SGA 2009 North Queensland Gold and Base Metals Field Trip. August, 2009

SECTION 1.1

GENERAL PAPERS ON NORTHEAST QUEENSLAND MINERALISATION STYLES

- **Morrison,G.W and Beams, S.D., (1998) Geological setting and mineralisation style of ore deposits of Northeast Queensland. In Beams, S.D., ed. *Economic Geology of Northeast Queensland, the 1998 Perspective.* Geological Society of Australia Inc. pp7-38.**

- Scott, M.,Brown, D.,Denaro, T., Cranfield, L.C. (2009) Mineralisation in the Townsville – Charters Towers – Bowen Region. In Hutton, L.J., and Cranfield, L.C., ed *Field Guide for the Townsville – Charters Towers – Bowen GSA-AIG Field conference.*

Geological setting and mineralisation style of ore deposits of Northeast Queensland

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Introduction

Northeast Queensland hosts some of the major gold and metal mines in eastern Australia. The region, with its geological diversity in terms of geological age, tectonic associations, lithologies, magmatic affinities, regolith and landscape evolution, and mineralisation styles, presents a challenge to the mineral exploration industry. The long and continuing history of mineral development in northeast Queensland is a measure of the success of explorationists in meeting this challenge.

This paper is a summary and update on the reviews of Murray (1990), Morrison (1988) and Berry et al. (1992). It includes new data on the age and geochemical character of many of the significant deposits.

Regional Settling

Northeast Queensland has a Mesozoic-Recent continental sedimentary cover on a Paleozoic continental margin assemblage and inliers of Proterozoic metamorphic basement (Figure 1). The Proterozoic terranes may be continuous beneath cover to the Mt Isa Inlier, whereas the Lower-mid Paleozoic terranes are comparable to the Lachlan Fold Belt of southeastern Australia. The Late Paleozoic terranes, particularly the Coast Range Igneous Province, are best developed in north Queensland and represent a distinctive tectonic regime that is the major influence on metallic mineralisation of this age.

The *Georgetown Province* consists of mid-Proterozoic dominantly continental sediments, progressively deformed and metamorphosed eastward from sub-greenschist up to granulite facies. In the Croydon area the metasediments are unconformably overlain by younger Proterozoic felsic volcanics with cogenetic granitoids. Possible Proterozoic metasediments comparable to these at Georgetown are basement in the *Coen and Yambo Provinces*. Those in the *Anakie Sub-Province* are compared with small inliers elsewhere in the Tasman Fold Belt. Their relationship to the Georgetown Province is uncertain (Withnall et al., 1994).

A major mylonite zone separates the Georgetown Province from the Cambro-Ordovician marine sediments and calc-alkaline volcanic rocks of the *Greenvale Sub-Province* and *Charters Towers Province*. Late Ordovician to Devonian deformation, and metamorphism up to amphibolite grade, was followed by granitoid emplacement, both in these provinces, and in the adjacent Georgetown Province. Similar granitoids are extensive under Paleozoic and younger cover to the south of Charters Towers, and may also underlie sections of the three younger Paleozoic Provinces.

The *Broken River* and *Hodgkinson Provinces* consist of Siluro-Devonian flysch sediments, deformed and metamorphosed in the Devonian, and unconformably overlain by Devonian to Carboniferous shallow marine clastic and carbonate sediments. Comparable Devonian to Carboniferous sediments also overlie the Charters Towers Province, and are extensive south of Charters Towers in the *Drummond Sub-Province*, where they are accompanied by Carboniferous intermediate volcanics. Carboniferous to Permian felsic granitoids constitute the *Coastal Range Igneous Province*, and erosional remnants of the coeval volcanic and subvolcanic complexes are preserved in all the adjacent provinces.

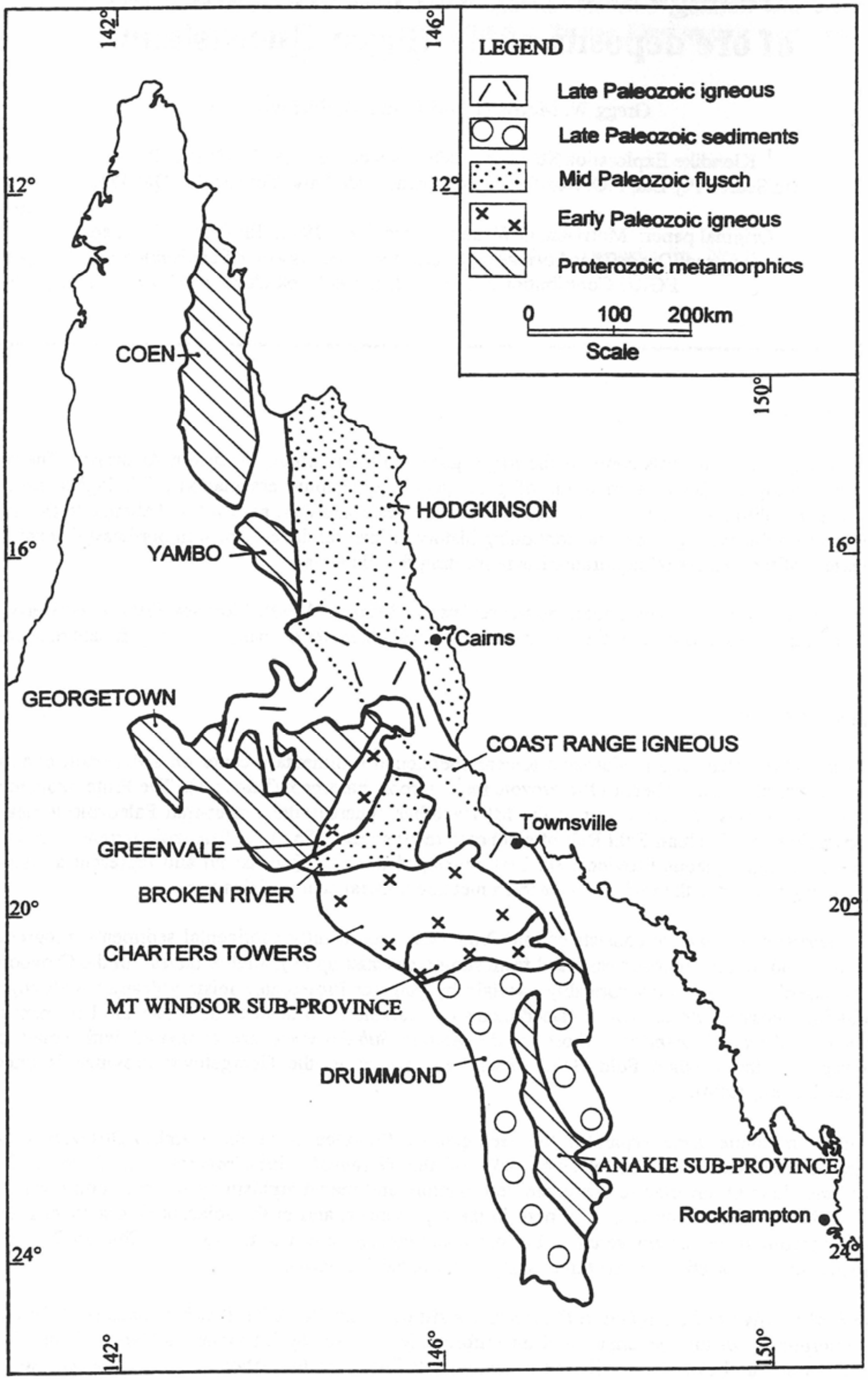


Figure 1 Geologic provinces and subprovinces of northeast Queensland (named), grouped according to age and tectonostratigraphic affiliation (patterns).

Styles of Gold Deposits

Morrison (1988) recognised five distinct environments of gold-mineralising hydrothermal systems in northeast Queensland. The mineralisation styles and their geochemical associations are summarised in Table 1 and Figures 2 and 3.

- The *slate belt* environment is characterised by deformed and metamorphosed flysch, with synsedimentary volcanic rocks and syn- to post-metamorphic granitoids (cf. the Victorian slate belt; Whiting and Bowen, 1976).

- The *plutonic* environment is characterised by batholith scale, pluton level granitoids. The mineralisation host may be older basement rocks, or coeval volcanic and sedimentary rocks. The distinctive features are the brittle-ductile deformation style and the paucity of subvolcanic intrusions (cf. the northern Mother Lode, California; Bohlke and Kistler, 1986).

- The *porphyry* environment is characterised by a complex of subvolcanic intrusions, locally with cogenetic plutons or volcanic and magmatic-hydrothermal products (cf. Laramide and Tertiary systems in the western USA; Proffett, 1978).

- The *volcanogenic* environment is characterised by dominantly submarine volcanic and volcano-sedimentary rocks locally with cogenetic intrusive bodies.

- The *epithermal* environment is characterised by dominantly subaerial volcanic and volcano-sedimentary rocks and cogenetic shallow intrusive bodies.

Quartz veins of various types are the most common style of mineralisation in northeast Queensland. Disseminated style deposits are significant in the epithermal environment, and skarn, stockwork, and breccia styles are major producers in the porphyry environment. The volcanogenic deposits are pipe or massive sulphide style. Replacement and shear-hosted lode styles also occur in the slate belt, plutonic and porphyry environments, but none of the deposits have been significant producers.

Models for the major gold mineralisation styles in the porphyry and epithermal environments are shown in Figure 2. The majority of historic gold production was from plutonic veins, whereas current production and reserves are in the porphyry related breccia systems, and epithermal vein and disseminated deposits (Table 1).

Slate Belt Deposits

Deposits in the slate belt environment are typically veins, fracture fillings and irregular replacement bodies localised by secondary brittle shears cutting larger, often regionally significant, shear zones. Small deposits of this type are widespread in the greenschist or lower metamorphic grade Siluro-Devonian flysch sequences of the Hodgkinson and Broken River Provinces.

Typical lodes have inclusion-rich lenticular quartz bodies in sheared and altered wallrocks. The quartz is massive, milky and deformed with abundant ribbons, stylolites and clear quartz veinlets. Total sulphide content is low (less than 5 percent) with pyrite, arsenopyrite and even pyrrhotite or stibnite dominant over basemetal sulphides. The gold is free, typically of high fineness (+900) and occurs as small irregular masses in the quartz not directly associated with the sulphides. Alteration is only locally observed as narrow phyllic or propylitic envelopes on mineralised veins or lodes.

K-Ar dating of alteration muscovite in the Hodgkinson Goldfield suggests mineralisation is mid-Carboniferous (Morrison, 1988). This post dates the major phases of folding, metamorphism and melange development in the Province, overlaps a phase of brittle reactivation and predates emplacement of nearby igneous complexes. Fluid inclusion and isotope data suggest a crustal fluid with a metamorphic or distal magmatic source and interaction with organic matter closer to the site of deposition (Peters et al., 1990).

TABLE 1: Major gold deposits of northeast Queensland

Classification		Size tonnes Au	Production 1994 oz	Mineralisation Age	Host Rock	Ore Element Association	Gold Fineness Average (Range)
EPITHERMAL							
Vein	Pajingo	13	30398	342	Carbonif. volcanics	Ag Cu Pb Zn ± As Sb Te	700 (632-798)
	Mt Coolon	9	---	316	" "	Ag	
	Woolgar	2	---	Carbonif	Prot. metamorphics	Ag Zn Cu As Sb	603 (550-660)
Hotspring	Wirralie	19	0	344	Carbonif. sediments	Ag As ± F Hg	
	Yandan	13	78825	346	" "	Ag Sb ± Se Hg Te As	~ 500 (460-530)
	Twin Hills	12		345	" "	Ag As Cu Zn F Ba ± U Mo Sn	550 (535-598)
	Hill 273	2		Carbonif	" "	Ag As Sb F ± Cu Zn Te	
VOLCANOGENIC							
Pipe	Highway	2.5	0	Ordovician?	Cambro-Ord volcanics	Ag Cu Zn Pb Ba As	
Massive	Thalanga	5	4650	"	" "	Ag Zn Pb Cu As Sb Bi Mo	830 (320-890)
sulphide	Liontown	2	---	"	" "	Ag Zn Pb Cu	
	Balcooma	2		500	" "	Ag Cu Bi Zn Pb As Sb Mo	740 (670-790)
PORPHYRY							
Breccia	Kidston	140	208962	335	Carbonif. breccia	Ag Bi Zn Pb Cu Mo ± Te F	880 (530-890)
	Mt Leyshon	106	233491	280	Carb-Perm breccia	Ag Bi Zn Cu Pb Mo ± Te Co As Sb	850 (770-898)
	Mt Success	1	---	Permian?	" " "	Ag Zn Cu Pb	
	Mt Wright	1	---	Carbonif?	Carbonif? breccia		
	Triple Crown	1		Carbonif?	" "	Ag Zn Pb Cu As	
Stockwork	Far Fanning	4	0	Permian?	Devonian sediments	Ag Zn Cu Pb Bi	870 (860-885)
	Horn Is	6	0	Carbonif?	Carbonif. granite	Ag Pb Zn As Cu	? 700 (625- 750)
Vein	Coen	4	---	"	Devonian granite	As Pb Zn	600 (460-615)
	Ravenswood	55	41975	310	" "	Ag Zn Cu As Pb	900 (460-940)
Skarn	Red Dome	39	43310	320	Silurian sediments	Ag Cu Zn Bi Te	? 900 (800-995)
PLUTONIC							
Vein	Charters Towers	224	0	400	Devonian granite	Ag Zn Pb Cu ± Te	810 (720-860)
	Croydon	35	0	Carbonif?	Proterozoic granite	Ag As Pb Zn Cu	720 (550-740)
	Etheridge	28	4432	420	" "		675 (660-690)
Lode	Mt Hogan	6	41993	420	" "	Ag Pb Cu Zn ± Sb	740 (705-770)
	Merrilands	1		Devonian?	Cambrian metasediments	Pb Cu As Zn	
	Belyando	5	5887	Devonian?	" "	Ag As Pb Cu Zn	780 (771-794)
	Rishton	8	38374	Devonian	Silurian granite	Ag Pb Cu Zn ± Sb As	>670?
	Christian Kruck	2		Devonian?	Ordovician granite	Ag Pb Cu Zn	

