinorial zones. (Scheibner, 1974).



GOLD DEPOSITS /FIELDS

1. Gunderbooka
2. Mt.Dijou-Bald Hills
3. Mt.Drysdale (+Ag)
4. C.S.A.(base met.+Ag)
8. New Cobar,Chesney, and New Occidental(+Cu)
10. The Peak Mines(+Ag)
11. Coronation , Beechworth
16. Gilgunnia
20. Mount Allen (+Fe,Bi)
22. Mount Solitary (+Bi)
24. Boppy Boulder
25. Canbelego group (+ base met)

Other deposits are mainly base metal occurrences, and are listed in Gilligan (1974a).

Figure 5.12 : Geology and mineral deposits of the Cobar - Mineral Hill Synclinorial Zones (Gilligan, 1974 a).

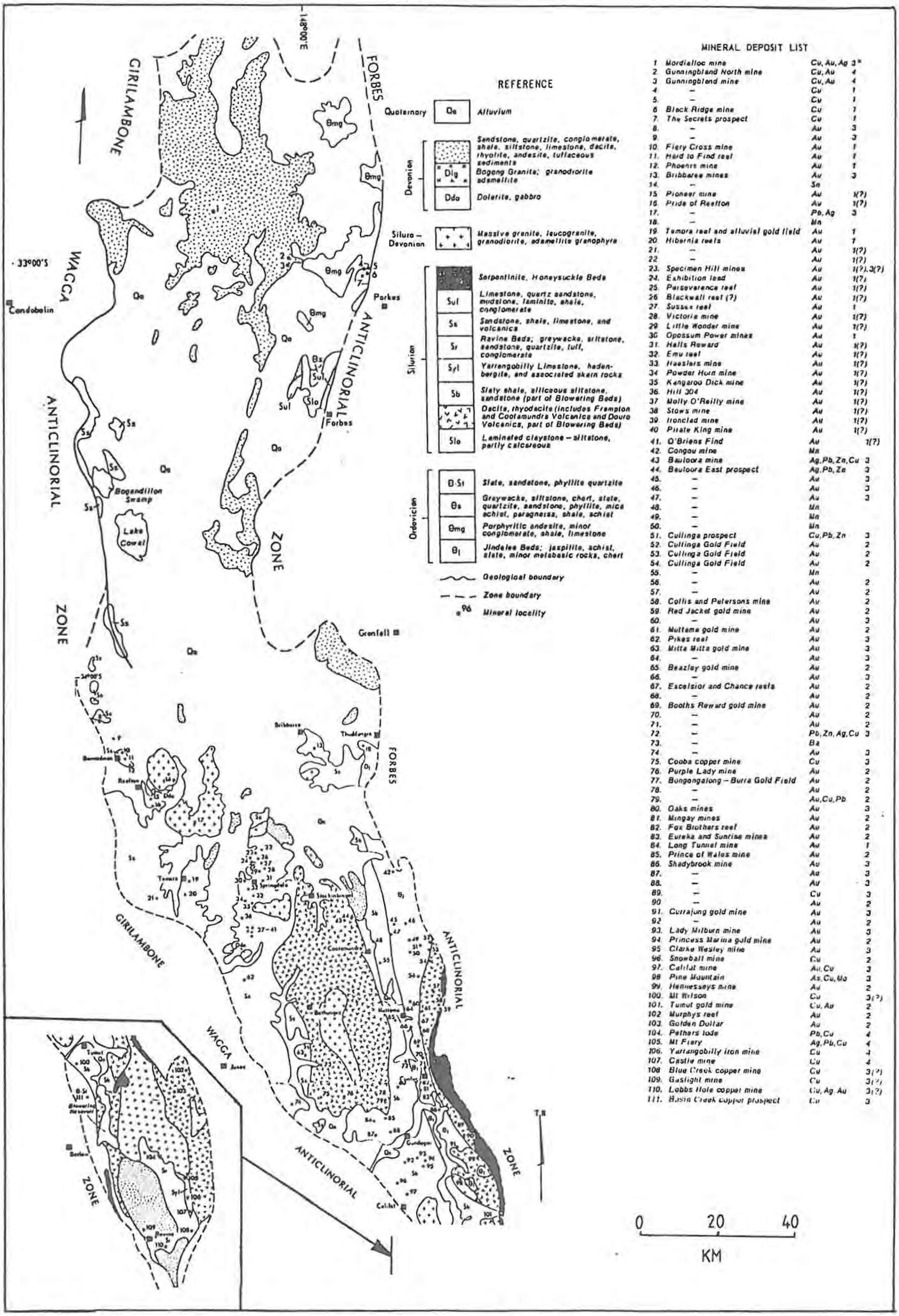
series of serpentinites and basic intrusives occur on the south-eastern margin and have been interpreted as a dismembered ophiolite sequence (Fitzpatrick, op. cit.). This fragment of ophiolites may represent the original basement to the Boqan Gate Zone or to the Forbes Zone to the east. The latter appears probable due to the presence of major thrust faults associated to the occurrence (Figure 5.13).

The Cowra-Yass Synclinorial Zone is dominated by volcanics with a lesser sedimentary component than other zones (Figure 5.14). The volcanics are dominantly acid in composition (Gilligan, 1974 b). The formation of the zone has been interpreted as a volcanic rift in the south and a volcanic arch in the north (Gilligan, 1974 b). The ages of rocks in the zone are dominantly mid-to late-Devonian acid volcanics and sediments, early-Devonian acid volcanics and sediments, and granitic intrusions (Gilligan op. cit.).

The Hill End Zone (Figure 5.15) consists of dominantly sedimentary rocks with some volcanics. The sediments consist of late-Silurian to middle-Devonian flysch sequences (shales, greywackes and conglomerates), while the volcanics consist of late-Ordovician andesites, mid-Silurian rhyolites and dacites, with other late-Silurian acid volcanics. The zone may have formed as a marginal sea evolved from a rift (Scheibner, 1974). The dominance of sediments in the sequence indicates a more passive environment than the Cowra-Yass or Bogan Gate Zones.

The Captains Flat Zone (Figure 5.14) is a fault-bounded volcanic rift zone consisting of mid- to late-Silurian volcanics and sediments, and early to late Devonian sediments, intruded by early-Devonian and Carboniferous granites (Gilligan, 1974 c).

The major difference between the rift zones in New South Wales and those in Victoria is that the former were active during the Silurian, a feature not observed in the latter. This is amply displayed by the relative abundance of volcanics in New South Wales as compared to Victoria, and the occurrence of numerous volcanic related mineral deposits (Section 5.1.2).



MINERAL DEPOSIT LIST

1	Mordialloc mine	Cu, Au, Ag	3*
2	Gunningbland North mine	Cu, Au	4
3	Gunningbland mine	Cu, Au	4
4.	–	Cu	1
5.	–	Cu	1
6	Black Ridge mine	Cu	1
7.	The Secrets prospect	Cu	1
8.	–	Au	3
9.	–	Au	3
10.	Fiery Cross mine	Au	1
11.	Hard to Find reef	Au	1
12.	Phoenix mine	Au	1
13.	Bribbaree mines	Au	3
14.	–	Sn	
15	Pioneer mine	Au	1(?)
16	Pride of Reefton	Au	1(?)
17.	–	Pb, Ag	3
18.	–	Mn	
19.	Temora reef and alluvial gold field	Au	1
20	Hibernia reefs	Au	1
21.	–	Au	1(?)
22	–	Au	1(?)
23.	Specimen Hill mines	Au	1(?),3(?)
24.	Exhibition lead	Au	1(?)
25	Perseverance reef	Au	1(?)
26	Blackwall reef (?)	Au	1(?)
27.	Sussex reef	Au	1
28.	Victoria mine	Au	1(?)
29	Little Wonder mine	Au	1(?)
30	Opossum Power mines	Au	1
31.	Halls Reward	Au	1(?)
32.	Emu reef	Au	1(?)
33	Haeslers mine	Au	1(?)
34	Powder Horn mine	Au	1(?)
35	Kangaroo Dick mine	Au	1(?)
36.	Hill 304	Au	1(?)
37	Molly O'Reilly mine	Au	1(?)
38	Stows mine	Au	1(?)
39.	Ironclad mine	Au	1(?)
40	Pirate King mine	Au	1(?)
41.	O'Briens Find	Au	1(?)
42.	Congou mine	Mn	
43	Bauloora mine	Ag, Pb, Zn, Cu	3
44.	Bauloora East prospect	Ag, Pb, Zn	3
45.	–	Au	3
46.	–	Au	3
47.	–	Au	3
48.	–	Mn	
49.	–	Mn	
50.	–	Mn	
51.	Cullinga prospect	Cu, Pb, Zn	3
52.	Cullinga Gold Field	Au	2
53.	Cullinga Gold Field	Au	2
54.	Cullinga Gold Field	Au	2
55.	–	Mn	
56.	–	Au	2
57.	–	Au	2
58.	Collis and Petersons mine	Au	2
59.	Red Jacket gold mine	Au	2
60.	–	Au	3
61.	Muttama gold mine	Au	2
62.	Pikes reef	Au	3
63.	Mitta Mitta gold mine	Au	3
64.	–	Au	3
65.	Beazley gold mine	Au	2
66.	–	Au	3
67.	Excelsior and Chance reefs	Au	2
68.	–	Au	2
69.	Booths Reward gold mine	Au	2
70.	–	Au	2
71.	–	Au	2
72	–	Pb, Zn, Ag, Cu	3
73.	–	Ba	
74	–	Au	3
75.	Cooba copper mine	Cu	3
76.	Purple Lady mine	Au	2
77.	Bongongalong – Burra Gold Field	Au	2
78.	–	Au	2
79.	–	Au, Cu, Pb	2
80.	Oaks mines	Au	3
81.	Mingay mines	Au	2
82.	Fox Brothers reef	Au	2
83.	Eureka and Sunrise mines	Au	2
84.	Long Tunnel mine	Au	1
85.	Prince of Wales mine	Au	2
86.	Shadybrook mine	Au	3
87.	–	Au	3
88.	–	Au	3
89.	–	Cu	3
90	–	Au	2
91.	Currajong gold mine	Au	3
92	–	Au	2
93.	Lady Milburn mine	Au	3
94	Princess Marina gold mine	Au	2
95	Clarke Wesley mine	Au	3
96.	Snowball mine	Cu	2
97.	Califat mine	Au, Cu	3
98	Pine Mountain	As, Cu, Mo	3
99.	Hennesseys mine	Au	2
100.	Mt Wilson	Cu	3(?)
101.	Tumut gold mine	Cu, Au	2
102	Murphys reef	Au	2
103	Golden Dollar	Au	2
104.	Pethers lode	Pb, Cu	4
105.	Mt Fiery	Ag, Pb, Cu	4
106.	Yarrangobilly iron mine	Cu	4
107.	Castle mine	Cu	4
108	Blue Creek copper mine	Cu	3(?)
109.	Gaslight mine	Cu	3(?)
110.	Lobbs Hole copper mine	Cu, Ag, Au	3(?)
111.	Basin Creek copper prospect	Cu	3

Figure 5.13 : Geology and mineral deposits of the Bogan Gate Synclinorial Zone (Fitzpatrick, 1974).

