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Exploration for orogenic gold deposits

Short course

NOTES TO ACCOMPANY HAND SPECIMEN DISPLAY

by

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Appendix 2. Location of gold occurrences from Central Lapland described in the report

Appendix 3. Location of West-Australian gold occurrences described in the report

INTRODUCTION

Drill core and grab samples from gold deposits and occurrences chiefly from Finland and Australia are described in this paper. In addition, some samples from Sweden, Czech Republic, Russian Far East, Ukraine, and Uzbekistan, are presented. Most of the samples are from orogenic gold deposits, but there also are a few samples from iron oxide-copper-gold, porphyry and epithermal deposits.

Samples from each deposit and associated wallrocks are presented in individual sections sorted by country. The Australian deposits are divided into groups according to their host rocks: ultramafic rocks, mafic rocks, intermediate and felsic igneous rocks, clastic metasedimentary rocks and banded iron formations (BIF). Within each host rock group, the Australian deposits are presented in order of increasing PT conditions (proven or inferred) for alteration and regional metamorphism.

The location of the deposits and occurrences in Finland is presented in Appendices 1 and 2 and those in Western Australia in Appendix 3.

In this report, 'dolomite' refers to Fe-bearing dolomite.

FINLAND

1. Deposits in Archaean rocks

1.1 Ilomantsi Greenstone Belt

All the Ilomantsi samples presented are from the Hattu Schist Belt which is located in the easternmost Finland and forms the east-central portion of the Ilomantsi Greenstone Belt. Most of the geological and explorational aspects related to these deposits are discussed in Nurmi and Sorjonen-Ward (1993), but additional information can be found, for example, in Nurmi et al. (1991), Nurmi (1993) and Rasilainen (1996). The following general description and the deposit descriptions are chiefly based on these publications.

The host rocks in all deposits are metamorphosed under conditions transitional between greenschist and amphibolite facies or at lower-amphibolite facies. Regional metamorphism in the area peaked at about 550±50°C. Gold mineralisation and related alteration took place in structurally favourable locations within the schist belt during deformation and metamorphism, probably at ca. 2.75-2.70 Ga (U-Pb zircon ages; Nurmi and Sorjonen-Ward 1993), although also later ages have also been presented, e.g. 2600 Ma (Stein et al. 1998).

Precipitation of gold was, probably, chiefly due desulphidation of the mineralising fluid and, possibly, by decomposition of Au-Te complexes of the fluid due to cooling and/or by changes in pH and f_{02}, at probably just below +500°C. The formation of many of the present Te and Bi minerals took place somewhat later, as subsolidus reactions with lowering the temperature from +500 to +200°C. The combination of arsenopyrite and oxygen isotope geothermometry, sphalerite geobarometry, and the dominance of pyrrhotite and calcite instead of pyrite and dolomite in the deposits, suggest that the PT conditions during gold mineralisation and alteration were transitional between greenschist and amphibolite facies: T = 450-500°C, p = 2-3 kbar.

There apparently is an Archaean post-mineralisation metamorphic overprint with low-degree deformation and porphyroblast overgrowth, but with no detected remobilisation of gold. There also is a Palaeoproterozoic regional thermal overprint which is shown by the ca. 1800 Ma K-Ar and Rb-Sr ages of micas in the Hattu Schist Belt. However, there is no indication of Proterozoic gold mineralisation nor any significant remobilisation of gold during the Proterozoic (Kontinen et al., 1992; O'Brien et al., 1993).

1.1.1 Korpilampi

Two hand specimens are on display from the Korpilampi deposit, which is located approximately 40 km NE from the town of Ilomantsi. The main host rock is an intermediate metatuffite or mica schist, while komatiitic metavolcanic rocks, granitic pegmatite and tonalite act as minor hosts to ore (Luukkonen et al. 2002). The mineralisation is formed by gently dipping lodes at the contacts of conformable tourmaline-bearing pegmatites and is characterised by ductile deformation. Gold mineralisation-related alteration is characterised by the formation of biotite, tourmaline, pyrrhotite and arsenopyrite.

<u>Hand specimen description</u>

Sample	*Description*
Korpilampi-1	Intermediate metatuffite; proximal alteration, quartz-carbonate veins and intense ductile deformation. Mineral assemblage: quartz - K feldspar - biotite - albite - muscovite - calcite(?) - pyrrhotite + possibly arsenopyrite, tourmaline, chlorite, garnet, scheelite, titanite, rutile and gold.
Korpilampi-2	Tourmaline-bearing pegmatite with a slice of tourmaline-rich, sulphidised wallrock.

1.1.2 Kuittila

The Kuittila deposit is located approximately 25 km NE from the town of Ilomantsi, in the SE marginal part of the Kuittila tonalite stock. The hosting tonalite is enveloped by the rocks of the Hattu Schist Belt and has an U-Pb zircon age of 2745±11 Ma (Nurmi and Sorjonen-Ward 1993).

The host rock at Kuittila is a tonalite which in the domain of gold mineralisation has a granodioritic mineral assemblage due to alteration: quartz - albite - muscovite - biotite - K feldspar - tourmaline - rutile - calcite -

epidote - pyrrhotite. Other ore minerals present are: pyrite, arsenopyrite, chalcopyrite, sphalerite, galena, molybdenite, pentlandite, a large set of tellurides, electrum, and gold. All molybdenite is related to a wide-spread, conjugate set of pre-gold mineralisation quartz veins which also contain abundant scheelite.

<u>Hand specimen description</u>

Sample	*Description*
Kuittila -1	A sample from the gold mineralisation. Intensely deformed and altered tonalite with thin quartz veins. For mineral assemblage, see above.
Kuittila -2	Auriferous tourmaline-, pyrrhotite- and arsenopyrite-bearing quartz vein.

1.1.3 Pampalo

The Pampalo deposit, which is also known by the name Ward, is located approximately 40 km NE from the town of Ilomantsi, and presently (August 2002) under a feasibility study and test mining by the Outokumpu Oyj. The size of the deposit, according to data released in 1993 (Nurmi 1993), is 0.59 Mt with 7.9 ppm Au and total in-situ gold of 4.7 metric tons (cut-off grade 2 ppm Au). However, the test mining intermittently performed during 1998-2001 has already produced 1784 kg Au (Esa Sandberg, pers. comm. 15/07/2001), and the present (late 2003) estimate suggests a resource of about 7000 kg Au (Mäkelä 2002, Dragon Mining 2003).

The major host rock at Pampalo is an intermediate metatuffite or mica schist. Felsic porphyry dykes and komatiitic metavolcanic rocks form significant minor hosts to the ore. Abundant biotite with idioblastic pyrite characterise the alteration related to gold mineralisation.

<u>Hand specimen description</u>

Sample	*Description*
Pampalo -1	A large sample representing the richest ore type (probably several tens of ppm gold) in the metatuffite. Mineral assemblage: biotite - quartz - K feldspar - albite - calcite - chlorite - epidote - pyrite - rutile - tremolite-actinolite - tourmaline - tellurides(?) - gold. The veins are dominated by quartz, K feldspar and pyrite.
Pampalo -2	A small sample from low-grade ore (1-4 ppm Au) in the metatuffite. Note the abundant biotite, deformed thin quartz veins and idioblastic pyrite porphyroblasts.
Pampalo -3, -4	High-grade, intensely biotitised and deformed ore with abundant pyrite.

1.1.4 Rämepuro

Three hand specimens are on display from the Rämepuro deposit, which is located approximately 35 km NE from Ilomantsi. The gold mineralisation is chiefly hosted by a tonalitic porphyry dike which is at the contact between an andesitic pyroclastic metavolcanic rock and a mica schist of sedimentary origin. The metasedimentary rock forms a minor host to ore. Garnet-biotite geothermometry gives a temperature range of 398-580°C for metamorphism, suggesting polyphase metamorphism with strong retrograde component; thermal peak was synchronous or outlasted deformation (Ojala et al. 1990). The released data for the deposit show a 0.25 Mt resource with the average gold grade at 5 ppm (Pekkarinen 1988).

Ore minerals detected at Rämepuro are: pyrite, arsenopyrite, chalcopyrite, sphalerite, molybdenite, pentlandite, a set of tellurides, native bismuth and native gold.

<u>Hand specimen description</u>

Sample	*Description*
Rämepuro-1, -2, -3	Typical tourmaline-quartz breccia close to the contact of the sericitised mica schist. The latter is present in the sample Rämepuro-2. Black tourmaline-dominated bands and fragments most probably represent intensely altered host rock.

1.2 Kuhmo and Suomussalmi Greenstone Belts

The Kuhmo and Suomussalmi greenstone belts, which are characterised by the dominance of tholeiitic and komatiitic metavolcanic rocks, are the most extensive well-preserved supracrustal units in the Archaean of Finland, extending over a strike length of nearly 200 km, though seldom exceeding 10 km in width. Extensive structurally controlled alteration systems have been delineated in these greenstone belts and found to contain several gold occurrences of the orogenic type (Luukkonen 1992, 1993, Poutiainen & Luukkonen 1994, Luukkonen et al. 2002). These deposits are related to late Archaean (2.75-2.67 Ga) metamorphism and D3-D4 stage deformation, and have mineral assemblages stable under upper-greenschist to lower-amphibolite facies PT conditions (Poutiainen & Luukkonen 1994, Sorjonen-Ward et al. 1997, Luukkonen et al. 2002).

1.2.1 Aittoranta

The Aittoranta, also known as Iso Aittojärvi, gold occurrence is in the central part of the Kuhmo Greenstone Belt, about 38 km NW from the town of Kuhmo. It is chiefly hosted by mafic metavolcanic rocks, but felsic schists and metakomatiites have also been detected hosting the mineralisation (Luukkonen et al. 1992). Regional metamorphic grade and the PT conditions of the mineralisation at Aittoranta are transitional between greenschist and amphibolite facies (Kimmo Pietikäinen pers. comm. 14/9/1998). Features characteristic for the mineralisation include biotitisation, quartz-tourmaline veins up to 50 cm wide, abundant arsenopyrite and dominantly ductile deformation (Luukkonen et al. 2002).

Hand specimen description

Sample	*Description*
Ai-1	Low-grade gold mineralisation in mafic metavolcanic rock. Intense biotitisation and tourmalinisation and quartz-tourmaline-arsenopyrite veins. Also alteration-related, green, calcic amphibole is present.
Ai-2	Folded, laminated, quartz-tourmaline vein from the gold mineralisation. The dominant ore mineral is arsenopyrite. Also alteration-related, green, calcic amphibole is present.
Ai-3, -4	Intensely tourmalinised host rock with brecciating quartz veins. Locally, Ca amphibole formed during alteration. Arsenopyrite both in veins and host rock.

1.2.2 Kuikkapuro

The Kuikkapuro deposit is in the central Suomussalmi Greenstone Belt. It is hosted by mafic metavolcanic rocks metamorphosed under lower-amphibolite facies PT conditions. High gold contents (up to >100 ppm) are encountered in quartz veins, whereas the altered host rocks only contains a few-ppm grade mineralisation. The mineralised zone at Kuikkapuro is >1 km long, 15-30 m wide, parallel with the local lithological units, and dips at 60° to the ENE (Pietikäinen et al. 2001).

The dominant ore minerals in the deposit are pyrite, pyrrhotite and arsenopyrite. Alteration is characterised by intense biotitisation. (Luukkonen et al. 2002)

Hand specimen description

Sample	*Description*
Kuikkapuro	Banded quartz vein with visible gold.

1.2.3 Mataralampi

The Mataralampi occurrence is in the central part of the Kuhmo Greenstone Belt, near the village of Härmänkylä, only about 2 km from the gold prospects of Timola and Naurispuro. The main host to gold is a deformed, homogeneous quartz porphyry. A heterogeneous quartz-feldspar porphyry unit, in contact with the quartz porphyry forms a minor host to mineralisation. The dominant ore mineral at Mataralampi is pyrite. Alteration is characterised by formation of sericite and calcite and destruction of feldspars and biotite. Mineral assemblage suggest mineralisation under transitional or lower-amphibolite facies conditions.

Hand specimen description

Sample	*Description*
ML-1	Proximally altered, intensely sheared, sericitised and carbonated quartz porphyry.
ML-2, -3,	Pyrite-rich, auriferous, banded quartz vein with intensely sericitised slices of quartz
ML-4, -5	porphyry. The samples are partially weathered, hence the brownish colour in parts of the samples.

1.2.4 Moukkori

The Moukkori deposit, also known by the name Housuvaara 1, is located in the Tormua Schist Belt which forms the NE part of the Suomussalmi Greenstone Belt. Moukkori is roughly 55 km NE from the town of Suomussalmi. The deposit is hosted by mafic uralite-porphyrite and intermediate metatuffite (volcanogenic metasedimentary rock) and has, apparently, formed under conditions transitional between lower-amphibolite and upper-greenschist facies, in brittle-ductile regime of deformation (Luukkonen et al. 1992, Luukkonen 1993, Poutiainen & Luukkonen 1994), probably at 2680 Ma (titanite U-Pb age, Luukkonen et al. 2002). It is in a D3 structure.

The dominant ore mineral is pyrrhotite; other ore minerals detected are marcasite, pyrite, sphalerite, galena, chalcopyrite, altaite, hessite, volynskite, tsumoite, petzite, carvellite and native gold (Chernet 1994). The latest resource estimate for Moukkori gives an indicated 0.0034 Mt @ 13.4 ppm + inferred 0.017 Mt @ 10 ppm + reconnaissance resource 0.1 Mt @ 10 ppm Au (cut off 2 ppm) (Parkkinen 2001).

Hand specimen description (outcrop samples, all slightly weathered)

Sample	*Description*
MO- l	Unaltered or distally altered intermediate metatuffite host rock. Mineral assemblage plagioclase - hornblende - biotite - quartz ± K feldspar and ilmenite.
MO-2	Low-grade gold mineralisation(?) in mafic or intermediate tuff or tuffite. Note the multiple ductile deformation.
MO-3	Unaltered or distally altered mafic metavolcanic host rock. Mineral assemblage probably plagioclase - hornblende - biotite - quartz - ilmenite. Minor post-mineralisation quartz-carbonate veins.
MO-4	High-grade gold mineralisation and intense alteration in metavolcanic or metasedimentary host rock. Mineral assemblage probably quartz - biotite - epidote(?) - plagioclase - K feldspar - calcite - pyrrhotite - rutile. Pyrrhotite-bearing, auriferous quartz veins.

1.2.5 Sepponen

The Sepponen gold occurrence is in a small (0.5 x 1.5 km) greenstone-belt fragment surrounded by Archaean TTG granitoids and gneisses 32 SE from Kuhmo and 45 NE from Nurmes. It is hosted by mafic amphibolites; mineral assemblages suggest formation under lower-amphibolite facies conditions (E. Luukkonen et al. 1992, Luukkonen 1993, Luukkonen et al. 2002). At Sepponen, gold shows a strong positive correlation with arsenopyrite, and the mineralisation is controlled by a D4 shear zone (Luukkonen et al. 2002).

Hand specimen description

Sample	*Description*
Se-1, -2	Gold mineralisation: biotitised and sulphidised amphibolite. Ductile deformation. Dominant ore minerals are arsenopyrite and pyrrhotite. Syn-deformation, mineralisation-related, auriferous quartz veins which also contain K feldspar, calcite and hornblende, and have a hornblende selvage.

2. Deposits in Palaeoproterozoic Lapland Domain

Finnish Lapland, which comprises a significant portion of the northern part of the Archaean Karelian craton, records a prolonged and episodic history of sedimentation, rifting and magmatism throughout the Palaeoproterozoic times. The Palaeoproterozoic greenstone belts in northern Finland include the Central Lapland greenstone belt, and Kuusamo and Peräpohja schist belts. These belts were all initially formed in intracratonic rift settings related to the Archaean craton (Hanski et al. 1997, Sorjonen-Ward et al. 2003).

According to Lahtinen et al. (2003), the Palaeoproterozoic evolution of the region after 1.92 Ga includes the following major epochs or orogens: 1) microcontinent accretion (1.92-1.88 Ga), 2) continental extension (1.88-1.85 Ga), 3) continent-continent collision (1.85-1.79), and 4) orogenic collapse and stabilisation (1.79-1.77 Ga). The first epoch includes collision of the Kola and Karelian cratons in the northeast and collision of the Norrbotten and Karelian cratons in the west. This resulted in the amalgamation of the Archaean parts of the Fennoscandian shield. This was followed by the formation of extensional basins in Lapland, in the far hinterland of subduction in the west (epoch 2). The third epoch is defined by the collision of Fennoscandia, Sarmatia and Amazonia (the latter being later rifted away). The 1.79-1.77 Ga epoch was a period of thermal resetting and post-orogenic magmatism. We consider all of the above-mentioned epochs as potentially significant for gold mineralisation in northern Finland, as also is suggested by Lahtinen et al. (2003) and by Weihed and Eilu (2003). Sorjonen-Ward et al. (2003) present two major orogenic epochs for the region: 1) crustal-plate collision and compression during 1.91-1.86 Ga, and 2) active deformation and regional metamorphism during 1.84-1.80 Ga due to crustal thickening or mantle underplating; they also suggest that orogenic mineralisation took place during the latter epoch.

The Central Lapland Greenstone Belt (CLGB) is the largest mafic volcanic-dominated province preserved in Finland. The sequence starts with bimodal komatiitic and felsic volcanic rocks, dated at ca. 2.5 Ga (zircon U-Pb data from felsic volcanic rocks, Peltonen et al. 1988, Manninen et al. 2001), which unconformably overlie Archaean basement and represent the onset of rifting (Peltonen et al. 1988, Lehtonen et al. 1998). Continued rifting of the Archaean crust resulted in the widespread emplacement of gabbro-norite layered intrusions in the region between 2.45-2.39 Ga. Terrigeneous clastic sedimentary rocks discordantly overlie these layered intrusions, with further episodes of mafic magmatism recorded as sporadic lavas and sills dated at ca. 2.2 Ga, ca. 2.10 Ga, and ca. 2.05 Ga (single-zircon U-Pb data, Huhma 1986, Vuollo et al. 1992, Huhma et al. 1996, Lehtonen et al. 1998, Vaasjoki 2001). All mafic igneous episodes mentioned above coincided with rifling and subsidence along the whole of the Karelian craton margin, recorded by coarse-clastic turbidites, carbonate rocks, iron formations and graphitic schists. Rifting culminated in extensive mafic and ultramafic volcanism and the formation of oceanic crust at ca. 1.97 Ga. Fragments of oceanic crust were subsequently emplaced back onto the Karelian craton, as the Nuttio ophiolite in Lapland and the Jormua and Outokumpu ophiolites further south (Kontinen 1987, Sorjonen-Ward et al. 1997, Lehtonen et al. 1998). The emplacement of the ophiolites was followed by the main compressional deformation associated with the Svecofennian synorogenic plutonism, between 1.90-1.86 Ga (Vaasjoki 2001). If we apply the scheme of Lahtinen et al. (2003) into above, the ophiolite emplacement and the compressional deformation in the present area of the CLGB belong to the accretional and collisional epochs at 1.92-1.88 Ga and 1.85-1.79 Ga, respectively.

The main deformational stages in the CLGB took apparently place as follows (Ward et al. 1989, Sorjonen-Ward et al. 1992, Mänttäri 1995, Patison in press): D_1 and D_2 during 1.90-1.88 Ga, D_3 either during 1.90-1.88 Ga or 1.84-1.80, and the latest, completely brittle, D_4 in ca. 1.77 Ga or slightly post-1.77 Ga. The D_1-D_4 evolution appears to fit into the evolutional epochs of Lahtinen et al. (2003) fairly well. Note, however, that the timing for D_1 to D_4 is chiefly indirect with a very few robust radiometric dates setting definite values for any of the stages; especially, the timing of D_3 may either be 1.90-1.88 Ga or 1.84-1.80 Ga (Patison in press). Similar geotectonic evolution, as for the CLGB, can be envisioned for both the Kuusamo and Peräpohja belts for the entire Proterozoic (e.g., Lahtinen et al. 2003).

In this main section, the deposits from the Central Lapland Greenstone Belt are described first and are followed by the description of samples from the Kuusamo and Peräpohja Schist Belts. The deposits in Kittilä area represent the western and the deposits in Sodankylä area the eastern part of the Central Lapland Greenstone Belt. The division to these sub-groups is only based on the geographical distribution of the deposits between the municipalities of Kittilä and Sodankylä. The Kolari IOCG-style(?) deposits are in the westernmost part of the CLGB.

All deposits from the Kittilä and Sodankylä areas presented here, except Kuotko, Ruoppapalo and Suurikuusikko in Kittilä and Koppelokangas, Pahtavaara and Sattasköngäs in Sodankylä, are located within 0-3 km from the W- to NW-trending Sirkka Line which is a major, crustal-scale shear and fault zone within the Central Lapland Greenstone Belt (Lehtonen et al. 1998, Eilu 1999). The Sirkka Line has, probably, formed a major fluid channelway for the mineralising fluids in the area. Gold was, apparently, precipitated from these fluids in the marginal areas of the Sirkka Line and its splays and subsidiary shear zones.