TABLE 1: Major gold deposits of northeast Queensland

Classification		Size tonnes Au	Production 1994 oz	Mineralisation Age	Host Rock	Ore Element Association	Gold Fineness Average (Range)
SLATE BELT							
Lode	Hodgkinson	10	0	328	Silurian flysch	As Pb Zn Cu ± Sb W Mo	810 (710-875)
	Maytown	3	---	Carbonif.	" "	As ± Sb Cu	
	Camel Creek	2	0	"	" "	Sb As ± Zn	
	Minnie Moxham	6	0	" ?	" "	Sb As	~ 900
	Tregoora	2		"	" "	Sb As ± Zn	
Stockwork	Belfast Hill	2		"	" "	Sb As Pb	

Classification:	Updated from Morrison (1988)
Size:	Based on Morrison (1988) updated by Woodall (1990) and data supplied by current operators
1994 Production:	Gold Mining Journal March 1995. 0 = production in last 10 years. --- = historic production only. blank = never produced.
Mineralisation Age:	Perkins et al. (1995), Morrison (1988)
Host Rock:	Morrison (1988)
Element Association:	NQ Gold database - Klondike Exploration
Gold Fineness:	Morrison et al. (1991), Rose (1987), Bobis (1992), Sennitt (1991), Digweed (1991)

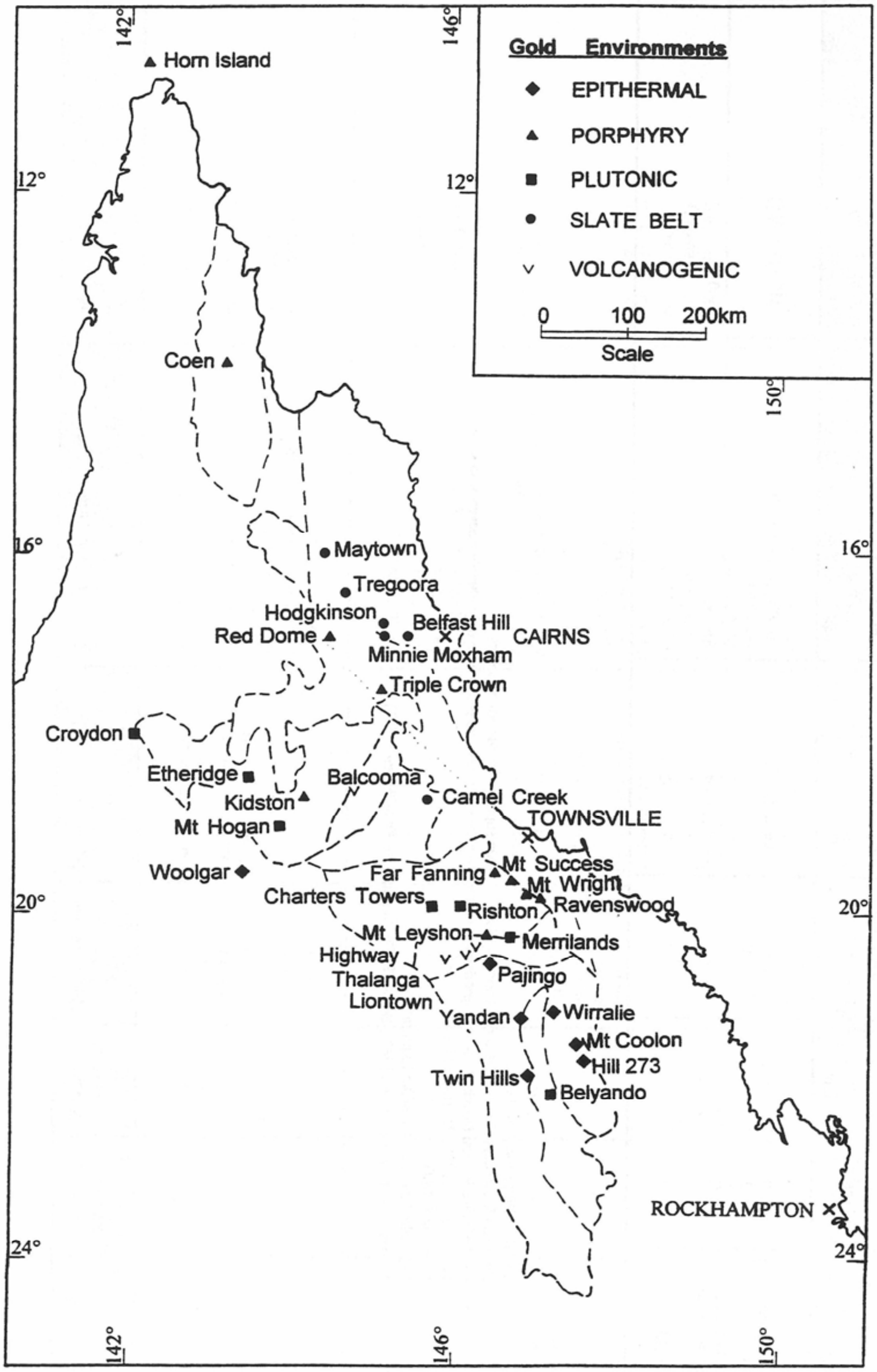


Figure 2 Northeast Queensland gold deposits with more than 1 tonne contained gold (Table 1). Classification by mineralising environment. Base is geologic provinces (Figure 1).

The association of basemetals in the ore and the relatively low gold fineness (average 810: Table 1) suggests the Hodgkinson field has some similarities to the deposits in the plutonic environment and in fact there are plutonic deposits of similar age in the province.

Plutonic deposits

Lodes in the plutonic environment are typically extensive tabular quartz reefs in fissures, particularly in granitoid hosts, or lenticular anastomosing quartz bodies in faults or shear zones. The most productive plutonic veins in the region occur in the Charters Towers area.

Quartz in the lodes is massive and consists of tightly interlocked euhedra; it is sheared, brecciated, cut by veinlets, and infilled with a further generation of vugh-forming quartz in the ore shoots. Mineralisation is restricted to the cross-cutting generations of quartz and is rarely in the primary quartz or the wallrock. A simple pyrite-basemetal sulphide assemblage constitutes up to 20 percent of the shoot, and gold occurs as free grains adjacent to the sulphides, particularly galena. Silver is generally only in gold grains with moderate fineness (approx. 770).

Alteration is a narrow selvage up to two or three times the width of the vein or lode. Close to the vein the assemblage is bright green sericite, with minor carbonate, pyrite and chlorite, and unaltered primary K-feldspar. Further from the vein, dark green montmorillonite-carbonate gives way to pink carbonate, then weak propylitic alteration. No distinct vertical zoning of alteration is evident, even in veins exposed at great depth. However, individual ore shoots may be enveloped by zoned alteration (Peters & Golding, 1989).

The distinctive features are the close spatial and timing relationships to granitoid emplacement in general, but a lack in detail of a specific causative intrusion and the classic magmatic fluid evolutionary path. If the fluid is of magmatic derivation, then it must have originated at deep crustal levels and not within the exposed intrusive bodies (Peters and Golding, 1989).

Porphyry-related deposits

Porphyry-related skarn, vein stockwork and breccia deposits are known from all the provinces but are best developed in the Georgetown and Charters Towers Provinces. All the significant occurrences are associated with Permo-Carboniferous subvolcanic complex with dykes, plugs, stocks and breccias of rhyolitic to trachytic composition. There are distinct clusters of camps adjacent to the major outcrop areas of Permo-Carboniferous granitoids and volcanics but very few occurrences actually hosted within these units. Rather the occurrences are in discrete corridors characterised by concentrations of subvolcanic intrusions and gravity and magnetic anomalies suggesting underlying plutons and in some cases crustal scale faults.

These deposits occur in a variety of forms, including hydrothermal breccias (e.g. Kidston, Mt Leyshon), skarns (e.g. Red Dome), veins (e.g. Ravenswood) and stockwork style mineralisation (e.g. Far Fanning) (see Figure 3).

Common characteristics of porphyry-related deposits are:

- localisation in, or adjacent to, a regional scale lineament;
- association with a multiphase subvolcanic intrusive complex, and demonstrably close timing between intrusive and mineralisation phases;
- brittle mineralised structures with a predominance of fissure fill and open space ore textures;
- early potassic alteration with Cu-Mo stockwork mineralisation formed from overpressured magmatic fluids at approximately 500°C and 30-50% salinity;
- main mineralisation stage with phyllic alteration and base metal-rich mineralisation formed from a magmatic gas condensate at approximately 300-400°C with less than 10% salinity and minor CO_2;

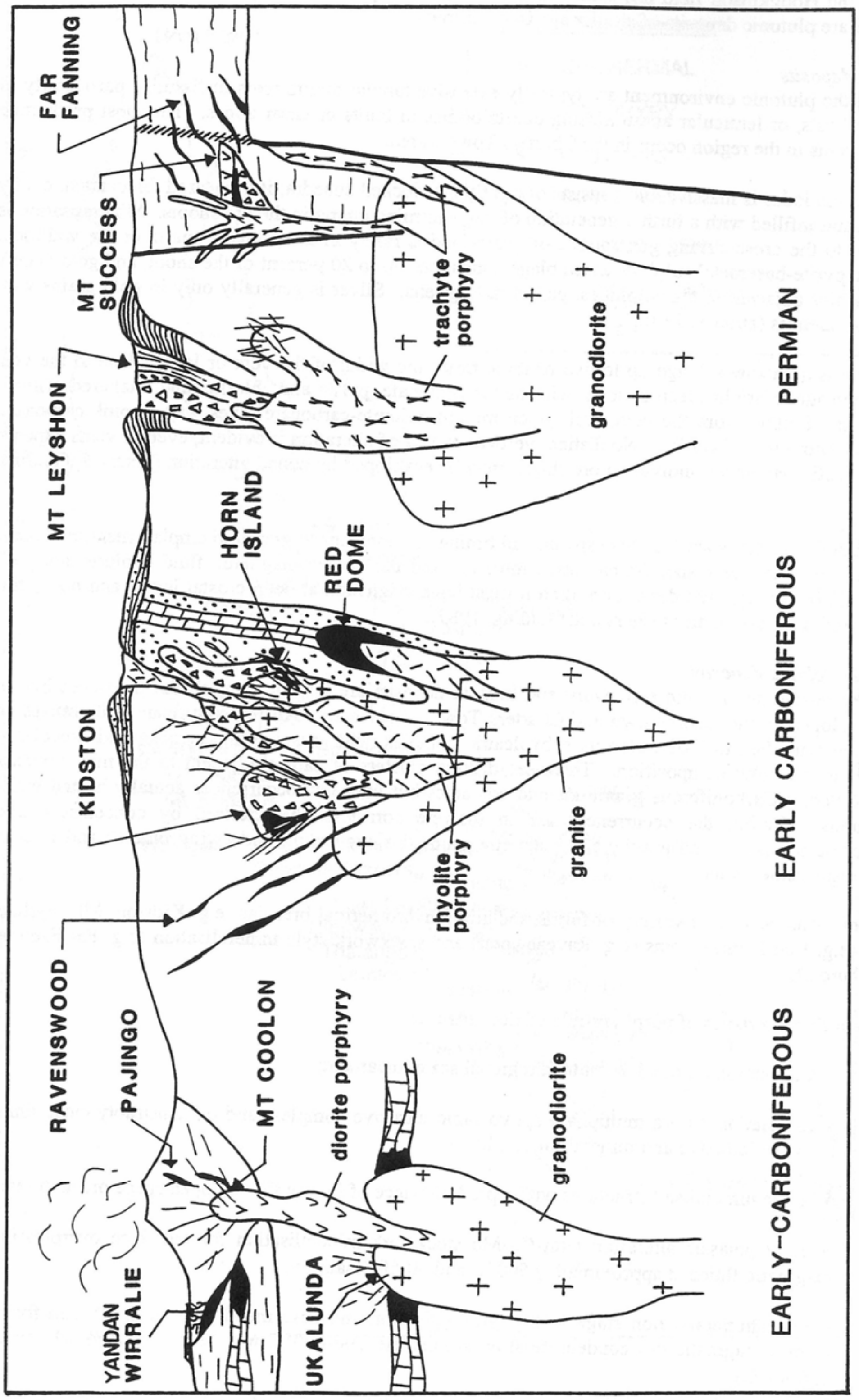


Figure 3 Porphyry and epithermal styles of gold mineralisation in different igneous associations in north Queensland.