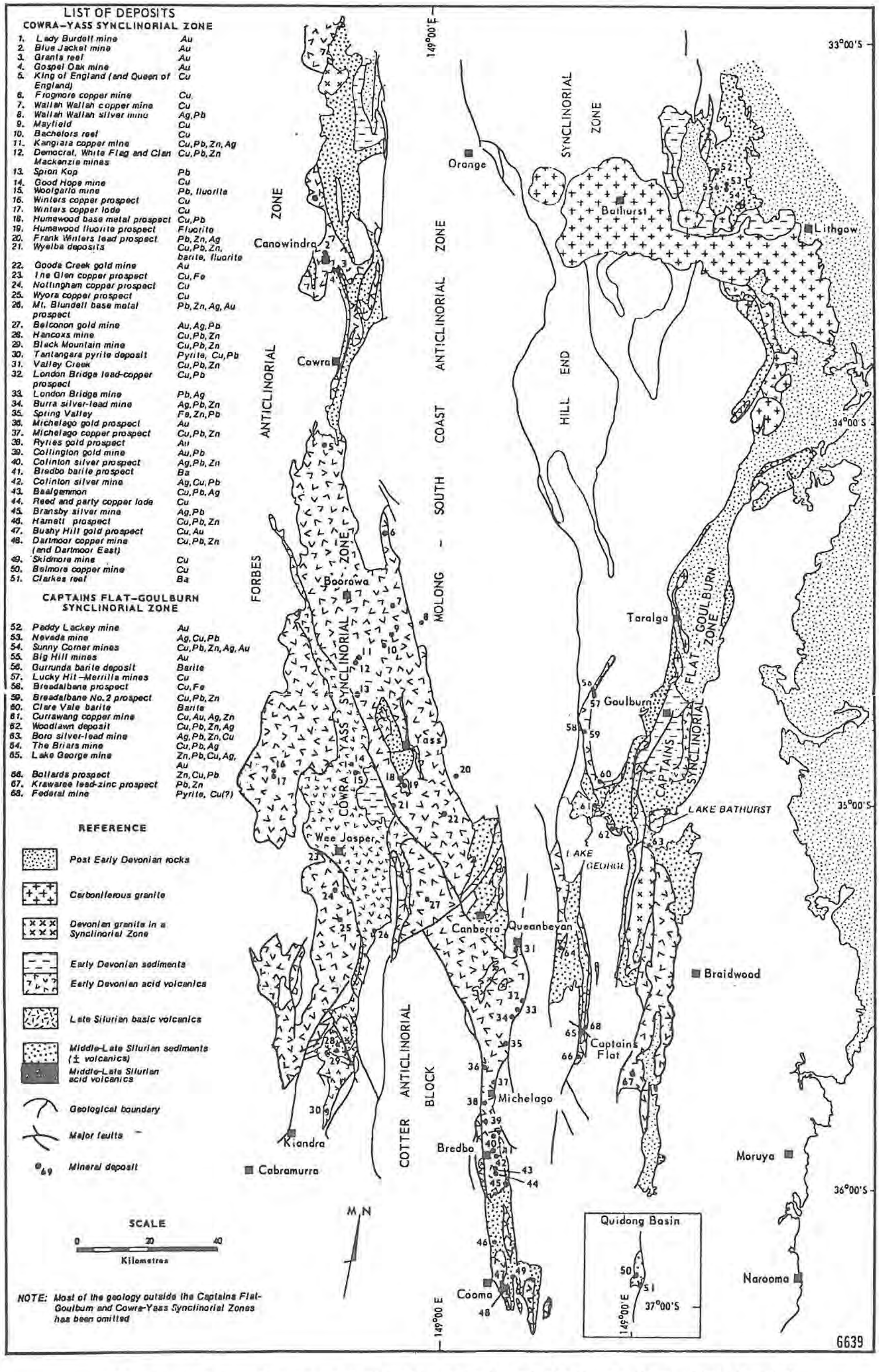
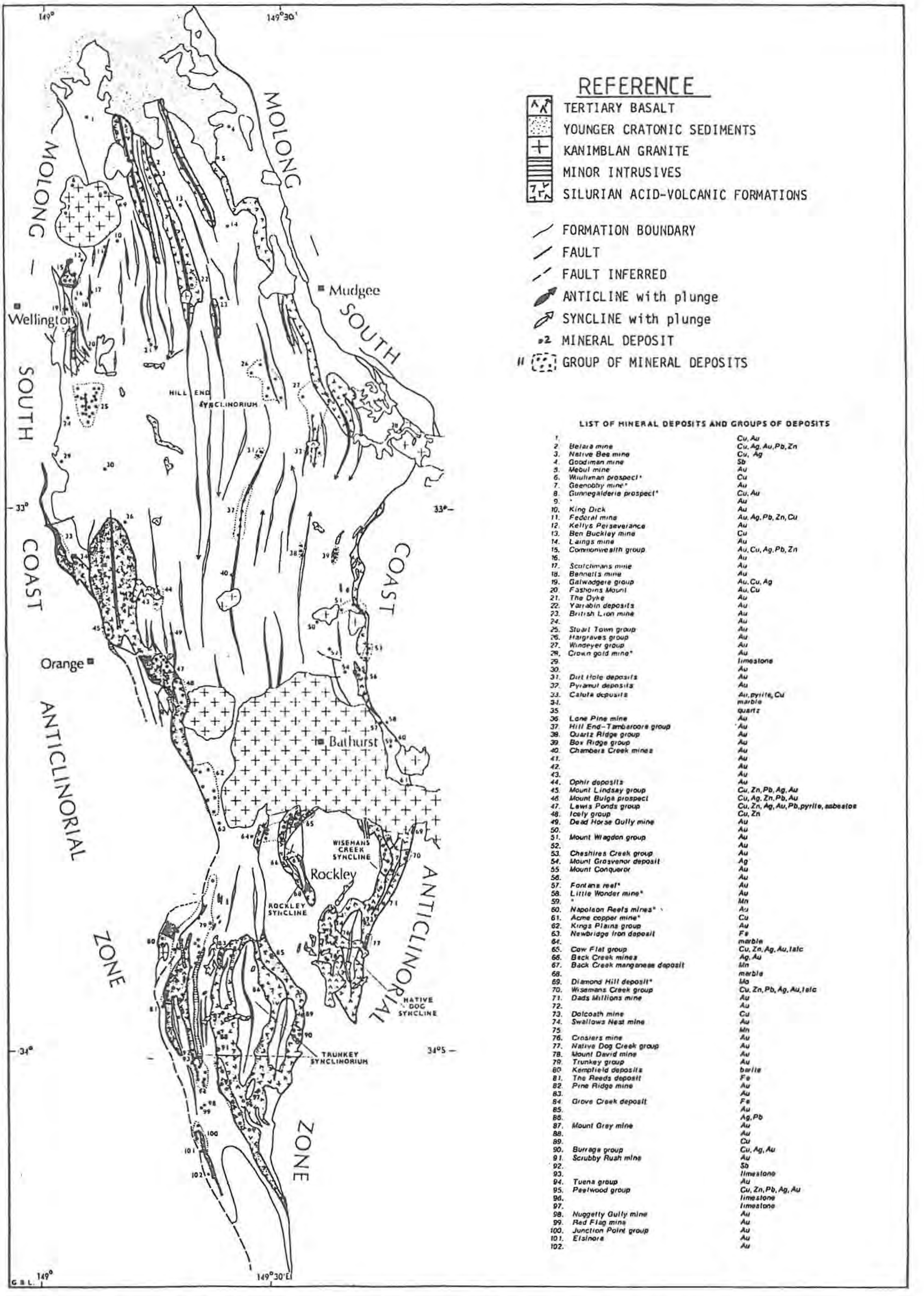


Figure 5.14 : Geology and mineral deposits of the Cowra-Yass Synclinorial Zone (Gilligan, 1974 b).



LIST OF MINERAL DEPOSITS AND GROUPS OF DEPOSITS

1.		Cu, Au
2.	Belara mine	Cu, Ag, Au, Pb, Zn
3.	Native Bee mine	Cu, Ag
4.	Goodiman mine	Sb
5.	Mebul mine	Au
6.	Wiuliman prospect*	Cu
7.	Geenobby mine*	Au
8.	Gunnegalderie prospect*	Cu, Au
9.	*	Au
10.	King Dick	Au
11.	Federal mine	Au, Ag, Pb, Zn, Cu
12.	Kellys Perseverance	Au
13.	Ben Buckley mine	Cu
14.	Laings mine	Au
15.	Commonwealth group	Au, Cu, Ag, Pb, Zn
16.		Au
17.	Scotchmans mine	Au
18.	Bennetts mine	Au
19.	Galwadgere group	Au, Cu, Ag
20.	Fashoms Mount	Au, Cu
21.	The Dyke	Au
22.	Yarrabin deposits	Au
23.	British Lion mine	Au
24.		Au
25.	Stuart Town group	Au
26.	Hargraves group	Au
27.	Windeyer group	Au
28.	Crown gold mine*	Au
29.		limestone
30.		Au
31.	Dirt Hole deposits	Au
32.	Pyramul deposits	Au
33.	Calula deposits	Au, pyrite, Cu
34.		marble
35		quartz
36	Lone Pine mine	Au
37.	Hill End–Tambaroora group	Au
38.	Quartz Ridge group	Au
39.	Box Ridge group	Au
40.	Chambers Creek mines	Au
41.		Au
42.		Au
43.		Au
44.	Ophir deposits	Au
45.	Mount Lindsay group	Cu, Zn, Pb, Ag, Au
46.	Mount Bulga prospect	Cu, Ag, Zn, Pb, Au
47.	Lewis Ponds group	Cu, Zn, Ag, Au, Pb, pyrite, asbestos
48.	Icely group	Cu, Zn
49.	Dead Horse Gully mine	Au
50.		Au
51.	Mount Wiagdon group	Au
52.		Au
53.	Cheshires Creek group	Au
54.	Mount Grosvenor deposit	Ag
55.	Mount Conqueror	Au
56.		Au
57.	Fontans reef*	Au
58.	Little Wonder mine*	Au
59.	*	Mn
60.	Napoleon Reefs mines*	Au
61.	Acme copper mine*	Cu
62.	Kings Plains group	Au
63.	Newbridge iron deposit	Fe
64.		marble
65.	Cow Flat group	Cu, Zn, Ag, Au, talc
66.	Back Creek mines	Ag, Au
67.	Back Creek manganese deposit	Mn
68.		marble
69.	Diamond Hill deposit*	Mo
70.	Wisemans Creek group	Cu, Zn, Pb, Ag, Au, talc
71.	Dads Millions mine	Au
72.		Au
73.	Dolcoath mine	Cu
74.	Swallows Nest mine	Au
75		Mn
76.	Crosiers mine	Au
77.	Native Dog Creek group	Au
78.	Mount David mine	Au
79.	Trunkey group	Au
80	Kempfield deposits	barite
81.	The Reeds deposit	Fe
82.	Pine Ridge mine	Au
83.		Au
84.	Grove Creek deposit	Fe
85.		Au
86.		Ag, Pb
87.	Mount Grey mine	Au
88.		Au
89.		Cu
90.	Burraga group	Cu, Ag, Au
91.	Scrubby Rush mine	Au
92.		Sb
93.		limestone
94.	Tuena group	Au
95.	Peelwood group	Cu, Zn, Pb, Ag, Au
96.		limestone
97.		limestone
98.	Nuggetty Gully mine	Au
99.	Red Flag mine	Au
100.	Junction Point group	Au
101.	Elsinore	Au
102.		Au

Figure 5.15 : Geology and mineral deposits of the Hill End Synclinorial Zone (Stevens, 1974).

Northern Area - Queensland

An important portion of the Lachlan Fold Belt which has not been reviewed in detail, is the Northern Area in Queensland, (Figures 5.1 and 5.2) previously identified as the Lolworth-Ravenswood Block and the Anakie Inlier (Olger, 1972; Fisher and Warren, 1975; Day et al., 1978).

The Northern Area of the Tasman Geosyncline is the exposed part of the Thomson Orogen of Murray and Kirkegaard (1978), which is covered by basinal cover sequences to the south-west (eg. Cooper Basin)(Figure 5.16). The Lolworth-Ravenswood Block consists of early-Palaeozoic sediments and volcanics including the Cape River Beds (a sequence of tuffaceous arenites, siltstones and black shales, Murray and Kirkegaard, 1978) and Mount Windsor volcanics (dominantly acid volcanics, with locally abundant andesites and basalts). Other important lithologies are the Argentive metamorphics and the Running River Metamorphics, which may (in part) be metamorphic equivalents of the Cape River Beds (Murray and Kirkegaard, op cit) (Figure 5.16).

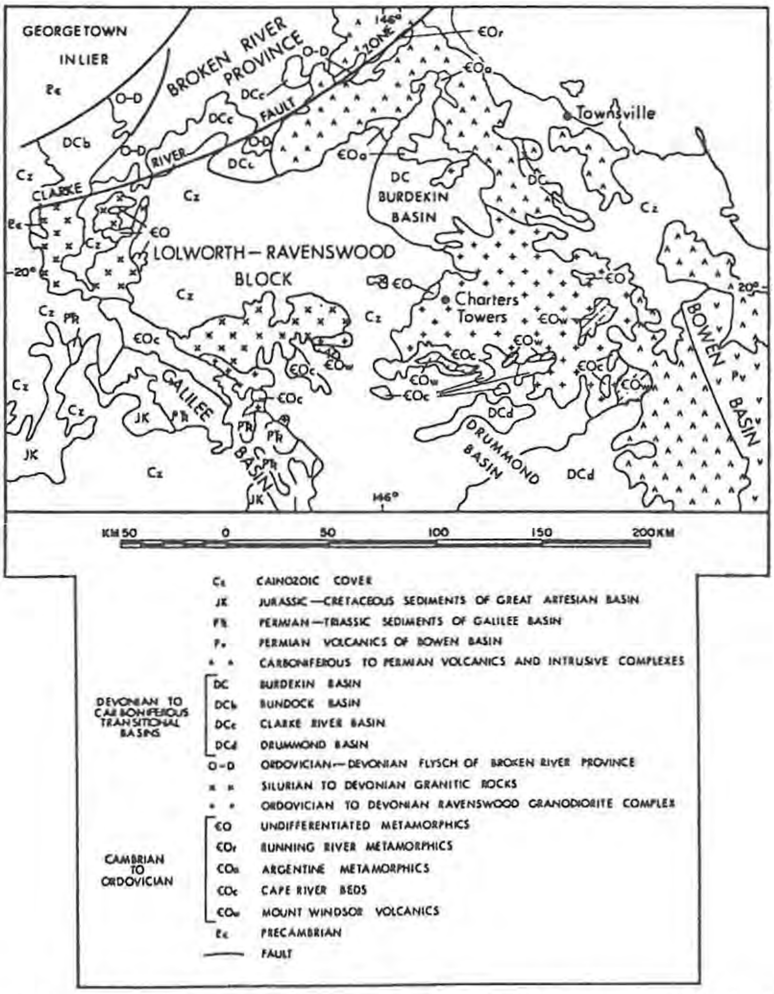


Figure 5.16 : Simplified geology of the Lolworth-Ravenswood Block (Murray and Kirkegaard, 1978).