All deposits in the Kittilä, Kuusamo and Peräpohja areas are in greenschist-facies rocks, while some deposits at Sodankylä may be in rocks transitional between greenschist and amphibolite facies (Eilu 1999).

The location of most of the deposits from the Central Lapland Greenstone Belt (Kittilä and Sodankylä areas) is shown in Appendix 2.

2.1 Kittilä area

2.1.1 Ahvenjärvi

The Ahvenjärvi gold occurrence, also known by the name Isomaa, is 15 km E from Kittilä. It is hosted by albitised quartzite and metasiltstone, located southwest of the Sirkka Line, and formed under greenschist-facies conditions (Ilvonen 1994, Lehtonen et al. 1998, Veikko Keinänen pers. comm. 20/8/1998). Pyrite, tourmaline, Au-Ag tellurides, native gold and molybdenite characterise the mineralisation.

Hand specimen description

Sample	*Description*
AJ-1	Altered sericite quartzite (metasiltstone?) from low-grade gold mineralisation. Earlier and later quartz-ankerite veins, both(?) related to gold mineralisation.
AJ-2	Auriferous, pyrite-bearing, laminated, quartz-tourmaline vein from the central parts of the Ahvenjärvi gold mineralisation.

2.1.2 Hirvilavanmaa

The Hirvilavanmaa gold deposit is located about 15 km NE from the town of Kittilä and is close to the Soretiavuoma and Soretialehto gold mineralisations and the Soretiapulju tungsten mineralisation. These are in a NW-trending, extensional part of the Sirkka Line shear zone. The deposit contains, at least, 0.11 Mt @ 2.9 ppm Au (Scan Mining 2002).

The gold mineralisation is hosted by intensely altered, metakomatiitic pyroclastic(?) rocks (Keinänen et al. 1988, Veikko Keinänen pers. comm. 24/11/1997). In the area, ultramafic rocks not affected by gold-related alteration have the regional metamorphic, hydrated and weakly carbonated, mineral assemblage talc - chlorite - calcite - chromite+magnetite - ilmenite. Alteration sequence and the siting of gold are described below, in sample descriptions.

Hand specimen description

Sample	*Description*
HIR-1	Distal alteration characterised by the formation of carbonate porphyroblasts and replacement of ilmenite by rutile. Primary pyroclastic texture with lapilli is apparently preserved. Mineral assemblage: talc - chlorite - Fe dolomite or ankerite - magnetite with chromite core - rutile.
HIR-2	Intermediate alteration characterised by deformation banding, intense brecciation, carbonation, albitisation and pyritisation. Porphyroblastic pyrite is replacing magnetite. Primary textures are completely destroyed. Mineral assemblage: talc - chlorite - Fe dolomite or ankerite - albite - pyrite - magnetite with chromite core - rutile. All albite and some of carbonate may, actually, be vein material.
HIR-3	Low-grade gold mineralisation and proximal alteration characterised by deformation banding, intense brecciation, carbonation, albitisation and pyritisation. Porphyroblastic pyrite, locally with haematite, has replaced most of magnetite. Mineral assemblage: talc - chlorite - Fe dolomite or ankerite - albite -

pyrite - rutile - haematite - magnetite with chromite core - chalcopyrite. Some of albite and carbonate are, most probably, vein material.

HIR-4 High-grade gold mineralisation and proximal alteration characterised by very intense brecciation, carbonation, albitisation and pyritisation. Nearly all talc, chlorite and magnetite have been replaced by carbonate+albite and pyrite, respectively. Mineral assemblage: Fe dolomite, ankerite and/or magnesite - albite - pyrite - talc - chlorite - rutile - magnetite with chromite core - chalcopyrite - gold - galena - tellurides - monazite. Inclusions of chalcopyrite, gold, galena, tellurides and monazite occur in pyrite. Abundant, deformed quartz-albite-carbonate-pyrite veins.

2.1.3 Jolhikko

The Jolhikko gold occurrence, also known by the name Hanhilampi 1-3 (official names of the claims in the area), is 12 km NW from Kittilä. It is characterised by carbonate-rich veins in metadolerite(s) (Inkinen 1991).

Hand specimen description

Sample	*Description*
Jolhikko	Auriferous ankerite-vein with minor quartz, pyrite and pyrrhotite and slices of intensely altered dolerite wallrock.

2.1.4 Kettukuusikko *(description by Veikko Keinänen 24/11/2002)*

The Kettukuusikko gold occurrence is next to, or possibly overlaps with, the previous prospects of Lälleävuoma, Päivänenä, and Ruostenenä, about 17 km NE from Kittilä. This area is now renamed as Kettukuusikko. The Kettukuusikko locality has been under exploration intermittently since mid-1980's (Outokumpu Oy: 1984-1991; Terra Mining: 1998-2003; GTK: 2001-2003). The deposit within the Sirkka Line shear zone which here has a NW-SE trend. Kettukuusikko is in proximity to an area where a NW-trending fracture zone (fault?) cuts across the Sirkka Line. The main host rock for gold is metakomatiite metamorphosed under lower- to mid-greenschist facies conditions. The gold mineralisation is related to a NNW-SSE trending, weakly magnetic (magnetic low), alteration and deformation zone which is about 300 m long and 50 m wide.

The occurrence extends from the surface to, at least, 85 m depth. The northern end of the mineralised zone is steeply eastward plunging, whereas its southern parts have shallow dip to the east. Main alteration minerals include carbonates, talc, chlorite and albite. Distal alteration is characterised by magnetite-bearing talc schist. The volume of pyrite, carbonate, chlorite and quartz increases towards the auriferous quartz-carbonate veins and breccias. Native gold occurs as small free grains in host rock and as inclusions and in fractures in pyrite. Other detected ore minerals include chalcopyrite, galena, tellurides, scheelite and tetrahedrite.

Hand specimen description

Sample	*Description*
KETTU-1	Auriferous vein having an assemblage carbonate - quartz - talc - pyrite. Pyrite contains native gold and various tellurides. Host rock consists of, at least, chlorite, talc and pyrite.
KETTU-2	Auriferous vein having an assemblage carbonate - quartz - talc - chalcopyrite. The metakomatiitic host rock is intensely pyritised.
KETTU-3	Quartz vein in fine-grained carbonate - albite - chlorite rock. Pyrite occurs both in the vein and disseminated in the host rock. Vein quartz contains carbonate in fractures. Pyrite contains galena, chalcopyrite, gold, tetrahedrite, barite and gersdorffite as inclusions.
KETTU-4	Carbonate-quartz veins in pyritised, fine-grained, carbonate - quartz - albite rock (Cr content about 1350 ppm). Host rock contains chlorite in fractures and chlorite - talc veinlets. Pyrite contains chalcopyrite, monazite, galena and rutile as inclusions.
KETTU-5	Intermediate alteration in metakomatiite. Mineral assemblage talc - chlorite - albite - pyrite - haematite. Vein comprises carbonate, talc, albite and pyrite. Carbonate is present also as megacrysts in the wall rock. In places, pyrite contains chalcopyrite, biotite, dolomite, galena, gold and chromite as inclusions, the latter enclosed by titanomagnetite.
KETTU-6	Fine-grained talc-chlorite-pyrite schist and albite - talc - carbonate - pyrite schist. The matrix also contains boudinaged segments composed of albite and carbonate. Pyrite in the carbonate-quartz veins contains gold, tellurides, chalcopyrite, haematite, magnetite and chromite.
KETTU-7	Distal alteration in metakomatiite (Cr content 1510 ppm). Rock contains alternating bands composed of talc + magnetite, chlorite + talc + magnetite and talc + albite, the latter coarser and more vein-like. The carbonate-albite vein contains magnetite rimmed by haematite and fine-grained pyrite.

2.1.5 Kuotko

The Kuotko gold deposit is about 45 km NE from Kittilä. It is chiefly hosted by mafic pyroclastic, Fe-tholeiitic metabasalts and also by felsic dykes (Härkönen & Keinänen 1989, Härkönen 1994, Mänttäri 1995, Ilkka Härkönen pers. comm. 24/8/1998). The deposit is in and close to a location where the NE-trending Kuotko Shear Zone and a minor NW-trending fault merge. The deposit is composed of four lodes.

Hand specimen description

Sample *Description*

KUO-1 Intensely weathered, pyrite-rich, high-grade gold mineralisation. Host rock probably a mafic metalava.

KUO-2 Auriferous, pyrite-bearing quartz vein (in mafic metavolcanic rock).

2.1.6 Kutuvuoma

The Kutuvuoma deposit is about 35 km east of Kittilä, near the village of Tepsa. It is a few km north of the Sirkka Line, and chiefly hosted by metakomatiite. Graphitic phyllite forms a minor host to ore. The host rocks are metamorphosed and the mineralisation formed under lower- or mid-greenschist facies PT conditions. Quartz-ankerite/Fe dolomite veins are common. The dominant ore minerals are pyrite and pyrrhotite. Upper part of the deposit was mined in 1999: about 25000 t of "high-grade ore" was extracted and treated at the Pahtavaara mine plant (Markku Kilpelä, pers. comm. 1999).

The deposit is characterised by quartz-ankerite veins with locally abundant pyrite and pyrrhotite, and minor chalcopyrite and gold.

Hand specimen description

Sample *Description*

KUTU-1 Pervasively carbonated, intensely brecciated host rock. Chiefly carbonate-rich vein material.

KUTU-2 Brecciated, altered metakomatiite, abundant quartz-carbonate vein material.

KUTU-3 Graphitic phyllite brecciated by quartz-carbonate and sulphide veins.

2.1.7 Levijärvi-Loukinen

The Levijärvi-Loukinen gold deposit is located about 17 km NNE from Kittilä. It is within the major structure of the area, the Sirkka Line (SL) shear and fault zone. Currently, four lodes are known from Levijärvi-Loukinen, along a 5 km section of the mineralised SL. The lodes are, from west to east, Levijärvi (Au-Ni), Paaminamaa (Cu-Au-Ni), Loukinen (Cu-Ni-Au), and Tienpää (Ni-Cu-Au). Although the area has been under exploration since early 1940's, the first gold lode, Levijärvi, was only discovered in 1993. The other three lodes were found between 1994 and 2001 by systematic percussion drilling through the overburden by the Geological Survey of Finland (GTK) (Veikko Keinänen pers. comm. 1998-2002).

The lodes are hosted by graphitic phyllite and tuffite, and metakomatiite. Although the relative abundance of these host rocks varies from lode to lode, the importance of fine-grained metasedimentary rocks as hosts seems to grow toward the west (Marko Holma pers. comm. 17/11/2003). The host rocks are metamorphosed and the mineralisation formed under lower- or mid-greenschist facies PT conditions. Proximal alteration related to the mineralisation is characterised by the formation of the mineral assemblage quartz-carbonate-sericite-albite.

At Levijärvi-Loukinen, higher gold-grade areas consist of quartz-carbonate-sulphide vein networks and breccias. Gold is associated with pyrrhotite, chalcopyrite, pyrite, gersdorffite and arsenopyrite (Riikonen 1997, Holma 2001, Holma et al. 2003). Other detected ore minerals include violarite, pentlandite, argentopentlandite, bismuthinite, cassiterite, sphalerite, galena, ullmannite, hessite, rutile, ilmenite, molybdenite, and native lead, bismuth and gold (Marko Holma pers. comm. 17/11/2003). Native gold, the main carrier of Au, is mainly related to sulpharsenides and pyrite (Holma et al. 2003).

Hand specimen description

Loukinen lode

Sample *Description*

L-1 Distal alteration in metakomatiite. Mineral assemblage talc - Fe dolomite - chlorite.

L-2 Proximal alteration, dominantly brittle deformation and gold mineralisation in low-Cr metakomatiite. Mineral assemblage quartz - Fe dolomite - sericite - pyrite. Auriferous veins: quartz-dolomite.

L-3 Intermediate to proximal alteration, dominantly brittle deformation and gold mineralisation in graphitic phyllite. Mineral assemblage quartz - Fe dolomite - sericite - pyrite - graphite with remains of chlorite(?). Auriferous veins: quartz-dolomite with pyrite and arsenopyrite.

L-4 Intense proximal alteration, dominantly brittle deformation and gold mineralisation in graphitic phyllite. Mineral assemblage quartz - Fe dolomite - sericite - pyrite - graphite with remains of chlorite(?). Auriferous veins: quartz-dolomite with pyrite and arsenopyrite.

L-5 Proximal alteration, dominantly brittle deformation and gold mineralisation in high-Cr metakomatiite. Mineral assemblage quartz - Fe dolomite - fuchsite - pyrite. Auriferous quartz-dolomite veins.

Levijärvi lode *(description by Marko Holma 24/11/2002)*

LEV-1 Typical unaltered mafic metavolcanic rock (Fe-tholeiite), from the footwall of the mineralised shear zone, unaffected by gold-related alteration. Late, frequent, calcite-filled veins in brittle fractures. In places, the veins contain pyrrhotite and minor chalcopyrite, but no gold.

LEV-2 Weakly carbonated, folded, graphitic phyllite, overprinted by brittle deformation. Cracks are filled by fine-grained carbonate and pyrrhotite, frequently following folded schistosity. No gold.

LEV-3 Proximal alteration in graphitic phyllite with mineral assemblage sericite - graphite - chlorite - albite - pyrrhotite - arsenopyrite - leucoxene. Three different types of bands in the host rock: (1) graphite + sericite, (2) albite + carbonate, and (3) chlorite + pyrrhotite. Especially the immediate wall rock against the carbonate-rich vein is chlorite-rich. The vein is about 5 cm wide and contains gersdorffite (NiAsS; large grey crystals in vein margins inside the vein), glaucodot ((Co,Fe)AsS), pyrrhotite, chalcopyrite, pyrite, sphalerite and gold. Gold is associated with sulpharsenides.

LEV-4 Very fine-grained, highly altered, rock with mineral assemblage carbonate-sericite-pyrrhotitechalcopyrite-pentlandite in pale bands and sericite-albite (± quartz) in dark bands. Thin crosscutting veins are dominantly carbonate, but also contain sericite, pyrrhotite and minor chalcopyrite and pentlandite. At least parts of the bedding-parallel carbonate - sericite - pyrrhotite - chalcopyrite - pentlandite bands are related to veins. All pentlandite occurs as flame-like exsolution lamellae in pyrrhotite.

LEV-5 Carbonate - quartz - albite - muscovite - pyrrhotite (partly haematitised) -chalcopyrite veins and brittle deformation. Two types of breccia clasts: (1) fine-grained albite rock (homogeneous, non-banded) and (2) fine-grained banded schist, the latter probably dominated by carbonate and sericite.

LEV-6 Intensely brecciated rock. The dark matrix is probably graphite- and chlorite-rich, whereas the clasts are dominantly quartz-rich. In places, similar breccias are enriched in gold.

Tienpää lode *(description by Marko Holma 24/11/2002)*

TIENP-1 Deformed carbonate vein in carbonated graphitic phyllite. Host rock contains abundant pyrrhotite and lesser chalcopyrite and pyrite. The relationship between the vein and the sulphides is ambiguous, but suggests that at least part of sulphides have been remobilised during post-vein emplacement events.

TIENP-2 Quartz-rich rock containing numerous thin quartz veins. It appears that most, if not all, of local silicification in rocks is spatially related to these deformed quartz veins which seem to predate gold mineralisation. Note also the stylolite structure across the sample indicating pressure solution during deformation.

2.1.8 Ruoppapalo

The Ruoppapalo gold occurrence is 53 km NE from Kittilä. It is in the contact zone between the Ruoppapalo synorogenic granitoid intrusion and mafic metavolcanic country rocks of the intrusion (Lehtonen et al. 1998) and is, apparently, in a subsidiary shear zone of the NE-trending Kuotko Main Shear Zone. The mineralisation was discovered in 1996 by the GTK and is hosted by intermediate dykes (`albitites'), the granitoid and the mafic metavolcanic rocks (Ilkka Härkönen pers. comm. 24/8/1998).

<u>Hand specimen description</u>

Sample *Description*

RUO-1 Carbonated, partially sericitised mafic metavolcanic host rock.

RUO-2 Felsic granophyre dyke, albitised. Altered and weakly sulphidised during gold mineralisation.

2.1.9 Saattopora

The Saattopora Au-Cu deposit is roughly 40 km NW from the town of Kittilä. The deposit was in production in 1988-1995 by Outokumpu Finnmines Oy. Mining started as open pit operation which shifted to underground on 1992. A total of 2.1 Mt ore was mined, with average grades of 3.29 ppm Au and 0.28% Cu (Korvuo 1997). The total production from the mine is 6279 kg Au and 5177 t Cu (Korvuo 1997, Reijo Anttonen pers. comm. 15/02/1998).

The ore is hosted by metasedimentary and metapyroclastic rocks which at Saattopora, due to their mineral assemblage, are commonly called albitites. In addition, komatiitic metavolcanic rocks form a minor host to ore. The ore minerals present are pyrite and pyrrhotite, which are the dominant sulphides, and chalcopyrite, gersdorffite, arsenopyrite, pentlandite, tucholite, uraninite, bismuthinite, niccolite and native gold (Lehtinen 1987a, Hugg 1991, Korvuo 1997). Native gold occurs in a few millimetres to several metres thick quartz- ankerite- dolomite-pyrite-pyrrhotite veins and their immediate, brecciated wallrock, closely associated with quartz and carbonate gangue.

The deposit has a distinct structural control, and is closely associated with the Sirkka Line shear zone which at Saattopora is E-W trending and displays brittle-ductile deformation (Korvuo 1997, Lehtonen et al. 1998, Eilu 1999). The auriferous quartz-carbonate veins have preferentially developed in the most competent rock units in the area, i.e. in the pre-gold mineralisation albitised volcanogenic metasedimentary rocks (tuffite). The veins have a N-S trend and form E-W trending clusters which also define the trend of mineable ore bodies.

To the N and NW, next to the structurally controlled Au-Cu mineralisation, there is a low-grade, syngenetic, Cu-Co mineralisation in graphite phyllites. This was the first mineralisation known in the area: all pre-1984 activity at Saattopora was concentrated on base-metal exploration. The gold mineralisation was found on 1984 by checking for Au grades in previously drilled core which initially was only analysed for base metals and sulphur (Lehtinen 1987a, Hugg 1991, Korvuo 1997).

Hand specimen description

Sampl	*Description*
SAA-1	Distal alteration in metatuffite. Mineral assemblage probably quartz - chlorite albite - calcite. Quartz-calcite veins (white) and brittle deformation related to gold mineralisation.
SAA-2	Intermediate alteration in metatuffite. Mineral assemblage probably quartz - chlorite - albite - Fe-dolomite - calcite - syngenetic pyrrhotite. Quartz-calcite-Fe dolomite veins (brownish where weathered!) and brittle deformation related to gold mineralisation.
SAA-3	Proximal alteration and low-grade ore in albitised metatuffite. Mineral assemblage probably quartz - sericite - albite - Fe dolomite - pyrite - pyrrhotite - chalcopyrite. Auriferous quartz-calcite-Fe dolomite/ankerite-pyrite-pyrrhotite veins related to brittle deformation synchronous with gold mineralisation.
SAA-4	Proximal alteration, intense and multiple, brittle-dominated deformation, and high-grade ore in albitised metatuffite. Mineral assemblage probably quartz - sericite - albite - Fe dolomite/ankerite - pyrite - chalcopyrite. Auriferous quartz-calcite-Fe dolomite/ankerite-pyrite veins difficult to distinguish from the host rock due to deformation.
SAA-5	Syngenetic Cu-Co mineralisation in carbonaceous phyllite. No signs of the lode-gold mineralisation, except, possibly, the brittle deformation and the remobilisation of the early sulphides into carbonate-bearing veins. Mineral assemblage quartz-albite-chlorite ± biotite, sericite, graphite, sulphides; sulphides in host rock and veins are pyrrhotite, chalcopyrite and, probably, gersdorffite and cobaltite (Lehtinen 1987a).
SAA-6	Proximal alteration and typical ore veins. The intensely albitised metatuffite has been a subject to purely brittle deformation, and auriferous quartz-carbonate-sulphides veins have filled the fractures formed.

2.1.10 Sirkka

The Sirkka gold deposit is 2-4 km to the west of the Sirkka village, 20 km NNW from the town of Kittilä. It was detected on 1939. Intermittently since then, it has been an exploration target: by Atri Oy during 1939-1953, Vuoksenniska Oy 1953-1966, Outokumpu Oy 1966-1978, and SES Finland Oy 1997- (Vesanto 1978, Inkinen 1985, Lehtinen 1987b, Alf Björklund pers. comm. 7/8/1998). In 1955-1956, 30,000 tons of ore was mined from the deposit (Räisänen 2001).