- main stage sulphide paragenesis and zoning Fe±As– Cu+Zn+Pb–Bi+Ag+Au±As,Sb,Te;

- gold locally throughout main stage, but best developed in the bismuth assemblage as free grains, inclusions in sulphides, or as alloys with Te, Ag;

- prominent zoning on a 100-500m scale, from deep barren quartz-pyrite, to intermediate quartz-base metal sulphides-bismuth phases-gold-carbonate to shallow carbonate;

- little or no development of advanced argillic alteration, and minor late stage meteoric water input.

These features are more typical of gold-bearing polymetallic continental felsic porphyry Cu-Mo systems such as Bingham or Battle Mountain than of island arc intermediate Cu-Au porphyry systems (cf. Sillitoe, 1983). The distinctive feature of the northeast Queensland deposits is the development of major low grade polymetallic gold deposits superimposed on sub-economic, poorly developed Cu-Mo mineralisation. In addition, all of the studied deposits have been shown to relate to magmatic hydrothermal systems with little or no evidence of meteoric water input or development of peripheral epithermal mineralisation. However, at Red Dome/Mungana there is a suggestion of peripheral epithermal mineralisation (Nethery et al., 1994) and at Ravenswood difficulties in distinguishing plutonic and porphyry characteristics.

Epithermal deposits

The majority of known epithermal deposits are in Permo-Carboniferous subaerial volcanic terranes with the best examples in the eastern part of the Drummond Sub-Province (Figure 2). Early Carboniferous andesitic volcanic rocks and intercalated sediments host simple vein deposits whereas rhyolitic volcanics and intercalated sediments intruded by flow dome complexes host a variety of vein, stockwork, breccia and disseminated styles collectively referred to as hotspring deposits (Tate et al., 1992).

The simple vein deposits, typified by Pajingo, are sulphide-poor, adularia-sericite types with the classical alteration, ore mineral and vein texture zonation modelled by Buchanan (1981), Heald et al., (1987) and Morrison et al., (1990). Ore shoots, which locally reach bonanza grades, are characterised by a strong silicic-sericitic-argillic alteration envelope, multiphase internal brecciation and a distinctive quartz texture assemblage dominated by crustiform, colloform and moss textures. They are localised by syn-mineralisation deactivation of the lode and its host structure which is commonly a regional scale extensional fault.

The hotspring class of epithermal mineralisation includes the Yandan, Wirralie and Twin Hills gold deposits. Each of these occurrences is characterised by a broad area of both stockwork and truly disseminated mineralisation below a siliceous cap rock. The siliceous cap rock takes the form of a sinter at Twin Hills, a siliceous alteration zone at Wirralie, and possibly both at Yandan. Other characteristic features include an association with major structures, which are often shallowly dipping, and the presence in the district, if not in the deposit itself, of rhyolitic flow dome complexes which may be contemporaneous with the mineralisation.

The characteristics of the north Queensland Late Paleozoic epithermal deposits are quite consistent with current models for Tertiary-Recent vein and hotspring deposits (of Buchanhan, 1981; Nelson, 1988). Fluid data from a range of deposits suggests the systems are dominated by meteoric water and that boiling of deep circulating heated fluids and mixing with cooler near surface fluid are the principal mechanisms of mineralisation. A magmatic source of metal cannot be proven or discounted from the fluid data, but distinct metal associations for epithermal districts containing intrusive rocks and porphyry style deposits of different chemical character suggest there may be a link (Tate et al., 1992; Figure 3).

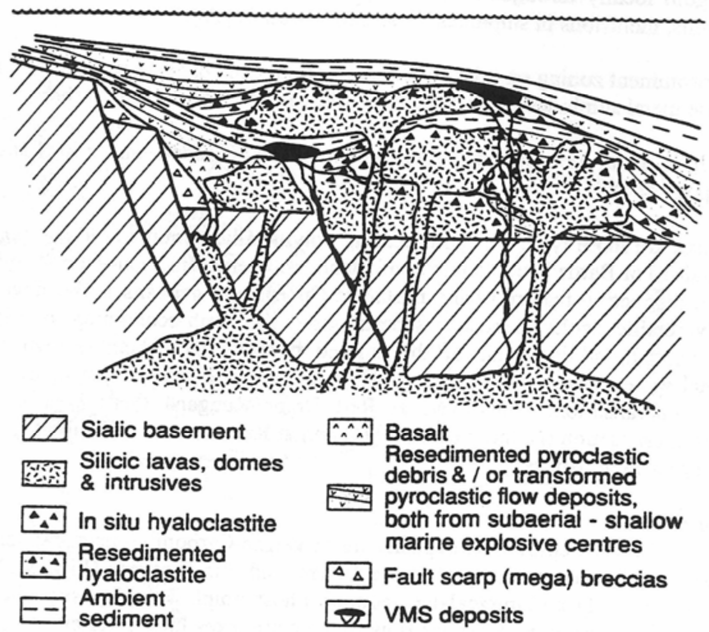


Figure 4 Schematic representation of relation of VHMS mineralisation to submarine silicic lava dome volcanism. From Cas, 1992.

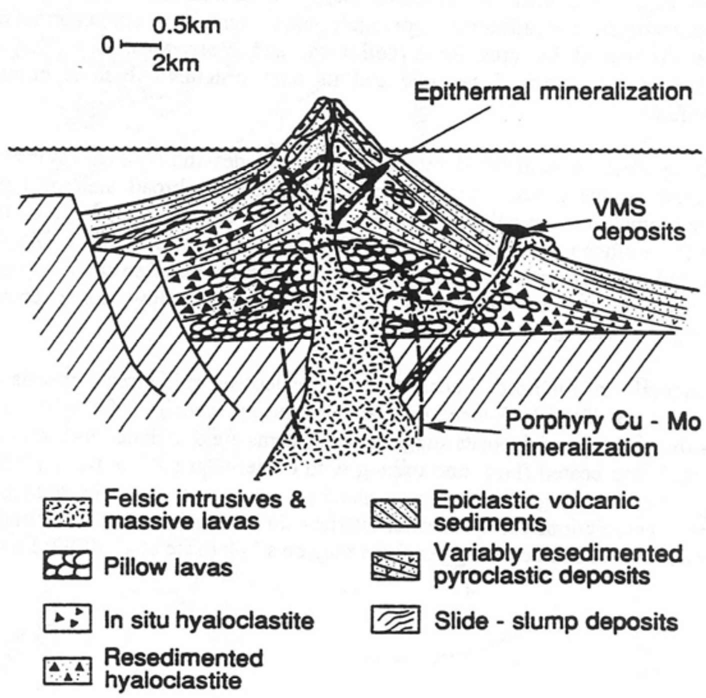


Figure 5 Facies architecture marine strato volcano showing relation to VHMS deposit and epithermal and porphyry mineralisation (Cas, 1992). In this context the VHMS deposit is likely to be derived from a mixture of magmatic and circulation of seawater fluids.

Styles of Polymetallic Base Metal Deposits

Volcanic-Hosted Massive Sulphide Mineralisation

The Cambro-Ordovician Mt Windsor Subprovince, south of Charters Towers, is the most prospective geological province for volcanic-hosted massive sulphide mineralisation in North Queensland.

A steadily increasing knowledge of the geology of the Mt Windsor Volcanic Belt, built up from prospect and regional scale mapping, has allowed interpretation with reference to genetic models of volcanic-hosted massive sulphide deposits. Explorationists have combined this geological understanding with systematically collected bedrock geochemical and (mostly electrical) geophysical data to discover all the known massive sulphide deposits, apart from Liontown, in a little over fifteen years.

The geological and geochemical models for the formation of volcanic hosted massive sulphide (VHMS) deposits have been considerably refined over recent years. Nowadays there is a much greater understanding of the volcanic facies architecture which allows interpretation of the host rock sequence. Figures 4 to 6 from Cas (1992) and Large (1992) show some of the styles of subaqueous volcanic systems and the relationships to massive sulphide mineralisation. Similar facies and relations are interpreted to occur in the North Queensland volcanic belts eg. subaqueous pumiceous breccia, quench fragmental lavas (hyaloclasites) and pepperites have all been recognized (Berry at al., 1992; Beams & Dronseika, 1995).

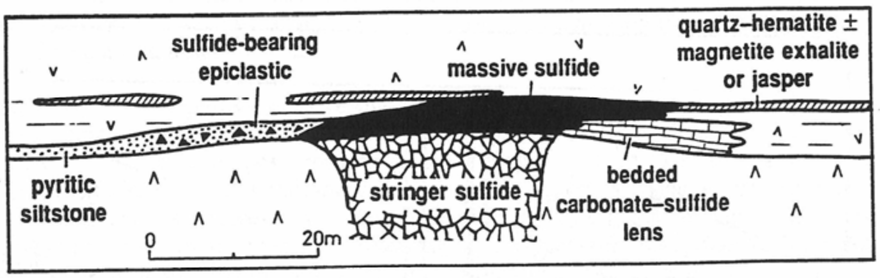


Figure 6 Relationship of mineralisation styles to a favourable horizon within typical Australian VHMS Deposits. Large, 1992.

Massive sulphide mineralisation in the Mt Windsor Subprovince is hosted in the volcanic and sedimentary sequence of the Seventy Mile Range Group (Henderson, 1986). At the base, the sequence consists of a thick series of interbedded micaceous sandstones and siltstones (Figure 7) of the Puddler Creek Formation, which contains no volcanic lithologies, and is derived from granitic/metamorphic basement. Overlying the Puddler Creek sediments are the Mt Windsor Volcanics, a complex suite of rhyolitic, rhyodacitic, and andesitic to basaltic lavas, fragmentals and volcaniclastics. The Mt Windsor Volcanics are overlain by the transitional Trooper Creek Formation, comprising interbedded basalt, andesitic to dacitic lavas and fragmentals, volcaniclastics, and non-volcanic arenites and black shales. The predominantly fine-grained, non-volcanic, sedimentary units of the Rollston Range Formation occur at the top of the sequence.

Subaqueous deposition for most of the Seventy Mile Range Group is indicated by features such a mafic pillow lavas, graded volcaniclastic units, and extensive epiclastic sediments. A graptolite fauna places the Trooper Creek Formation in the Lower Ordovician; the lower units are possibly Cambrian (Henderson, 1983). The sequence is intruded and metamorphosed by Upper Ordovician to Devonian granitoids of the Ravenswood Batholith. Much of the southern and western sections of the Mt Windsor Belt are covered by Tertiary to Recent fluviatile sediments and laterite.