The Lolworth-Ravenswood Block contains two periods of granite emplacement. The Ravenswood Granodiorite Complex has up to 8 different sub-units, and ages confined to 454 ± 30 Ma and 394 ± 30 Ma (mid- or late-Devonian and late-Silurian or early Devonian respectively). All rocks of the Complex are strongly deformed. The Cape River Beds and Mount Windsor volcanics, are interpreted as part of a Cambro-Ordovician volcanic island arc system, separated from the Georgetown Inlier by a marginal sea (Murray and Kirkegaard, 1978).

The Anakie Inlier consists of low-grade metamorphics (Anakie Metamorphics) intruded by late Devonian granodiorites, in the south. The metamorphics are contained in two units, an older albite-muscovite-quartz schist and a quartz-albite-chlorite-actinolite-epidote schist (Murray and Kirkegaard, 1978). At present the geology of the Anakie Inlier is poorly understood, but current active exploration in the area, will help in the delineation of geology and history of the area.

5.1.2 Gold Mineralization

Important gold deposits of the Lachlan Fold Belt are shown on Figures 5.17. The most important deposits occur in the central Lachlan Fold Belt, particularly in the Ballarat Trough.

Southern Area - Tasmania

The main gold producing areas in the southern area of the Lachlan Fold belt, are the Rosebery and Mt. Lyell deposits in the Dundas Trough (gold-base metal association), and the Beaconsfield, Lefroy and Marthinna deposits in the north and northeast (generally gold only).

The Rosebery zinc-lead-copper deposit is in the Mt. Read volcanics of the Dundas Trough (Figure 5.6 and 5.18), possibly related to the postulated caldera structures of Corbett (1981). Gold was initially discovered and mined in the gossan, overlying the sulphide orebodies. The average grade was 3.8 g/t gold in the sulphide bodies (Burton, 1975; Green et al., 1981). Alluvial deposits of gold derived from ore-bodies, contributed substantially to the production in early days of mining (Hall et al., 1965). The main

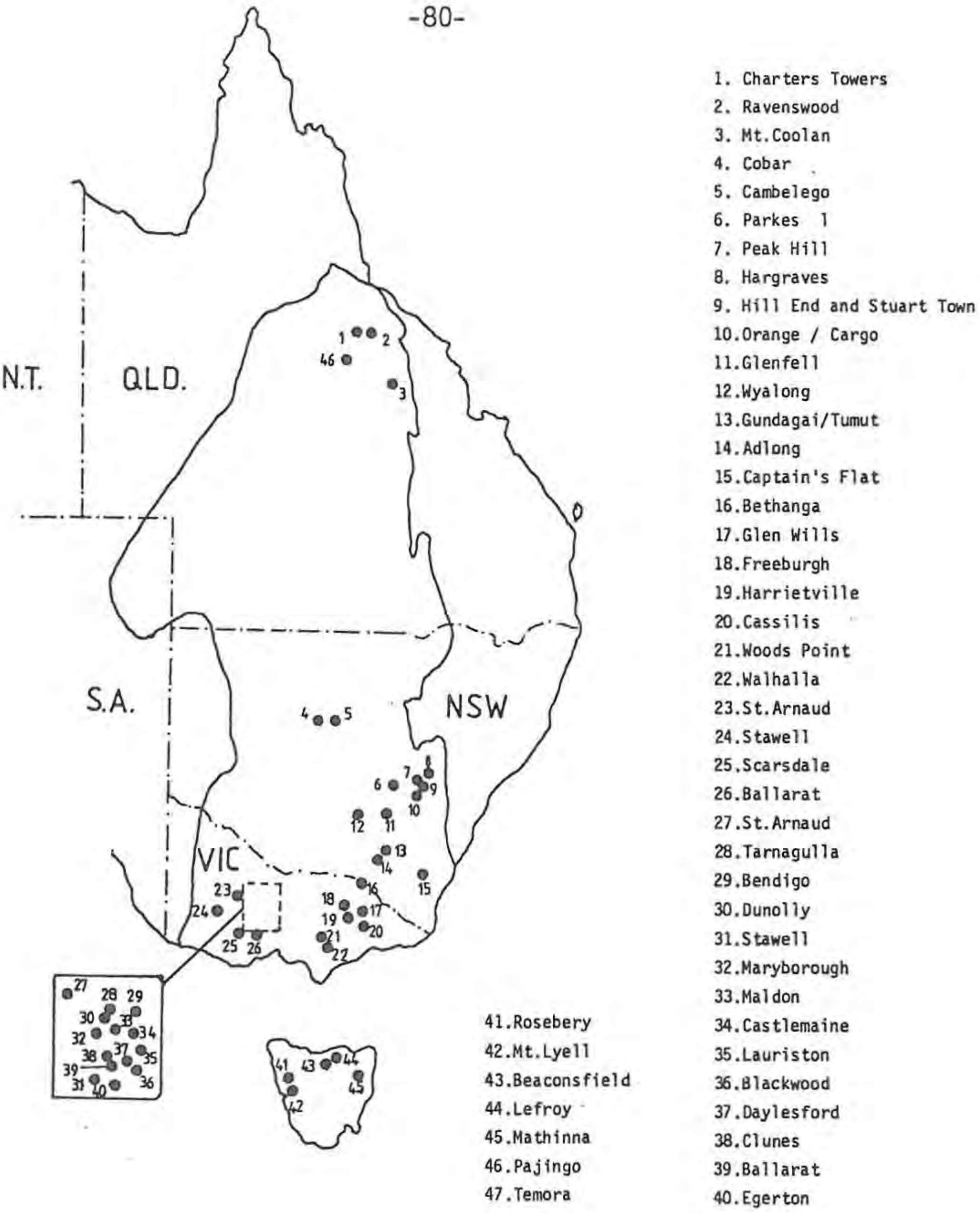


Figure 5.17 : Distribution of important gold deposits of the Lachlan Fold Belt (after Woodall, 1979).

sulphides of the orebody at Rosebery are chalcopyrite, sphalerite, pyrite and galena, with the distribution of gold grades having an apparent spatial association to the distribution of zinc grades (Green et al., 1981). The origin of the sulphide mineralization is interpreted as submarine exhalative with a volcano sedimentary association.

The Mt. Lyell deposit (Figures 5.6 and 5.18) is a similar form and style to the Rosebery deposit, with a higher degree of deformation. The gold occurs in the sulphide orebodies, with a gold-rich gossan originally being mined.

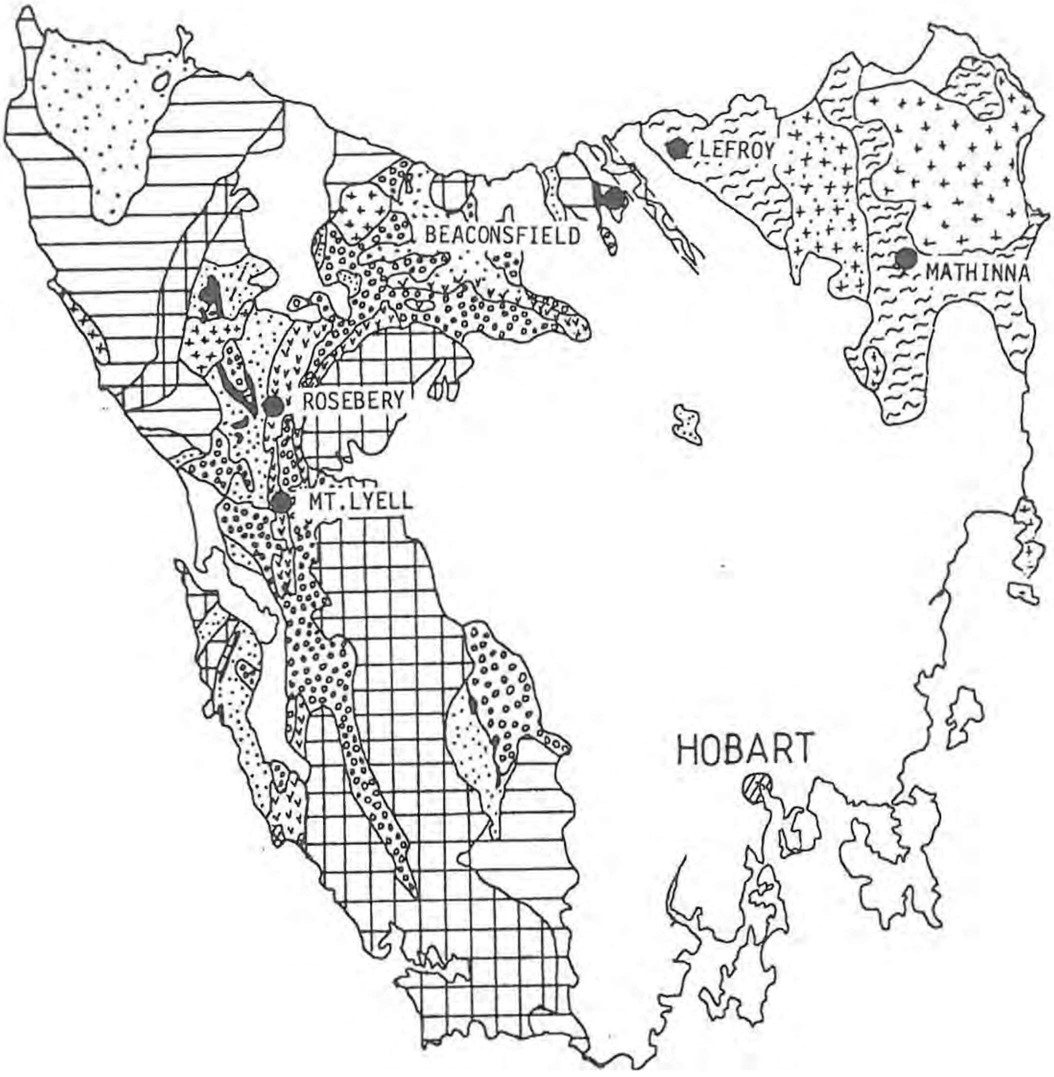


Figure 5.18 : Important gold producing areas in Tasmania (after Williams et al, 1975, Adams et al, 1985, Burton et al, 1975). Geology same as Figure 5.3.

(Solomon and Elms, 1965; Walshe and Solomon, 1981), with grades ranging from 0.4-2.0 g/t Au (Reid, 1975). The deposit occurs in the same volcano-tectonic rift system hosting the Rosebery deposit, with the period of volcanism (mineralization) being of the longer duration (Cox, 1981), and changes in facies in the associated sequences possibly related to caldera collapses (Cox, op. cit).

The Beaconsfield gold deposit has yielded in excess of 26,6 t of gold until 1977 (Woodall, 1979), with a current resurgence of interest defining 670 000 tonnes of ore at 24 g/t gold. (Gold Gazette, Nov. 10. 1986). The deposit occurs within the Cambrian Caroline Creek sandstone (Register of Australian

Mining 1981) marginal to the Tertiary Tamon Fracture Zone (Figures 5.4. and 5.18). The mineralization appears to be in fracture controlled quartz veins, dislocated by later faulting (Naldart and Threader, 1965). Age and genesis of the mineralization are not available but may be related to the Devonian Tabberabberan Orogeny (± 400 Ma).

The Lefroy deposits occur on the western margin of the Mathinna Beds in highly deformed sediments, as an enechelon fault system (Noldart and Threader, 1965). Main mineralization is pyrite, stibnite, chalcopyrite and arsenopyrite, and gold associated to the pyrite and stibnite. Supergene enrichment of the upper portions of the reef was the primary source of gold (grade ± 30 g/t), and only minor patches of pyrite ore at depth, contained greater than 3 g/t gold. (Noldart and Threader, 1965). This mineralization may be related to the intrusion of Devonian granites at depth, similar to the Mathinna deposits to the east (Figure 5.19)(Green, 1975).

The Mathinna deposit (Figures 5.18 and 5.19) (and associated deposits) occur in a 70km long NNW trending shear zone between two major batholiths, the Blue Tier and Scottsdale Batholiths, (Noldart and Threader, 1965; Williams et al., 1975). The Mathinna Beds are a series of lower- Palaeozoic (Devonian) sandstones, siltstones and shales with transgressive quartz veins in the shear zone. Associated sulphides include asenopyrite, pyrite, chalcopyrite sphalerite and galena. Gold appears to be free in the quartz veins. The gold-bearing shear zone developed during the deformation of sediments during the Tabberabberan Orogeny and mineralization is synchronous or slightly post-dating this event. Production from Mathinna field is estimated to be 8.4 t of gold metal (Woodall, 1979).

Central Zone - New South Wales and Victoria

The most important gold producing district in the Tasman Geosyncline, is the Ballarat Trough Region of the Lachlan Fold Belt in Victoria (Figures 5.7 and 5.20) The mineralization of the Lachlan Fold Belt in Victoria, has been previously described by Baragwanath (1953), Coldham (1953 a), Thomas (1953), (and other references in Edwards, 1953), McAndrew (1965 b), Bowen and Whiting (1975), Woodall (1979) and (in part) Leeming (1985). The distribution of important goldfields in Victoria is shown on Figure 5.20.