The mineralisation comprises, at least, eight distinct lodes within 2 km along the strike of the E-W trending Sirkka Line shear zone. Mineralisation is chiefly hosted by volcanogenic(?) metasedimentary rocks of dominantly intermediate primary composition (Vesanto 1978, Lehtinen 1987b). Metakomatiitic rocks and mafic metalavas form a minor host to the mineralisation. Mineral assemblages detected (Inkinen 1985, Vesanto 1978) indicate that mineralisation took place under mid- or upper-greenschist facies conditions. Main ore minerals at Sirkka are pyrite, pyrrhotite and chalcopyrite. In addition, gersdorffite, pentlandite, Ag pentlandite, sphalerite, mackinawite, violarite, cobaltite, melnikovite and native gold have been detected (Hänninen 1977, Vesanto 1978, Inkinen 1985, Lehtinen 1987b). Native gold chiefly occurs associated with gersdorffite and arsenopyrite (mostly as inclusions) at Sirkka (Hänninen 1977, Vesanto 1978, Inkinen 1985, Lehtinen 1987b).

Hand specimen description

Sample	*Description*
Sirkka-1	Partially sericitised(?) tuffite/phyllite. Mineral assemblage probably quartz - albite - sericite - chlorite ± graphite, pyrrhotite, rutile.
Sirkka-2	Probably, distal alteration in tuffite/phyllite. Abundant quartz-calcite veins.
Sirkka-3	Intensely deformed graphitic phyllite. Main ore minerals present: gersdorffite, pyrrhotite, pyrite and chalcopyrite. Veins: quartz-ankerite/Fe dolomite-sulphides.
Sirkka-4	Quartz-carbonate-sulphide vein. Brittle deformation. Note also the black stylolite structure across the sample indicating pressure solution during deformation.

2.1.11 Soretialehto

The Soretialehto gold occurrence is about 15 km NE from the town of Kittilä and only 400 m to the west from the Hirvilavanmaa occurrence. It is chiefly hosted by intensely altered metakomatiitic pyroclastic(?) rocks; graphitic phyllites and felsic dykes form minor hosts to ore (Keinänen 1994). Proximal alteration is characterised by the mineral assemblage quartz - Fe dolomite - magnesite - pyrite ± fuchsite (Keinänen 1994, Riikonen 1997). The fuchsite-bearing type of altered komatiite is bright-green and has commonly been called "chromean marble" or "green marble" in Finland, although it is not of sedimentary origin. Ultramafic rocks not affected by gold-related alteration have the mineral assemblage talc - chlorite - calcite.

Pyrite is the main ore mineral; other ore minerals detected are chalcopyrite, galena, gersdorffite, ullmannite and native gold; in metakomatiite, also millerite and vaesite, and in phyllite arsenopyrite has been detected (Keinänen & Hulkki 1992, Riikonen 1997). Gold at Soretialehto occurs as inclusions in pyrite and in pyrite grain margins with small chalcopyrite grains (Veikko Keinänen pers. comm. 24/11/1997).

<u>Hand specimen description</u>

Sample	*Description*
SOR-l	Intensely deformed and brecciated, high-grade gold mineralisation. Mineral assemblage: Fe dolomite, ankerite and/or magnesite - quartz - pyrite - rutile- chalcopyrite - gold. Native gold is chiefly present in pyrite grain margins. Abundant, strongly deformed quartz-carbonate-pyrite veins. The occurrence of rutile and a smaller grain size are the best indicators to distinguish host rock fragments from the deformed veins.
SOR-2	Proximal alteration and intense brittle deformation with abundant quartz-carbonate veins in metakomatiite. Mineral assemblage quartz - fuchsite - Fe dolomite - magnesite - pyrite. Veins: quartz-albite-Fe dolomite with minor pyrite.
SOR-3	Proximal alteration and brittle deformation (overprinting ductile deformation) with minor quartz-carbonate veins in metakomatiite. Mineral assemblage mineral assemblage quartz - fuchsite - Fe dolomite - magnesite - pyrite. Veins: quartz-albite-Fe dolomite + minor pyrite.

2.1.12 Soretiavuoma-N

The Soretiavuoma-N occurrence is about 17 km NE from the town of Kittilä and about 2 km NW of the Hirvilavanmaa and Soretialehto, along the strike of the Sirkka Line shear zone. The gold occurrence is chiefly hosted by metakomatiites; tholeiitic metabasalt forms a minor host to ore (Härkönen & Keinänen 1989, Keinänen 1997).

In the area, the least altered metakomatiites have the mineral assemblage talc - chlorite - calcite. Pyrite is the main ore mineral; other ore minerals detected are chalcopyrite, pyrrhotite, arsenopyrite, galena, bismuthinite, violarite, millerite and native gold (Härkönen & Keinänen 1989, Keinänen & Hulkki 1992). Gold at Soretiavuoma-N is chiefly in fractures and as inclusions in pyrite (Härkönen & Keinänen 1989).

<u>Hand specimen description</u>

Sample	*Description*
SVN-1	Intermediate to proximal alteration(?) in metakomatiite. Mineral assemblage probably chlorite - talc - sericite(?) - quartz - albite(?) - Fe dolomite - magnesite - pyrite.
SVN-2	Proximal alteration in metakomatiite. Mineral assemblage probably sericite(?) - quartz - albite(?) – Fe-dolomite - magnesite - pyrite with minor chlorite, talc and fuchsite.

2.1.13 Suurikuusikko

The Suurikuusikko deposit is about 50 km NE from Kittilä. The deposit was discovered on 1986 by the GTK (Härkönen 1992, 1997) and is presently (since 1998) under exploration and feasibility studies by Riddarhyttan Resources AB (Riddarhyttan 2002). The latest resource estimate is 12.7 Mt at 5.1 ppm Au (Riddarhyttan 2003).

The deposit is in the N-S trending, brittle, Suurikuusikko or Kiistala Shear Zone which is gold-mineralised along strike probably for more than 15 km (Härkönen 1992, 1997, Vesa Kortelainen pers. comm. 03/11/2003). Host rock for the mineralisation is carbonaceous phyllite or tuffite of intermediate primary composition (Härkönen and Keinänen 1989). The carbon in the host rocks is not graphite but has an amorphous form. The host rocks belong to the Kautoselkä or Porkonen Formation of the Kittilä Group of the CLGB.

Main ore minerals are arsenopyrite and pyrite, minor ore minerals detected include pyrrhotite, native gold, maldonite and native bismuth (Nurmi et al. 1991). Most (93%) of gold is as `invisible' in the lattice of arsenopyrite (Härkönen 1992, Härkönen et al. 1999, Kojonen & Johanson 1999).

Hand specimen description

Sample	*Description*
SUK-1	`Unaltered' tuffite. A sample off the main shear zone, unaffected by gold-related alteration. Early, albite±pyrite veins.
SUK-2	High-grade ore: intense brecciation and abundant arsenopyrite and pyrite.
SUK-3	Gold mineralisation in totally albitised tuffite/phyllite. Albitisation pre-dates gold mineralisation(?). Abundant pyrite porphyroblasts.

2.1.14 Tuongankuusikko

The Tuongankuusikko gold occurrence is about 28 km east of Kittilä. It is hosted by albitised graphitic phyllite and, locally, by mafic to intermediate metavolcanic rocks (Inkinen 1992). It is, apparently, located at the crossing of the Sirkka Line and a smaller shear or fault zone.

Hand specimen description

Sampl	*Description*
TGK-1	Intermediate(?) alteration in fairly intensely sheared phyllite. Quartz-ankerite/Fe dolomite veins.
TGK-2	Proximal alteration and gold mineralisation in phyllite. Mineral assemblage probably sericite - quartz - albite - Fe dolomite - pyrite - rutile. Quartz-ankerite/Fe dolomite ± pyrite, arsenopyrite veins.
TGK-3	Intensely brecciated, albitised and gold-mineralised phyllite. A larger quartz-carbonate±pyrite, arseno-pyrite vein. Early, white, albite±quartz veins?

2.2 Sodankylä area

2.2.1 Kaaresselkä

The Kaaresselkä gold deposit is 20 km NW from the town of Sodankylä. It comprises several lodes and is hosted by several rock types, chiefly by albitised volcanogenic metasedimentary rocks with an intermediate primary composition, but also by dolerite, metakomatiite, metaconglomerate and quartzite (Eelis Pulkkinen pers. comm. 21/08/1998, Pulkkinen 1998 and 1999). The deposit is, apparently, located in shear zones subsidiary to the Sirkka Line, slightly the south of the Sirkka Line (Nicole Patison, pers. comm. 09/06/2001). Ore minerals so far detected at Kaaresselkä are pyrite, chalcopyrite, Ni arsenide(s) and native gold (Pulkkinen 1998). Gold chiefly occurs in free, native form (locally visible to the naked eye), commonly associated with carbonates; minor volumes of gold is in the lattice of pyrite and chalcopyrite (Pulkkinen 1999).

Gold-related alteration at Kaaresselkä is characterised by biotitisation and carbonation with minor chlorite, sericite, tourmaline, adularia and sulphides. Regional albitisation of variable degree, detected in all rock types, has preceded gold mineralisation. Mineral assemblages suggest that metamorphism and mineralisation took place under upper-greenschist facies PT conditions. Hence, sericite is not common and fuchsite not detected in ultramafic rocks, while biotite is the typical product of K metasomatism related to gold mineralisation.

Hand specimen description

Sample	*Description*
KAA-1	Sulphidised, biotitised tuffite from the main shear zone of the area. Intense, ductile-dominated deformation.
KAA-2	Proximal alteration and gold mineralisation in tuffite from the main shear zone at Kaaresselkä. Mineralassemblage probably biotite - sericite - quartz - Fe dolomite - pyrite - Ni arsenide(s).
KAA-3	Proximal alteration in tuffite from the main shear zone. Mineral assemblage probably biotite - sericite - quartz - albite - Fe dolomite - pyrite - Ni arsenide(s).
KAA-4	Proximal alteration and gold mineralisation in tuffite. Mineral assemblage probably sericite - albite - quartz - Fe dolomite - pyrite - biotite(?). Quartz-Fe dolomite-albite(?)-pyrite veins; visible gold has been detected in these veins.

2.2.2 Koppelokangas

The Koppelokangas gold occurrence, which is also known by the name Rimpelä, is about 35 km NW of Sodankylä. It is hosted by albitised metasedimentary rocks, graphitic phyllite and mafic or intermediate metavolcanic rocks (Eelis Pulkkinen pers. comm. 21/08/1998). Metamorphic grade and the PT conditions of mineralisation are, apparently, at upper-greenschist facies.

Hand specimen description

Sample	*Description*
013860A	Intermediate to proximal(?) alteration in a volcanogenic metasedimentary rock, possibly a crystal tuffite with plagioclase phenocrysts, or a deformed andesitic lava. Mineral assemblage probably albite-chlorite-quartz - sericite - Fe dolomite - rutile - pyrite.

2.2.3 Pahtavaara

The Pahtavaara mine is located 25 km NW from the town of Sodankylä in the eastern central part of the CLGB, within the extensive, predominantly pyroclastic Sattasvaara metakomatiite complex (Korkiakoski 1992). The mine was active in 1996-2000 and was reopened in October 2003. During 1996-2000, total production was 3300 kg gold from the average grade of 4 ppm Au (Heino Alaniska, pers. comm. 1998, 1999, Heikki Vartiainen, pers. comm. 2001). The mine has an open-pit mineable proven reserve of 0.256 Mt @ 2.33 ppm Au, and an underground resource of 1.007 Mt @ 4.82 ppm Au (Scan Mining 2003).

The deposit comprises a set of lodes generally 5-10 m wide, trending roughly NW-SE and dipping to the north at about 70-80° (Korkiakoski & Kilpelä 1997). This and the regional structures suggest that the local control for ore is formed by the location where the NW-trending faults cut across an E-W trending shear zone possibly branching from the SSZ.

Albitisation and part of carbonation may have preceded gold mineralisation, "preparing ground", i.e. making the host rock locally more competent than the surrounding talc-chlorite schist and, hence, a structurally favourable site for the mineralising fluids to precipitate gold. Biotitisation (sample 6), formation of nematoblastic tremolite (samples 3, 7 and 8) and additional carbonation, with formation of abundant quartz veins, [is] most probably related to the syn-peak metamorphic gold mineralisation. Formation of overprinting tremolite porphyroblasts (see sample 1) took place after gold mineralisation at Pahtavaara. Mineralisation probably took place under upper-greenschist facies PT conditions. This relationship between different types of alteration and the gold mineralisation, and of PT conditions of mineralisation is based both on earlier studies (Korkiakoski et al. 1989, Korkiakoski 1992, Korkiakoski and Kilpeläinen 1997) and on visits at the site by the author of this report.

The opaque minerals present at Pahtavaara are magnetite (up to 5-10%, see sample 7), pyrite (on average, 1%), pyrrhotite, chalcopyrite, pentlandite, chromite, ilmenite, rutile, native gold (see sample 8) and rare tellurides. Nearly all gold is free native form, chiefly between silicate, carbonate and baryte grains, but locally also as inclusions in magnetite; minor gold occurs as inclusions in pyrite and chalcopyrite (Kojonen and Johanson 1988, Korkiakoski 1992).

Hand specimen description

Sample	*Description*
Pahtavaaraa-1	Unmineralised metakomatiite with distal alteration related to gold mineralisation or regional carbonation. This sample is laterally about 10 m from the ore. It has a mineral assemblage of talc - chlorite - calcite - tremolite. The tremolite porphyroblasts are black, up to 2 cm long and easy to detect. No primary textures preserved.
Pahtavaaraa-2	Intensely tremolitised ore with minor quartz veins. Note also the abundant, late tremolite porphyroblasts and the very small total volume of sulphides that characterise the gold mineralisation. The quartz veins contain minor amounts of baryte.
Pahtavaaraa-3	High-grade ore: abundant quartz vein material and intensely tremolitised (green) and biotitised (black) host rock.
Pahtavaaraa-4	Unaltered, pyroclastic metakomatiite from the Sattasvaara Group, Pahtavaara. Mineral assemblage: tremolite - talc - dolomite(?) - chlorite. Primary volcaniclastic(?) textures are well preserved.
Pahtavaaraa-5	Similar to sample 1, except no tremolite porphyroblasts or calcite present. Unmineralised metakomatiite with distal alteration related to gold mineralisation or regional carbonation.
Pahtavaaraa-6	Talc-biotite-dolomite/ankerite schist. Typical host rock with minor pyrite dissemination and abundant talc-carbonate veins. Microscopic free gold.
Pahtavaaraa-7	Baryte-ankerite(?) vein with relatively abundant magnetite and minor pyrite. Gold ore. Tremolite-rich wallrock material on margin of the sample.
Pahtavaaraa-8	High-grade ore with visible gold in the vein-wallrock boundary. Intensely tremolitised host rock brecciated by quartz veins. Ankerite (pale brown) and, possibly, baryte (pink) also abundant in the veins. Traces of scheelite present in the quartz veins.

2.2.4 Sattasköngäs

The Sattasköngäs gold occurrence is about 30 km NW from Sodankylä. It is hosted by completely albitised and brecciated graphitic phyllite (Eelis Pulkkinen pers. comm. 21/08/1998).

Hand specimen description

Sample	*Description*
Sattasköngäs	Albitised, intensely brecciated, mineralised graphitic phyllite. Abundant pyrite. Note the intense bleaching of the originally nearly black rock.

2.3 Kolari area

Several magnetite orebodies (ironstone) and skarn-like units of diopside-hornblende rock in the Kolari area of the westernmost Central Lapland greenstone belt host Cu-Au mineralisation (IOCG-class?). All deposits have a structural control and are located in or close to a fault or shear zone. The ironstone bodies are hosted by a supracrustal sequence containing abundant mafic metavolcanic rocks and marbles (calcitic and dolomitic), and are close to, or at the contact with, a ca. 1.86 Ga synorogenic monzonite intrusion (Hiltunen 1982, Lehtonen et al. 1998). Magnetite deposits at Rautuvaara and Hannukainen have been exploited as iron ores, but gold and copper have been extracted only from the Laurinoja ore body at Hannukainen (Hiltunen 1982).

Magnetite contents in the ironstones are typically 20-80%, and that of sulphides at 1-5%. Gangue chiefly comprises diopside and hornblende with minor tremolite-actinolite, albite K-feldspar, scapolite, calcite and quartz. The main sulphide minerals are chalcopyrite, pyrite and pyrrhotite which form dissemination, millimetre-wide veins and weak stockworks. Gold is closely associated with sulphides, particularly chalcopyrite, and occurs in native form (Hiltunen 1982, Niiranen & Eilu 2003).

Early regional, structurally-controlled alteration in nearly all rock types in western Lapland includes weak-to-moderate albitisation and scapolitisation. This Na-Ca alteration is followed by at least two stages of local alteration extending for hundreds of metres to kilometres along strike and tens to hundreds of metres across the strike of the host rocks. The first stage produced magnetite, diopside, titanite and minor iron sulphides in the ironstones surrounded by abundant hornblende, diopside and plagioclase, and minor K feldspar, biotite, garnet, titanite, magnetite and scapolite. In the second stage, most of the sulphides and gold, with hornblende and variable but minor amounts of albite, quartz, calcite, K feldspar, biotite, calcite, talc and epidote, overprint the ironstone. The adjacent granitoids also show the effects of hydrothermal alteration, including formation of albite, quartz, hornblende, epidote, biotite, ± pyrite and chalcopyrite (Tero Niiranen, unpublished data).

2.3.1 Laurinoja

The Laurinoja deposit is the largest known Cu-Au deposit in western Lapland. It is one of the ore bodies of the Hannukainen mine which comprises a set of magnetite rock bodies located in the contact zone between a 1.86 Ga monzonitic pluton and the supracrustal country rocks of the intrusion (Hiltunen 1982).

The Laurinoja deposit is hosted by massive magnetite rock containing 0.1-4 ppm Au and 0.1-2 % Cu. The "best ore" mined comprised 4.6 Mt @ 0.95 ppm Au, 0.88% Cu, and 43 % Fe, but the entire Laurinoja body was 33 Mt in size prior to mining (Hiltunen 1982).

Ore minerals present are magnetite, pyrite, pyrrhotite, chalcopyrite and native gold. The main gangue minerals are diopside and hornblende. Ore mineral assemblages suggest that magnetite precipitation preceded sulphidation and gold mineralisation at Laurinoja.

Hand specimen description

Sample	*Description*
R170 69.85	Magnetite-diopside-chalcopyrite-pyrrhotite-apatite rock. 7.41% S, 2.21% Cu, 1.30 ppm Au.
R170 85.30	Magnetite-diopside-hornblende-chalcopyrite-pyrrhotite rock. Thin pyrite veins. 2.48% S, 1.08% Cu, 0.90 ppm Au.

2.3.2 Cu-Rautuvaara

The Cu-Rautuvaara is one of the orebodies of the Rautuvaara mine, 10 km south of Laurinoja (Hannukainen mine). Its geological setting and mineral assemblages are similar to that at Laurinoja. Cu-Rautuvaara has been drilled but never exploited.

Hand specimen description

Sample	*Description*
CuRl09 227.00	Albite rock (altered diorite or monzonite). K-feldspar - quartz - biotite - albite - magnetite - pyrrhotite - pyrite - chalcopyrite.
CuR109 236.00	Diopside - biotite - magnetite - hornblende - chlorite - chalcopyrite - pyrite. Biotite partially is replaced by chlorite. 0.077 ppm Au, 1.20% Cu, 30% Fe, 3.23% S, 4.8 ppm Se, 0.9 ppm Te.
CuRl09 236.40	Diopside - hornblende - chalcopyrite - biotite - magnetite - pyrite - calcite - chlorite. Biotite is partially replaced by chlorite.

2.4 Kuusamo Schist Belt

The Kuusamo gold occurrences are mainly hosted by the two lowermost, dominantly sedimentary, supracrustal formations (Sericite Quartzite and Siltstone Formation) of the belt. Although the known deposits are preferentially in certain stratigraphic units, the main regional and local control for mineralisation is structure: two roughly SW- to NW-trending antiforms in the middle of the KSB, Hyväniemi-Maaninkavaara and Käylä-Konttiaho anticline, control all gold occurrences. In deposit scale, the main controls for mineralisation are the intersections between antiforms and shear and fault zones and, probably, also the regional Pre-gold albitisation (Pankka 1992, Pankka & Vanhanen 1992). Most of the deposits are strongly elongated along the local shearing lineation. Individual lodes may be controlled by smaller structures; for example, the mineralised pipes at Konttiaho appear to be in hinges of meso-scale folds (J. Ojala, pers. comm. 2001).

Uranium, Fe-sulphide and Au-Co-Cu±U deposits have been discovered in the KSB (Pankka 1992, Pankka & Vanhanen 1992, Korteniemi 1993, Vanhanen 2001). Except for most of the uranium deposits, which belong to the stratiform sandstone type, the deposits are epigenetic. The Au-Co-Cu±U deposits can be divided into two end members based on structural setting: 1) replacement mineralisation (e.g., Juomasuo) in a ductile deformation regime, and 2) breccia mineralisation (e.g., Konttiaho) in a brittle deformation regime (Vanhanen 2001). The Fe-sulphide deposits are essentially comprised of pyrrhotite and pyrite, are weakly enriched in cobalt but lack precious metals or uranium.