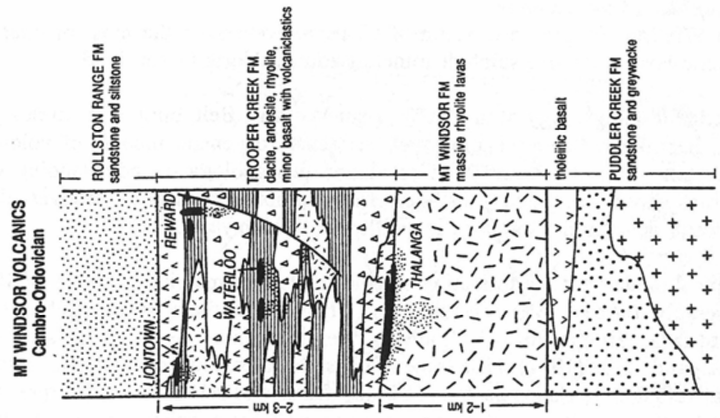
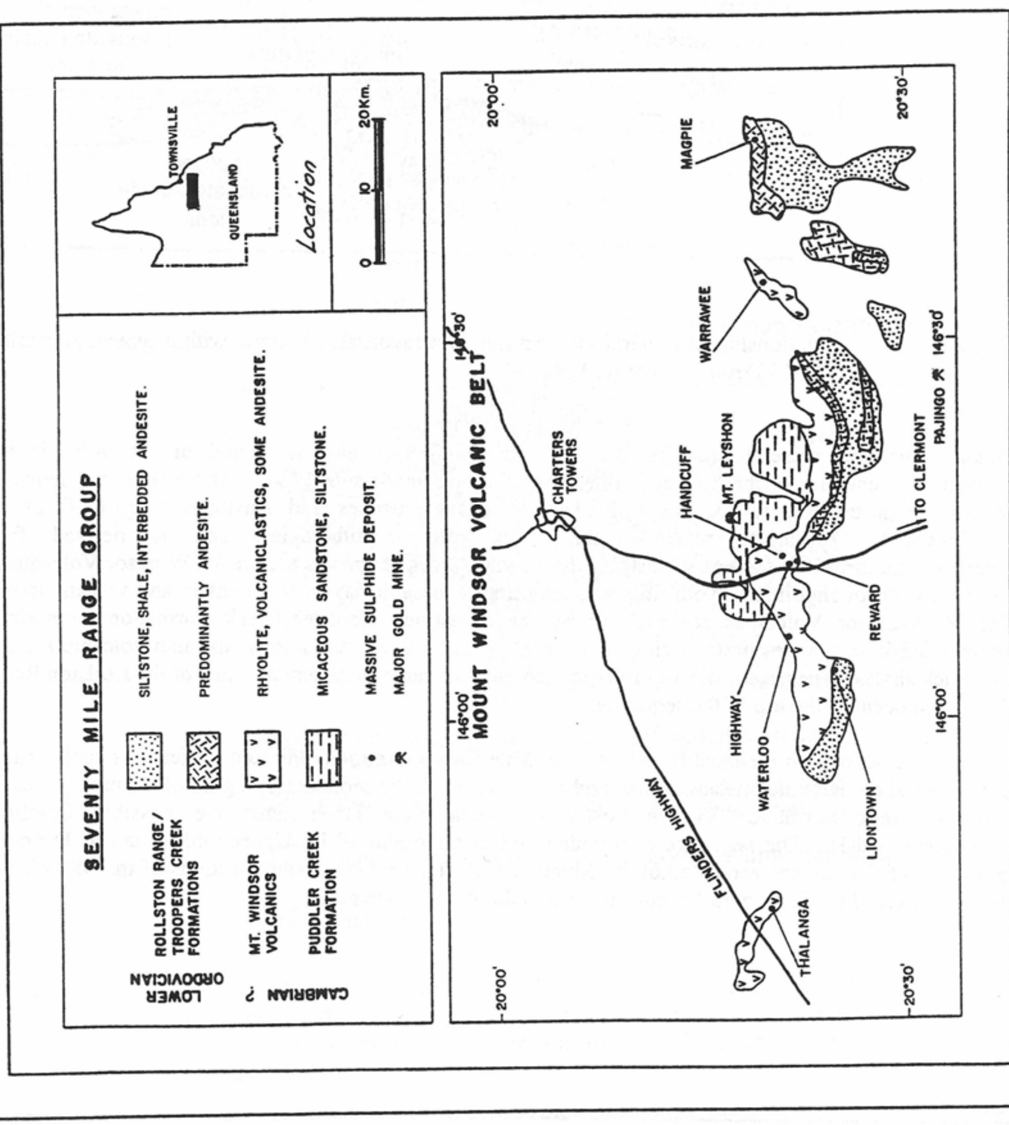


Figure 7
Location & regional stratigraphic relations
Mt Windsor Subprovince.



The succession generally strikes east-west and youngs to the south. It is characterised by low grade slate belt-type deformation of lower greenschist facies, with simple open folding about a subvertical slaty cleavage that trends east-west. Structural complications occur locally, notably in the Highway Synclinorial Zone in the central part of the Belt.

Volcanic hosted polymetallic massive sulphide mineralisation occurs along the length of the Belt (Figure 7). In addition, massive sulphide mineralisation at Balcooma, 250km to the north west in the Greenvale Province (see Figures 1 and 11) is hosted by metamorphosed volcanics which are correlated with the Mt Windsor Sub-Province (Huston et al., 1992, Withnall et al., 1991). Geological setting and mineralisation styles of some of the key deposits in the Mt Windsor Volcanic Belt are illustrated in Figures 8 and 9. Table 2 lists key characteristics of the mineralisation styles. The deposits are described in Berry et al., 1992.

The most prominent deposit is Thalanga; other significant deposits are Liontown, Highway, Waterloo, Reward and Magpie. The mineralisation at Thalanga and Liontown occurs mainly in bedding-parallel lenses of banded sulphides, with barite and fine grained silica + carbonate, interlayered with siliceous volcanic sediments and rare Fe-Mg rich alteration zones (chlorite-carbonate rocks) now interpreted as altered mafic volcanics (Herrmann, 1995). The massive sulphide lenses and associated sediments occur at breaks within the predominantly rhyolitic volcanic pile.

The chemical sediments and banded, predominantly Zn-rich, sulphides are interpreted as volcanic exhalative in origin, formed contemporaneously with the host volcanic sequence (see Berry et al., 1992). Handcuff, Waterloo and Liontown are low total sulphide systems containing only minor massive pyrite and characterised by fine grained, iron poor sphalerite.

At Reward and Highway, large pipe-like massive pyrite-chalcopyrite bodies are transgressive to the stratigraphy. Beams et al., 1989, interpreted the Reward pyrite pipe as being emplaced syn- or post-cleavage development, at the time of peak metamorphism. However, the close association with stratabound/stratiform sulphides (hosted by volcaniclastic units) still suggests a volcanogenic affiliation. More recent work by Aberfoyle Resources Ltd. and their consultants (Beams & Dronseika, 1995; this volume) interpret the pyrite-chalcopyrite pipes as representing high temperature sub-surface replacement feeder zones, at the centre of a large hydrothermal system. These pipes are surrounded by a halo of altered pyritic rocks containing sporadic lower temperature zinc-lead-barite mineralisation as disseminations, veinlets and small exhalitive lenses.

Nearby at Highway, gossanous barite-silica pipe-like breccia bodies are oxidised equivalents of a Reward-type pipe.

Magpie is a small massive sulphide deposit hosted in andesitic to basaltic lavas. Intrusion of granodiorite and gabbro has subsequently metamorphosed the altered volcanic sequence to cordierite-andalusite schists and recrystallised the massive sulphides (Mulholland, 1991).

Feldspar-destructive hydrothermal alteration is associated with all the deposits. Sericite, silica and pyrite dominate the alteration envelopes. Many of the original textures in the stratigraphic footwall are obliterated, whereas fresh feldspar-bearing volcanics occur in the hanging wall sequences overlying the deposits.

In the Greenvale Subprovince the Balcooma deposit occurs as a series of stacked massive zinc-rich sulphide lenses and copper rich stronger zones in a deformed pelitic lens within a sedimentary sequence dominated by metagreywackes (Figure 10, Huston et al., 1992). Nearby the Dry River South massive sulphide consists of a single Zn-Cu-Pb lens which occurs at the contact between intensely altered footwall volcanics and hanging wall metagreywacke.

TABLE 2: VHMS Deposits of Northeast Queensland (After Berry et al., 1992; Huston et al., 1992; Beams, 1993)

DEPOSIT	Thalanga	Liontown	Waterloo	Highway	Reward	Handcuff	Magpie	Balcooma	Dry River South
RESOURCES Grade & Tonnage								Balcooma District	
Primary	7.5mt @ 1.6% Cu, 9.3% Zn, 3.0% Pb, 77 g/t Ag, 0.4 g/t Au	2mt @ 0.5% Cu, 6.6% Zn, 2.3% Pb, 50 g/t Ag, 0.9 g/t Au	0.372mt @ 3.8% Cu, 19.7% Zn, 2.8% Pb, 94 g/t Ag , 2.0 g/t Au	1.2mt @ 5.5% Cu, 6.5 g/t Ag, 1.2 g/t Au	0.2mt @ 3.5% Cu, 13 g/t Au, 1.0 g/t Au	1mt @ 0.4% Cu, 0.2% Pb, 7.4% Zn, 8.8 g/t Au, 0.2 g/t Au	0.25mt @ 1.2% Cu, 1.7% Pb, 8.3% Zn, 37 g/t Ag, 0.2 g/t Au	Polymetallic Primary 3.4mt @ 0.97% Cu, 3.6% Pb, 10.14% Zn, 77 g/t Ag, 0.7 g/t Au Copper Primary 2.1mt @ 3.27% Cu, 19 g/t Ag, 0.5 g/t Au	
Supergene	0.667 mt @ 5.8% Cu, 8.3% Zn, 2.1% Pb, 83 g/t Ag , 0.8 g/t Au				0.3mt @ 11.6% Cu, 21 g/t Ag, 1.8 g/t Au				
Oxide	0.184 mt @ 96 g/t Ag, 1.7 g/t Au			0.07 mt @ 6.04 g/t Au	0.1mt @ 33 g/t Ag, 6.49 g/t Au			Oxide Polymetallic 0.37mt @ 1.4% Cu, 6.0% Pb, 2.5% Zn, 96 g/t Ag, 1.0 g/t Au Oxide Copper 0.36mt @ 4.4% Cu, 15 g/t Ag, 0.4 g/t Au	
Reference	Herrmann, 1995 (this volume) Berry et al., 1992	Berry et al., 1992	Berry et al., 1992	Russell, 1986 Aberfoyle, 1995	Aberfoyle, 1995	Aberfoyle, 1995	Aberfoyle, 1995	Moore, 1995 (this volume)	Moore, 1995
STRATIGAPHIC POSITION	Contact between the Mt Windsor and Trooper Creek Formations	Contact between Trooper Creek and Rollston Range formations	Central Trooper Creek Formation	Central Trooper Creek Formation	Central Trooper Creek Formation	Central Trooper Creek Formation	Central Trooper Creek Formation	Clayhole Creek Beds	Contact Dry River Volcanics & Clayhole Creek Beds
Geometry	Tabular blanket	Tabular	Lens	Pipe	Pipe	Tabular	Lens	Stacked Lenses	Lens

TABLE 2: VHMS Deposits of Northeast Queensland (After Berry et al., 1992; Huston et al., 1992; Beams, 1993)

DEPOSIT	Thalanga	Liontown	Waterloo	Highway	Reward	Handcuff	Magpie	Balcooma	Dry River South
FOOTWALL LITHOLOGY	Rhyolitic volcanics	Rhyolitic volcanics	Dominantly andesitic and lesser felsic volcaniclastic rocks	Rhyolitic to rhyodacitic lavas and volcaniclastic rocks	Rhyolitic lavas and volcaniclastic rocks	Rhyolitic and dacitic to andesitic lavas	Sediments and intermediate to mafic volcanics	Metagreywacke & volcaniclastics	Rhyodacitic metavolcanics
HANGING WALL LITHOLOGY	Dominantly dacite with lesser andesite	Siltstone, shale, arenite and crystal-rich dacite	Felsic volcaniclastic rocks, argillite and greywacke	Rhyolitic to rhyodacitic lavas and volcaniclastic rocks	Rhyolitic lavas and volcaniclastic rocks	Very coarse rhyodacitic to dacitic fragmental rocks	Dacitic lavas and fragmental rocks	Metagreywacke	Metagreywacke
STYLE OF ALTERATION	Dominantly quartz-sericite-pyrite±chlorite	quartz-sericite-pyrite±carbonate ± sphalerite	sericite-pyrite±quartz	chlorite-anhydrite and quartz-sericite-pyrite	quartz-sericite-pyrite(?)	quartz-sericite-pyrite	chlorite-sericite and quartz-sericite metamorphosed	pyrite-magnetite chlorite schist, quartz-muscovite	pyrite-quartz-muscovite
Year Discovered	1975	1905	1985	1953/1990	1987	1981	1981	1978	1986
Total Sulphide Content	High	Low	Low	High	High	Low	High	High	High
Metal Association									
Primary	Zn-Pb-Cu-Ag-Au	Zn-Pb-Cu-Ag-Au	Zn-Cu-Pb-Ag-Au	Cu-Au-Ag	Cu-Au-Zn-Ag	Zn-Cu-Pb-Ag-Au	Zn-Pb-Cu-Ag	Zn-Pb-Cu-Ag-Au	Zn-Pb-Cu-Ag-Au
Minor & Trace	Magnetite, Bi, Mo, quartz		Arsenopyrite				Pyrrhotite, magnetite	Gahnite, magnetite pyrrhotite, Bi	Magnetite, Bi, Sn, Pyrrhotite
Gangue	Barite, chlorite, carbonate	Barite, carbonate, uartz	Barite, sericite, carbonate, quartz	Barite, quartz	Gypsum, anhydrite, barite	Quartz, barite, carbonate	Quartz, anthophyllite, cordierite	Quartz, cordierite	Quartz, cordierite