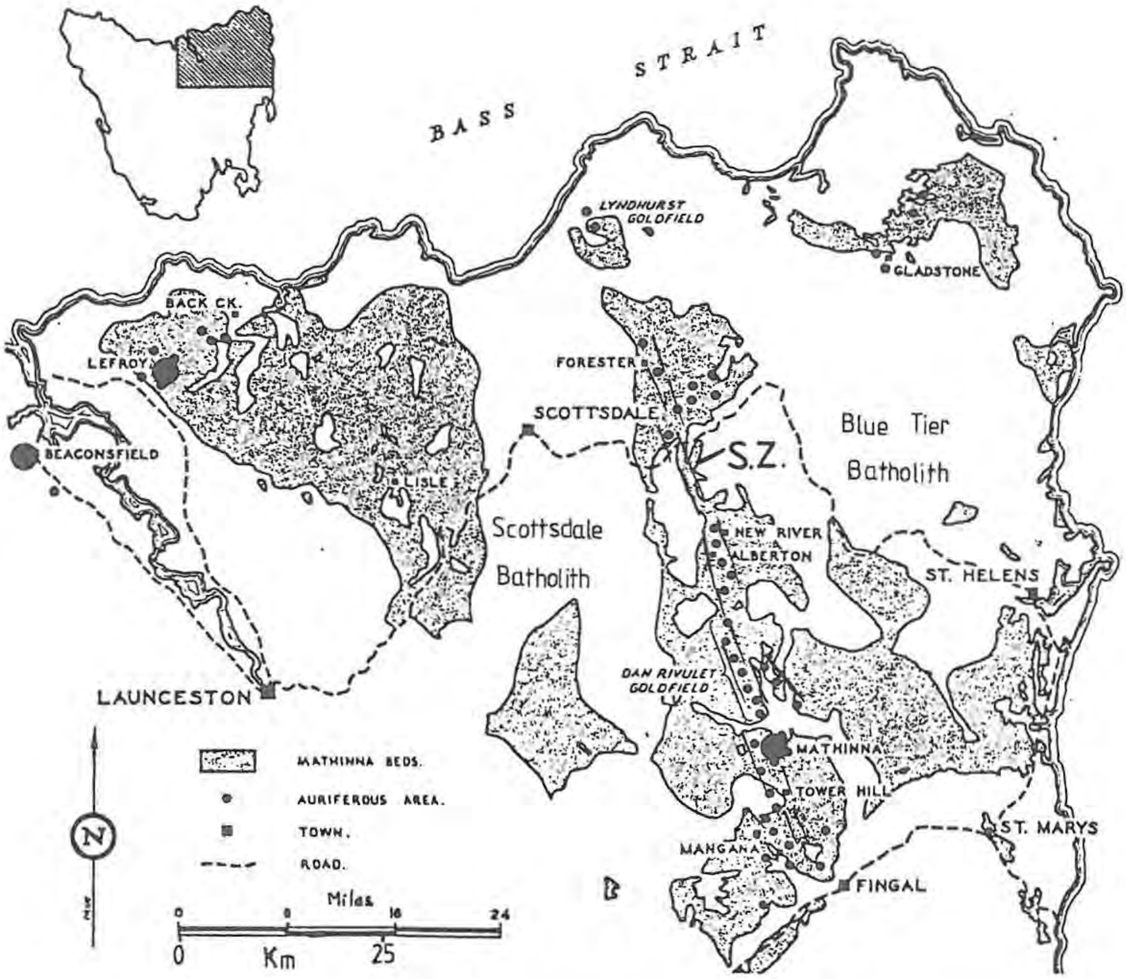
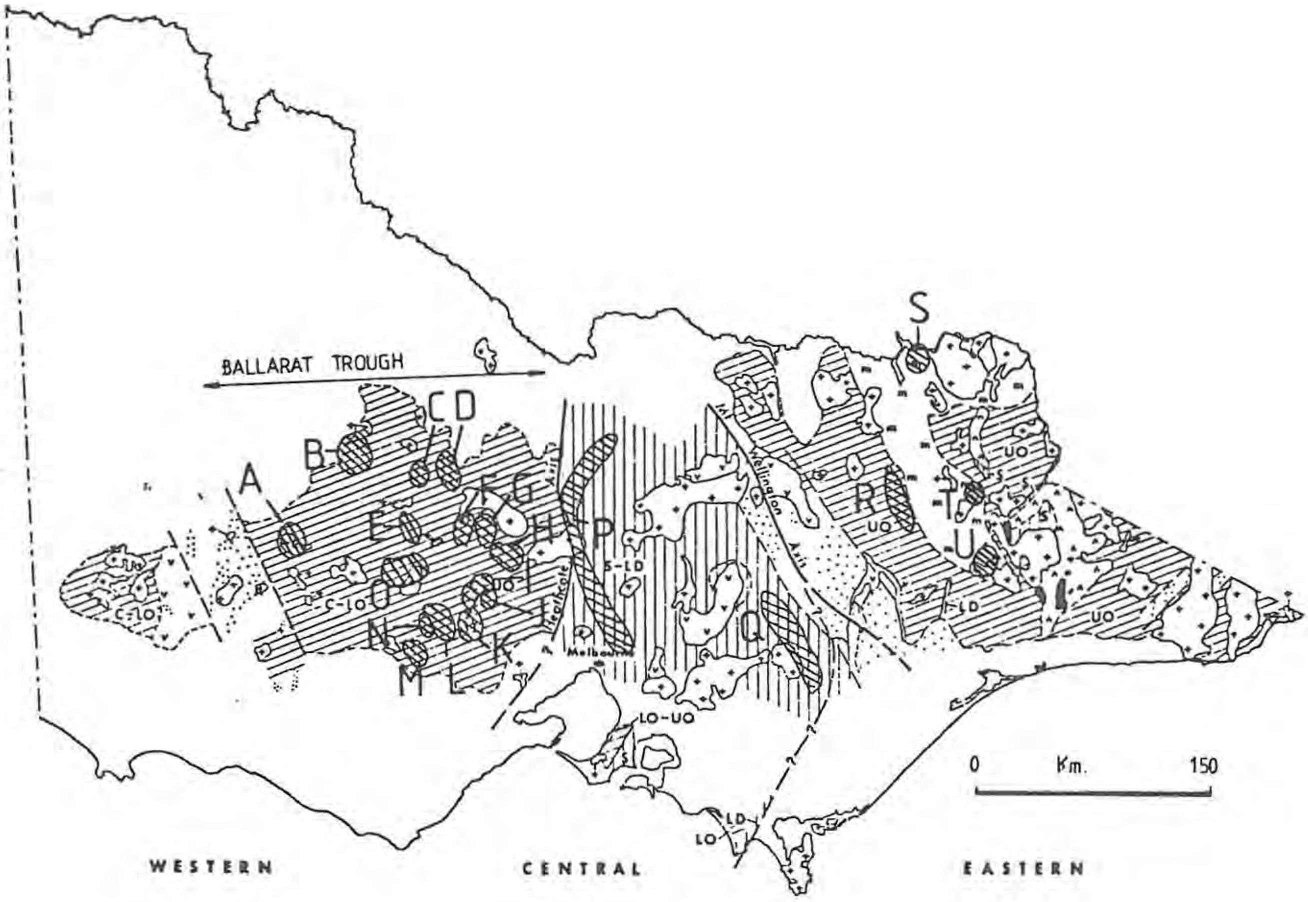


Figure 5.19 : Distribution of gold occurrences and deposits in NE Tasmania (Naldart and Threader, 1965).

There are seven distinct but related types of gold mineralization in the Lachlan Fold Belt (Bowen and Whiting, 1975).

(i) Veins in sedimentary rocks - concordant
(ii) Veins in sedimentary rocks - discordant
(iii) Veins in igneous rocks
(iv) Disseminated deposits
(v) Shallow alluvial deposits
(vi) Deep leads
(vii) Nuggets in a surficial environment.

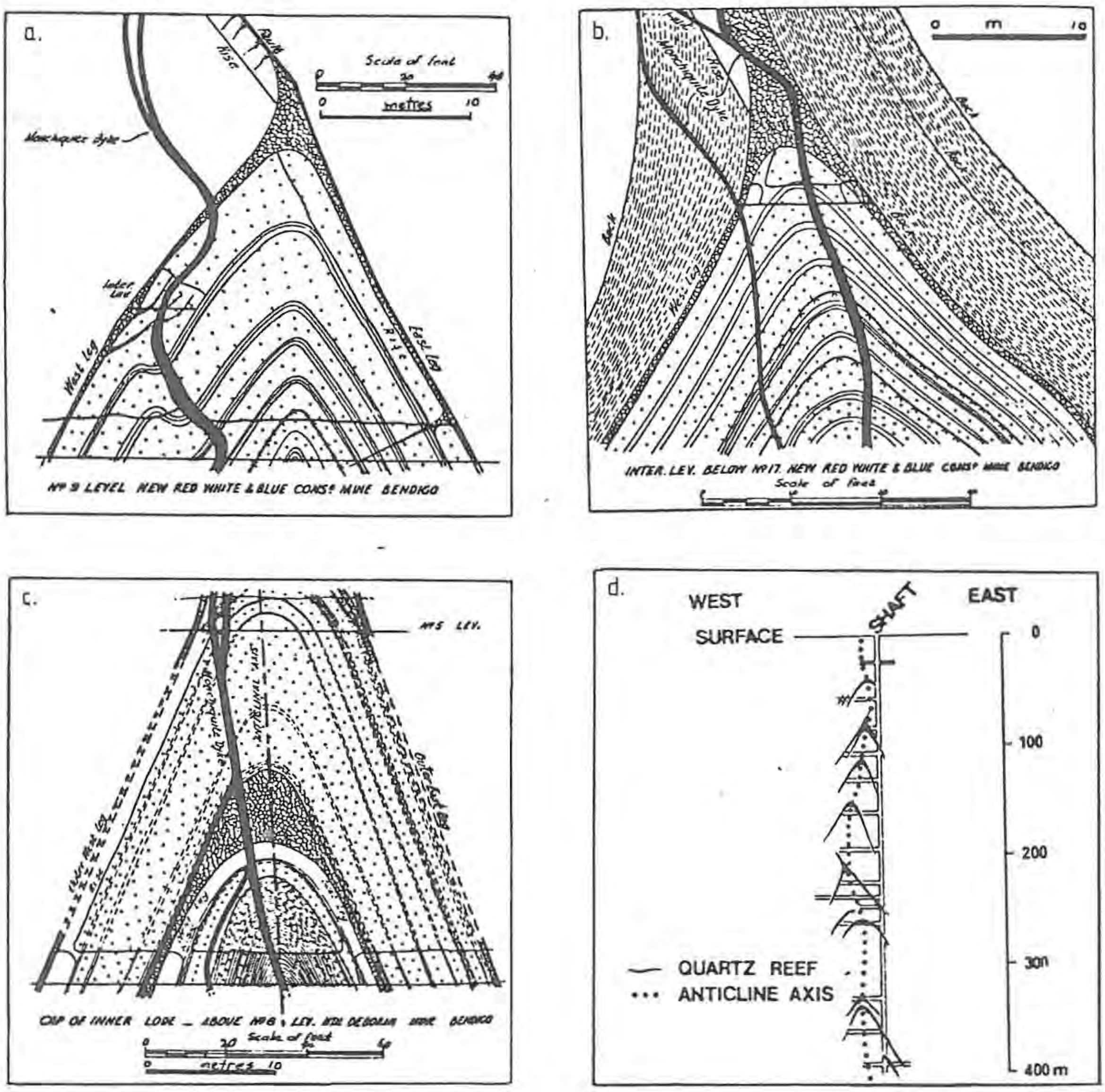
The most important gold deposits are hosted in quartz veins, concordant to sedimentary strata usually in anticlinal strucutres. The most important of these deposits are those in the Ballarat - Bendigo Goldfield in the eastern



A. Stawell
B. St.Arnaud
C. Dunolly
D. Tarnagulla
E. Maryborough
F. Maldon
G. Castlemaine-Chewton
H. Lauriston
I. Dalesford
J. Blackwood
K. Egerton-Gordon

L. Ballarat East
M. Scarsdale-Berringa
N. Ballarat West
O. Clunes
P. Central Victoria
Q. Walhalla-Woods Point
R. Harrietville-Bright
S. Bethanga
T. Maude and Yellow Girl
U. Cassilis

Figure 5.20 : Distribution of goldfields in the Lachlan Fold Belt in Victoria (after Jones and Vandenberg, 1975; and Bowen and Whiting, 1975).



Figure, 5.21 : Cross-sections of saddle reefs in the Bendigo Goldfield (a.b.c, Thomas, 1953; d Woodall, 1979).

portion of the Ballarat Trough (Figure 5.20). Examples of this type of mineralization are shown in Figure 5.21. One of the notable features of the gold occurrences in the Ballarat Trough, is the concentration of deposits toward the eastern side. Woodall (1979) notes the restriction of Ordovician graptolites in this area, even though the lithologies across the trough are similiar. Beerbower (1968, p 432), suggests that graptolites in general may be preserved in anoxic environments, and destroyed in an oxidixing environment, which by implication, may be interpreted as indicating deep and shallow environments in the same depository (respectively). The presence of organic matter decaying in an anoxic environment may supply sulphur to the system, and reduce any iron present to form the pyritic black shales, commonly found in association to gold deposits in the Ballarat Trough region. Subsequent low-grade metamorphism and deformation would remobilize some sulphur from these beds, as well as fluids. The formation of fluids derived from metamorphism and deformation, of a sedimentary pile (particularly turbidites), and subsequently leaching metals from surrounding rocks, and depositing these metals in structurally or chemically suitable traps, is often referred to as the 'metamorphogenic' type ore system (Pirajno, 1985). The intrusion of Devonian granites in the area may be partly responsible for the generation of fluids in the system.