Alteration is extensive and multistage in the KSB. The whole belt was affected by the first three main stages of alteration (Vanhanen 2001): 1) Diagenetic, partial albitisation of feldspars and sericitisation of clay minerals in all sedimentary units. 2) Local, partial to total albitisation of clastic sedimentary units and spilitisation of volcanic units when the ca. 2.206 Ga mafic sills and dykes generated fluid circulation near the contacts of the intrusions. 3) The early spilitisation and diagenetic albitisation are overprinted by much more extensive albite and scapolite alteration and variable carbonatisation across the belt. Intensity of the latter alteration varied from weak (<10% albite) to strong, locally resulting in almost pure albite rocks (99% albite + traces of carbonate, rutile, quartz).

In addition to the regional styles of alteration, the sites of structurally controlled fluid flow have been affected by a number of hydrothermal alteration stages of local extent. The best known of such areas are the gold occurrences and their immediate surroundings. Below, we use the Juomasuo and Konttiaho deposits as examples to describe typical alteration directly related to the KSB gold occurrences, as these two are among the most intensely investigated deposits in the belt.

2.4.1 Honkilehto

The Honkilehto gold occurrence is about 26 km NW from Kuusamo. The deposit is hosted by sericite quartzite, metasiltstone and, possibly, mafic metavolcanic rock. Metal association at Honkilehto is Au-Cu-Co and ore minerals reported are pyrite, pyrrhotite, chalcopyrite, Co pentlandite and native gold. (Heikki Pankka, pers. comm. 26/8/1998)

Hand specimen description

Sample	*Description*
Ho-1	Albitised sericite quartzite or metasiltstone.
Ho-2	Gold mineralisation.

2.4.2 Isoaho

The Isoaho gold occurrence is about 35 km N from Kuusamo. The mineralisation is hosted by sericite quartzite (the main host), mafic metatuffite and mafic lava (Vanhanen 1992). Metal association at Isoaho is Au-U and ore minerals reported pyrite are pyrrhotite (Pankka and Vanhanen 1992).

Hand specimen description

Sample	*Description*
Isoaho	Mineralised sericite quartzite. Mineral assemblage probably quartz - albite - sericite - pyrite ± biotite and pyrrhotite.

2.4.3 Juomasuo

The largest known gold deposit in the Kuusamo Schist Belt is Juomasuo which is located about 37 km N of the town of Kuusamo. The mineralisation is hosted by mafic metavolcanic rocks (main host) and sericite quartzite (Pankka 1992). Metal association at Juomasuo is Au-Co-U, main ore minerals pyrite and pyrrhotite, and minor ore minerals Co pentlandite, magnetite, cobaltite, linneaite, chalcopyrite, molybdenite, uraninite, galena, native gold, altaite, calaverite, frohbergite, melonite, rucklidgeite, tellurobismuthinite, mattagamite and kawazulite (Pankka et al. 1991, Pankka 1992, Pankka & Vanhanen 1992, Korteniemi 1993, Pankka 1997).

According to Pankka et al. (1991) and Pankka and Vanhanen (1992), the Juomasuo deposit contains, at least, 0.86 Mt ore at 5.2 ppm Au and 0.15% Co. In this ore, native gold is chiefly associated with Bi and Te minerals as inclusions in pyrite, cobaltite and uraninite, between silicates and in tiny Au-Bi-Te veinlets (Pankka 1992).

Hand specimen description

Sample	*Description*
JUO-1	Albitised sericite quartzite(?), distal to ore. Mineral assemblage quartz - albite - sericite - rutile (Pankka 1992).
MO-2	Proximal alteration in mafic(?) rock. Mineral assemblage sericite - albite - chlorite - quartz - rutile - pyrrhotite ± biotite.
JUO-3	Proximal alteration and gold mineralisation in mafic rock. Mineral assemblage sericite - quartz - albite - chlorite - biotite - carbonate - pyrrhotite - pyrite.
JUO-4	Proximal biotite-rich alteration and gold mineralisation in mafic rock. Mineral assemblage quartz - albite-biotite - carbonate - pyrite ± chlorite, magnetite.

2.4.4 Kantolahti

The Kantolahti gold occurrence is about 32 km NW of Kuusamo. The mineralisation is formed by three distinct lodes hosted by mafic to intermediate tuffites (main hosts) and sericite quartzite (Pankka et al. 1991, Pankka 1992). Metal association at Kantolahti is Au-Co-Cu and ore minerals detected pyrite, pyrrhotite, chalcopyrite, cobaltite, magnetite and native gold (Pankka et al. 1991, Pankka 1992).

Hand specimen description

Sample	*Description*
Kantolahti	Proximal alteration and gold mineralisation in mafic tuff or tuffite. Mineral assemblage probably chlorite - quartz - sericite - pyrrhotite - pyrite. Quartz-calcite veins.

2.4.5 Konttiaho

The Konttiaho gold occurrence is 25 km N of Kuusamo. It is chiefly hosted by sericite quartzite and intermediate(?) tuffite; in addition, dolerites form minor host to the mineralisation (Vanhanen 1991b, Vanhanen 2001). The host rocks were intensely albitised and carbonated and chloritised prior to gold mineralisation. Gold mineralisation-related alteration at Konttiaho includes carbonation, sericitisation, biotitisation and sulphidation (Pankka et al. 1991, Vanhanen 1991b, Pankka & Vanhanen 1992, Vanhanen 2001). The deposit, which was discovered in 1985 by the GTK and is presently held by Polar Mining Oy, is characterised by brittle deformation and comprises at least four distinct lodes (hydrothermal replacement(?) pipes in fold hinges) within an area of 0.5 km (Vanhanen 1991b, 2001).

Hand specimen description

Sampl	*Description*
KON-1	Intensely albitised sericite quartzite with a pervasive haematite dissemination.
KON-2	A sample from the largest, pipe-formed, lode. Chiefly quartz-albite-carbonate breccia fill. The host rock fragments are, probably, intensely altered dolerite with mineral assemblage albite - paragonite - carbonate - pyrite - rutile - remains of chlorite. The best known section across this ore pipe contains a grade of 9 ppm Au for 10 m (Vanhanen 1991b).

2.4.6 Murronmaa

The Murronmaa gold occurrence is about 23 km N from Kuusamo. It is hosted by albitised metasedimentary rocks (conglomerates?) which were brecciated and mineralised, probably, after the albitisation (Vanhanen 1991a, Heikki Pankka, pers. comm. 26/8/1998).

Hand specimen description

Sample	*Description*
Murronmaa	Albitised, brecciated and mineralised metasedimentary rock. Mineral assemblage probably albite - chlorite - quartz - sericite - calcite - rutile - pyrrhotite - pyrite.

2.4.7 Pohjaslampi

The Pohjaslampi gold occurrence is about 35 km N of Kuusamo. It is hosted by intermediate volcanogenic metasedimentary rocks (Korteniemi 1993). Metal association at Pohjaslampi is Au-Cu-U and ore minerals detected are pyrite, pyrrhotite, chalcopyrite and uraninite (Korteniemi 1993, Heikki Pankka, pers. comm. 26/8/1998).

Hand specimen description

Sample	*Description*
Pohjaslampi	Proximal alteration and gold mineralisation in tuffite. Mineral assemblage probably sericite - biotite - chlorite - albite - quartz - calcite - pyrite - pyrrhotite. Quartz veins.

2.4.8 Sakarinkaivulamminsuo

The Sakarinkaivulamminsuo gold occurrence, which is also known by the name Juomasuo II, is about 37 km N of Kuusamo. It is hosted by sericite quartzite. Metal association at Sakarinkaivulamminsuo is Au-Co-Cu and ore minerals detected are pyrrhotite, pyrite and chalcopyrite (Vanhanen 1992, Heikki Pankka, pers. comm. 25/8/1998).

Hand specimen description

Sample	*Description*
SKS-1, -2	Proximal alteration and gold mineralisation in sericite quartzite. Mineral assemblage probably albite - quartz - sericite - biotite - pyrrhotite - pyrite.

2.4.9 Sivakkaharju

The Sivakkaharju gold occurrence is about 27 km N from Kuusamo. It is hosted by sericite-biotite-albite-quartz rock (main host), originally, possibly, a silt-dominated unit in the Sericite Quartzite Formation of the Kuusamo Schist Belt, and by mafic metalava (Vanhanen 1988, Pankka et al. 1991). Metal association at Sivakkaharju is Au-Cu-U ± Co, Mo and ore minerals detected are pyrite, chalcopyrite, molybdenite, Co pentlandite, uraninite, selenides, tellurides, melonite, covellite, bornite and native gold (Vanhanen 1988, Pankka 1992, Pankka et al. 1991).

The known reserves contain 40,000-60,000 ton at about 7 ppm Au (Heikki Pankka, pers. comm. 26/8/1998). Native gold is sited as free grains between silicates, associated with uraninite, and, locally, as inclusions in molybdenite and pyrite, and intergrowths with tellurides, with a grain size of <0.01 mm (Vanhanen 1988, Pankka 1992).

Hand specimen description

Sample	*Description*
Sivakkaharju	Intensely sulphidised “sericite schist”. Mineral assemblage probably sericite - quartz - albite - biotite - pyrite - rutile.

2.5 Peräpohja Schist Belt

Five drilling-indicated gold deposits are known from the Peräpohja Schist Belt (PSB), four of which are orogenic and one, Vähäjoki, is of iron oxide-copper-gold (IOCG) type. The overall control on gold mineralisation is not well known because of scarcity of detailed investigations, but it possibly is the antiform structures and the cross-cutting faults, a situation similar to Kuusamo. All deposits are in rocks metamorphosed under upper-greenschist facies conditions, and all orogenic gold deposits are hosted by metadolerites and have a metal association of Au-Cu.

2.5.1 Kivimaa, Tervola

The Kivimaa Au-Cu deposit is about 15 km N of Tervola and 50 km NE of Kemi. It is hosted by a metamorphosed, 2.2 Ga, dolerite sill (main host) and mafic metavolcanic rocks (Rouhunkoski & Isokangas 1974, Ayräs 1988). Mineral assemblages in the mineralisation and its alteration halo (Rouhunkoski & Isokangas 1974, Lehtinen and Eilu 1987a, Ayräs 1988) indicate formation under upper-greenschist facies PT conditions. The deposit is essentially defined by an E-W trending, 350 m long and 1-6 m wide, auriferous calcite-quartz vein in metadolerite (Rouhunkoski & Isokangas 1974). The vein is in a dip-slip fault and enveloped by an alteration zone that is characterised by the mineral assemblage calcite-chlorite-biotite-albite-pyrite.

Ore minerals detected at Kivimaa are pyrite, magnetite, chalcopyrite, arsenopyrite, pyrrhotite, bismuthinite, native bismuth, native gold, galena and fahlore (Rouhunkoski & Isokangas 1974, Eilu 1987, Lehtinen & Eilu 1987a). Native gold and bismuth occur as inclusions in arsenopyrite.

Production from the deposit (during 1968-69 by Outokumpu Oy) was 16000 ton of ore with (poor) recovery grades at 1.2% Cu and 2 ppm Au (Rouhunkoski & Isokangas 1974).

Hand specimen description

Sample	*Description*
Kivimaa-1, -2	Ore; vein material and altered dolerite. Mineral assemblage in dolerite is albite - biotite - chlorite - calcite - quartz - sulphides (Lehtinen and Eilu 1987a). Quartz-carbonate vein contains minor pyrite and chalcopyrite, and thin slices of intensely altered dolerite.

2.5.2 Petäjävaara, Rovaniemi

The Petäjävaara Au-Cu occurrence, also known by the name Rosvohotu, is about 25 km SW form the city of Rovaniemi, in the Rovaniemi rural municipality. It is hosted by a differentiated dolerite (main host), quartzite and mafic metavolcanic rocks (Sarala & Rossi 1998). The mineralisation is up to 20 m wide and is known to extend for about 1 km along the strike of the hosting shear zone (Seppo Rossi pers. comm. 14/08/1998).

Hand specimen description

Sample	*Description*
Petäjävaara	Mineralised and deformed dolerite or mafic metavolcanic rock. Mineral assemblage probably biotite - albite - quartz - calcite - chlorite(?) - pyrite. Deformed quartz-pyrite veins.

2.5.3 Pukinselkä, Tervola

The Pukinselkä occurrence is about 15 km NNE of Tervola. The mineralisation is, as like as Kivimaa and Vinsa, hosted by a dolerite dyke or sill metamorphosed and altered under upper-greenschist facies PT conditions (Seppo Rossi pers. comm. 14/08/1998, investigations by the author of this report). The dolerite has recently been exploited for railway ballast: part of gold mineralisation used in railway maintenance?

Hand specimen description

Sample	*Description*
Pukinselkä-1, -2	Mineralisation in dolerite. Abundant pyrite, biotite and haematite enveloping the quartz-calcite-pyrite veins.
Pukinselkä-3	Mineralisation in dolerite. Exceptionally pyrite-rich quartz-calcite vein enveloped by biotitisation, pyritisation and haematitisation in the enveloping dolerite.

2.5.4 Vinsa, Rovaniemi

The Vinsa Au-Cu occurrence is about 35 km SW form the city of Rovaniemi, in the Rovaniemi rural municipality. It is hosted by a Fe-tholeiitic dolerite sill and, as interpreted from the mineral assemblages present in the mineralisation and its alteration halo (Eilu 1987, Lehtinen & Eilu 1987b, Ayräs 1991), formed under upper-greenschist facies PT conditions.

Average grade of the mineralisation is estimated at 3 ppm Au and 3% Cu (Rouhunkoski & Isokangas 1974, Ayräs 1998, 1991). The main ore minerals at Vinsa are chalcopyrite, pyrite and pyrrhotite, and minor ore minerals Co pentlandite, sphalerite, mackinawite, tellurobismuthinite, hessite, native bismuth and native gold (Rouhunkoski & Isokangas 1974, Lehtinen & Eilu 1987b, Ayräs 1988).

Hand specimen description

Sample	*Description*
Vinsa-1	Unaltered or distally altered dolerite. Mineral assemblage, if unaltered, albite - actinolite - epidote - quartz ± calcite.
Vinsa-2	Proximal alteration in dolerite. Mineral assemblage probably albite - quartz - biotite - calcite - futile - pyrite ± chlorite.
Vinsa-3	A sample from the main vein: quartz-pyrite-chalcopyrite-pyrrhotite with small, black, fragments of intensely altered wall rock.

3. Deposits in the Svecofennian Domain of Finland

The plate tectonic paradigm has been widely applied in interpreting crustal growth, deformation and metallogenesis in the Svecofennian domain. Northeast-vergent emplacement of ophiolites onto the Karelian craton foreland is inferred to record the initial collision with a Svecofennian oceanic island arc, generating primitive tonalites from a low-K tholeiitic source. Reversal of subduction polarity following collision, or a further arc-arc collision is invoked to explain the most extensive phase of volcanism, magmatism and deformation in southern and western Finland between 1.89-1.86 Ga. (Kähkönen & Nironen 1994, Mänttäri et al. 1997, Patchett & Kouvo 1986, Sorjonen-Ward & Nurmi 1997, Sorjonen-Ward et al. 1997)

Overwhelmingly, the dominant Au mineralisation type in the Svecofennian domain is of orogenic gold type (e.g. Osikonmäki, Laivakangas; Kontoniemi & Nurmi 1998). These deposits have an obvious structural control and show a similar style with those in the Archaean domain and in Lapland. However, a few mineralisations directly related to granitoids, e.g. Kopsa, are present in the central parts of Pohjanmaa, western Finland. They are hosted by synorogenic granitoids and their immediate wallrocks, and commonly have an element assemblage of Au-Cu ± Ag, B, Co, Mo, Sb (Gaal & Isohanni 1979). There are, however, structural indications that they may, in fact, be porphyry-type, low-grade base-metal deposits overprinted by orogenic gold mineralisation. In the Tampere Schist Belt, in southern Finland, and in the south-westernmost Finland, there also are a few gold-only deposits with alteration and certain features of structure suggesting an epithermal origin, e.g. Kutemajärvi (Poutiainen & Grönholm 1996, Peter Sorjonen-Ward pers. comm. 1997, Rosenberg 2000).

3.1 Häme–Tampere region

All of the gold deposits presented in this section are from the Palaeoproterozoic Tampere Schist Belt, the Vammala Migmatite Belt and the Hämeenlinna-Somero Volcanic Belt. The Tampere and Vammala belts evolved in a short time frame at 1.90-1.885 Ga ago: magmatism with widespread mafic to felsic volcanism and felsic to intermediate plutonism in a back-arc and marginal basin to island arc setting was quickly followed by polyphase deformation (Kähkönen & Nironen 1994, Kilpeläinen et al. 1994, Luukkonen 1994).

3.1.1 Haveri, Viljakkala

Four samples are presented from the Haveri deposit which is located in the westernmost part of the Tampere Schist Belt, about 1 km NW from the tiny town of Viljakkala and about 40 km NW from the city of Tampere. The deposit was mined in 1942–1962 by Vuoksenniska Oy, and is presently (2003) under exploration and feasibility study by Baltic Minerals Finland Oy (Mountain Glen Mining & Northern Lion Gold JV). During 1942-1962, 1.5 Mt or ore was mined and about 4.4 t Au and 6000 t Cu produced (Isokangas 1978, Mäkelä 1980, Karvinen 1997). The latest reserve estimate suggests that there still is 6.6 Mt ore @ 3.5 ppm Au, 0.5 % Cu (Vision Gate 2003).

The deposit is in a sequence of submarine mafic lavas and hyaloclastites, possible felsic pyroclastic rocks, cross-cutting felsic porphyries, and mica and black schists (Kähkönen and Nironen 1994). The main host rocks are the hyaloclastites and felsic(?) metavolcanic rocks (Mäkelä 1980, Karvinen 1997). Inter-flow carbonate bands, exhalite layers(?), up to 30 cm wide, are common in the mafic lava and hyaloclastite sequence.

The sulphides were probably deposited from a synvolcanic hydrothermal system forming the pyrrhotite-chalcopyrite mineralisation (Mäkelä 1980, Vaasjoki and Huhma 1987, Karvinen 1997). According to Mäkelä (1980), the deposit is of Cyprus-type. It is unclear, however, if all gold within the mineralisation was introduced during that stage or was there a significant gold input during deformation and metamorphism. All significant structural aspects of the area, especially the details, are clearly not well understood. The host rocks are deformed and metamorphosed under low-amphibolite facies conditions, at about 550°C and 2.5 kbar (Mäkelä 1980). Alteration is characterised by biotitisation and Fe-Mg metasomatism (formation of amphibole and chlorite). In addition, bleached haloes up to 3 cm wide characterise the host rocks around amphibole- and chlorite-filled veins. These alteration features, except biotitisation, are typical for a synvolcanic submarine hydrothermal system. Biotitisation, on the other hand, is typical for lode-gold mineralisation under uppermost-greenschist and lower-amphibolite facies PT conditions (Eilu et al. 1998).

Ore minerals detected at Haveri are: pyrrhotite, pyrite, magnetite, chalcopyrite, cobaltite, sphalerite, gersdorffite, molybdenite, vallerite, hessite, cubanite, tellurides, and native gold. Native gold occurs mainly along grain boundaries of Co and As minerals and as very fine-grained inclusions in cobaltite and larger inclusions in silicates (Mäkelä 1980). According to Glenmore Highlands (1997), gold appears to occur in two settings, high grade (>10 ppm) in siliceous zones of a few metres wide in altered felsic volcanic rocks where Cu content is low (<0.02%), and low grade (2-10 ppm) with sulphides which form irregular masses, stringers and groups of semi-massive to massive lenses along with Cu sulphides with an average Cu content of 0.2-0.35%

<u>Hand specimen (HS) and thin section (TS) descriptions</u>

Sample	*Description*
Haveri Mine Zone -1	Sample from the Mine Zone, i.e. from the old mine area. Pyrite-dominated mineralisation in intensely altered felsic pyroclastite (Karvinen 1997) or originally mafic hyaloclastite (Mäkelä 1980). The slightly weathered band at the other end of the sample is a carbonate exhalite layer(?).
Haveri, Peltosaari-1	Sample from the Peltosaari Zone, about 1 km from the old mine. Pyrrhotite-chalcopyrite mineralisation in mafic, pillowed, metalava.
Haveri, Peltosaari-2	Sample from the Peltosaari Zone. Magnetite-pyrrhotite-chalcopyrite mineralisation in mafic, pillowed, metalava.
Haveri, Peltosaari-3	Sample from the Peltosaari Zone. Pyrrhotite-chalcopyrite mineralisation in mafic, pillowed, metalava. Sulphides have probably precipitated in breccia fractures of the host rock.