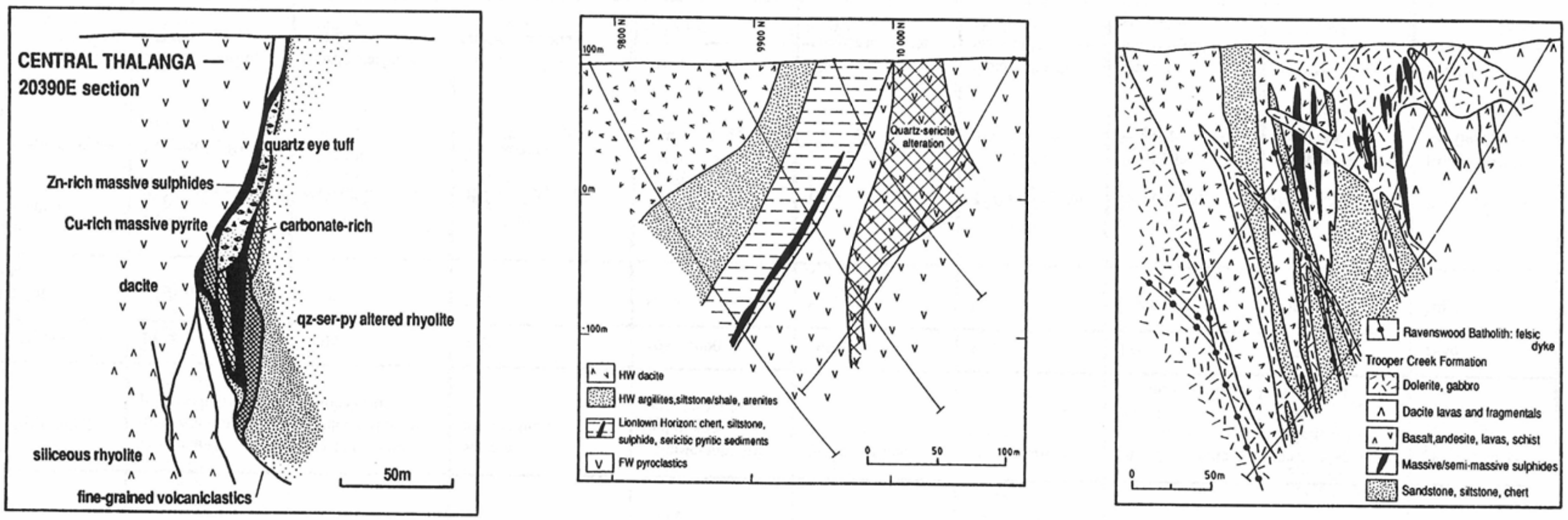


Figure 8 Mt Windsor volcanic hosted massive sulphide deposit styles (From Berry et al. 1992).

A. Thalanga: blanklet like deposit at major volcanic and alteration break. Associated with volcaniclastic units.

B. Liontown: Thin lense hosted in volcaniclastic sediments at major break in volcanism. Massive sulphide also associated with quartz-sericite alteration zone.

C. Magpie: Thin lenses hosted within contract metamorphosed basaltic to dacitic lavas.

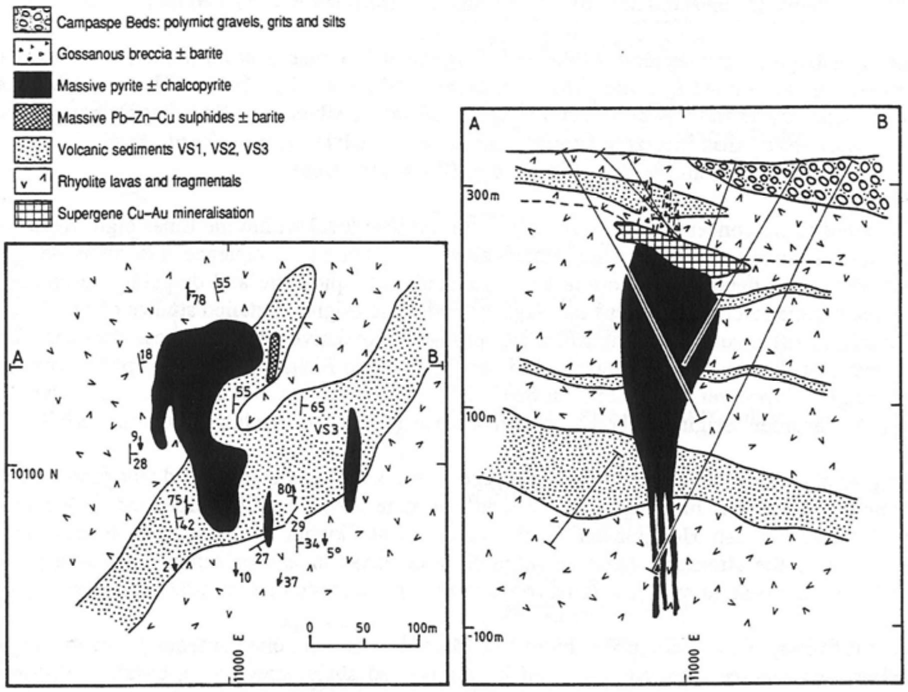


Figure 9 Mt Windsor Subprovince pipe like massive sulphide. Reward deposit plans & section. After Beams et al., 1989; Berry et al., 1992.

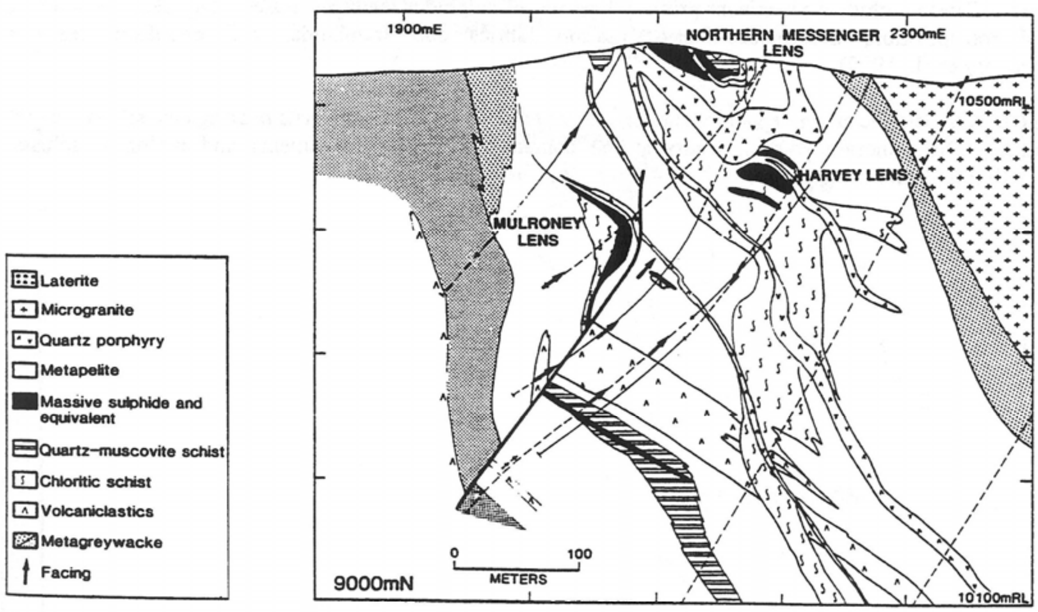


Figure 10 Balcooma, Greenvale Subprovince. Stacked massive sulphide lenses hosted by deformed metasediments. Huston et al., (1992).

Other Base Metal Deposits

Other northeast Queensland base metal deposits of various styles are listed in Table 3.

The Einasleigh Metamorphics within the Georgetown Province host more than twenty small base metal deposits in the Einasleigh and Gilberton areas. (Bain et al., 1990). These are generally massive stratabound concentrations of iron and copper sulphides ± silver (e.g. *Einasleigh*), iron and zinc sulphides (e.g. *Eveleigh*), iron-lead-zinc-copper sulphides ± silver (e.g. *Mount Misery*), and cupriferous, ferruginous, siliceous and baritic gossans (e.g. *Werrington* area).

The deposits are concentrated at a common stratigraphic level within the Einasleigh Metamorphics: at the transition between a lower, dominantly calcareous psammitic sequence and an upper psammopelitic sequence. The deposits are commonly associated with epidositic and diopsidic quartzite, and quartzo-feldspathic granofels and gneiss that may be of volcanic origin. Detailed studies of the Einasleigh deposit (Patrick, 1978) argued for a stratiform and probably exhalative nature of these deposits. It seems likely that most of the other base metal sulphide deposits in the Einasleigh Metamorphics have a similar form and origin. However, recent interpretation by graduate students at James Cook University indicate a skarn replacement origin for the Einasleigh deposits (Mike Rubenach, pers. comm. 1995).

Gregory et al. 1980 described the *Dianne* deposit as a stratiform copper- and zinc-rich pyritic body which forms a small steeply pitching lens within an overturned sequence of interbedded shale and greywacke of the Siluro-Devonian Hodgkinson Formation. No stockwork mineralisation is evident. The strike extension of the stratiform massive sulphide mineralisation is represented by a thin pyritic chert and locally by stratabound pyrite, chalcopyrite and minor sphalerite in a sericitic shale host.

The Mt Molloy deposit comprises two lenses of mineralisation, one cupreous pyrite and the other layered copper- and zinc-rich horizon enclosed in interbedded shale, greywacke, basaltic siltstone breccia and minor basalt. Pyritic chert forms the hanging wall to one lens. A pyritic siliceous siltstone defines a distinct zone in association with the mineralisation and its strike extension.

The deposits have a surface expression as massive to banded gossans. The lower limit of supergene enrichment extends vertically to about 90m with oxidation down to 27m.

Texturally, the deposits show features typical of volcanogenic mineralisation at low greenschist facies grade. These include a prominent primary layering of sulphides, slump features, slaty cleavage folding and transposition, deformation-recrystallisation fabrics and framboidal and colloform textures (Gregory et al., 1980).

The Mt Garnet zinc skarn deposit occurs in a near vertically dipping sphalerite bearing calc silicate garnet skarn. The mineralised host occurs at the contact of Paleozoic sediments and mylonitic schists. (Hartley & Williamson, 1995.)

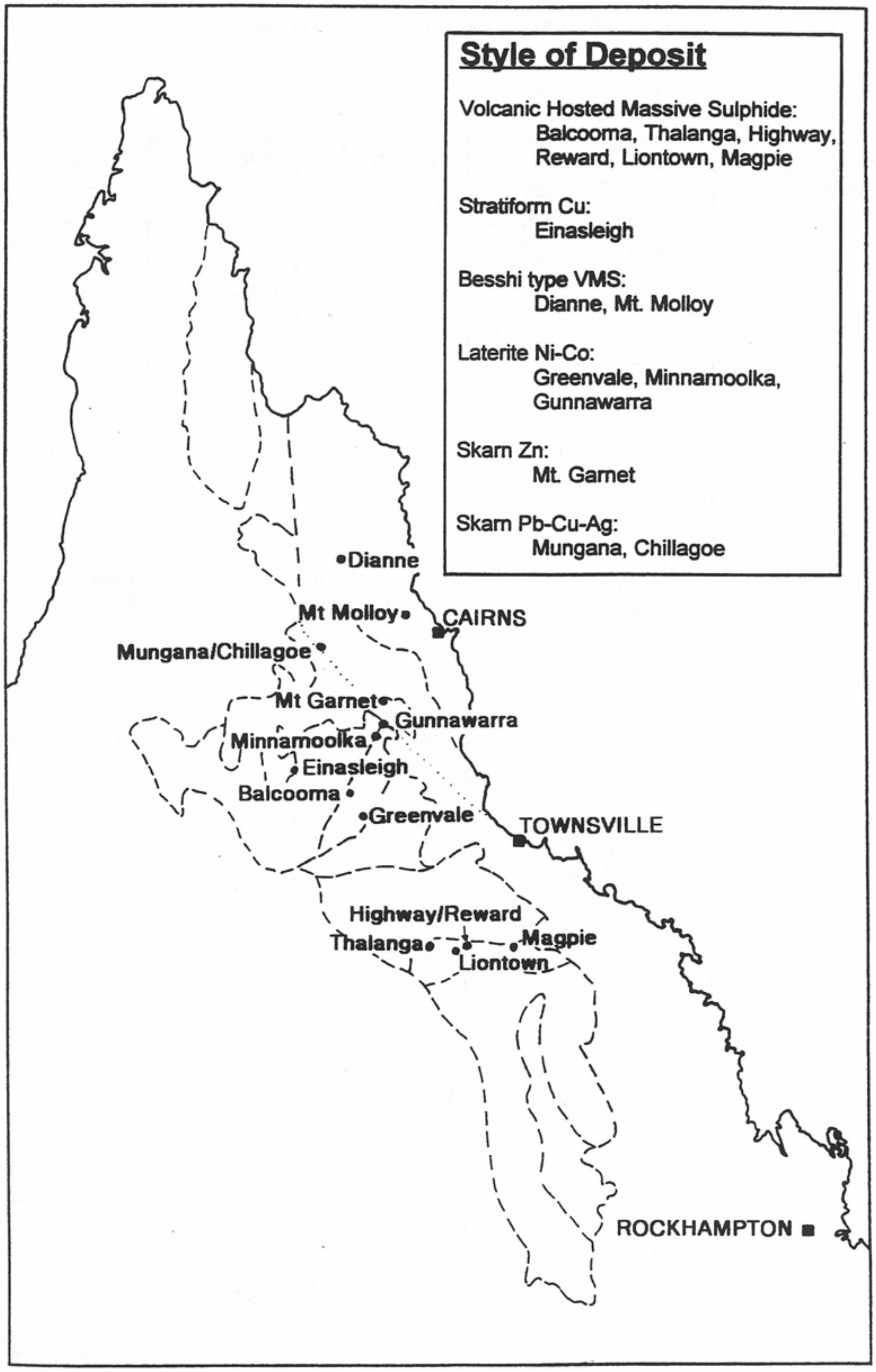


Figure 11 Base metal deposits of northeast Queensland.