The source of gold in the deposits, is at present unresolved, but the Heathcote greenstone belt (Crawford et al., 1984), may represent a source area, similar to that proposed for greenstone belt gold mineralization in the Archaean (Keays, 1984). The deposits around Ballarat are possibly related to deformation during the Tabberabberan Orogeny, but as yet no detailed work has been undertaken on the timing of the mineralizing events. The mineralization in the Ballarat West goldfield is conformable in a 20 to 30m thick horizon containing numerous carbonaceous black slate beds, which generally are North-north-east trending anticlinal structures (Figure 5.20).

Within the Bendigo gold field, gold mineralization is confined to 13 adjacent sub-parallel anticlines (Figure 5.22) and is generally known as saddle reefs, examples of which are shown of Figure 5.21. General features of the Ballarat and Bendigo Goldfields include a generally low overall sulphide content. Tonnages and production figures from various mines are detailed in Bowen and Whiting (1975).

Discordant veins in sediments are usually confined to reverse faults (eg. New Normandy Mine, Ballarat East), and show a marked enrichment where faults intersect any indicator beds of black carbonaceous shale (Bowen and Whiting, 1975). The faults are commonly steeply dipping, and where they intersect anticlinal axis, tend to flatten and cut across bedding toward adjacent syncinal axis (Bowen and Whiting, 1975).

Veins in igneous rocks are generally confined to basic dykes of middle-Devonian age (Vandenberg, 1978), particularly in the Walhalla district.

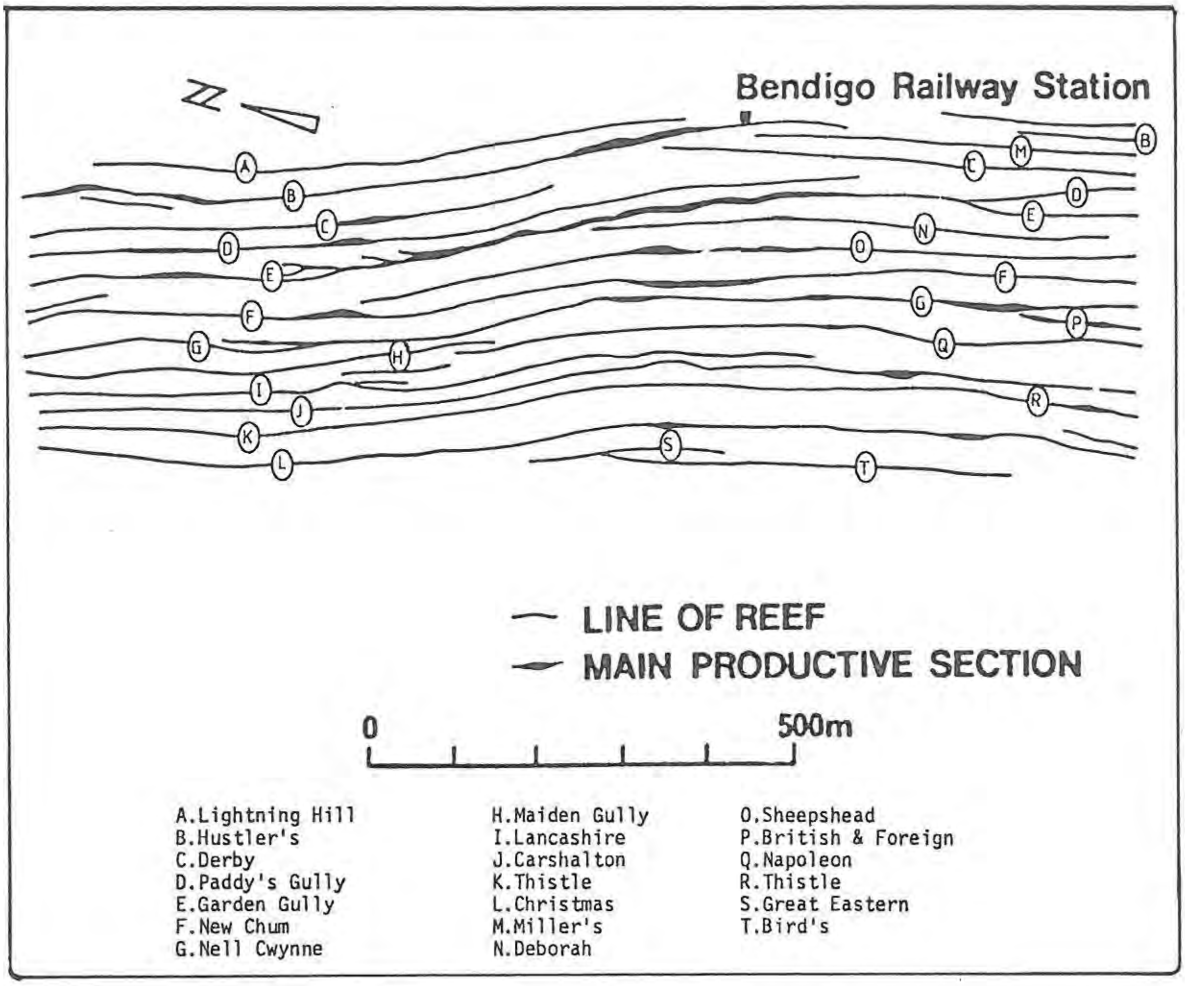


Figure 5.22 : Distribution of anticlinal axial-lines in the Bendigo Goldfield (after Thomas, 1953 and Woodall, 1979).

Mineralization occurs either along, or sub-parallel to dyke walls, or in shears and fractures within the dykes (Bowen and Whiting, 1975).

Disseminated gold occurrences are apparently confined to pitted slates (Bowen and Whiting, 1975) with unknown internal distribution. The Golden Mountain Mine near Tallangalook, produced 142 kg of gold from 56 000 tonnes of ore and is the largest known example of this type of gold occurrence (Bowen and Whiting, 1975). This deposit occurs in a pyritic hornfels adjacent to the Strathbogie granite (probably Devonian). The disseminated style of mineralization is poorly documented. It is however probable, that the gold minerazlization is related to the granite intrusion, and gold was derived from a pre-existing gold occurrence, such as an enriched sedimentary horizon or bedded veins (Bowen and Whiting, op. cit.).

The deep lead deposits are alluvial occurrences, preserved by Tertiary Basalt flows as exemplified in the Ballarat West Goldfield. Mineralization is confined to gravels or wash up to 1 metre thick, and can occur to depths of 150m (Bowen and Whiting, 1975). The alluvial deposits of Victoria were responsible for the initial gold rush during the 1850's. The deposits are spatially associated to other types of mineralization particularly vein deposits. The nuggets of the Victorian Goldfields are famous, particularly the Welcom Stranger, with a net weight of 71.06 kg. Occassional nuggets continue to be found in the gold-fields by people using metal detectors.

The Lachlan Fold Belt in New South Wales contains numerous occurrences of gold mineralization, particularly in synclinorial or rift areas. The different rift zones described in Section 5.1.1 contain gold mineralization in different environments, which tend to reflect the differences in rift geology. In areas dominated by sediments, free gold occurs in metamorphogenic type deposits, while in areas with dominantly volcanic rocks, gold occurs (mostly) in association to base metals in massive sulphide deposits. It is beyond the scope of this dissertation to describe all the gold deposits in New South Wales, and hence the emphasis is on describing the different types of deposits in the main zones of the area.

The Cobar-Mineral Hill Zone contains two important types of gold occurrence, base-metal (probable volcanogenic origin) type, and stockwork quartz vein type. The most important is the base-metal associated deposits, such as those in the Cobar Mining Field (Figure 5.12). Here the sulphide mineralization occuring within sediments of the Cobar group, consists of three types, (Thomson, 1953 p 893), siliceous, siliceous-pyritic, or massive sulphide types. The siliceous type consists of disseminated gold and chalcopyrite within a silicified slate. Associated sulphides include pyrrhotite and pyrite with minor occurrences of galena, sphalerite, arsenopyrite, native bismuth, bismuthinite and galena-bismutite (?). The latter two types of mineralization rarely have associated gold mineralization. These deposits (base-metal associated) are interpreted as structurally modified volcanogenic massive sulphide deposits (Gilligan, 1974 a), with original controls on deposition of mineralization, being facies variations in the succession. Remobilization of sulphides (and gold) may have occurred during deformation by shearing, as is evident by broad silicification and alteration zones associated to areas of deformation (Gilligan, 1974 a).

The Canbelego Area (Figure 5.12), hosts the second type of gold mineralization found in the Cobar-Mineral Hill Zone, as stockwork quartz veins. This mineralization is associated to an unconformity between a lower highly deformed phyllite schist and quartzite unit (Grilambone Beds), and the overlying early-Devonian polymictic conglomerate and sediment unit. In a broad sense the mineralization occurs within a second order parassitic synclinal fold on a major fold (Gilligan, 1974 a). Genesis of this type of mineralization is conjectual at present but is most likely a metamorphogenic type related to the deformation during Devonian age deformation.

The Bogan Gate Zone contains three main types of gold mineralization, (Fitzpatrick, 1974) in addition to a fourth recently discovered type. The three main types are (i) gold associated with Basic (Dioritic) Intrusives
(ii) Gold associated with acid igneous rocks
and (iii) Gold in quartz veins in sediments.

The gold mineralization in basic intrusives appears to be related to major lines of weakness which controlled the emplacement of the basic intrusives, which may have been the source of gold (Fitzpatrick, 1974). Gold occurs within quartz reefs with minor associated sulphides. The most important of these deposits, is the Barmedman deposit which yielded 254 kg of gold (Fitzpatrick, op. cit.) (Figure 5.13). Gold mineralization is associated with acid igneous rocks and occurs along the margins of granite and porphyry intrusions and rhyolite-dacite volcanics. The largest field of gold occurrences is the Cullinga Gold Field (Figure 5.13), which produced in excess of 1240 kg of gold. Gold is usually patchy in quartz reefs, with minor sulphides. The origin of the gold mineralization may be related to the associated igneous rocks, or possibly to the zones of weakness occurring on the margins of those rocks. The gold occurrences in sediments are relatively insignificant and appear to be structurally controlled (Fitzpatrick, 1974). These deposits are not related to any nearby igneous rocks.

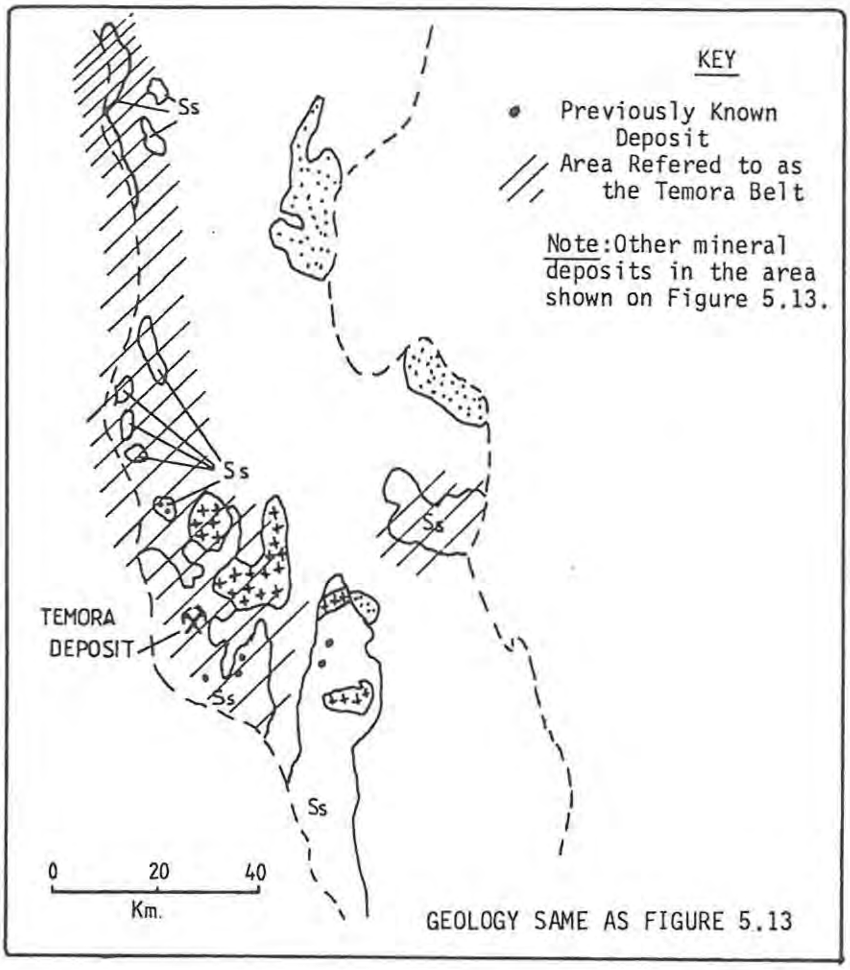


Figure 5.23 : Locality map of the Temora Gold Deposit, Bogan Gate Zone (F. Pirajno unpublished information).