3.1.2 Järvenpää, Ylöjärvi

The Järvenpää deposit is hosted by intermediate metavolcanic or volcanogenic metasedimentary rocks (A. Luukkonen et al. 1992, Luukkonen 1994). The deposit is in the western part of the Tampere Schist Belt, in the municipality of Ylöjärvi, about 20 km NW from the city of Tampere. It is 100-300 m from a major shear zone which separates the Central Finland Granite Batholith and the rocks of the schist belt. The sericite-rich alteration enveloping the deposit extends >1 km along strike and 200 m laterally (Esa Sandberg pers. comm. 1997). The host rocks have been metamorphosed under conditions transitional between greenschist and amphibolite facies.

It is suggested here that, as like as for the Kutemajärvi deposit (see below), also the Järvenpää deposit is of metamorphosed epithermal type.

Hand specimen description

Sample	*Description*
Järvenpää-1, -2, -3	Typical sericitised and pyritised mineralisation. Mineral assemblage: quartz - sericite - pyrite - gold.

3.1.3 Jokisivu, Huittinen

The Jokisivu deposit is 7 km SSW from Huittinen, in the western part of the Vammala Migmatite Zone. It is hosted by deformed dioritic rock (Luukkonen 1994), and is reported to contain 0.15 Mt of ore @ 7.8 ppm Au (Dragon Mining 2003). However, The resource estimate above only includes one of the several lodes at Jokisivu, and is open at the depth of 60 m (Dragon Mining 2003).

Ore minerals detected at Jokisivu include pyrrhotite (dominant), ilmenite, arsenopyrite, chalcopyrite, loellingite, sphalerite, pyrite, marcasite, magnetite, galena, native gold, altaite, tsumoite, tellurobismuthinite, rucklidgeite, maldonite, hedleyite, joseite-B, pilsenite, tetradymite, aurostibite, ullmannite, and costibite (Luukkonen 1994). There is chiefly free gold occurring in quartz veins, locally also related to arsenopyrite and tellurides; minor amounts of Au is in aurostibite and tellurides (Luukkonen 1994).

Hand specimen description

Sample	*Description*
JOKI-1	Sulphidised host rock, auriferous quartz vein.
JOKI-2	Sulphidised host rock, abundant auriferous quartz vein material, visible gold(?).

3.1.4 Kaapelinkulma, Valkeakoski

The Kaapelinkulma gold occurrence is 5 km SE from Valkeakoski and 35 km SE from the city of Tampere. It is hosted by a quartz dioritic dyke which forms a large xenolith (megalith) in a synorogenic tonalite intrusion, and is estimated to contain, at least, 0.13 Mt ore at 8.2 ppm Au (Rosenberg 1997). Alteration related to gold mineralisation is characterised by the replacement of hornblende by biotite ± quartz (Petri Rosenberg pers. comm. 15/10/1998). The mineralisation is formed under lower-amphibolite facies PT conditions; ore minerals detected are arsenopyrite, pyrrhotite, chalcopyrite, loellingite, native bismuth and native gold (Rosenberg 1997).

Hand specimen description

Sample	*Description*
Kaapelinkulma -1	Unaltered quartz diorite host rock. Mineral assemblage plagioclase - hornblende - quartz.
Kaapelinkulma -2	Gold mineralisation in quartz diorite. Mineral assemblage plagioclase - biotite - quartz. Auriferous, arsenopyrite-bearing quartz vein.

3.1.5 Kutemajärvi, Orivesi

The Kutemajärvi mine is 35 km ENE from Tampere, in the central part of the Tampere Schist Belt. It is hosted by intermediate metavolcanic or volcanogenic metasedimentary rocks which are characterised by very intense Al-Si alteration (A. Luukkonen et al. 1992, Luukkonen 1994). The gold deposit is formed by a number of subvertical pipes which have a diameter of up to 10-20 m and extent along plunge several hundreds of metres. So far, five pipe-formed lodes (I-V) are found to be large enough to be mined. The Pipe V is the main ore body, and is open at the depth of 1000 m below the present surface (Mäkelä 2002).

Mining at Kutemajärvi started 1994 as open pit development and has then shifted into underground. Ore reserves in early 2001 were 0.414675 Mt at 8.3 ppm Au + 0.067 Mt at 9.9 ppm Au (Heikki Saarnio pers. comm. 14/06/2001). Total production during 1994-2003 was 15640 kg Au (A. Seppänen pers. comm. 23/05/2003).

The mineral assemblages in altered rocks, quartz - pyrophyllite - andalusite, quartz - andalusite, quartz - topaz, quartz, and combinations of these, with very low contents of Ca, Fe, K, Mg and Na (Luukkonen 1994, Poutiainen and Grönholm 1996), are typical for rocks altered in zones of argillic and advanced argillic alteration in synmagmatic, high-sulphidation epithermal systems presently active, e.g., in New Zealand, Yellowstone, and the Solomon Islands (for a review, see, e.g., Berger and Bethke 1986) and metamorphosed after alteration. In these zones of the epithermal systems, nearly all major components are leached from the rock with only Al and Si remaining. When such rocks are metamorphosed, quartz and minerals with a high Al content but very poor in other metals, e.g., pyrophyllite, andalusite, sillimanite and/or topaz, will form.

Ore minerals detected at Kutemajärvi include: pyrite, chalcopyrite, pyrrhotite, sphalerite, galena, calaverite, hessite, sylvanite, petzite, krennerite, tellurobismuth, frohbergite, altaite, melonite, native gold (the main Au carrier), native silver, native tellurium, electrum, native copper, native bismuth (Aulis Kärki, pers. comm. 14/06/2001). In 2000, the Au/Ag in ore was about 9.7/2.3 (Heikki Saarnio, pers. comm. 14/06/2001).

Based on fluid inclusion investigations, Poutiainen and Grönholm (1996) suggest that gold mineralisation at Kutemajärvi was formed under upper greenschist-facies conditions during regional metamorphism at 1.83-1.89 Ga ago. They do not, however, suggest that the host rocks were altered then, but support the hypothesis of synmagmatic epithermal alteration. According to Peter Sorjonen-Ward (pers. comm. 1/10/1997) also the gold mineralisation is epithermal.

Hand specimen description

Sample	*Description*
Piippu V	Several samples from the mine, pipe-formed main ore body V. Mineral assemblage: quartz - pyrophyllite - andalusite - Au-tellurides: all ore minerals visible are tellurides. Au content in the fragments 2-5 ppm, in matrix 20-50 ppm.
Sarvisuo NW	Sample from a small mineralised pipe, about 300 m from the mine. Mineral assemblage: quartz - pyrophyllite - andalusite - Au-tellurides.

3.1.6 Lavajärvi, Ylöjärvi

The Lavajärvi gold occurrence is in the western part of the Tampere Schist Belt, 13 km NW from Ylöjärvi and 25 km NW from the city of Tampere. The occurrence is in the northern margin of the synorogenic Hämeenkyrö Batholith and comprises two main lodes (Kärkkäinen et al. 2003): Pässärinvuori (hosted by granodiorite, in west) and Lepomäki (hosted by felsic metavolcanic rocks, in east).

Auriferous quartz, quartz-tourmaline and tourmaline veins and bleaching around the veins characterise the occurrence. Main ore minerals are pyrite and arsenopyrite, with chalcopyrite, pyrrhotite, sphalerite and native gold occurring in minor to trace amounts. Gold is closely related to arsenopyrite, both in veins and host rock. (Kärkkäinen et al. 2003)

Hand specimen description

Sample	*Description*
LEPO- 1	Sample from the Lepomäki lode, from outcrop surface. Note the tourmaline ± quartz veins and the brittle style of deformation in the felsic metavolcanic host rock.

3.1.7 Liesjärvi, Tammela

The Liesjärvi gold occurrence is in the western part of the Hämeenlinna-Somero (Häme) Volcanic Belt. The host rock is partially silicified porphyric granodiorite. The outcropping part of the mineralisation contains 0.2-6.4 ppm Au, 1-27% As, 0.1-0.5% Cu (analyses from hand samples; Jyrki Liimatainen, pers. comm. 15/07/2002).

Hand specimen description

Sample	*Description*
Pl-JPP-89?	Typical disseminated mineralisation in porphyric host rock. The main ore minerals are arsenopyrite, pyrite or pyrrhotite and chalcopyrite.
LIES-2, -3, -4	Gold-copper mineralisation in granodiorite. More intensely silicified, more chalcopyrite, and less arsenopyrite than in the sample "Pl-JPP-89?".

3.1.8 Satulinmäki, Somero

The Satulinmäki gold occurrence is in the western part of the Hämeenlinna-Somero (Häme) Volcanic Belt, in the northernmost part of the Somero municipality.

Native gold occurs in both quartz veins and in the silicified, tourmalinised and sericitised wallrocks of the veins (Niilo Kärkkäinen, pers. comm. 14/05/2002). The silicified proximal alteration zone is up to 100 m wide and >600 m long at Satulinmäki. It is within a 10 km long, continuous domain of altered and mineralised felsic to intermediate metavolcanic rocks. The main ore mineral is arsenopyrite; magnetite, pyrite, chalcopyrite, scheelite, galena, ilmenite, native gold, maldonite, aurostibite, native antimony, gudmundite, jordanitegeochronite, ulmannite, native bismuth, willyamite, breithauptite, tellurobismuth, klinosafroite-safroite, sillenitevismite, joseite-b are present in minor volumes. Metal association in the mineralisation is Au-As-Sb-S-B-Te-Bi. Most of gold is as inclusions and in grain boundaries of arsenopyrite, typically with Au-bismuth and Au-Sb minerals. Apparently, the mineralisation belongs to the epithermal category and is deformed and metamorphosed at lower- or mid-amphibolite facies PT conditions. (Perälä 2003, Kärkkäinen et al. 2003)

Hand specimen description

Sample	*Description*
SATU- 1	An auriferous quartz-tourmaline vein.
SATU-2	Bleached host rock with abundant tourmaline and a few quartz-tourmaline veins.

3.1.9 Vatanen, Pirkkala

The Vatanen gold occurrence is 10 km SW from the centre of the city of Tampere. It is hosted by a synorogenic granodiorite which locally grades into diorite (Rosenberg 1990). The mineralisation is formed under amphibolite-facies conditions, and ore minerals detected are arsenopyrite, pyrrhotite, pyrite, chalcopyrite, loellingite and native gold (Rosenberg 1990). Gold occurs as inclusions in arsenopyrite.

Hand specimen description

Sample	*Description*
Vatanen	Gold mineralisation in granodiorite. Mineral assemblage probably plagioclase - biotite - quartz with a pervasive arsenopyrite dissemination. Brittle deformation with arsenopyrite-bearing quartz veins.

3.2 Pohjanmaa area

3.2.1 Kopsa, Haapajärvi

The Kopsa deposit is about 4 km WNW from the town of Haapajärvi. It has intermittently been under exploration since 1939. The latest activity in the area has been by Glenmore Highlands Inc. and SES Finland Oy joint venture in the late 1990's to present (2003) (Belvedere Resources 2003). The estimated reserves are, according to Gaal and Isohanni (1979), 25 Mt @ 0.4 ppm Au, 2.3 ppm Ag, and 0.08% Cu.

The deposit is hosted by a late-orogenic tonalite stock which has intruded a Palaeoproterozoic supracrustal sequence near the SW edge of the Raahe-Ladoga Zone (Gaal and Isohanni 1979, Weihed and Mäki 1997). According to Gaal and Isohanni (1979), it is a porphyry-type deposit. According to Peter Sorjonen-Ward (pers. comm. 1/10/1997), the mineralisation has an obvious structural control, however. It is possible that, at Kopsa, there is a low-grade porphyry-Cu mineralisation which has been overprinted by a syn-peak metamorphic lode-gold mineralisation. In any case, there are 1-3 cm wide shear zones throughout the tonalite, and these shear zones contain most of the sulphides visible to the naked eye in outcrop. Significant sulphides also occur disseminated in the host rock. Sulphide-bearing quartz veins occur throughout the tonalite stock, but they are narrow, generally <5 cm wide, and form less than 1-3% of the total volume of rock.

Hand specimen description

Sample	*Description*
Kopsa-1	Kopsa tonalite with a typical cross-cutting, sulphide-bearing shear zone. The mineral assemblage in the host rock is: plagioclase - quartz - biotite - hornblende. Sulphides present are: chalcopyrite, arsenopyrite (the most abundant in this sample), pyrrhotite, loellingite, and possibly cubanite, sphalerite, molybdenite, and gold. There also is a fine-grained sulphide dissemination in the unfoliated host rock beyond the shear zone.
Kopsa-2	A sample from a small, arsenopyrite-bearing quartz vein. This might represent a vein formed during the suggested metamorphic gold mineralisation.

3.2.2 Kurula, Ylivieska

The small Kurula occurrence is 2 km N from the town of Ylivieska. It is characterised by quartz-tourmaline veins and breccia located in a contact zone between a massive mafic metavolcanic rock, probably a metalava, and pyroclastic intermediate metavolcanic rock unit (Csongradi et al. 1983).

Hand specimen description

Sample	*Description*
Kurula- 1	Tourmaline-vein network and local bleaching in the mafic host rock. Low-grade arsenopyrite dissemination.
Kurula-2	Abundant arsenopyrite and fine-grained tourmaline in gold-mineralised mafic host rock.

3.2.3 Laivakangas-N, Raahe

The Laivakangas-N deposit is about 16 km S from the town of Raahe. It is hosted by quartz diorite and mafic metavolcanic rock(s) in a set of parallel, 1-150 cm wide shear zones (Mäkelä and Sandberg 1985). The deposit contains indicated 0.3 Mt @ 3.3 ppm + inferred 0.2 Mt @ 5 ppm + reconnaissance resource 2.5 Mt @ 3 ppm Au (cut off 2 ppm) (Parkkinen 2001).

Mineralisation-related alteration at Laivakangas is characterised by the formation of the assemblage K feldspar - biotite - diopside - plagioclase - quartz - arsenopyrite (Mäkelä and Sandberg 1985, Mäkelä et al. 1988). The present (Dec 2003) holder is Endo Mines Oy and the deposit is under a feasibility study.

Hand specimen description

Sample	*Description*
Laivakangas-N- 1	Altered quartz diorite and auriferous quartz veins. Relatively abundant arsenopyrite.

Laivakangas-N-2	A sample from an auriferous quartz vein in the mafic host rock. A slice of intensely foliated and altered host rock in the margin of the sample.
Laivakangas-N-3	A sample of auriferous quartz veins in quartz diorite. Abundant biotite and diopside in the altered host rock.

3.2.4 Louetjärvi-Kukko, Sievi

This small occurrence is about 11 km W from Sievi. It is in late tourmaline-quartz veins and their immediate wallrocks both containing abundant arsenopyrite. The auriferous veins are 1—5 cm wide and seem to occupy the axial plane of late folds (D2 or D3). The extent of gold mineralisation beyond the veins is only a few cm (Olavi Kontomemi pers. comm. 30/9/1997). The host rock is a banded intermediate metatuffite or a volcanogenic metasedimentary rock.

<u>Hand specimen description</u>

Sample	*Description*
Louetjärvi-Kukko	Wallrock of an auriferous tourmaline-quartz vein. The occurrence of arsenopyrite is the only visible indication of gold mineralisation in this sample.

3.2.5 Oltava, Pyhäjoki

The Oltava gold occurrence is 20 km E from Pyhäjoki and 40 SW from Oulu. It is in a `pocket' formed by dextral faults in the contact between a synorogenic diorite intrusion and mica schist, chiefly hosted by the latter rock type. Ore minerals so far detected are pyrrhotite, pyrite, arsenopyrite, molybdenite, chalcopyrite, loellingite and native gold. (Nikander2001)

<u>Hand specimen description</u>

Sample	*Description*
Oltava-1, -2	Gold mineralisation in a `silicified' mica schist.
Oltava-3	Unaltered(?) mica schist host rock.
Oltava-4	Unaltered(?) diorite host rock.
Oltava-5	High-grade gold mineralisation in `silicified' mica schist. `Silicification' means here the deformed quartz veins. Abundant molybdenite, also arsenopyrite and pyrite present. This sample contains 236 ppm Au.

3.2.6 Pöhlölä, Haapavesi

This gold occurrence is about 20 km W from the town of Haapavesi, about 500 m SW from a NW-striking major (>100 m wide, >100 km long) shear zone. The gold mineralisation is hosted by late, 0.5-10 cm wide quartz veins and their immediate wallrock, intensely deformed granodiorite (Sandberg 1986, Mäkelä et al. 1988, Taipale 2000).

<u>Hand specimen description</u>

Sample	*Description*
Pöhlölä-1,-2,-3	Samples from auriferous, arsenopyrite-bearing, sheared quartz veins.

3.2.7 Vesiperä, Haapavesi

Vesiperä is another small gold occurrence near the NW-striking major (>100 m wide, >100 km long) shear zone about 20 km W from the town of Haapavesi (Weihed and Mäki 1997). In addition to Pöhlölä, other known gold deposits in the area, close to the major shear zone, are: Kiimala, Tiitola, Angesneva and Angeslampi. The Vesiperä deposit is hosted by a hypabyssal gabbro (Taipale 2000). It has ore reserves of 0.3 Mt with 2.5 ppm Au and 0.8% As (Sipilä 1988). Narrow (10-50 cm wide) shear zones with arsenopyrite dissemination and quartz veins are characteristic to the deposit (Taipale 2000). The dominant sulphides are arsenopyrite, pyrrhotite and loellingite. Gold occurs as free grains in silicates and with As and Te minerals. The mineral assemblage of unaltered host rock is: plagioclase - hornblende - biotite - quartz - titanite + locally occurring, retrograde sericite, carbonate, chlorite and epidote (Sipilä 1988, Västi 1991).

<u>Hand specimen description</u>

Sample	*Description*
Vesiperä-1	Typical, intensely sheared, sulphidised and altered host rock from a 30-40 cm wide shear zone associated with the auriferous quartz veins. Mineral assemblage: plagioclase - quartz - biotite - hornblende - titanite - arsenopyrite ± tremolite-actinolite, telluride(s), gold, and, locally, retrograde (= post-gold) epidote, chlorite and sericite. Practically all sulphides are weathered in this sample.

3.3 Savo area

3.3.1 Osikonmäki, Rantasalmi

The Osikonmäki deposit is in southeastern Finland, about 7 km SW from the town of Rantasalmi, in southern Savo. It is within the Raahe-Ladoga Zone, in a conjugate(?), E-W trending smaller shear zone between the major, NW-trending, shear zones. The deposit is hosted by the synorogenic Osikonmäki tonalite. It is pre-peak metamorphic, and has also been slightly modified by late retrograde metamorphism (Kontoniemi 1997). The deposit is in sillimanite-K feldspar metamorphic zone as indicated by the mineral assemblages of the tonalite (Kontoniemi 1998). The retrograde reactions are shown by locally abundant sericite and chlorite.

The total known length of the gold-mineralised part of the ductile Osikonmäki Shear Zone is 3 km. Indicated resource is 0.3 Mt @ 5.5 ppm, inferred 0.1 Mt @ 5 ppm, and a reconnaissance resource 1.0 Mt @ 4 ppm Au (cut off 2 ppm) (Parkkinen 2001). Ore minerals present are arsenopyrite, loellingite, pyrrhotite, chalcopyrite, gold, electrum, and a number of Bi-Se-Te minerals (Kontoniemi et al. 1991).

<u>Hand specimen description</u>

Sample	*Description*
Osikonmäki- I	Typical unaltered, hypidiomorphic tonalite a few metres away from the gold-mineralised shear zone. Mineral assemblage: quartz - plagioclase - biotite - hornblende - diopside.
Osikonmäki-2	Altered and sheared, banded and granoblastic tonalite from the gold-mineralisation. Pervasive, fine-grained arsenopyrite dissemination. Mineral assemblage: quartz - plagioclase - microcline - biotite - arsenopyrite.

3.3.2 Pirilä, Rantasalmi

The Pirilä deposit is about 12 km SW from the town of Rantasalmi, in southern Savo, near to one of the major NW-trending shear zones of the Raahe-Ladoga Zone. It is chiefly hosted by intermediate metavolcanic rocks (Makkonen 1987, Makkonen & Ekdahl 1988). At Pirilä, gold chiefly occurs in deformed quartz veins; gold is detected in those zones of altered wallrock which contain abundant cummingtonite and arsenopyrite (these zones are only detected next to quartz veins) (Olavi Kontoniemi pers. comm. 7/10/1997). Indicated reserves are 0.1 Mt @ 7.5 ppm, inferred 0.2 Mt @ 6 ppm, and a reconnaissance resource 1.0 Mt @ 6 ppm Au (cut off 2 ppm) (Parkkinen 2001).

<u>Hand specimen description</u>

Sample	*Description*
Pirilä- 1	Auriferous quartz vein and intensely altered intermediate metavolcanic rock dominated by cummingtonite; abundant arsenopyrite and some gold in the vein and in the wallrock.
Pirilä-2	Arsenopyrite-poor quartz vein.
Pirilä-3, -4	Arsenopyrite- and gold-rich parts of quartz veins.