TABLE 3: Other Styles of Base Metal Deposits, Northeast Queensland.

DEPOSIT	TYPE & AGE	RECORDED PRODUCTION & YEAR	RESOURCE	REFERENCES
Greenvale	Tertiary to Recent Ni-Co laterite	39 mt @ 1.5% Ni, 0.1% Co, 1974-1992	40 mt @ 1.57% Ni 0.12% Co	Bain & Withnall, 1980. Burger, 1979 Queensland Nickel, 1992
Gunnawarra	Tertiary to Recent Ni-Co laterite		9.8 mt @ 1.55% Ni	Bain & Withnall, 1980
Minnamoolka	Tertiary to Recent Ni-Co laterite		3.15 mt @ 1.27% Ni	Bain & Withnall, 1980
Einasleigh	Proterozoic stratiform	0.14 mt @ 6% Cu 31 g/t Ag, 0.5 g/t Au 1900-1924		Patrick, 1978
Dianne	Besshi-Kieslager type volcanogenic massive sulphides of Siluro-Devonian age	1500t Cu 1000kg Ag 1980-1983		Murray, 1990 Gregory et al., 1980
Mt Molloy	Besshi-Kieslager type volcanogenic massive sulphides of Siluro-Devonian age	3870t Cu 1903-1910		Murray, 1990 Gregory et al., 1980
Mungana/Chillagoe Almaden	Skarns in calcareous rocks at contacts with Carboniferous granite	12225t Cu, 42340t lead, 129600kg Ag 1894-1927		Murray, 1990 Gregory et al., 1980
Mt Garnet Copper	Lenses & pipes in calc silicate skarn at contact with Carboniferous granitoid	0.1 mt @ 4.5% Cu, 30 g/t Ag, 4.7% Zn 1901-1903		Hartley & Williamson, 1995
Mt Garnet Zinc	Skarn within Palaeozoic sediments adjacent to mylonite		2 mt @ 9% Zn 0.5% Cu 25 g/t Ag	Hartley & Williamson, 1995

Regolith Related Deposits: Ni-Co Laterite

Nickel-cobalt deposits have been concentrated to economic grade during Cenozoic weathering of ultramafic complexes on the edge of the Greenvale Subprovince.

The only mined deposit (1974-1994), Greenvale has been described by Fletcher & Couper (1975); Burger (1979), and Burger (1995, this volume). Figure 12 is a schematic representation of the styles of mineralisation at Greenvale (after Burger, 1979).

The Greenvale Orebody comprises a series of contiguous laterite profiles developed terrace-like during the Cainozoic over a serpentinized harzburgite intrusive emplaced within Proterozoic schists. Each terrace displays individual characteristics of metal distribution. Topographically higher (older) profiles have been partially eroded and metal concentrations reworked.

Within the laterite profile, metals have been concentrated or depleted according to their relative solubilities. At tropical temperatures, acidic meteoric waters have progressively depleted the ultrabasic parent rock of Si and Mg, leaving Al and Fe to form a surface duricrust. Ni, Co, Mn and Cr have accumulated in the lower and middle levels of the weathering mantle. Only Ni and Co have accumulated to exploitable grades. Fractures control the depth of weathering and grade, more siliceous "pinnacle areas" were generally uneconomic.

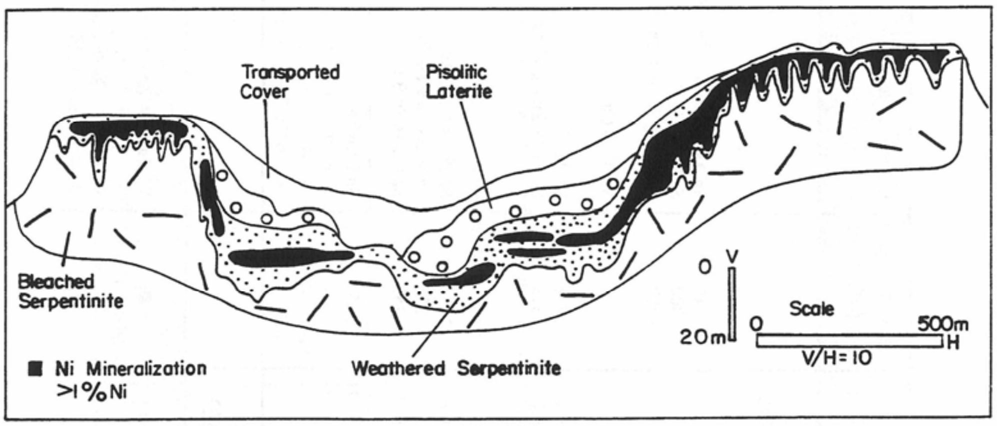


Figure 12 Schematic section showing Greenvale laterite profile and location of main zones of nickel mineralisation. After Burger, 1979.

Tin and Tungsten Deposits

Approximately 200,000 tonnes of tin concentrate have been won from numerous small alluvial and hard rock showings principally in the Herberton-Tate River, Cooktown and Kangaroo Hills Tinfields. Reserves remain in all the fields and in six large low grade deposits (Table 4). Tungsten production is approx. 31,000 tonnes WO_3 of which more than half come from the Mt Carbine mine. Much of the remainder was from two other W-Mo-Bi deposits (Wolfram Camp and Bamford Hill) and approx. 5000 tonnes as by-product from tin mining (Hall, 1980).

Tin and tungsten mineralisation is present in all the provinces N and W of Townsville, but is well developed in the Coast Range Igneous (C.R.I.P.), Hodgkinson and eastern Broken River Provinces (Figure 13). All the major deposits of both tin and tungsten have a Paleozoic sedimentary basement. The most common host in Siluro-Devonian flysch but Permo-Carboniferous granitoids and Proterozoic metamorphics are also locally important.

TABLE 4: Major Sn, W, U deposits of north Queensland

Classification	Name	Size	Production	Reserves		Mineralisation Age	Element Association	Host
Sn-W SUBVOLCANIC		x10³t Sn	t Sn con.	m.t.	%Sn			
vein/pipe	Herberton	77	140,000			315	Sn As Cu Pb Zn Bi W ± Ag Sb Mo, U, In, F	I-type granite + flysch
	Koorboora	8.1	14,600			~ 300	Sn Pb Cu As B	S-D flysch
	Kangaroo Hills	5	9,000			~ 300	Sn Cu Ag Pb As ± Zn, W, Mo, Bi, B, F	I-type granites & S-D flysch
pipe	Vulcan	8	13,712				Sn Bi Pb Cu	S-D flysch
dissem/greisen	Sailor	13		13.5	0.1	315?	Sn, W, F	I-type granite & S-D flysch
dissem/stockwork	Baalgammon	28		11	0.25	313	Sn Cu Pb Zn Ag W As Bi	porphyry + S-D flysch
PLUTONIC								
vein	Jeannie River	54		6.7	0.8	? 275	Sn Pb Zn Cu As W	S-D flysch I-type granite
	Cooktown	8	14,000			?275	Sn W As Cu ± Pb Zn Mo Bi	S-D flysch S-type granite
dissem/sheet vein	Collingwood	28		4	0. 7	257	Sn Cu As Zn B F	S-type granite
skarn	Gillian	13		2	0.67	~ 315?	Sn F Cu Zn	I-type granite & S-D carbonate
	Pinnacles	8		3.2	0.26	314	Sn F Cu Zn As ± Pb, W, Bi, Be	" "
W-Mo-Bi SUBVOLCANIC		x10³t W	t WO_3	m.t.	WO_3			
vein	Mt Carbine	20	16,400	28	0.1	280	W, Sn, F, B, Zn Cu Mo Bi Cu As	S-type granite & S-D flysch
pipe/greisen	Wolfram Camp	3	7,100			291	W Bi Mo As Cu Zn Pb Sn Ag B, F, Be Te Sb	I-type granite
	Bamford Hill	1	2,250			297	Bi W Mo As F, B, Pb, Zn Cu Ag Au	I-type granite
PLUTONIC								
skarn	Watershed	39				Early Carb?	W As Cu Sn ± Zn, F	S-type granite + brokenite

TABLE 4: Major Sn, W, U deposits of north Queensland

Classification	Name	Size	Production	Reserves		Mineralisation Age	Element Association	Host
U-Mo-F		x10³t U		m.t	%U			
vein/dissem	Ben Lomond	4.0		1.9	0.21	282?	U, Mo, P ± Cu, Pb, Zn, As, Sb, Ba, B	Early Carb felsic volcanics
replacement	Maureen	2.5		1.65	0.15	Carboniferous?	U, F, Mo P ± Pb Zn Cu As Ba	Early Carb continental seds.

Notes: Production, Reserves, element associations & some geologic data from Murray (1990) and papers referred to therein.
Size calculated from production + reserves assuming tin concentrate at 70% SnO_2
Mineralisation age, interpreted from closest associated granite. Age & composition from Bultitude & Champion (1992) and Champion & Chappell (1992)
Data on Watershed courtesy R. Skryzienski, BHP Minerals pers. comm., 1995.

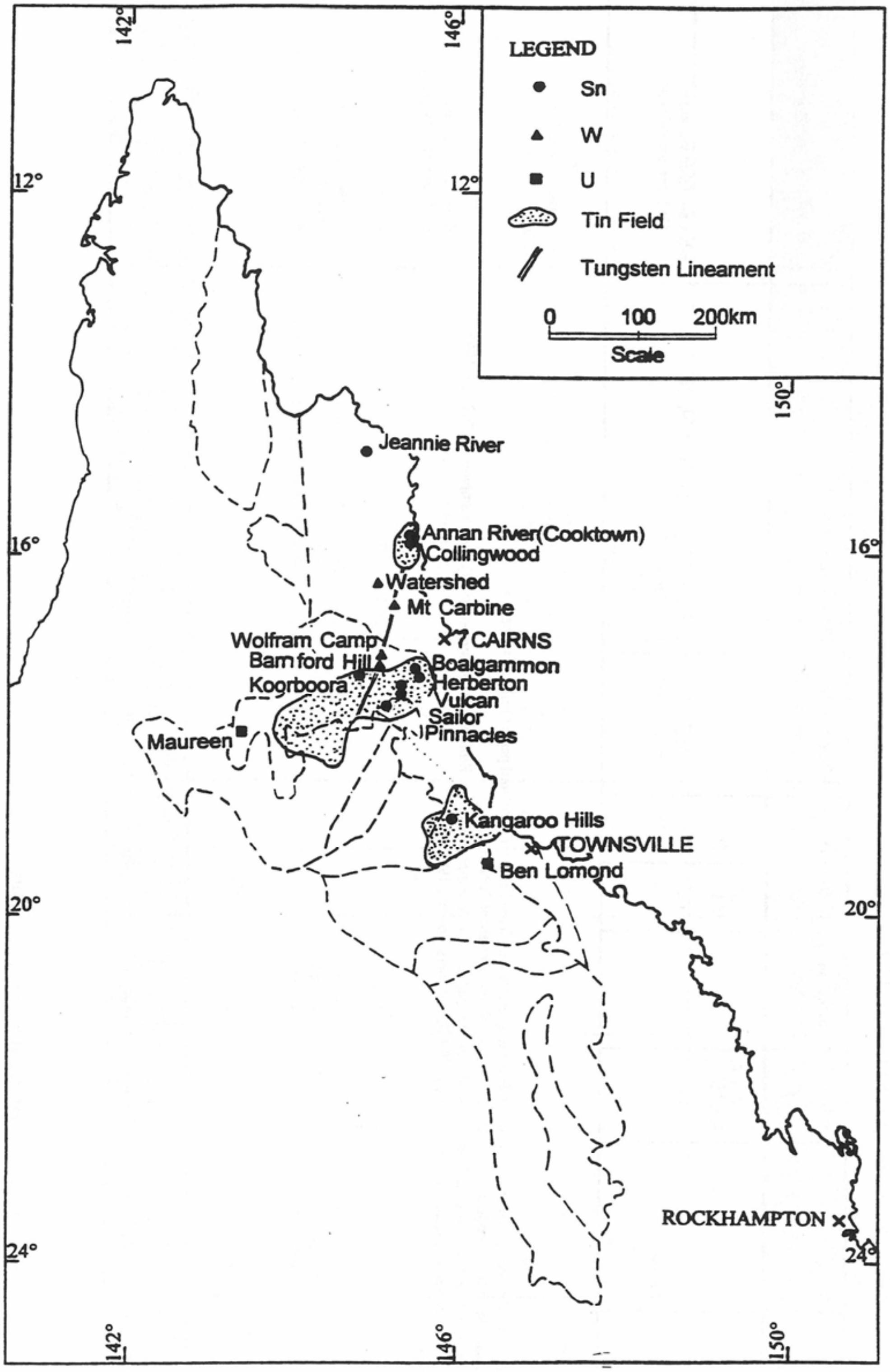


Figure 13 Major Sn, W, U deposits in northeast Queensland and extent of major tinfields.