The recent discovery of the Temora Gold deposit, has sparked off a major gold exploration boom in the Bogan Gate Zone, for epithermal type mineralization, which was previously not recognized in the area. The area is referred to as the Temora Belt, and is confined to the western margin of the Bogan Gate Zone (Figure 5.23). Host rocks are propylitically altered volcanics (andesites), which have been extensively replaced by chalcedonic silica. At present very little information is available, with current exploration and evaluation under way. The reserves at the Temora deposit are estimated at 5.6 Mt at 2.5 g/t gold and 7 g/t silver. The ore body at Temora is characterized by an ore bearing, pyritic, chalcedonic core surrounded by a zone of pyropyllite-alunite-pyrite, within the surrounding extensive propylitic alteration. The altered andesite volcanics are overlain by underformed sedimetns. Age of the mineralization is tentatively proposed as mid- to late-Devonian.

The Cowra-Yass Zone contains base metal associated gold deposits and quartz-gold vein deposits. The base-metal associated deposits are of minor importance in terms of tonnages, but may in some places be representative of deeper levels of an epithermal system. The quartz-vein gold occurrences such as the Tyies prospect and the Blue Jacket Mine, may be the upper portions of an epithermal system. The alteration products identified at the latter deposits include sericite, chlorite and carbonate within the acid volcanic host rocks. Mineralization at the Blue Jacket Mine is transgressive into overlying shale units, and may be related to late stage subvolcanic processes (Gilligan, 1974 b). In light of the recent discoveries at Temora, it is highly probable that this area has potential for further epithermal gold occurrences.

The Hill End Zone contains a number of different types of gold occurrences, (Figure 5.15) sub-divided on the basis of host rock lithology (Stevens 1974). These include those hosted by acid volcanics, slates, basic and intermediate volcanics, and those contained in faults and folds. Acid volcanic-hosted gold deposits are frequently altered (eg. Wisemans Creek area; talcose and sericitic schists hosting mineralization), commonly with quartz, sericite and clays with some carbonate alteration. In terms of genetic models, these deposits may be epithermal deposits not previously identified as such, although Stevens (1974) recognized a hot spring or fumarolic origin for some of the deposits.

Deposits from the Hill End Zone hosted in slates, appear to have the characteristics of metamorphogenic type deposits described earlier. Gold occurs in quartz veins associated to structural features such as faults and joints, and as saddle reefs in anticlines adjacent to carbonaceous shale horizons. These deposits show no apparent spatial association to any igneous rocks. (Markham 1975). Grades of gold in these deposits range from 1 to 1000 g/t, with the gold usually occurring free and occasionally with associated sulphides. The gold mineralization associated to basic rocks, is usually confined near the margins or contact of slates with volcanics. In general these contacts, may have acted as fluid channelways for mineralizing fluids, which deposited gold in structurally favourable sites. Faults and folds have also acted as fluid channelways for the deposition of gold mineralization but in overall terms, folds are the most important (see above).

The Captains Flat Zone, although of a similar tectonic origin to previous zones, has a paucity of gold occurrences and an abundance of base-metal sulphide occurrences (eg. Woodlawn, Captains Flat). Minor gold occurrences are recorded from the northern part of the zone (Gilligan, 1974 c).

It is important to note the numerous gold occurrences in the anticlinoral zones in the Tasman Fold Belt (Figure 5.7). These occurrences are of relatively minor importance when compared to those in the synclinorial zones and have been described in Markham and Basden (1974). Numerous occurrences of alluvial gold are noted in the New South Wales portion of the Lachlan Fold Belt, particularly in areas of metamorphogenic or slate hosted primary gold deposits (Markham and Basden (op. cit.). A genetically important occurrence of gold mineralization, outside the synclinorium zones is the Brown's Creek Copper - Gold skarn deposit in the Molong rise (Figure 5.7). This deposit occurs on the contact between Ordovician limestones and Carboniferous granites (Taylor, 1983). The origins of gold and copper are tentatively concluded to be the sediments (active leaching by a meteoric water dominated hydrothermal cell generated by the intrusion of granite) or the granite (magmatic late-stage differentiates).

Northern Area - Queensland

The two main tectonic elements of the Lachlan Fold Belt in Queensland are the Lolworth - Ravenswood Block and the Anakie Inlier (Murray and Kirkegaard, 1978; Palfreyman, 1984). The Lolworth - Ravenswood Block is particularly rich in gold occurrences, with the main (historical) producing areas around Charters Towers and Ravenswood (Murray, 1975). The mines around Charters Towers are in simple or composite quartz veins in the Ravenswood Granodiorite Complex. Veins are controlled by fractures and shear zones with some enrichment at fault intersections (Murray, 1975). The deposits, are spatially associated to a series of sub-parallel diorite dykes trending north-east, which are normal to an interpreted north-west trending alignment of folds (Blatchford, 1953). The veins appear to be locally structurally controlled around the axis of these folds (Blatchford, 1953), although imformation on controls of mineralization is sparce. Originally the deposits were classed as 'mesothermal', and occurred dominantly shallower than 600m, and up to 50m from surface (Blatchford, 1953).

The Lolworth-Ravenswood Block is currently being re-evaluated in search of new gold deposits, as evidenced by the Disraeli - Highway discoveries, 35 km south-west of Charters Towers (Gold Gazette, Nov. 10, 1986). The Ravenswood deposits are similiar in nature to those at Charters Towers but tend to have a higher sulphide content (Blatchford, 1953). The association of minor gold deposits (Murray, 1975) to volcanics, post-dating (possibly Carboniferous) the Ravenswood Granodiorite Complex, constrains the mineralization to the Carboniferous or later (Murray, 1975). The deposits occurring in the complex, are the only gold deposits hosted in granites, of any significance in the Lachlan Fold Belt, indicating that these deposits have been generated through processes different to other deposits in the belt (ie : possibly related to deep seated Carboniferous granites).

The Anakie Inlier contains little known gold mineralization but as discussed in Section 6, potential does exist for discovery. The known mineralization is quartz-gold lodes in the Anakie Metamorphics (Olgers, 1972), and ages have been interpreted as Permian.

5.2 New England Fold Belt

5.2.1 Geology

The New England Fold Belt (Figure 5.24) developed from late - Silurian, with an initial deposition of calc-alkaline volcanics and limestones (Day et al., 1978). The New England fold Belt is possibly the most structurally complex area in eastern Australia, and this is reflected in the interpreted tectonic models proposed for it. Harrington and Korsch (1985 a,b) define nine tectonic periods of evolution for this Fold Belt, subdivided into four sets on the basis of similarity of tectonic features. This subdivision of tectonic units, describes the features characteristic to different areas, but does not present a cohesive tectonic model for the belt. The model preferred is by Day et al., (1978).

The main tectonic and structural features of the New England Fold Belt are

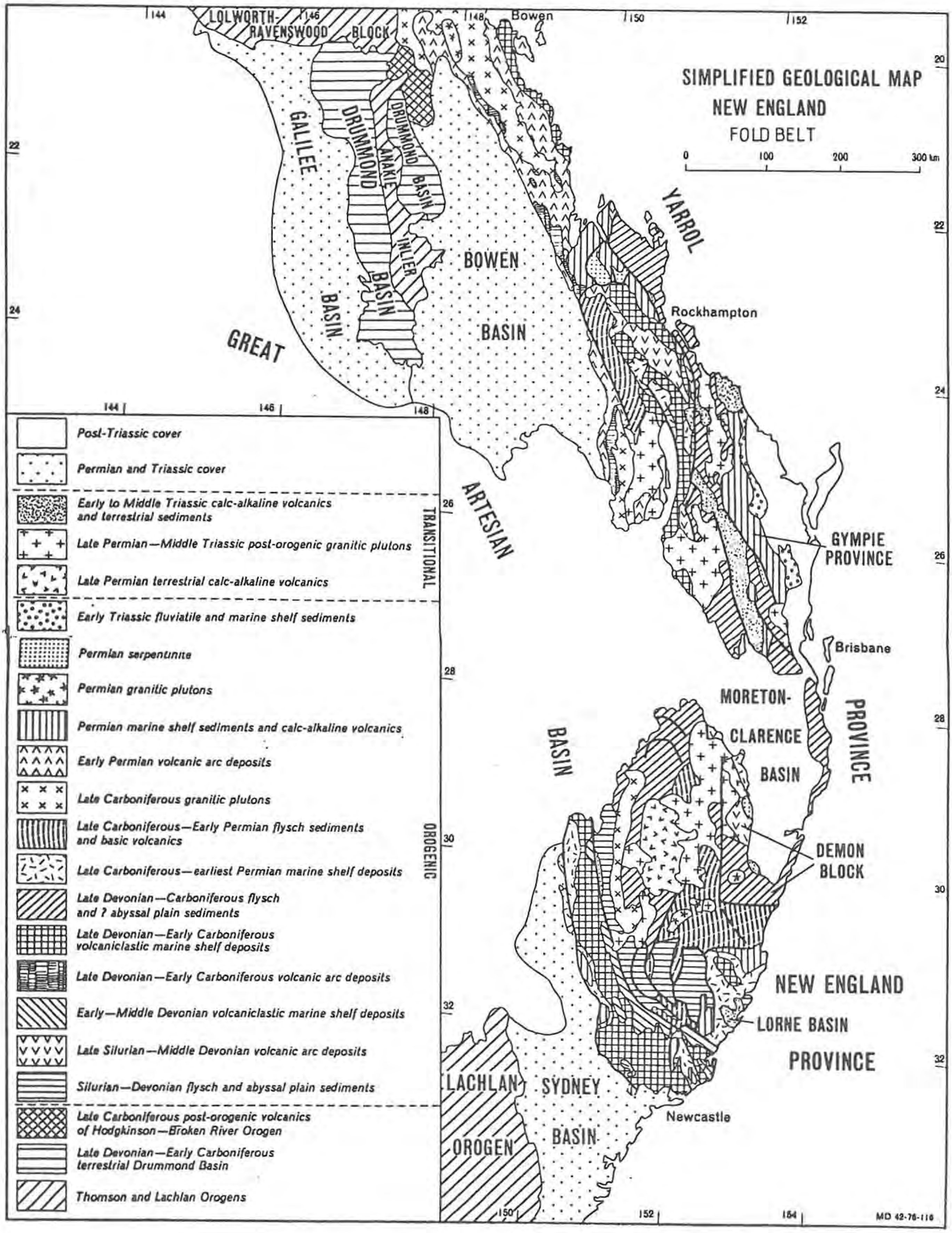


Figure 5.24 : Simplified geological map of the New England Fold Belt (Day et al, 1978).

shown on Figure 5.24. The Yarrol Province contains remnants of an island arc system (Calliope Island Arc), with a marginal basin separation from the main Australian continent, and possible basin and slope sediments to the east. This volcanic arc was deformed during middle Devonian tectonism which may have been in part synchronous with the Tabberabberan Orogeny in the Lachlan Fold Belt. The presence of extensive ultramafic rocks in the Yarrol Basin, of 'suspected' Devonian age (Murray, 1974) indicates the potential for an arc, back-arc basin system developed on oceanic crust.

Development of an Andean-type volcanic arc is interpreted along the western margin of the New England Fold Belt, during late-Devonian and early-Carboniferous times (Day et al., 1978). East of this volcanic arc, deposition of marine shelf sediments occurred, consisting of dominantly volcano-clastic sediments and primary volcanics, with late carbonate sediments in the early Carboniferous. Deeper water sediments occur to the east of these sediments. Granite batholith emplacement in the Yarrol Basin Province reduced the amount of sedimentation into the Basin.

In the south and central zones of the New England Fold Belt, calc-alkaline volcanism was evolving towards acidic members, while sedimentation occurred in marginal environments (eg. Wandilla and Woolomin Slope and Basin sequences). Granite intrusion occurred on the western margin of the Woolomin slope and basin environment, with deformation and metamorphism affecting all the sequences from the late Carboniferous to early Permian (Day et al., 1978). The main period of tectonism in the New England Fold Belt, was terminated in the middle- to late-Permian Hunter Bowen Orogeny (Plumb, 1979 a). Overall the tectonism can be subdivided into two (areas or) types : (i) oceanic-basin areas with intense folding, low grade metamorphism (intermediate pressure, and local areas of low pressure amphibolite facies metamorphism, and

(ii) marginal marine shelves with characteristic thrusts, open folds and low grade metamorphism (Plumb, 1979 a).

Further sedimentation, granitic plutonism and deformation occurred after the Hunter-Bowen Orogeny, resulting in the present distribution of structural and lithological units.

5.2.2 Gold Mineralization

The New England Fold Belt is generally a gold-poor tectonic province with the exception of the Mount Morgan, Gympie, Cracow, Hillgrove and Eidsvold goldfields (Woodall, 1979) (Figure 5.25). The Mount Morgan deposit is the largest of these goldfields having produced in excess of 245t of gold. The deposit occurs within the "probable early-Devonian" Capella Creek beds in the Yarrol trough (Frets and Blade, 1975) (Figure 5.25). The main ore minerals are pyrite, chalcopyrite, pyrrhotite and magnetite, with native gold and gold tellurides. The genesis of this deposit is uncertain (see Frets and Blade, 1975), but the main features suggest an epigenetic deposit of Devonian age, similiar to numerous other deposits in the Tasman Fold Belt, and possibly predates the intrusion of the Mt. Morgan tonalite near-by (Frets and Blade, 1975). The gold-copper mineralization appears to be the last phase of a mineralizing event which formed the deposit.