4. SWEDEN

4.1 Aitik

The Aitik Au-Cu open pit is 15 km E from the town of Gällivare, in Svecofennian northern Sweden. The mine is operated by Boliden AB and has been in production since 1968. The average grades are 0.2 ppm Au, 0.38% Cu and 4 ppm Ag; production is presently 17 Mt/a and the reserves approximately 250 Mt (Abrahamsson 1997, Abrahamsson & Wulf 1997).

Sulphides occur as dissemination and veinlets in metamorphosed, altered and sheared quartz monzonite (Abrahamsson 1997). During a visit to the site, one can detect that potassic metasomatism (muscovite and biotite) is the dominant features of alteration, but that, locally, the formation of garnet is also characteristic. The dominant sulphides are chalcopyrite, pyrite and pyrrhotite.

Presently, the most popular genetic theory for the mineralisation is that it is a porphyry-copper type deposit. However, the deposit is in a major shear zone and has, hence, an obvious structural control. Open question is, whether or not the deposit is syn-metamorphic, epigenetic. In any case, the deposit is in the NW extension of the NW-SE trending Raahe-Ladoga Zone, also called the "Kiruna-Ladoga Zone" (Abrahamsson 1997), where a number of epigenetic gold deposits have been discovered in Finland.

<u>Hand specimen description</u>

Sample	*Description*
Aitik-1	The dominant ore type. Intense sericitisation, weak sulphide dissemination.
Aitik-2	Ore containing biotite in addition to abundant sericite; exceptionally high sulphide content.

Aitik-3 , -4	More biotite-rich, garnet-bearing ore close to the hangingwall contact.
Aitik, malmi	Biotitised host rock, ore. Mineralisation-related(?) quartz veins. Also, a late zeolite-pyrite vein in the sample margin — ***Handle with care, the zeolites are soft!***

4.2 Pahtohavare

The Pahtohavare deposit is about 8 km SE from the town of Kiruna, in Svecofennian northern Sweden. The mine was operated during 1989-1997 by Viscaria AB (owned by Outokumpu Oy). The total production from open pit and underground operations was 1.69 Mt with 1.89% Cu and 0.88 ppm Au (Martinsson 1997).

The host rocks are so-called albite felses, intensely albitised mafic metatuffites and black schists. Chalcopyrite and pyrite are the dominant ore minerals occurring in microbreccias, veinlets and quartz-carbonate veins (Martinsson 1997). The dominant style of deformation is brittle.

Hand specimen description

Sample	*Description*
Pahtohavare-1	Quartz-carbonate-pyrite veins brecciating mafic metavolcanic rock.
Pahtohavare-2	Sample from a quartz-carbonate-sulphide vein. The carbonate present is Fe-bearing, either ankerite or Fe dolomite.

4.3 Björkdal

The orogenic gold-style Björkdal deposit is in the central part of the Svecofennian (Palaeoproterozoic) Skellefte belt, northern Sweden, in the continuation of the Raahe-Ladoga belt. The mine has been owned and run by Terra Mining AB in 1990's.

The deposit is hosted by a synorogenic granitoid which intrudes a 1900 Ma old supracrustal sequence and consists of a network of quartz veins between two minor shear zones (Broman et al. 1994). An interesting feature at Björkdal is that there is no arsenopyrite in the deposit; there are no indications of As enrichment.

Hand specimen description

Sample	*Description*
Björkdal	Quartz veins in biotitised quartz diorite. Abundant chalcopyrite and pyrite in vein-wallrock contacts and with wallrock fragments in the veins. No calcite.

4.4 Akerberg

Hand specimen description

Sample	*Description*
Akerberg	Minor quartz veins in altered gabbro containing traces of scheelite. Typical, weak sulphidation. No calcite. Orogenic gold mineralisation

4.5 Nautanen, Gällivare

The Nautanen IOCG-style deposit is 15 km to the west of Malmberget. In 1902-1907, about 72,000 t of ore was mined for Cu (Cu at 1-1.5%) (Martinsson & Wanhainen 2000). The present resource estimate is 0.63 Mt @ 2.36% Cu, 1.3 ppm Au and 11 ppm Ag.

The deposit is in a shear zone in a partially volcanogenic metasedimentary rock unit. Main ore minerals are magnetite, pyrite and chalcopyrite. Sphalerite, carrolite, bismuthinite, molybdenite, scheelite, bornite have been detected in minor to trace amounts. Main gangue mineral are K feldspar, garnet, clinopyroxene, biotite and epidote. In addition, sericitisation and tourmalinisation characterise the most intensely sheared parts of mineralisation (Martinsson & Wanhainen 2000)

Hand specimen description

Sample	*Description*
Nauta-1, -2	Chalcopyrite-rich magnetite rock, ore.
Nauta-3	Garnet-clinopyroxene rock

4.6 Jälketkurkkio, Vittangi

The Jälketkurkkio IOCG-style Cu occurrence is about 10 km to the NW of the village of Vittangi. The Cu mineralisation is in "albite felsite" in contact zone between graphitic mica schist and a metadolerite. Elements distinctly enriched in the occurrence include Au, Co, Cu, Na, and S. The main host rock is either dolerite or a felsic intrusive (Martinsson & Wanhainen 2000)

Hand specimen description

Sample	*Description*
Jälket- 1	Albite-rich rock with variable amounts of clinopyroxene, amphibole, magnetite, pyrite, calcite.

4.7 Nunasvaara, Vittangi

The Nunasvaara IOCG-style magnetite occurrence 10 km NW from Vittangi village represents the Fe-rich, sulphide-poor subtype. It is hosted by a mafic sills (Martinsson & Wanhainen 2000).

Hand specimen description

Sample	*Description*
Nunas-1	Coarse-grained hornblende-magnetite rock with minor pyrite, calcite, biotite and sericite.

5. CZECH REPUBLIC, BOHEMIAN MASSIF

5.1 Mokrsko

The Mokrsko gold deposit, 50 km south of Prague, is located in an E-W trending fracture (shear) zone in the contact zone between granodioritic rocks of the Central Bohemian Pluton of Hercynian age (280-360 Ma) and the surrounding, metamorphosed volcano-sedimentary units (Boiron et al. 1995). The average grade of the deposit is 2 ppm Au and the in-situ reserves approximately 100 t Au (Moravek et al. 1989).

The deposit comprises an extensive set of sheeted veins which according to Bouchot et al. (2003) are tension gashes. Alteration related to gold mineralisation is difficult to detect, but comprises of formation of microcline, biotite and chlorite (Cliff and Moravek 1995). The deposit was formed at ca. 339-338 Ma (Bouchot et al. 2003).

Hand specimen description

Sample	*Description*
Mokrsko west	Quartz-dolomite/ankerite veins and altered, carbonated and biotitised wallrock. Arsenopyrite porphyroblasts in the vein-wallrock contact.
Mokrsko east	Quartz vein with intensely altered wallrock fragments. Large arsenopyrite porphyroblasts in the wallrock.

5.2 Petrackova hora

Petrackova hora (Petra Mountain) is a porphyry Au-Mo deposit related to a small granodiorite stock intruded into a sequence of volcanic and sedimentary rocks in the central part of the Bohemian Massif (Stein et al. 1997, 1998). Re-Os ages for molybdenite indicate an age range of 342-345 Ma for mineralisation (Stein et al. 1998). According to Shepherd et al. (2000), Petrackova hora is an orogenic gold deposit formed at about 500-600°C from fluids with salinity varying at 5-35% NaCl eq.

Only weak potassic alteration (formation of K-feldspar) and silicification has been detected; there are, apparently, no indications of phyllic or propylitic alterations at the site (Zacharias et al. 2001). Ore minerals detected in the deposit are pyrite, chalcopyrite, native gold, loellingite, bismuth, arsenopyrite, pyrrhotite. Zacharias et al. (2001) report on distinct pulses of mineralising fluid with each pulse showing a change from high to low salinity, NaCl-$CaC1_2$-KCl fluid.

Hand specimen description

Sample	*Description*
Petrackova Hora *1, 2*	Quartz vein samples; contain tiny arsenopyrite grains and very thin, sericitised slices of wallrock in sample margins. Abundant scheelite forming the thin, white lamellae in the vein quartz.

5.3 Kasperske hory

The Kasperske hory (Casper Mountains) gold deposit is located in the southern Czech Republic. It is a typical epigenetic lode-gold deposit with a structural control probably formed during Hercynian regional metamorphism and deformation in Proterozoic and Lower Palaeozoic gneisses of the Moldanubicum terrane (Stein et al. 1997, 1998). Re-Os ages for molybdenite indicate a Hercynian age, similar to that of Petrackova Hora, 342-345 Ma, for mineralisation (Stein et al. 1998). The mineralisation was formed at 400-500°C and 100-450 MPa, under brittle deformation regime (Durisova et al. 1995).

According to a company geologist (pers. comm. 26/8/1995), the average grade in the Kasperske Hory deposit is 9 ppm Au.

Hand specimen description

Sample	*Description*
Kasperske Hory	Quartz vein; small dolomite/ankerite, arsenopyrite and pyrrhotite grains.

6. FRANCE, MASSIF CENTRAL

6.1 Laurieras

Laurieras is one of the about 20 known Variscan (Hercynian) gold deposits in the Saint Yrieix district (Limousin) in the French Massif Central area. The Laurieras deposit is controlled by a brittle-ductile, NE-trending shear zone, it was formed at ca. 310-305 Ma (Ar-Ar data on sericite), under PT conditions of somewhere between 300-400°C and 1-2 kbar (Bouchot et al. 2000, Nicaud & Floc'h 2000).

The deposit comprises a 200 m long, 2-18 m wide quartz vein with an average grade at 23 ppm Au hosted by paragneiss (Limousin Gneiss) (Bouchot et al. 2000). The host rocks were metamorphosed under upperamphibolite facies conditions significantly before gold mineralisation, at ca. 380 Ma ago (Nicaud & Floc'h 2000).

Hand specimen description

Sample	*Description*
Laurieras-1, -2	Visible gold in banded quartz veins in altered felsic or intermediate gneiss. Pyrite, auriferous arsenopyrite(?) and minor gold in the bleached host rock.
Laurieras-3, -4	Visible gold in intensely silicified host rock and in minor quartz veins

6.2 Moulin de Cheni

Moulin de Cheni is another Saint Yrieix district gold deposits. It is hosted by a Hercynian granite, characterised by quartz veins, formed from fluids with 6-8% NaCl eq. salinity under conditions of 250-300°C and <1 kbar (Vallance et al. 2000) at ca. 310-305 Ma (Bouchot et al. 2000).

The average grade at Moulin de Cheni is 11.9 ppm Au (Bouchot et al. 2000). Main ore minerals are pyrite and arsenopyrite, and sericitisation the typical alteration in the hosting granite (Vallance et al. 2000).

Hand specimen description

Sample	*Description*
Moulin de Cheni-1, -2	Auriferous quartz vein with small fragment of host rock
Moulin de Cheni-3, -4	Pervasively sericitised granitic host rock with sugary, post-gold mineralisation, quartz veins.

7. UKRAINE

7.1 Skelevatske-Magnetitove, Krivoi Rog

The Skelevatske-Magnetitove open pit in the Krivoi Rog greenstone belt, central Ukrainian Shield was visited in 22 September 2002. The Skelevatske-Magnetitove open pit operation is part of the JUGOK mining and processing combinate in the south-central part of an greenstone belt, in the 150 km long Krivoi Rog banded iron formation. There seem not to be any radiometric dating for the supracrustal sequence containing the BIF, but its age is supposed to be 2.3-2.0 Ga (Bobrov et al. 2002). Mineral composition of unaltered BIF varies from magnetite-haematite-quartz to amphibole-chlorite-quartz and biotite-chlorite-quartz (Bobrov et al. 2002).

All the samples described are from orogenic gold occurrences located in the eastern part of the Skelevatske-Magnetitove pit, and hosted by the BIF.

Hand specimen description

Sample	*Description*
JUGOK-1	Sulphide-bearing quartz vein in BIF.
JUGOK-2	Cross-cutting, gold-related quartz veins in BIF. Note the carbonation and sulphidation around the veins.
JUGOK-3	Typical banded BIF with no indications of gold mineralisation or alteration.
JUGOK-4	Folded BIF. Note the difference in behaviour between competent and plastic (non-competent) layers during deformation.

8. MAGADAN REGION, RUSSINA FAR NORTHEAST

The Magadan region gold deposits, in the Yana-Kolyma Belt, Magadan, Russian Far Northeast, were visited and sampled in 20-22 August 2002.

8.1 Natalka

The Natalka deposit is near the mining town of Omtsuk and 300 km to the NW from the city of Magadan, in the Omchanksky gold camp, in the Yana-Kolyma orogenic belt. The belt is Mesozoic collision zone between the Siberian and Kolyma Plates (Goryachev & Edwards 1999).

Natalka was discovered in 1942, has been in production since 1944, and through 1999 has produced 85 t Au (Goryachev & Edwards 1999). Presently (2002), the deposit has reserves of 500 t Au, has an average grade of 4-5 ppm Au, and the mine annually produces 1-1.5 t Au (Chief Mine Geologist Alexander Kodolov, pers. comm. 20/08/2002). The mine at Natalka is itself called Matrosov. The underground mine was, in August 2002, 600 m deep. The entire mineralised zone at the present surface is 5 km long and 450 m wide.

The host rocks, the Permian carbonaceous shales and lithic greywackes, are metamorphosed under prehnite-pumpellyite or lower-greenschist facies PT conditions (Goryachev & Edwards 1999). Possibly, the mineralisation was formed in these conditions, too, and belongs to the slate-belt subtype of the orogenic gold mineralisation category. The deposit is in a major anticlinorum of the region, in the Ayan-Uryakhsky anticlinorum. Style of deformation related to mineralisation is brittle: the deposit is a thoroughly brecciated domain between two major fault zones of Mesozoic age (Belkov et al. 1992). The faults have a normal and a strike-slip component. This breccia has also been described as stockwork typically comprising 1 mm - 3 cm wide quartz veins which form about 5% of the total volume of ore.

Main ore minerals are idiomorphic arsenopyrite and pyrite. In the slate, the gold is generally submicroscopic and occurs in both arsenopyrite and pyrite. In veins, gold is more coarse, and typically is visible to the naked eye. Minor and trace ore minerals detected at Natalka include galena, chalcopyrite, sphalerite, fahlore, bournonite, boulangerite, stibnite, millerite and cobaltite. (Goryachev & Edwards 1999)

The Natalka deposit probably also is the main source for the local placer in the Omtsuk River valley close to the mine. In total, 160 t gold has been extracted from this placer since late 1930's.

<u>Hand specimen description</u>

Sample	*Description*
NAT-1	High-grade ore (8-20 ppm Au). Sugary quartz vein with arsenopyrite, gold and host rock fragments.
NAT-2	Average ore: abundant, narrow, brecciating quartz veins and pervasive arsenopyrite-pyrite dissemination in shale.
NAT-3	Low-grade ore (2-2.5 ppm Au): small volumes of very thin quartz veins in shale.
NAT-4	Weathered ore: quartz-ankerite veins in shale.
NAT-5	Proximal alteration, silicification, sericitisation and carbonation, thin quartz veins, pervasive arseno-pyrite-pyrite dissemination, low-grade(?) gold ore in spessartite (pre-gold lamprophyre).

8.2 Shkolnoe

The Shkolnoe mine is at 61°29'N, 148°59'E, in Magadan oblast, Tenka municipality, 81 km N of the town of Ust-Omtsug, and 320 km NW of the city of Magadan. It is in the Yana-Kolyma orogenic belt, in the Dunskaya gold camp. The belt is Mesozoic collision zone between the Siberian and Kolyma Plates (Goryachev & Edwards 1999).

Shkolnoe (School) was discovered in 1981, by school children in their summer camp in the area. The deposit has been in production since 1985. Annual mining is only 50,000 t of ore at @ 7 ppm Au. Only the upper few hundreds of metres of the deposit is or has been under mining. The deposit crops out at the present surface and is known to extend, at least, to the depth of 600 m (Nikolai Goryachev, pers. comm. 20/08/2002). All known ore reserves are within the zone of permafrost. Annual production is 600 kg Au. Ore is treated by two Knelsons + a hydrocyclone, and the daily production is 3.5-7 kg Au. The mine employs 160 people (Alexander Nasonov, pers. comm. 21/08/2002).

The deposit is hosted by the 150 Ma Burgagy granodiorite stock and sets of felsic to intermediate dykes that have intruded the stock. The stock is 2.6 km^2 in plan at the present surface (Belkov et al. 1992). A 124 Ma mafic dyke cuts across the mineralisation. The auriferous quartz lodes extend to the surrounding metasedimentary country rocks, but pinch out close to the stock. Hence, the metasedimentary rocks apparently do not form any significant host to gold mineralisation. Structurally, the deposit is confined to a wedge-shaped block bounded by three faults of which the 500-1500 m wide Yuzhny Fault Zone (YFZ) forms the main control to mineralisation. The three main ore bodies are in diagonal feathering structures of the YFZ.

Most of the gold is in en echelon, hundreds of metres long quartz veins which are surrounded by carbonated and sericitised host rock. There are three major lodes: the Zapadnaja which is in average 1.7 m wide @ 40 ppm Au, the 1.5 m wide Vostochnaja @ 35 ppm Au, and the 1.4 m wide Promezhutochnoje @ 35 ppm Au. In the 0.5-10 m wide berezites (= the proximal alteration zone) surrounding the quartz lodes, the gold grade varies at 1-5 ppm. In all, 75% of gold is in the main quartz lodes and the rest in narrow quartz-carbonate veinlets and in the proximal alteration zone (berezite). Metals forming a primary geochemical anomaly around the deposit include Ag, As, Au, Sb and W. (Belkov et al. 1992, Sidorov & Volkov 2000)

Main ore minerals are arsenopyrite and pyrite. Minor and trace ore minerals detected include gold, freibergite, boulangerite, molybdenite, sphalerite, chalcopyrite, galena, jamesonite, bournonite, pyrargyrite, stromeyerite and stibnite (Sidorov & Volkov 2000). Ore minerals form 1-3% of the total rock volume. The Au/Ag is about 1. Free native gold is predominant.

Major placer gold deposits occur and have been exploited since 1950's near Shkolnoe, in the valleys of the river Anich.

Hand specimen description

Sample	*Description*
SKO-1	High-grade ore. Sulphide-bearing quartz vein with very thin slices of wall rock.
SKO-2	High-grade ore. Sulphide-bearing quartz vein with fragments of intensely altered wallrock.
SKO-3	High-grade ore. Quartz vein with minor ankerite, visible gold.
SKO-4	Intensely altered host rock (granodiorite), intense sericitisation and sulphidation, low-grade gold ore.

8.3 Vetrenskoe

The Vetrenskoe (Windy) mine is in the Magadan oblast, Tenka municipality, 110 km NNE of the town of Ust-Omtsug, and about 350 km NW of the city of Magadan. It is in the Yana-Kolyma orogenic belt which is a Mesozoic collision zone between the Siberian and Kolyma Plates (Goryachev & Edwards 1999).

The deposit is hosted by Lower-Jurassic carbonaceous shales. Mineralisation is mainly controlled by NW-trending fault zones related to the larger, Pogranichny Fault, and characterised by intense brittle deformation and abundant quartz veins (Belkov et a. 1992). The favoured host to gold is the most carbon-rich shale in the area.

The main ore minerals reported are pyrite, arsenopyrite and native gold. Minor ore minerals include galena, sphalerite, chalcopyrite, pyrrhotite and scheelite. Nearly all gold is free, native and mostly occurs in large quartz veins. Typical alteration in the host rocks is sericitisation associated with a distinct potassium enrichment (Belkov et a. 1992). The metasomatic sericite has an Ar-Ar age of 104-107 Ma.

Mining has been problematic at Vetrenskoe. The following is from personal communications by the chief mine geologist at Vetrenskoe and by Nikolai Goryachev, in 21/08/2002: The first ore reserve estimate was made in 1974 and suggested 24 t Au at the grade of 20 ppm. Mining was only started in 1989, but this company only produced 60 kg of Au in four years. During 1993-97 another company operated the mine and produced 1500 kg Au. Then there was a production break of 5 years. A new company took hold of the deposit and production restarted early 2002; until August this company produced 200 kg and had nearly finished the construction of a new treatment plant. The present production is from open pit where the ore has an average grade of 17 ppm Au.

Hand specimen description

Sample	*Description*
VETR-1	High-grade ore. Sulphide-bearing quartz vein with thin slices of sulphidised and carbonated wallrock (shale).
VETR-2	Intensely brecciated and sulphidised shale. Low-grade ore?

9. UZBEKISTAN

9.1 Introduction

Geological descriptions of the deposits and the outline of the geology of the Central Asia presented here are chiefly directly derived from an excursion guide edited by Shayakubov et al. (1999c).