A distinct group of W-Mo-Bi deposits with little or no Sn are distributed along a NNE trending "tungsten lineament" that crosses both tectonic and igneous provinces (Figure 13). There may be a deep crustal influence on the development of these deposits as there is on the magmas with which they are associated (Champion and Chappell, 1992).

With the exception of the Proterozoic deposits near Croydon, all the studied deposits are genetically related to Permo-Carboniferous igneous rocks. In the C.R.I.P., which includes the Herberton and Kangaroo Hills tinfields, they are felsic I-type granites of Late Carboniferous (320-290 Ma) age (Champion and Chappell, 1992). In the Cairns-Cooktown area, they are S-type granites of Early Permian (~ 280 Ma) age (Bultitude and Champion, 1992). Tin-dominant and tungsten-dominant deposits are associated with both the S- and I-type granites., In the Herberton region tin deposits are associated with the most strongly fractionated supersuite, W deposits with a less strongly fractionated supersuite and basemetal-gold deposits with the most mafic supersuite of the I-type granites. The degree of fractionation may also influence metal ratios within the S-type supersuites.

The tin and tungsten deposits can be classified according to their level of formation in the magmatic hydrothermal system and the style of mineralisation (Table 3, Figure 14). The dominant style of mineralisation is veins and pipes formed by fracture filling and replacement near the contact of intrusives and sediments. Discrete high grade lodes of this style are typical of the shallow to deep subvolcanic environment in the Herberton Field (Figure 14). Elsewhere, particularly at Cooktown, there are sheet veins, networks or greisen style complexes that form larger but lower grade deposits more typical of the deep subvolcanic to plutonic environment (Figure 14). Skarns and replacement bodies also occur in this environment where there are carbonate or mafic volcanic hosts, particularly along the western margin of the Hodgkinson Province. Hydrothermal breccia pipes are present in the subvolcanic environment, but no significant deposit has yet been found in them. Rare veins occur in volcanic rocks and some as at Orient Camp and Dover Castle, have an epithermal character but little or no Sn-W mineralisation at this level.

There are distinct zoning patterns for alteration and ore minerals related to the level of emplacement of the magmatic hydrothermal system and position relative to fluid source and channelways. The general sequence represents declining temperature through feldspar/skarn/tourmaline to biotite-chlorite to greisen and argillic alteration. Metal zoning is typically Sn + W + Fe (oxide) $\pm$ Mo, Bi, F, As $\rightarrow$ Cu $\pm$ Sn $\rightarrow$ Pb Zn Ag $\pm$ Sb, Au. All or part of these sequences may be present in any particular camp but at some scale the zoning pattern is usually the best vector to mineralisation of various element associations.

U-Mo-F Deposits

Two deposits and numerous small uranium occurrences are associated with the volcanic and subvolcanic parts of the C.R.I.P. (Table 4). Typical deposits are fault localised veins or shear infill hosted in massive volcanics or basement rocks. Fracture networks with replacement zones are in porous hosts such as clastic sediments or volcaniclastics where they are capped by impermeable volcanics. The sedimentary sequences in or below Carboniferous-Permian ignimbrites are favoured, but basement units cut by fault zones that are boundaries to the volcanic fields may also be utilised.

Ore minerals are U-bearing complex phosphates, sulphates or molybdates (e.g. autunite, uranopilite or iriginite) associated with fluorite, Ba phases, minor basemetal and As, Sb sulphides and apatite. Clays, sericite, chlorite, silica and hematite are typical alteration phases.

As noted by Bain (1977) the character and setting of the deposits is most comparable to volcanic hosted hydrothermal deposits. The element association and alteration types, particularly the presence of basemetals and As suggests the deposits are of telethermal/epithermal type and possibly part of a larger zoned hydrothermal system. The distribution of the deposits within the C.R.I.P. and the presence of U minerals in some of the lode Sn-W deposits at Herberton suggest they may be the distal part of zoned polymetallic Sn-W hydrothermal systems.

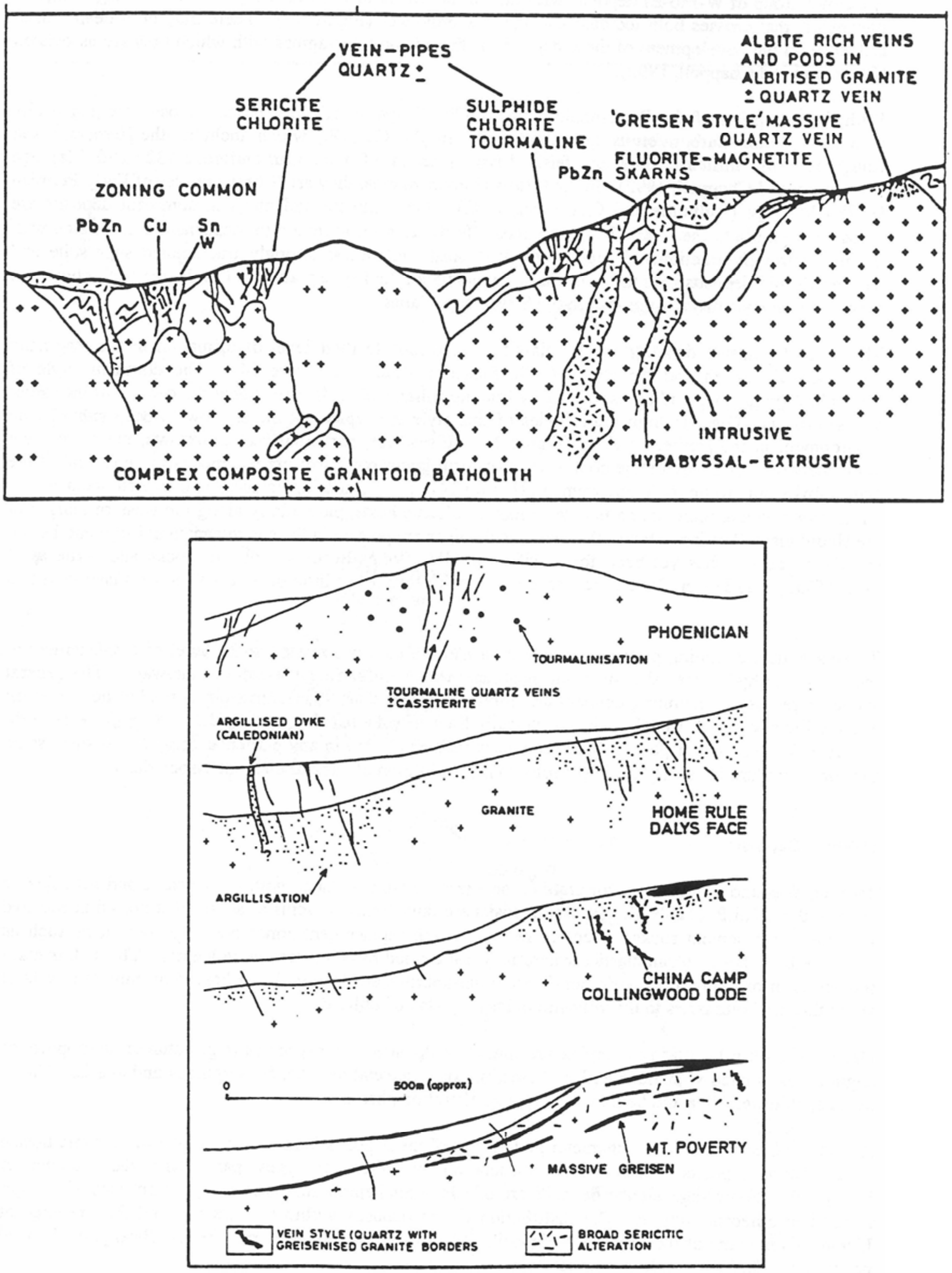


Figure 14 Styles of mineralisation typical of northeast Queensland tinfields.
A. Subvolcanic environment represented by Herberton.
B. Plutonic - deep subvolcanic environment represented by Cooktown.
From Gregory et al. (1980).

Element Associations and Zoning

A compilation of metallic element associations and typical zoning patterns for representative examples of hydrothermal deposits in northeast Queensland (Table 5) demonstrates overlap between deposit classes and consistency within the zoning patterns. The most consistent overall feature is the classic hydrothermal zoning pattern: Sn, W, Mo → basemetals → Au Ag As Sb which is suggestive of deposition on a declining geothermal gradient in all the deposit classes.

The fundamentally polymetallic nature of the deposit classes and partial overlap in element association between classes suggests a common source for the mineralisation. Isotopic studies undertaken on ore fluids (e.g. Baker and Andrew, 1991; Peters and Golding, 1988) and on granitoids associated with mineralisation (Champion and Chappell, 1992; Champion and Bultitude, 1994) suggest a dominant lower crustal source for both magmas and ore fluids. Within the group of magmatic hydrothermal deposits, the difference between Cu-Mo, W-Mo-Bi and Sn-W deposits is partly explained by differences in the nature of the lower crustal, granite source regions and partly by processes that take place in the magma during its ascent (cf Blevin and Chappell, 1992). The confinement of Cu-Mo porphyry deposits to the Charters Towers and Georgetown Provinces is consistent with the interpretation of a dominant I-type source for Permo-Carboniferous magma in these provinces. The extension of Sn-W and W-Mo-Bi deposits from the dominantly S-type source terrane in the eastern Hodgkinson Province into the dominantly I-type C.R.I.P. suggest a composite I-S source for the C.R.I.P. In the northern C.R.I.P. the Sn-W deposits are associated with more fractionated supersuites than the W-Mo-Bi deposits.

In the case of VHMS deposits, it is likely that the metals are derived from a mixture of magmatic fluid and seawater convection and leaching of the volcanic pile (Large, 1992). Seawater convection is likely to contribute more soluble metals: Zn, Pb, Ba, Ag, and Au as a bisulphide complex. Magmatic fluid contributes Cu-Au and possibly less soluble metals such as Bi, Mo (Large 1995). Applying this model to the northeast Queensland context, the Reward Cu-Au pyrite pipe maybe closer to a magmatic centre, likewise the Balcooma deposits with high background Cu, Bi. Deposits dominated by Zn, Ba, Au (eg. Handcuff, Liontown, Reward volcaniclastic hosted Pb-Zn-Ag-Au) are likely to be derived largely from hydrothermal seawater circulation.

Metallogenic Epochs and Tectonic Models

Four epochs of hydrothermal mineralisation are recognised in northeast Queensland.

1) Middle Proterozoic (~ 1550 Ma) represented by the Sn deposits at Croydon.

2) Cambro-Ordovician (~ 510 Ma) represented by the massive sulphide deposits of the Mt Windsor and Greenvale Sub-provinces.

3) Siluro-Devonian (420-400 Ma) represented by the mesothermal (plutonic) gold-quartz veins in the Charters Towers, Georgetown, Anakie and Coen Provinces.

4) Permo-Carboniferous (330-280 Ma) represented by mesothermal (Slate Belt and Plutonic) gold-quartz veins and by a wide range of magmatic-hydrothermal (Porphyry-Epithermal) deposits with Sn, W, Mo, basemetals, U and Au. These deposits are spread through the provinces but are genetically linked to emplacement and evolution of the Coast Range Igneous Province.

The Middle Proterozoic epoch is well represented in the Mount Isa Inlier and the Cambro-Ordovician epoch is best compared with western Tasmania. The Siluro-Devonian epoch overlaps with the major phase of magmatism and gold mineralisation in the Lachlan Fold Belt of Victoria and central N.S.W. The tectonic setting during these mineralising epochs is poorly constrained for north Queensland.