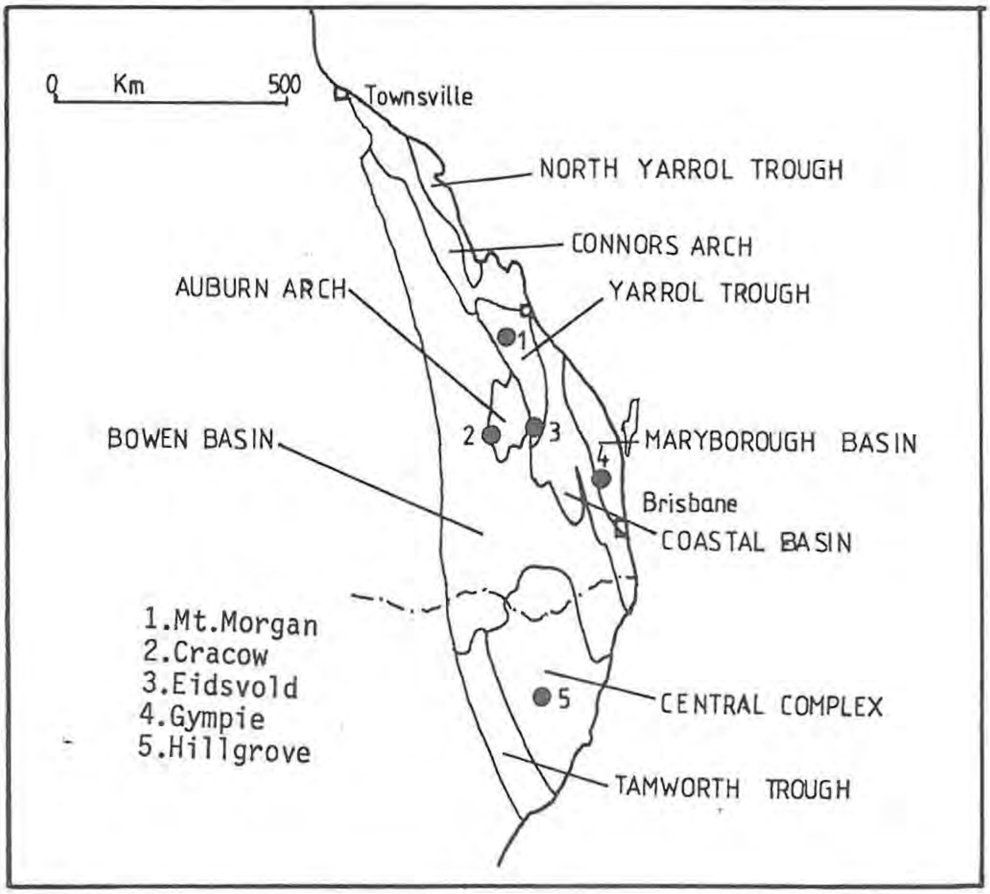


Figure 5.25 : Distribution of important gold occurrences in the New England Fold Belt (Woodall, 1979).

The Cracow area (Figure 5.25) contains the Golden Plateau deposits, a series of quartz-filled veins, fissures and breccias (Ransom and Knight, 1975), within the early - Permian Camboon Andesites. The gold is usually associated with the sulphides (pyrite, sphalerite, chalcopyrite, bornite) in the lodes. The surface trends of lodes show a northeast orientation of two zones, linked by a third zone trending east-west. The genesis of the deposit is unclear, but Knight (1971, in Ransom and Knight, 1975) has interpreted from aerial photographs a possible caldera structure which may be related to the deposit. In light of the above features the deposit is regarded as hydrothermal, (Section 5.4). The deposit occurs on the margin of the Bowen Basin and the Auburn Arch (Figure 5.25).

The Gympie Goldfield (Figure 5.25) produced over 100t of gold from gold-quartz reefs (Jones and Carruthers, 1965). These deposits are similar to those within the Drummond Basin (Section 5.4). The mineralization at Gympie has an apparent close spatial association to beds of carbonaceous shales. Gold occurs in the free form, and associated to minor sulphides (ie. pyrite, galena chalcopyrite, sphalerite and hessite (Murray, 1975). Records of mining operations and geology are rare from this field. The mineralization is of two possible origins, either hydrothermal, related to the intrusion of acid intrusives in the area, or metamorphogenic, derived from metamorphism and dewatering during deformation of the basin. The former is likely with only minor deformation affecting the area during the intrusion of granites. The gold deposits are poorly documented (in some instances) and understood.

5.3 Hodgkinson Fold Belt

5.3.1 Geology

The third main tectonic province in the Tasman Fold Belt is the Hodgkinson Fold Belt (Figure 5.26), which is separated from the New England Fold Belt by the northern fragment of the Tasman Fold Belt (Day et al., 1978; Plumb, 1979 a; Palfreyman, 1984). The Fold Belt was deposited (in part) on an older Proterozoic basement complex, the Georgetown, Coen and Yambo Inliers. The succession in the Hodgkinson Fold Belt consists of quartz-rich flysch and mafic volcanics (subjected to pre-lithification slumping and deformation) with overlying shallow marine carbonate rich sediments (Figure

5.26). The latter sediments are Silurian - Devonian in age. Controls on sedimentation may have been rifting adjacent to the Precambrian basement, with volcanics related to an Andean-type volcanic chain in the east (Day et al., 1978).

Of particular importance is the late-Carboniferous and early-Permian acid

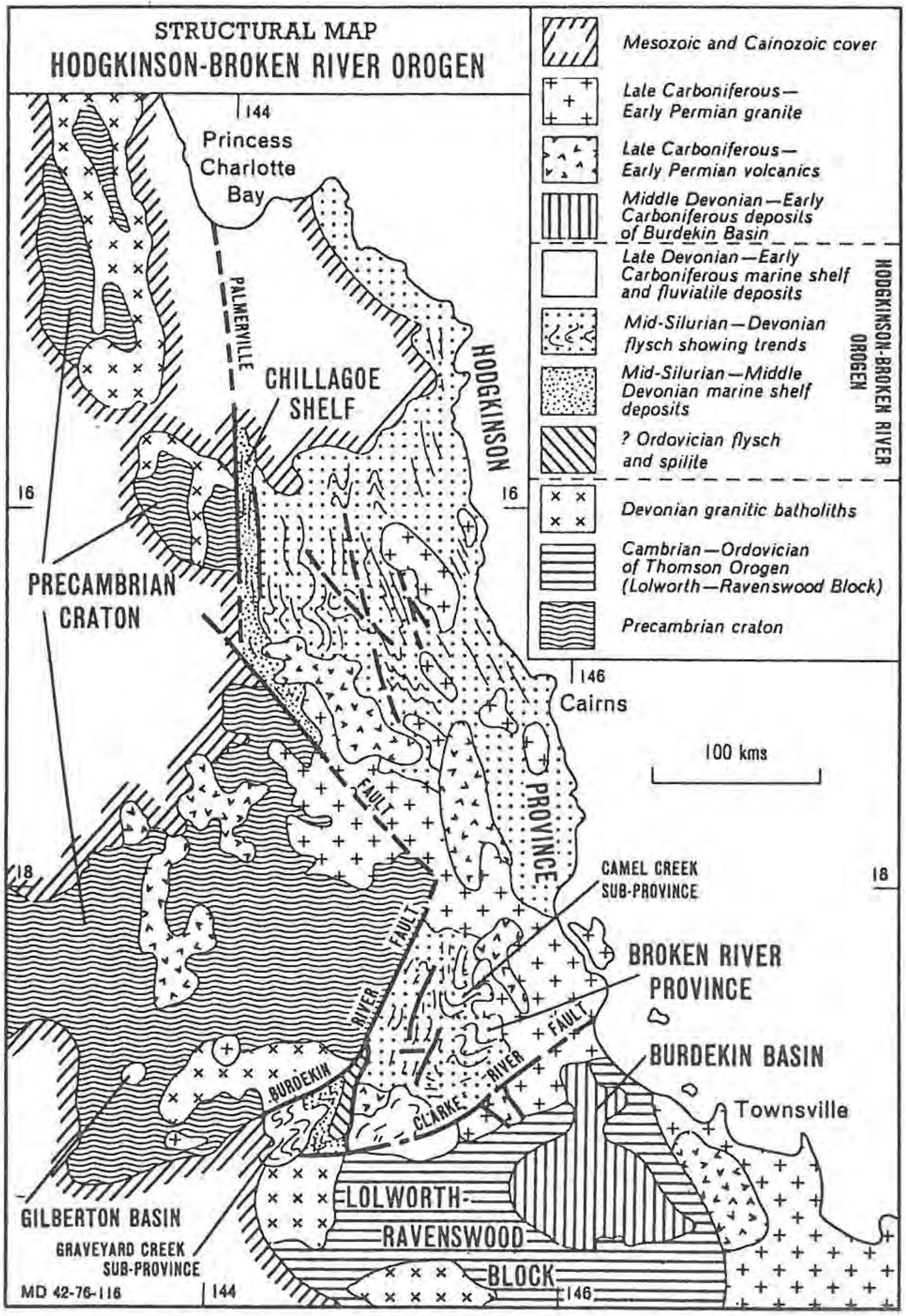


Figure 5.26 : Geology of the Hodgkinson Basin and surrounding areas (Day et al, 1978).

volcanism and plutonism which affected the Hodgkinson Fold Belt (Day et al., 1978; Branch, 1966). This period of igneous activity also affected the Proterozoic Georgetown, Coen and Yambo Inliers, and (probably) the late Devonian Drummond Basin (see Section 6). Although the timing of these events is uncertain, there is a high probability of the events being related (Section 6).

The Broken River Embayment is part of the Hodgkinson Basin which was developed in a fault (one-side) bounded trough, between the Precambrian Georgetown Inlier (fault contact), and the Lachlan Fold Belt's Lolworth-Ravenswood Block (Murray, 1975). The geology of the Broken River Embayment is dominantly shallow water and trough sediments in the lower part of the stratigraphy (shales, siltstones, sandstone turbidites and greywackes) with dominantly turbidites grading up into shallow water limestones in the top of the stratigraphy. Deformation occurred during the late-Silurian, early Devonian (including granite intrusions) early-Carboniferous and late-Carboniferous. This deformation included folding, doming and basin development.

5.3.2 Gold Mineralization

The gold mineralization known from the Hodgkinson Basin is predominantly alluvial from the Palmer River Goldfield, with a small proportion being derived from gold quartz veins in sediments (Murray, 1975).

Little published data is available on this area. The mineralization in quartz lodes is dominantly free gold, pyrite and arsenopyrite, with minor amounts of chalcopyrite, sphalerite and galena. The deposits may be genetically related to intrusives (at depth) (Murray, 1975). The ages of granites in the area appear to be dominantly late-Carboniferous to early-Permian, intruding flysch-type sediments of the same age and Devonian shelf sequences.

The most important aspect of the volcanism that has affected the Hodgkinson Basin, and possibly generated the gold mineralization, is the development of calderas and cauldrons in the Georgetown Inlier at the same time (Section 4.4). These calderas, have associated gold mineralization such as that at

Kidston, and the potential exists for significantly more gold occurrences in the Hodgkinson Basin, marginal to these granite bodies.

5.4 Drummond Basin

5.4.1 Geology

The Drummond Basin consists of three sedimentary cycles separated by periods of volcanism (Olgers 1972, Murray, 1975). The first cycle is dominantly a shallow water (and some continental) sedimentary sequence, followed by a period of continental sedimentation west of the Anakie Inlier, and a final sedimentary cycle which deposited volcanic and lithic sediments over the whole basin. The intervening periods of volcanism occurred in late-Devonian or early Carboniferous, and early-to mid-Carboniferous extending through the third sedimentary cycle. The sedimentation was terminated by volcanism in the late-Carboniferous, and by east-west compression giving rise to broad gentle folds and by acid magmatism. The main geological units of the Drummond Basin are shown on Figure 5.27. Of particular note are the two elongate northerly trending zones of late-Carboniferous acid volcanic centres, generally andesitic in composition.

5.4.2 Gold Mineralization

The Drummond Basin until recently, contained only a single known mineral occurrence, the Coolan gold mine. This deposit lies within late-Devonian to early-Carboniferous rhyolitic volcanics, hosted by andesites (Murray, 1975 b). The mineralization was related to a thin shear zone laterally persistent, within a zone of silicification (Murray op. cit.). Primary gold was fine grained and associated with pyrite (Coldham, 1953 b), in the main vein which ranged up to 15 cm in width, consisting of dominantly quartz gangue.