The late Palaeozoic (Hercynian) fold belt of Tian Shan in Kyrgyzstan and Uzbekistan hosts the major gold deposits of Central Asia. This zone is marked, from N to S, by the juxtaposition of a middle to late Palaeozoic platform sequence, Neoproterozoic to early Palaeozoic oceanic sedimentary and volcanic rocks, and late Palaeozoic melange and ophiolite (Berger et al. 1994). All three sequences are intruded by synorogenic alkaline to calc-alkaline intrusions. Closure of an ocean during the late Palaeozoic (Hercynian) orogeny resulted in southward thrusting of the oceanic and platform sequences over previously (Caledonian orogeny) metamorphosed and deformed oceanic flysch and volcanic rocks. North to the suture zone are remnants of a magmatic arch, which is best exposed in the Chatkal and Kurama Ranges SE of Tashkent. In general, deeper portions of the fore-arch are exposed progressively to the S of the magmatic arch in higher elevations of the Tian Shan and to the W in the Kyzyl Kum Desert (Berger et al. 1994).

According to Shayakubov et al. (1999b, p. 5), bedrock in the central and western Tian Shan is composed of deformed Palaeozoic rocks underlain by a Precambrian basement. In the desert plains, the Palaeozoic formations are overlapped by Mesozoic and Cainozoic, unmetamorphosed, sedimentary cover. The W- to NW-trending late-Hercynian Kyzyl Kum-Alai collisional zone is the principal tectonic unit of the region. This zone extends along the Bukantau-South Fergana ophiolitic suture and separates the passive margin of Palaeotethian Alai-Tajik microcontinent in the south from the active margin of the Baikalian North Kazakhstan-Kyrgyz microcontinent in the north. Note however, that according to Sengör et al. (1993), a set of ophiolites in the Altaid orogenic domain does not, necessarily, indicate a structural marker to delineate former palaeotectonic entities as they do in Himalayan and Alpine–type collision orogens.

The Palaeozoic geological history of the region comprises the following stages (Shayakubov et al. 1999b):

1. Breakdown and pull-apart of Precambrian basement with an opening of the Turkestan palaeo-ocean during middle Ordovician to early Silurian.
2. Subduction and collision during late Silurian and Devonian.
3. Closure of the Turkestan palaeo-ocean during early to middle Carboniferous accompanied by the collision of crustal plates and emplacement of granitic plutons. The destruction of continental crust was shifted southward to the Alai–Tajik microcontinent where riftogenic structures were formed. In the north, the oceanic crust was subducted beneath the North Kazakhstan–Kyrgyz microcontinent with a formation of the Bukantau–Tamdytau–Nuratau island arc and marginal continental volcanic belt including its Beltau–Kurama segment; both contain calc-alkaline extrusive and intrusive rocks.
4. Intense deformation and magmatic activity during middle to late Carboniferous. A new, vast, area of granitic plutons arose in the Zarafshan, Nuratau, and Kyzyl Kum mountains. The Beltau-Kurama volcanic belt continued to evolve.
5. Emplacement of postcollisional granites and development of related hydrothermal mineralisation in late Carboniferous to Permian.

In addition, Shayakubov et al. (1999b) state that:

The early to middle Carboniferous collision resulted in the formation of nappes with lateral displacements measured by a few tens of kilometres, in the doubling of stratigraphic sections and the folding of Palaeozoic sedimentary rocks into extended, E-W trending anticlines and synclines. Postcollisional, NE-trending, faults control the magmatic activity and related Au, Ag, and Cu mineralisation. For example, Muruntau, Amantaitau, Asaukak, Daughyztau, Vysokovoltnoe, and Sarybatyr Au deposits of the western part of the southern Tien Shan are located along the Daughyztau–Muruntau Fault (DAMF). They are related in the Central Kyzyl Kum gold ore belt, which extends for about 150 km along its NE trend.

9.2 Amantaitau–Daughyztau ore field

The gold deposits in the Amantaitau–Daughyztau area are located in the Kyzyl Kum ore district in central Uzbekistan, about 80-90 km south from the mining town of Zarafshan. Deposits were discovered by geochemical exploration. Ore resource in the two major deposits, Amantaitau and Daughyztau, are 9.4 Mt containing 117.7 t Au and 16 t Ag, and 46.2 Mt containing 185.7 t Au and 101 t Ag, respectively. Presently (1999), there are no mining operations. There are good sealed and dirt roads to the deposits and high-voltage electricity lines crossing the area. Shayakubov et al. (1999c)

The gold deposits are hosted by turbiditic metapelites of the middle Ordovician to lower Silurian Besapan Formation (Berger et al. 1994, Zverev et al. 1999). The host rocks, graphitic phyllite, metasiltstone and arkosite, are metamorphosed and deformed under sub- to mid-greenschist facies PT conditions.

The deposits are located close to a major shear zone, the NE-trending Daughyztau–Amantaitau–Muruntau fault (DAMF). Mineralisation is controlled by intersections of NE-trending faults and NW-trending shear zones (Berger et al. 1994, Zverev et al. 1999),In any case, the entire DAMF is anomalous in Au (Yuri Zverev, pers. comm. 28/08/99).

Locally, there are no signs of magmatic activity. However, following the traditional lines of Soviet and Russian ore geological theories, presence of a hidden granitic pluton 3-4 km below Amantaitau and 5 km below and Daughyztau, and a magmatic origin for mineralisation are anticipated by many local geologists working in the area (Shayakubov et al. 1999c). All features of mineralisation suggest that mineralisation in the Amantaitau-Daughyztau area is of orogenic type (Berger et al. 1994, Drew et al. 1996). This explanation was also favoured by Yuri Zverev, the chief exploration geologist in the area (Goskomgeologija, Uzbekistan), on August 1999, contrary to what is presented in the paper by himself and others (Zverev et al. 1999) about the origins of the deposits.

Four alteration-related mineral assemblages are present in the host rocks:

1. Albite + quartz+ chlorite:

   This apparently represents syn-diagenetic albitisation as it only occurs in sandy and silty interlayers and is commonly obliterated by a subsequent regional metamorphism later alterations.
2. Quartz+sericite+chlorite ± ankerite, pyrite, pyrrhotite:

   With "low and high intensity of sericitisation", this probably represents distal or intermediate and proximal alteration, respectively, related to gold mineralisation.
3. Quartz + chlorite + ankerite+calcite+ albite:

   This is very localised alteration around the gold mineralisation-related quartz-carbonate ± sulphide veins. That is, it is the most proximal alteration surrounded by the quartz + sericite + chlorite zones described above. It is associated with intense enrichment in Ag, As and Au, moderate enrichment in Bi, Mn, Sb, and Sr.
4. Quartz+calcite:

   This clearly is a very late event expressed by thin quartz-calcite veinlets cutting across all other textures of the host rocks. It is something you see practically everywhere when greenschist-facies rocks are studied more closely.

9.2.1 Amantaitau deposit

The deposit is a system of subparallel, NW-trending lodes, smoothly curved in plan, dip steeply to the northeast conformably with the host rocks. In all, 12 major lodes have been discovered in the area. Their shape varies from lenticular bodies and veins to flat stratabound zones; *en echelon* arrangement of the lodes is characteristic. NE- and E-W trending major faults, apparently, form boundaries for the entire mineralised domain. The lodes comprise stockworks of quartz-carbonate±pyrite veins. Generally, individual veins are 1-5 mm wide, but there also are up to 2 m wide, laminated, quartz veins. Economic ore has only been discovered within the shear zones (Yuri Zverev, pers. comm. 28/08/99).

Only the gold-arsenopyrite-pyrite assemblage is of economic importance, although the younger silver-rich mineralisation similar to that at the Au-Ag Vysokovoltnoe deposit nearby is traced locally. For example, the Au-Ag mineralisation was detected in the southern part of the Amantaitau deposit, where it is represented by a brecciated gold-arsenopyrite-pyrite ore cemented with quartz and associated with silicified and quartz-sericite altered rocks. The superimposed silver-sulphide-sulphosalt veinlets are closely related to the silicification and carbonation. Average ore at Amantaitau contains 3.7 ppm Ag, 26 ppm Au, 146 ppm As, 38 ppm Sb and 10 ppm Se (Shayakubov et al. 1999c).

<u>Hand specimen description</u>

Sample	*Description*
Amantaitau-1, -5, -6	Small polished samples. Carbonate- and pyrite-rich vein from ore.
Amantaitau-2	Larger sample. Carbonate- and pyrite-rich vein from ore. Textures suggest that the pyrite-rich domains are intensely sulphidised wallrock fragments and slivers in the vein.
Amantaitau-3	Quartz-carbonate veins in sulphidised and proximally altered, graphite-bearing phyllite; probably ore.
Amantaitau-4	Quartz-carbonate veins in bleached and sulphidised metasiltstone, ore? Mineral assemblage in the rock most probably: quartz + sericite + albite + ankerite + pyrite + arsenopyrite.

9.2.2 Daughyztau deposit

The Daughyztau deposit is located 10 km SW from Amantaitau and is controlled by the Daughyztau offset of the DAMF. This offset cuts the folded, flyschoid, carbonaceous metasedimentary host rocks. There has been pilot mining for 1 Mt, but no other mining activity: the test-mined ore is just stockpiled at site (in 1999).

The deposit is hosted by metasilt and metasandstone, and related to the intersection of the NNE-trending Daughyztau fault (part of the DAMF) and ENE-trending Asaukan fault zone, and is located both in the southern limb and axial part of the Daughyztau Anticline. The mineralised zone, 2.5 km long and 100 - 450 m wide, contains *en echelon*-arranged lodes which are a few tens of meters to a few hundreds of meters long and from a few meters to a few tens of meters wide. Each lode is a quartz-vein stockwork. The vertical extent of mineralisation reaches 650 m.

The ore-related alteration is represented by quartz-sericite (outer zone) and sericite-carbonate-pyrite (inner zone) assemblages in the host rock. They are visually recognised due to the bleaching, i.e. the removal of dispersed, black, carbonaceous, graphite-like matter and the replacement of Fe-Mg micas and chlorite by sericite. Thin quartz veinlets with minor albite and scheelite are associated with this style of alteration (Zverev et al. 1999).

Three ore mineral assemblages have been detected at Daughyztau are arsenopyrite-pyrite, sphalerite-fahlore, silver-sulphoantimonite(-boulangerite-antimonite), and the irregular Hg-Au-Te mineral assemblage. Apparently, this also is the order from the earliest to the latest assemblage - Zverev et al. (1999) are quite vague here. The arsenopyrite-pyrite assemblage appears to be the only significant for economic ore; it is represented by dissemination and veinlets in the inner part of the sericite-carbonate-pyrite halo.

<u>Hand specimen description</u>

Sample	*Description*
Daughyztau-1	Quartz-ankerite veins in carbonated and sulphidised, graphite-bearing phyllite or metasiltstone; probably ore.
Daughyztau-2, -3, -4	Small polished samples from ore containing avg. 7 ppm Au. Quartz-ankerite veins in bleached and sulphidised metasiltstone. Mineral assemblage in the rock most probably: quartz + sericite + albite + ankerite + pyrite + arsenopyrite.

9.3 Muruntau

Muruntau is the largest and, by far, the most famous gold deposit in Uzbekistan. It is located 35 km E of Zarafshan (at about 41°31'N, 64°35'E). First indications of ore at Muruntau were discovered on 1931–1932 when visible gold was detected in quartz veins in outcrop by the geologists of the Kyzyl Kum Expedition of the Academy of Sciences of the USSR. However, it was only in 1958 when the first lodes of economic size were delineated, and mining and gold production at site finally started on 1967 (Shayakubov et al. 1999d). The mining town of Zarafshan chiefly serving the Muruntau mine, now home for 50000 people, was built on the 1960's by dissident and criminal convict labour (Vitaly Shatov and Reimar Seltmann, pers. comm. 28/08/1999).

Muruntau is, probably, the largest gold-only deposit in production in Eurasia and one of the largest gold mines in the world. It has produced 1186 t Au during 1967–1995 and the proven reserves on 1995 were estimated at 2230 t Au. During a visit to the mine in 30/08/1999, the open pit was 370 m deep and extended for 3800x2800 m at the present surface. The next phase of the open pit mining is planned for as an extension down to 700 meters. It is, also, inferred that additional 1830 t Au are contained in the deposit at the depth of 700-1500 m below surface (Shayakubov et al. 1999d). There apparently are no plans for underground mining. Annually, about 90 Mt rock is mined of which 22–23 Mt is ore. Average grade of the mill feed is 3 ppm Au (from 1 to 29 ppm), the cut-off grade is 1 ppm and the tailings contain 0.18-0.20 ppm Au; in addition, the Ag content of ore is 0.8-7.2 ppm and W from 3 to 6000 ppm (A. Obraztsov, pers. comm. 30/08/99). The number of employees in the mine and the processing plant is 5000 (numbers from 1999).

The Muruntau ore field is located in the Central Kyzyl Kum desert, in the westernmost part of the Tien Shan formations. The Palaeozoic basement consists of the intensely deformed carbonaceous sedimentary sequence of middle Ordovician to lower Silurian age and the carbonate rocks of middle Devonian to lower Carboniferous (Shayakubov et al. 1999d). The ore field is related to the northern limb of the Taskazgan Anticline and controlled by a branch of the Southern Tamdytau shear zone and the DAMF. The Muruntau deposit proper is hosted by the flyschoid, middle Ordovician to lower Silurian, Besapan Formation (Shayakubov et al. 1999d).

Igneous rocks exposed at the surface near Muruntau are dykes which strike at NE-SW and E-W. Following general sequence of magmatic activity in the Muruntau region has been proposed: (1) rare silicic dykes of early Palaeozoic age; (2) isolated gabbro-diorite stocks at middle Carboniferous; (3) a number of small granodiorite stocks at late Carboniferous, exposed southeast of Muruntau, and suggested to be offsets of the Sardara hidden granitoid pluton; (4) numerous, diverse dykes of Permian age.

Drilling has transsected several granite porphyry and lamprophyric dykes near Muruntau. Dykes are assumed to be related to the Sardara granitoids of late Carboniferous to early Permian age. The K-Ar and Rb-SR ages of granitic rocks is estimated as 260–270 Ma and that of the lamprophyres between 244–386 Ma (Shayakubov et al. 1999d) postdating the peak of regional Caledonian metamorphism and being simultaneous with the Hercynian orogeny (Obraztsov, pers. comm. 30/08/99). Cross-cutting and overprinting relationships clearly show, however, that gold mineralisation postdates the intrusion of the dykes.

The Silurian greenschist-facies metamorphism in the southern Tamdytau and, in particular, in the Muruntau ore field is related to Caledonian orogeny. The K-Ar age of metamorphism is within a range of 410-440 Ma (Kostitsyn 1996).

Muruntau is, essentially, a large set of stockwork lodes. The mineralisation is within a halo of biotite-orthoclase-albite-quartz alteration, which is most intense in metasiltstone, less obvious in metasandstone, and least distinctly developed in metapelite (Shayakubov et al. 1999d). The biotite-potassic feldspar-quartz alteration affects the entire volume of deposit forming an up to 800 m thick body, which extends from the NW to the SE for, at least, 4 km and is 2 km wide.

Roughly E-W trending faults (often defined as shear zones) are main ore-related structures. Displacements along the Southern Fault characterise it as a combination of reversed-sinistral strike-slip fault; vertical displacement is about 500 m and lateral displacement more than 1000 m. The northeastern faults are favourable for potassic alteration and silicification. The Northeastern Fault extends across the central part of the Muruntau deposit (Shayakubov et al. 1999d). Thick, E-W trending, extension fractures filled with Au-rich quartz veins, here referred to as axial veins, reveal spatial and, likely, genetic relations to the Northeastern Fault. They are extensively developed at the surface in the central part of the deposit, where *en echelon*-arranged veined domains are located in cores of narrow anticlines (Shayakubov et al. 1999d). The maximum thickness of these veins is 14 m. One stockwork, 40–100 m wide, has been traced down from the surface for 500 m.

The metal association is Au-As-Bi-W; enrichment of Sb and Ag are less characteristic. Bulk ore at Muruntau contains 7.3 ppm Au, 0.8 ppm Ag, 689 ppm As, 10.2 ppm Co, 32.5 ppm Cu, 10.0 ppm Mo, 13.6 ppm Pb, 8.0 ppm Sb, 17 ppm Sn, 9.6 ppm Th, 8.9 ppm U, 50 ppm W, and 66 ppm Zn. (Shayakubov et al. 1999d)

About ore mineral 90 species have been detected: native gold, scheelite, pyrite, and arsenopyrite are major ore minerals; pyrrhotite, marcasite, chalcopyrite, molybdenite, galena, sphalerite, and Bi minerals are of subordinate importance. Main gangue minerals are quartz, feldspar, and biotite; tourmaline, actinolite, hornblende, muscovite, apatite, and carbonates are much less abundant. Commonly, Bi and Se tellurides are closely associated with native gold. In sulphide-rich parts, gold commonly occurs as submicroscopic inclusions in sulphides, but elsewhere the native, free gold dominates.

Hand specimen description

Sample	*Description*
MUR- 1	Silicified and/or K-feldspar altered and weakly sulphidised metasedimentary rock. From the intermediate or proximal alteration zone, with subeconomic Au mineralisation.
MUR-2	Stockwork ore. Quartz veins brecciate the exceptionally intensely sulphidised metasedimentary host rock which is intensely bleached.

Note the increase in the degree of bleaching when approaching the veins and, also, that certain lamina are more easily bleached than others. The most proximal subzone of alteration is intensely sericitised, whereas biotite and brown colour characterise the rest of the proximal alteration. Mineral assemblage in the host rock probably: quartz + K feldspar + sericite + biotite + pyrite.

MUR-3 Stockwork ore. Quartz veins brecciate the weakly sulphidised metasedimentary host rock. Mineral assemblage in the host rock probably: quartz + K feldspar + sericite + pyrite.

MUR-4 Sample from a central vein of a stockwork ore. This quartz vein is approx. 10 m wide; it is the same vein as represented samples MUR-5 and -6. The sample also contains intensely sulphidised slices of wallrock. This is high-grade ore, and the dominant ore mineral present is arsenopyrite.

MUR-5 Sample from the same central vein as MUR-4 and -6, from stockwork ore containing a few idiomorphic arsenopyrite grains. High-grade ore.

MUR-6 Sample from a central vein as MUR-4 and -5, from stockwork ore containing idiomorphic pyrite. High-grade ore.

MUR-7 A piece of polished drill core from typical ore between the quartz-vein rich stockworks. Thin quartz-sulphide veins brecciate the sedimentary host rock containing beds of dark-grey phyllite and pale-grey metasiltstone. Although the rock is altered, bleaching and other features of alteration are difficult to detect. This is a typical feature for a fine-grained metasedimentary host rock, practically anywhere, hosting a mesothermal gold mineralisation.

MUR-8 Brecciated, high-grade ore. Exceptionally high sulphide content in veins. Host: bleached sedimentary rock (turbidite?).

9.4 Almalyk and Saukbulak ore fields

Almalyk and Saukbulak ore fields are in the Chatkal–Kurama ore district, SE Uzbekistan. Its significance is predominantly defined by large porphyry-copper deposits, but it also contains base-metal and epithermal gold deposits. The Almalyk and Saukbulak ore fields are in the magmatic arc north of the WNW-trending suture zone (Berger et al. 1994).

Proven reserves in three porphyry deposits, Kalmakyr (Table 1), Dalnee, and Sarycheku, are 22 Mt of Cu; 57.4% of this is in Dalnee, 40% in Kalmakyr, and 2.6% in Sarycheku. In 1996, the deposits were estimated to contain 2000 t Au, 12,500 t Ag, 229,000 t Mo, 13200 t Se, 1000 t Te, and 566 t Re. The potential resource in waste dumps and tailings of mines and processing plants amount to hundreds of Mt. In particular, about 130 Mt of 'ore' (chiefly <0.2% Cu) remain in dumps, including 13 Mt of oxidised ore with 0.5–0.6% Cu. The tailings occupy an area of 4 x 2 km near Almalyk, and their mass reaches 450 Mt. Shayakubov et al. (1999a)

Table 1. Principal characteristics of ores at Kalmakyr (after Shayakubov et al. 1999a).

Ore	**Characteristics**	
Primary sulphide	*Grade, %:*	
	Cu	0.54
	Mo	0.0051
	S (sulphide)	1.81
	Ore mineral content, %:	
	Pyrite	2.40
	Chalcopyrite	1.46
	Total amount of sulphide ore, %	96
	Pyrite I chalcopyrite ratio	1.64
	Major ore minerals	Chalcopyrite, pyrite, magnetite
	Major gangue minerals	Quartz, anhydrite
	Subordinate ore minerals	Fahlore, galena, sphalerite, haematite
Secondary sulphide	Cu grade, %	1.50
	Total amount of secondary ore, %	1.50 3.0
	Major ore minerals	Chalcocite, cuprite, bornite, covellite, malachite
Oxidised	Cu grade, %	0.86
	Total amount of oxidised ore, %	1.0
	Major ore minerals	Malachite, azurite, chrysocolla, Cu-halloysite, ehlite, libethenite

In the area, Ordovician and Silurian clastic metasedimentary rocks of are overlain by lower Devonian volcanic rocks which are followed by the carbonate sequence of middle Devonian to lower Carboniferous and then by upper Palaeozoic sedimentary and volcanic rocks. In addition, Mesozoic and Cainozoic sediments occur locally (Shayakubov et al. 1999a). Widespread Hercynian intrusive magmatism is represented by older monzonite, gabbro and diorite, younger granitoids of the Kurama batholith, minor porphyry intrusions (granodiorite porphyry is most abundant rock) and numerous and diverse late dykes.