Table 5: Zonation of Element Association for Hydrothermal Ore Deposits in North Queensland
Brackets indicate anomalous but minor zones

ORE	U	Sn	Sn	Au	W	Au	Au	Au	Au	Au Cu Pb Zn
ENVIR	Telethermal	Porphyry	Plutonic	Epithermal	Porphyry	Epithermal	Porphyry	Plutonic	Slate Belt	VHMS
E.G.	Maureen	Herberton	Collingwood	Yandan	Wolfram Camp	Pajingo	Mt Leyshon	Charters Towers	Hodgkinson	Reward
Shallow/Late	U, Mo, F			(Sb, F)						
		(Sb, Au)	(As, F)	Au Ag As	(Sb, Au)	Au, Ag, As	Au, Ag (As)	Au, Ag	Au, As, Sb	Au Zn Ba
	(Pb Zn Cu As)	Pb Ag Cu (Zn)	(Zn Pb Ag) Cu Bi	(Cu, Pb, Zn)	Pb, Ag, Cu, Zn	(Pb, Zn, Cu)	Zn Cu Pb Bi	(Pb, Zn, Cu)	(Pb, Zn, Cu)	Pb Zn Ag Cu (Au)
		(W, Mo, Bi, F)	(W, Mo)	(W, Mo)	W, Mo, Bi, F				(W, Mo?)	
Deep/Early	(Sn, W)	Sn, W	Sn, B				(Cu, Mo)			

For the Permo-Carboniferous epoch, mineralisation can be related to emplacement of the Coast Range Igneous Province during transtensional disruption of the established Late Devonian-Early Carboniferous Sumatran-type continental arc (e.g. Morrison et al., 1992). Initial crustal scale dewatering gave rise to the mesothermal deposits and was followed by large scale, deep crustal melting centred on one of the major transtensional faults. Hydrothermal fluid evolution in these magmas at subvolcanic levels and interaction with near surface fluids localised the magmatic-hydrothermal deposits.

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References

Aberfoyle, 1995. Mt Windsor Joint Venture summary. Compiled by E.V. Dronseika, Unpublished Report.

Bain J.H.C., 1977. Uranium mineralisation associated with late Paleozoic acid magmatism in northeast Queensland. *BMR Jl. Geol Geophys*. v.2,137-147.

Bain, J.H.C. and Withnall, I.W., 1980. Mineral deposits of the Georgetown region, northeast Queensland. In: *The Geology and Geophysics of Northeastern Australia* (Eds. R.A. Henderson and P.J. Stephenson) pp. 129-148 (Geological Society of Australia, Qld. Div. Brisbane).

Bain, J.H.C., Withnall, I.W., Oversby, B.S. and Mackenzie, D.E., 1990. North Queensland Proterozoic inliers and Palaeozoic igneous provinces - regional geology and mineral deposits. In: *Geology of the Mineral Deposits of Australia and Papua New Guinea* (Ed. F.E. Hughes), pp.963-978 (The Australasian Institute of Mining and Metallurgy: Melbourne).

Baker, E.M. and Andrew, A.S., 1991. Geologic, fluid inclusion and stable isotope studies of the gold-bearing breccia pipe at Kidston, Queensland. Australia. *Econ. Geol*. v.86, 810-830.

Beams, S.D., Laing, W.P. and O'Neill, D.M., 1989. The exploration history and geology of the polymetallic Reward deposit, Mt Windsor volcanic belt, North Queensland: *North Queensland Gold '89 Conf*., Townsville, Queensland, April 1989, Proc., pp.95-102.

Beams, S.D., 1993. An evolving history of massive sulphide exploration from outcropping to blind targets: The Mt Windsor Volcanic Belt, North Queensland. In: *Economic Geology of the Charters Towers Region (*Ed. R.A. Henderson), pp.77-79. 1993 Field Conference, Qld Division Geological Society of Australia.

Beams, S.D. & Dronseika, E.V., 1995. Exploration history, geology and geochemistry of the polymetallic Reward & Highway deposits, Mt Windsor. In: *Mineral Deposits of Northeast Queensland: Geology and Geochemistry* (Ed. S.D. Beams), pp.137-153. EGRU Contribution 52, James Cook University.

Berry, R.F., Huston, D.L., Stolz, A.J., Hill, A.P., Beams, S.D., Kuronen, U. and Taube, A., 1992. Stratigraphy, structure and volcanic hosted mineralisation of the Mt Windsor Subprovince, North Queensland, Australia. *Econ. Geol*. v.87, 739-763.

Blevin, P.L. and Chappell, B.W., 1992. The role of magma sources, oxidation states and fractionation in determining the granite metallogeny of eastern Australia. *Trans. Roy. Soc. Edinburgh: Earth Sciences*, v.83, 305-316.

Bobis, R.E., 1992. Setting and origin of an epithermal gold-silver deposit at Pajingo northeast Queensland, Australia. PhD. thesis, James Cook University. Unpubl. p318.

Bohlke, J.K. and Kistler, R.W., 1986. Rb-Sr, K-Ar and stable isotope evidence for the ages and sources of fluid components of gold-bearing quartz veins in the northern Sierra Nevada Foothills metamorphic belt, California. *Econ. Geol.*, v.81,296-322.

Buchanan, L.J., 1981. Precious metal deposits associated with volcanic environments in the southwest. In: *Relationship of tectonics to ore deposits in the southern Cordillera*. (Eds. W.R. Dickinson and W.D. Payne). *Arizona Geol. Soc. Digest*, xiv, pp.237-262.

Bultitude, R.J., and Champion, D.C., 1992. Granites of the eastern Hodgkinson Province - their field and petrographic characteristics. Qld. Dept. Res. Ind. Record 1992/6.

Burger, P.A., 1982. The Greenvale laterite nickel-cobalt deposit. In: *1982 Field Conference, Charters Towers-Greenvale Area* (Ed. I.W. Withnall), pp.52-61. *Geol. Soc. Austr.* Qld Div., Brisbane.

Burger, P.A., 1995. The Greenvale Nickel Laterite Orebody. In: *Mineral Deposits of Northeast Queensland: Geology and Geochemistry* (Ed. S.D. Beams), pp. 182-195. EGRU Contribution 52, James Cook University.

Cas, R.A.F., 1992. Submarine Volcanism: Eruption Styles, Products, and Relevance to Understanding the Host-Rock Successions to Volcanic-Hosted Massive Sulfide Deposits. *Econ. Geol.* v.87, 511-541.

Champion, D.C. and Chappell, B.W., 1992. Petrogenesis of felsic I-type granites: an example from northern Queensland. *Trans. Roy. Soc. Edinburgh: Earth Sciences*, v.83,115-126.

Champion, D.C. and Bultitude, R.J., 1994. Granites of the eastern Hodgkinson Province II. Their geochemical and Nd-Sr isotopic characteristics and implications for petrogenesis and crustal structure in north Queensland. Qld Dept. Minerals Energy Record 1994/1.

Digweed, J.M., 1991. The geology and zoning of epithermal gold-quartz veins at Woolgar, north Queensland. M.Sc thesis, James Cook University. Unpubl.

Gregory, P.W., Taylor, R.G. & White, A.H., 1980. Mineralisation in the Broken River and Hodgkinson Provinces. In: *The geology and geophysics of northeastern Australia.* (Eds. R.A. Henderson and P.J. Stephenson). pp.191-200 *Geol. Soc. Austr.* Qld Div., Brisbane.

Hall, G.C., 1980. The Eight Mile Wolfram Prospect. Seminar Presentation. M.Sc. course, James Cook University.

Hartley & Williamson 1995. Mt Garnet zinc rich stream. In: *Mineral Deposits of Northeast Queensland: Geology and Geochemistry* (Ed. S.D. Beams), pp.239-245. EGRU Contribution 52, James Cook University.

Heald, P., Foley, N.K., Hayba, D.O., 1987. Comparative anatomy of volcanic hosted epithermal deposits: acid-sulfate and adularia-sericite types. *Econ. Geol.* v.82, 1-26.

Henderson, R.A., 1983. Early Ordovician faunas from the Mt Windsor subprovince, northeastern Queensland: Assoc., *Australasian Palaeontologists Mem.* 1, 145-175.

Henderson, R.A., 1986. Geology of the Mt Windsor Subprovince a lower Paleozoic volcano-sedimentary terrane in the northern Tasman Orogenic Zone. *Austr. J. Earth Sci.*, v.33, 343-364.

Herrmann, W., 1995. Geochemical aspects of the Thalanga massive sulphide deposit. In: *Mineral Deposits of Northeast Queensland: Geology and Geochemistry* (Ed. S.D. Beams), pp.155-170. EGRU Contribution 52, James Cook University.

Huston, D.L., Taylor, T., Fabray, J., Patterson, D.J., 1992. A Comparison of the Geology and Mineralization of the Balcooma and Dry River South Volcanic-Hosted Massive Sulfide Deposits, Northern Queensland. *Econ. Geol.*, v.87,739-763.

Large, R.R., 1992. Australian Volcanic-Hosted Massive Sulfide Deposits: Features, Styles and Genetic Models. *Econ. Geol.* v.87,471-510.

Moore, S., 1995. Balcooma volcanic hosted massive sulphide project Greenvale Sub-Province. In: *Mineral Deposits of Northeast Queensland: Geology and Geochemistry* (Ed. S.D. Beams), pp.196-207 EGRU Contribution 52, James Cook University.

Morrison, G.W., 1988. Paleozoic Gold Deposits of northeast Queensland. *Bicentennial Gold 88.* Geol. Soc. Austr. Ext. Abstr. 22, pp.91-101.

Morrison, G.W., Tate, N.M. and Johns, H.J., 1992. Gold metallogeny for the late Paleozoic of north Queensland. Geol. Soc. Austr. Abstr. v.32,45.

Morrison, G.W., Guoyi Dong & Jaireth, S., 1990. Textural zoning in epithermal quartz veins. AMIRA Project P247 Field Manual, James Cook University, unpubl.

Morrison, G.W., Rose, W.J., and Jaireth, S., 1991. Geological and geochemical controls on the silver content (fineness) of gold in gold-silver deposits. *Ore Geol. Rev.* v.6,333-364.

Mullholland, I.R., 1991. The geology, petrology and alteration geochemistry of the Magpie volcanogenic massive sulfide prospect, North Queensland, Australia. *Econ. Geol.*, v.86,1387-1400.

Murray, C.G., 1990. Tasman fold belt system in Queensland. In: *Geology of the mineral deposits of Australia and Papua New Guinea* (Ed. F.E. Hughes),pp.1431-1450 (The Australasian Institute of Mining and Metallurgy: Melbourne).

Nelson, C.E., 1988. Gold deposits in the hotspring environment. In: *Bulk Mineable Precious Metal Deposits of the Western United States* (Eds. R.W. Schafer, J.J. Cooper, P.G. Vikne) Geol. Soc. Nevada Symp. Proc., p.417-431.

Nethery, J.E., Barr, M. and Woodbury, M., 1994. Chillagoe district gold, silver, basemetal deposits - hypothermal to epithermal overprinting. In: *New Developments in Geology and Metallogeny: Northern Tasman Orogenic Zone* (Eds. R.A. Henderson, B.K. Davis), pp.71-74. Contrib 50, EGRU James Cook University.

Patrick, J.P., 1978. The geology and origin of the sulphide deposit and the high grade Precambrian metamorphic rocks at Einasleigh, north eastern Australia, M.Sc. thesis (unpublished), James Cook University of North Queensland.

Perkins, C., Walshe, J.L. and Morrison, G.W., 1995. Metallogenic Episodes of the Tasman Fold Belt System, Eastern Australia. *Econ. Geol.* in press.

Peters, S.G. and Golding, S.D., 1989. Geologic, fluid inclusion and stable isotope studies of granitoid hosted gold-bearing quartz veins, Charters Towers, northeastern Australia. *Econ.Geol.* Monogr. 6, p.260-273.

Peters, S.G., Golding, S.D. and Dowling, K., 1990. Melange and sediment hosted gold-quartz veins, Hodgkinson Goldfield Queensland, Australia. *Econ. Geol.* v.95,312-327.

Proffett, J.M., Jr., 1978. Ore deposits of the Western United States: A Summary, *Nev. Bur. Mines Geol. Rept* 33,13-32.

Queensland Nickel, 1992: QNI Limited Prospectus.

Rose, W.J., 1987. The silver content of gold: a method for distinguishing North Queensland ore deposits of differing genesis. Unpubl. M.Sc. thesis, James Cook University of North Queensland, p.116.

Russell, R.T., 1986. Exploration at the Highway gold deposit. In: *Gold exploration and development, North Queensland conference, Charters Towers*, pp.74-77. (The Australasian Institute of Mining and Metallurgy: North Queensland Branch).

Sennitt, C.M., 1991. Aspects of Epithermal Gold Mineralisation, Twin Hills, Queensland. Unpubl. M.Sc. thesis, James Cook University of North Queensland, p.236.

Sillitoe, R.H., 1983. Styles of low grade gold mineralization in volcano-plutonic arcs. *Nev. Bur. Mines and Geol.* Rept 36,52-68.

Tate, N.M., Morrison, G.W. and Johns, H.J., 1992. Gold mineralisation in the Drummond Basin, north Queensland. Gold Metallogenic Bulletin 16. AMIRA Project P247. James Cook University, unpubl.

Taylor, R.G., 1979. Geology of tin deposits. Elsevier, Amsterdam, p543.

Whiting, R.G., and Bowen, K.G., 1976. Gold. In: *Geology of Victoria* (Eds. J.G. Douglas and J.A. Ferguson). Geol. Soc. Austr. Spec Publ. 5, pp.434-454.

Woodall, R., 1990. Gold in Australia. In: *Geology of the mineral deposits of Australia and Papua New Guinea* (Ed. F.E. Hughes) pp.45-67. (The Australasian Institute of Mining and Metallurgy: Melbourne).