Recent work in the area has resulted in the discovery of a major gold deposit at Pajingo, approximately 120 km north-west of the Mt. Coolan Deposit (Australian Business, September 4, 1985). This deposit is expected to produce in excess of 1.7t gold per annum (1.4 Mt at 12.6 g/t) when it comes on stream in 1988. The mineralization is epithermal, associated with

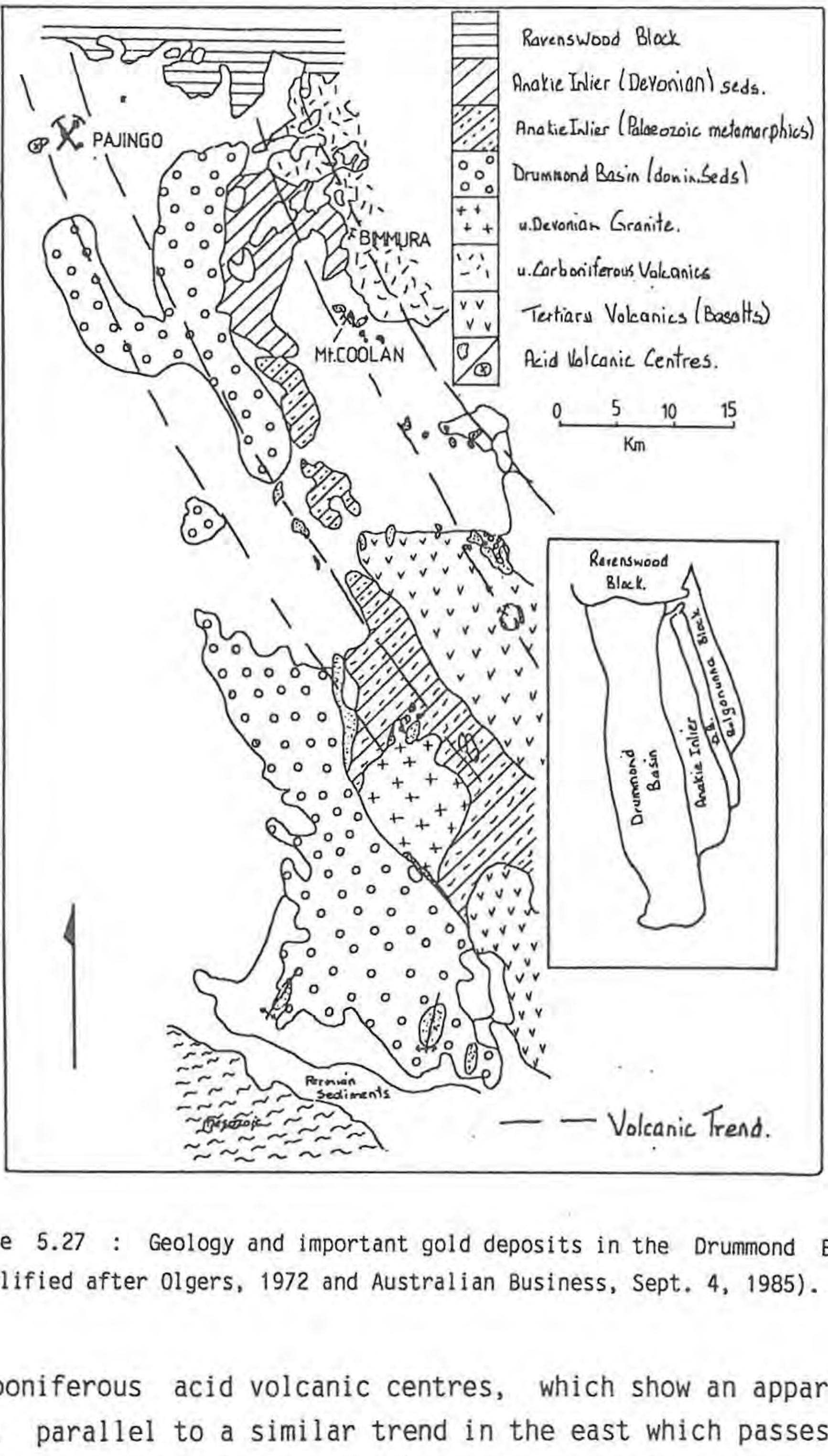


Figure 5.27 : Geology and important gold deposits in the Drummond Basin (simplified after Olgers, 1972 and Australian Business, Sept. 4, 1985).

lower-Carboniferous acid volcanic centres, which show an apparent trend to the north, parallel to a similar trend in the east which passes through the Mount Coolan deposit (Figure 5.27). Another gold occurrence recently discovered, is the Bimurra prospect, 34 km north of Mt. Coolan in a similiar geological setting to Pajingo. The deposit is possibly the higher levels of an epithermal system which has been preserved (Gold Gazette, March, 1986). Alteration of the rocks at Bimurra prospect, included silicic, quartz-sericite, argillic and propylitic, indicative of the hydrothermal nature of the deposit.

The mineralization is pyrite, marcasite, gold, silver sulphide, galena and magnetite. Pyrite is spatially associated to zones of intense alteration. Gold can occur either as free gold or in pyrite.

Initial genetic modelling, based primarily on the Bimurra prospect, indicates the mineralization is most likely related to caldera collapse structures as shown in Figure 5.28 (Gold Gazette, 1986). It is to be noted that this is a tentative interpretation and includes the mineralization at Cracow, previously discussed in Section 5.2.2. The characteristics of these deposits (Pajingo, Bimurra) indicate epithermal mineralization (Figure 5.28).

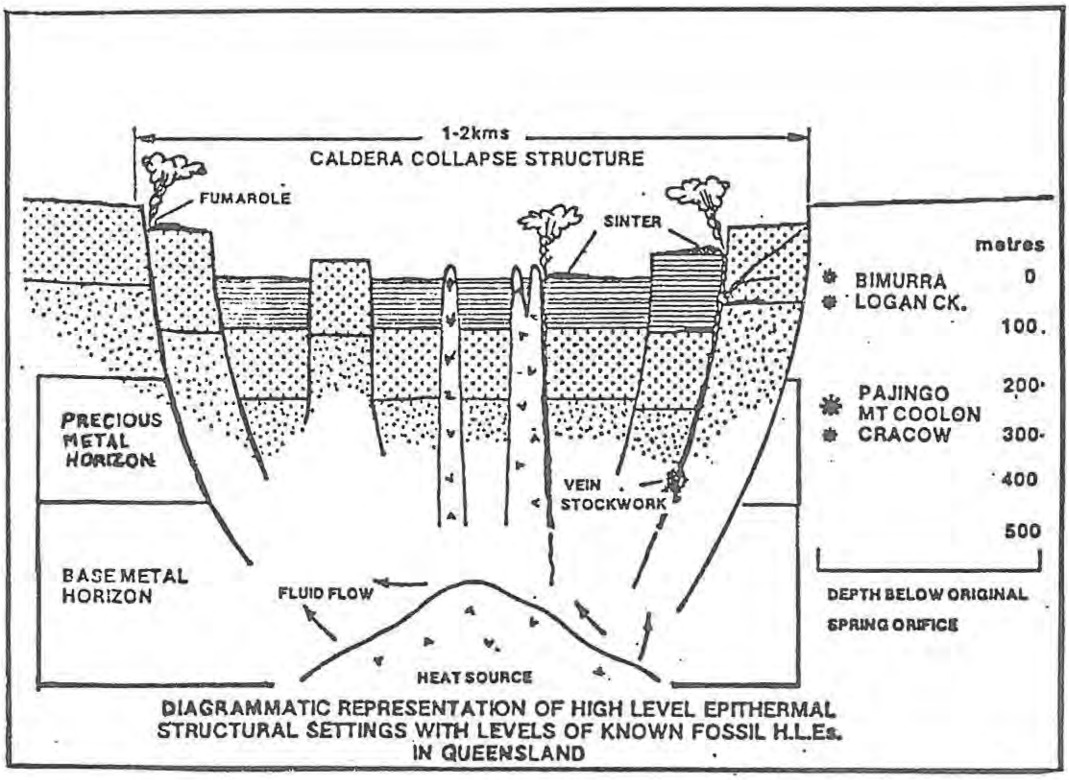


Figure 5.28 : Schematic section showing the relationship of mineralization to caldera structure, in the Drummond Basin (Gold Gazette, March, 1986).

6. SYNTHESIS AND CONCLUSIONS

The current boom in gold exploration in Australia has resulted in the exploitation of numerous small deposits, previously regarded as sub-economic. These depoists are poorly documented, and at present only limited information is available. The Yilgarn Craton in Western Australia is the centre of this boom, with new discoveries including the laterite-hosted Boddington deposit. Other new deposits are vein/shear zone hosted deposits occurring near surface (open pit mining) with grades above 3g/t.

The majority of deposits in the Yilgarn Craton are associated to mafic-ultramafic host-rocks, with a lesser number of deposits associated to felsic volcanics and sediments. The potential for further gold occurrences is predominantly in mafic host rocks, within zones of faulting, shearing or deformation. The known gold mineralization is preferentially associated to rift-phase greenstones in younger granite-greenstone terrains. The Big Bell deposit, is a 'Hemlo type' deposit in felsic volcanics, with a strong lithological and structural control. The charactersitic features of this deposit, include alteration of felsic volcanics, prior to deformation and the mineralization. The deposits hosted in B.I.F.s are presently poorly documented and understood. Areas of future research that may help in the elucidation of genetic aspects of this type of deposit, includes the determination of total iron content, in, and surrounding the known deposits (depletion or enrichment zones), and total chemistry of the B.I.F.'s in relation to interpreted tectonic environments. Gole (1981), has undertaken some work in this direction, which may be used as a basis for future work.

The gold deposits hosted in laterites (eg. Boddington) are important additions to the types of Archaean gold deposits. In economic terms, the deposits are low-grade large-tonnage deposits suitable for open pit exploitation, but importantly these deposits result (in part) from near-surface migration and enrichment of gold. The latter is important, due to the extensive cover on the Yilgarn Craton, and the present limited amount of information on gold in the surficial environment. Exploitation of these deposits should assist in understanding of this environment, and particularly assist in exploration in areas of cover (laterite, calcrete, silcrete etc).

Areas with greatest potential for discovery are the Murchison Province, and the Norseman-Wiluna Sub-province in the Yilgarn Craton, for Hemlo type and Kalgoorlie type respectively. The Southwestern Province has potential for further laterite hosted deposits, and the Southern Cross Subprovince has potential for B.I.F.-hosted deposits.

The Proterozic rocks of Australia offer only limited potential for further discoveries due to the extensive erosion in these domains. The Roxby Downs deposit is an example of preservation beneath younger cover, of a unique gold occurrence. It is suggested, that in the Proterozoic Provinces described in this dissertation, further deposits occur either close to, or beneath latter cover sequences, particularly in the North Australian Craton. Due to the ages and orogenic history of the Proterozoic rocks in Australia, detailed tectonic analysis are presently at an early stage.

The Georgetown, Yambo and Coen Inliers have the best potential for mineralization, of all the Proterozoic terrains in Australia., This mineralization is tentatively related to the Permo-Carboniferous granites and volcanics within the Proterozoic basement sequence. Available data is insufficient to propose a definitive model of evolution for the mineralization, but is is tentatively suggested that the ring complexes and cauldrons of the Inlier (Branch, 1966), and related mineralization, are geneticly related to the mineralization and deposits in the Drummond Basin (epithermal high level deposits). The deposits of the Drummond Basin are tentatively dated as Permo-Carboniferous, related to acid volcanic centres, which may be equivalent to the eroded upper portions of the ring complexes in the Georgetown Inlier. Although this is a tentative suggestion, in terms of regional exploration, and tectonic history of the area, this requires further detailed research, to evaluate the possibility, that these spatially separate occurrences of gold mineralization, may in fact be different manifestations of the same tectonic event.

The other gold occurrences in the Proterozoic terrains of Australia, are predominantly metamorphogenic or possibly magmatic related deposits. The controls on these mineral occurrences are structural and some lithological.

The Phanerozoic gold deposits of Australia are predominantly metamorphogenic (turbidite-hosted) and hydrothermal deposits. The potential for further mineralization, is best in far north Queensland related to the Permo-Carboniferous magmatic/tectonic event mentioned above. It is likely that further gold occurrences/deposits will be discovered in the Drummond Basin, related to these acid volcanic centres. Furthermore, it is suggested that in the Drummond Basin, marginal to the Anakie Inlier and the Lolworth-Ravenswood Block, potential exsists for disseminated Carlin type gold occurrences. Controls on this type of mineralization would be structural and lithological. The turbidite-hosted deposits of New South Wales and Victoria are primarily related to a Devonian period of deformation and metamorphism.

As discussed above, the suggestions are tentative and further detailed work in selected areas is necessary.

Aside from the suggested relationship of deposits in the Georgetown Inlier and the Drummond Basin, the most important conclusions of this dissertation are as follows :

(i) The broad tectonic framework of gold deposits in Australia is presently poorly understood and further work in this area is suggested.

(ii) The majority of deposits may be broadly classified in terms of tectonic environment and associated lithologies.

(iii) Archaean gold deposits can be classified as Kalgoorlie type, Hemlo type or B.I.F. type deposits.

(iv) Proterozoic gold deposits are either metamorphogenic types or related intra-plate magmatism (eg. Roxby Downs). The gold deposits of the Proterozoic domains are also related to Palaeozoic magmatic activity, particularly on the margins of the Proterozic Australian continent (eg. Georgetown Inlier). These deposits are included in the Proterozoic section of this dissertation, as a matter of convienence.

(v) Phanerozoic gold deposits are predominantly Palaeozoic in age, due to the relatively active tectonic history during this time. Mesozoic and latter history of Australia, is dominantly a period of stability and development of stable platforms.

(vi) Considerable potential for more gold deposits in the surfical environment exists, including areas of Western Australia and the historically high producing areas of eastern Australia.

(vii) The alluvial deposits of the Palmer River Goldfield, in the Hodgkinson Basin, may be related to the erosion of the elevated Proterozoic Inliers (ie : Georgetown, Coen and Yambo), hence accounting for the large amount of alluvials in relation to primary occurrences.

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