Ore is mainly hosted by the plutonic rocks which are related to the large Almalyk monzonitic pluton extending far beyond the deposits Shayakubov et al. (1999a). The Cu mineralisation is controlled by both the porphyry stocks and by the ENE-trending faults. The steeply dipping Karabulak, Kalmakyr, and Burgundy faults are clearly expressed as zones of intense deformation and hydrothermal alteration. The Kalmakyr and Burgundy faults dip southward while the Karabulak Fault dips in opposite direction at upper levels and changes the inclination with depth becoming parallel to the above faults.

9.4.1 Kalmakyr deposit

The Kalmakyr deposit is located 3 km SE from the Almalyk town. First indications on ore mineralisation were detected on 1925-1927. Exploration started on 1931 and periodically continued until 1996. The total economic reserves are estimated at 2000 Mt of ore above the cut-off grade of 0.2% Cu and 1500 Mt of mineralisation at 0.15-0.19% Cu (Shayakubov et al. 1999a). The deposit has been under active open-pit mining since 1954 and >4 Mt of Cu has been produced during this time.

In 02/09/1999, the open pit was 3750 m long, 2000 m wide and 660 m deep. Bench height in the pit was 15.0-22.5 m, and the annual mining was 27 Mt of ore.

The Kalmakyr deposit is located south of the Kalmakyr Fault and extends towards the Burgundy Fault. The main volume of this tectonic block is occupied by the monzonite, although remnants of Devonian volcanic rocks and carbonate rocks are locally preserved (Shayakubov et al. 1999a). The distribution of ore is controlled by the morphology of porphyry stocks and dykes and by linear fracture zones related to the Kalmakyr and Karabulak faults. As a result, the mineralised stockwork is a cone surrounding the quartz-monzonite porphyry; its lower part extends towards the monzonite. The most intense fracturing and high-grade ore are related to intersections of the contact of the porphyry stock and the E-W and NE-trending faults.

Being located around a porphyry intrusion, the ore stockwork extends farther to the southeast. The shape of the entire stockwork is, roughly, an overturned cup. The horizontal dimensions of the stockwork are 3520x1430 m; the maximum vertical extent is 1240 m. The inner zone of high-grade ore is substantially smaller: 1740x500 m with the maximum vertical thickness of 450 m. The barren core is confined to the porphyry stock.

Primary ore contains 0.54% Cu, 0.05% Mo, 0.5 ppm Au, 3 ppm Ag, 1.5-2.0% S and some Se, Te, Re, Bi, and In. Gold shows a fairly good positive correlation with Cu. Hence, chalcopyrite is regarded as the main concentrator of gold (Shayakubov et al. 1999a). Native gold occurs as inclusions in chalcopyrite. The contribution of pyrite-related gold is insignificant. In the central part of the deposit and at deeper levels, the Au-bearing mineralisations contoured by 0.4 and 0.6 ppm Au almost completely coincide with Cu orebodies. At flanks, Au enrichment forms a wide halo enveloping the Cu ore.

<u>Hand specimen description</u>

Sample	*Description*
Kalmakyr-1	Typical ore and proximal alteration of porphyry-type mineralisation. Apparently, multiple stages of brecciation Veins: quartz - pyrite - chalcopyrite - gold - molybdenite. Possibly, also the late zeolite - anhydrite veins. Host rock (quartz-monzonite porphyry?): quartz + sericite + calcite + magnetite + anhydrite(?) + remains of plagioclase + traces of haematite.
Kalmakyr-2	Typical ore and proximal alteration of porphyry-type mineralisation. Apparently, multiple stages of brecciation; note, also, the sulphide-filled veins

9. 5 Kochbulak–Kairagach ore field

The Kochbulak–Kairagach epithermal ore field is related to the Kochbulak–Kairagach (Karatash) caldera which is located at the intersection of the Southern Angren and Lashkerek–Dukent faults (Islamov et al. 1999). The caldera is filled with middle to upper Carboniferous andesites and dacites, and upper Carboniferous to lower Triassic rhyolites and associated subvolcanic intrusions. Ore deposits are confined to the northern flank of the caldera close to the Shaugaz Fault.

Numerous K-Ar, Ar-Ar, and Rb-Sr datings (Islamov et al. 1999) indicate that mineralisation at Kochbulak peaked during 280-290 Ma. The Pb-isotope composition in pyrite, galena, and altaite, as well as the Sr-isotope composition in feldspars and whole rock samples suggest a mixed mantle-crustal source of ore-bearing hydrothermal solutions.

9.5.1 Kochbulak deposit

The Kochbulak deposit is 15 km south of town of Angren. The deposit was discovered in 1960 (Islamov et al. 1999). According to Islamov et al. (1999), the potential resources at Kochbulak are estimated as 120 t of Au and 400 t of Ag. The developed reserves are 5.6 Mt of ore at 74.9 t Au, and 330 t Ag. The ore contains 13.4 ppm Au, 120 ppm Ag, 0.2% Cu, 4 ppm Se, 101.6 ppm Te, and 100 ppm Bi. The deposit is opened for mining down to the depth of 550 m (in 1999).

The deposit is hosted by andesitic to dacitic lavas, lahars, debris flows and lacustrine tuffaceous sedimentary rocks. Berger et al. (1994) consider it not as a caldera sequence but to be related to a central-vent, constructional andesitic-dacitic volcanic edifice.

The lodes are concentrated within the area of near-vent facies of the middle to late Carboniferous stratovolcano rimmed by subvolcanic intrusions. About 120 lodes have been detected. The pipe-like lodes, which are composed of mineralised explosion breccia, terminate steeply dipping veins related to N-S trending faults. Flat lodes are located at intersections of these faults with interformational detachments. A few tens of meters apart from the intersections, the detachments are accompanied by zones of quartz veinlets and silicification with low-grade sulphide mineralisation (Islamov et al. 1999). The explosion pipes are traced downward 400 m below the present surface and pass into steep veins at lower levels.

The most intense early chlorite - epidote alteration is related to fault zones. Hallow-seated pipe-like lodes are accompanied with intense silicification and formation of variable amounts of sericite, alunite and diaspore (Islamov et al. 1999). In the Russian literature, such an alteration product is commonly referred to as a 'secondary quartzite'. Regular, zoned, sequences of altered rocks are formed near the steeply dipping, veined lodes and conjugated flat lodes. The sequence of alteration zoning is: lode, hydrosericite zone, adularia-sericite zone, chlorite-carbonate zone, unaltered wallrock (Islamov et al. 1999). All altered rocks contain pyrite (from 10% in the chlorite-carbonate zone to 30% in the hydrosericite zone).

The mineral assemblages in the altered rocks, especially the abundant presence of adularia, alunite and diaspore, suggest that the deposit belongs to the type of low-sulphidation (= adularia-sericite) epithermal mineralisation (c.f., Sillitoe 1993, Hedenquist et al. 1996).

Massive, banded, brecciated, incrustate, festoony structures and their combinations are typical for the Kochbulak ore (Islamov et al. 1999). The dominant gangue mineral is quartz (coarse-grained, metacolloidal, chalcedony-like, amethyst-like, drusy). Carbonates and baryte are of subordinate importance and chiefly postdate the Au-Ag mineralisation. The bulk sulphide content in steep and flat orebodies does not exceed 10% but, with Sb, Bi, Sn sulphosalts and tellurides, reaches 20% in the pipes. Three gold-related ore-mineral assemblages are present (from early to late): gold-pyrite, gold-polysulphide, and gold-telluride (Islamov et al. 1999). Due to the telescoping superposition of mineral assemblages formed at different stages of mineralisation, all three ore-mineral assemblages are often spatially combined.

The specific feature of the ore mineralogy is the great abundance of tellurides. Their diversity is especially attractive in the pipe-like lodes, where the grain size of tellurides may reach up to a few centimetres. In addition to the above-mentioned Au and Ag tellurides, small amounts of coloradoite (HgTe), melonite ($NiTe_2$), frohbergite ($FeTe_2$), and weissite (Cu_2Te) have been reported. On the other hand, goldfieldite is among major ore minerals in the pipe-like lodes. All lodes, especially the pipes, contain Sn minerals, mainly cassiterite. In addition, mawsonite ($Cu_6Fe_2SnS_8$), kuramite (Cu_2CuSnS_4), and mokhite (Cu_2SnS_3) have been detected, and chatkalite ($Cu_6FeSn_2S_8$), kesterite (Cu_2ZnSnS_4), chemusite (Cu_6MoSnS_8), and stannoidite ($Cu_2Fe_3Sn_2S_{12}$) occur in steep veins and flat lodes. (Islamov et al. 1999)

<u>Hand specimen description</u>

Sample	*Description*
KOB-1	Intensely sulphidised host rock, ore. Mineral assemblage in the host rock (andesite or dacite) probably: quartz + sericite + adularia + pyrite.
KOB-2	Intensely and multiply(?) sulphidised, multiply brecciated host rock, ore. Sample is from a hydrothermal breccia zone. Mineral assemblage in the host rock (andesite or dacite) probably: quartz + sericite + adularia + pyrite.
KOB-3	Brecciated and sulphidised host rock, ore. Mineral assemblage in the host rock (andesite or dacite) probably: quartz + sericite + adularia + pyrite.

10. SOUTH AFRICA

10.1 Western Deeps

The gold mineralisation is hosted by gently dipping Archaean conglomerates (Haslett 1994, Frimmel 1998, Phillips and Law 1997). There are two alternative hypotheses for explaining the formation of the Witwatersrand gold deposits.

1) All or most of gold, as well as pyrite and uraninite, was originally deposited as placers in probably braided river systems. Gold was later mobilised, in a very local scale, within some millimetres to centimetres, during sub- or low-greenschist facies regional metamorphism somewhere between 2600 and 2020 Ma (Frimmel et al. 1993, Frimmel 1997, Groves et al. 2003).

2) All gold is hydrothermal in origin, deposited by a regional metasomatism extending far into the Witwatersrand basin, and gold was precipitated as a consequence of interactions of the fluid with shale-derived hydrocarbons and Fe in detrital oxides present within the basin (Barnicoat et al. 1997, Phillips and Law 1997). This took place between 2.7 and 2.6 Ga, possibly related to a super-continent break-up (Phillips and Law 1997). In addition, there is practically no relationship between U and Au: U is from percolating oxidised surface waters and deposited by chemical precipitation due to reduction by hydrocarbon-rich rocks (Phillips and Law 1997).

<u>Hand specimen description</u>

Sample	*Description*
Western Deeps	Gold-mineralised conglomerate from the Main Zone. Approximately 2600 m below the present surface. Mineral assemblage is quartz-pyrite-chlorite-sericite-gold-zircon. Note the roundness of many of the pyrite clasts. Gold occurs with pyrite grains in the matrix.

10.2 Fairwiew

The Fairwiew mine is one of the oldest and largest gold producers within the Barberton greenstone belt, South Africa. It is located in Eastern Transvaal (Mpumalanga), about 280 km E of Johannesburg. Most of the mineralisation, which is structurally controlled, is hosted by the Fig Tree Group greywackes and shales which have been metamorphosed and altered under greenschist facies PT conditions (Wigget et al. 1986). The alteration sequence related to gold mineralisation is formed by distal quartz-carbonate, intermediate fuchsite-quartzcarbonate, and proximal sericite-quartz-sulphides zones. Pyrite and arsenopyrite are the dominant sulphides. According to de Ronde et al. (1992), the age of mineralisation is between 3126±21 and 3084±18 Ma.

<u>Hand specimen descriptions</u>

Sample	*Description*
F-2	Sulphidised, massive metasedimentary rock hosting ore.
F-3	Green, non-mineralised, serpentinite ultramafic wallrock from a minor shear zone.

10.3 Renco

The Renco gold mine is located in central SE part of Zimbabwe, in the NW flank of the NE part of the Limpopo mobile belt. It is hosted by granulite-facies felsic, intermediate and mafic rocks which probably are sedimentary and volcanic in their origin (Böhmke and Varndell 1986). According to data in Böhmke and Varndell (1986), the relationship between metamorphism and mineralisation is unclear. According to Blekinsop and Frei (1996), the age of the enderbitic host rock is 2.57 Ga (U-Pb zircon age); they also suggest that the mineralisation formed at greenschist facies PT conditions at about 2.0 Ga (as deduced from cooling of biotite of 1.88 Ga Rb-Sr age). According to Kolb & Meyer (2002), gold mineralisation is slightly post-peak metamorphic and took place at about 680°C (i.e., under higher-amphibolite facies conditions).

<u>Hand specimen description</u>

Sample	*Description*
Renco	Felsic, sulphidised, brecciated granulite hosting ore. Mineral assemblage: quartz - orthoclase - plagioclase - calcite - pyrrhotite - chalcopyrite - arsenopyrite.

11. CANADA

11.1 Wawa

The Wawa Subprovince forms part of the Archaean Superior Province in the Canadian Shield. A number of gold mineralisations and showings occur in the BIFs and other rock types within the subprovince. The samples on display are from a gold showing in BIF outcrops near the northern shore of Lake Superior. The regional metamorphic PT conditions are at greenschist-amphibolite facies transition.

<u>Hand specimen descriptions</u>

Sample	*Description*
12216	Auriferous quartz vein in BIF. Visible gold in vein margin or selvage with biotite and chlorite.
12217	Auriferous quartz vein with abundant altered wall rock slivers. The wall rock is oxide-facies BIF. Visible gold the quartz vein. The sample is slightly weathered.

AUSTRALIA

12. Ultramafic host rocks

12.1 Phar Lap

One hand specimen is on display from the Phar Lap gold deposit, which is located about 35 km south of Meekatharra, in the Murchison Greenstone Belt. The main host rock is metakomatiite, and albititic dykes, cross-cutting the ultramafic rocks, form minor host to ore. `Unaltered' komatiite is talc-chlorite±carbonate rock (Jackson 1990). The host rocks are metamorphosed and altered under sub-greenschist facies PT conditions (<290°C, Jackson 1990). The major ore mineral is the deposit is pyrite; other opaques detected are tetrahedrite, gersdorffite and native gold (Jackson 1990).

Hand specimen description

Sample	*Description*
Phar Lap	Metakomatiite from proximal alteration zone. Mineral assemblage (Jackson 1990): fuchsite (green) - quartz (grey) - magnesite (white) - rutile (yellow-brown) - pyrite ± Fe dolomite. The host rock is brecciated by quartz-carbonate ± pyrite veins.

12.2 Kerringal

One hand specimen is on display from the Kerringal deposit, which is located approximately 50 km SSE from Laverton, in the north eastern part of the Eastern Goldfields Province. The main host rock is metakomatiite. Mafic rock, probably basaltic lava, also acts as a minor host to ore. The host rocks are metamorphosed and altered under low- or mid greenschist facies PT conditions. `Unaltered' komatiite is talc-chlorite schist. Proximal alteration in the ultramafic host rock is characterised by the mineral assemblage of fuchsite-magnesite-quartz. Gold mineralisation is related to quartz vein stockwork.

Hand specimen description

Sample	*Description*
KERRINGAL	Ultramafic host rock with proximal alteration, quartz-carbonate veins and intense brittle-ductile deformation. Partially weathered sample: most of sulphides and carbonates are weathered. However, the green colour of the proximal alteration zone, due to presence of fuchsite, is preserved.

12.3 Sunrise Dam—Cleo

The Sunrise Dam-Cleo gold deposit is 55 km south of Laverton, about 2 km NE from Lake Carey, in the Eastern Goldfields Province of Western Australia, at lat. 29°05'S, long. 122°25'E. The deposit is divided by a tenement boundary to an eastern part (Sunrise Dam) owned by the Granny Smith Joint Venture (GSJV) and a western part (Cleo) owned by Acacia Resources Ltd (as 31/12/1998).

Gold mineralisation at Cleo is hosted by a sequence dominated by volcanogenic sedimentary rocks (Eilu 1998, Newton et al. 1998b). Other rock types present in the sequence are ultramafic rocks (komatiites), intermediate dolerites (and possibly lavas of similar composition), banded iron formation (BIF) interbedded with intermediate tuffites or tuffs (the latter are also called as magnetite tuffites), and felsic porphyries. All of these rock types may host ore, but the major hosts are intermediate volcanogenic sedimentary rocks and BIF.

Gold mineralisation is in two parallel, gently NW-dipping brittle-ductile shear zones, the Upper Shear Zone (USZ) and the Sunrise Shear Zone (SSZ), and in brittle fracture zones between the USZ and SSZ and below the SSZ. The most significant brittle fracture zone-host for gold is the steeply NW-dipping, 1-20 m wide Western Shear Zone (WSZ) which is located between the USZ and SSZ.

Wallrock alteration is pervasive and intense throughout all the gold-mineralised shear zones detected in the area, and alteration extends laterally for more than 100-200 m from the main shear zones. The alteration haloes around individual mineralised structures overlap resulting in complex alteration patterns which are further complicated by the variation in primary lithology. However, the paragenetic alteration sequence is distinct and the main alteration zones are the same in all rocks and around all mineralised structures. The main zones are, from the most distal to the most proximal: the calcite-chlorite, ankerite-calcite-chlorite, ankerite-chlorite±sericite and ankerite-sericite zones.

Hand specimen description

Sample	*Description*
CD218 334.5	Intermediate alteration in komatiite. Mineral assemblage talc - ankerite - chlorite - magnetitechromite. Brecciated by ankerite-quartz veins.
CD215 314.9	Proximal alteration in intensely deformed komatiite from the SSZ. Mineral assemblage fuchsite (green) - ankerite - quartz + minor pyrite; no magnetite or chromite left. Brecciated by ankeritequartz veins containing minor pyrite and telluride(s).
CD272 130.8	Proximal alteration, part of a komatiite clast in intensely deformed conglomerate from the USZ. Mineral assemblage fuchsite (green) - ankerite - quartz + minor pyrite and arsenopyrite.

12.4 Crown and Mararoa, Norseman

A set of three samples from the Crown and Mararoa deposits at Norseman, at the southern end of the Norseman-Wiluna greenstone belt, are on display. According to Mueller (1990a) and McCuaig et al. (1993), the Crown and Mararoa deposits are hosted in mafic and ultramafic metavolcanic rocks metamorphosed and altered under low-amphibolite facies PT conditions.

The alteration sequence in mafic rocks ranges from the unaltered assemblage of hornblende + actinolite + plagioclase + ilmenite, through to distal hornblende + actinolite + biotite + plagioclase + ilmenite, intermediate biotite + quartz + actinolite + plagioclase + pyrrhotite + ilmenite, and proximal actinolite + quartz + calcite + pyrite + rutile mineral assemblage (McCuaig et al. 1993). Alteration in ultramafic rocks is characterised by carbonation and the formation of the mineral assemblage actinolitic hornblende + biotite + quartz + calcite + plagioclase in proximal alteration zones (Mueller 1990a).

Hand specimen descriptions

Sample	*Description*
109615	Ultramafic host rock with proximal alteration + quartz veins from the Crown deposit. Pod of pyrrhotiterich wallrock enclosed in laminated quartz reef.
109618	Laminated quartz vein with minor amounts of galena, sphalerite, gold and Pb-Bi-Ag tellurides. Crown deposit. Intensely altered ultramafic host rock present at the other end of the sample.
109624	Proximal alteration in metabasalt. North Royal Shaft. Foliation parallel quartz veins. Arsenopyrite, pyrite and scheelite in the host rock and veins.

12.5 Redeemer

The Redeemer gold deposit is in the Agnew area in the Norseman-Wiluna greenstone belt, near the contact between greenstone belt and surrounding granitoids. It is chiefly hosted by ultramafic volcanogenic conglomerates which are intensely foliated and altered into biotite-tremolite rock within and close to the mineralisation.

Hand specimen descriptions:

Sample	*Description*
R-1	Gold mineralisation in ultramafic volcanogenic metaconglomerate. Biotite, tremolite, pyrrhotite and arsenopyrite.
R-2	Proximal alteration in ultramafic volcanogenic metaconglomerate. Mineral assemblage: tremolite, biotite and talc with minor quartz, ilmenite, rutile, scheelite, pyrrhotite and chalcopyrite.

12.6 Marvel Loch

According to Brabham and Johnson (1995) and Mueller (1995), the gold mineralisation in Marvel Loch, approximately 40 km SE from Southern Cross, is chiefly hosted by ultramafic metavolcanic rocks. Mafic metavolcanic rocks and dolerites also form minor hosts to ore. The host rocks have been metamorphosed and altered under mid-amphibolite facies PT conditions. Unaltered ultramafic rocks have a mineral hornblende + cummingtonite + chlorite + ilmenite + chromite mineral assemblage and mafic rocks have a hornblende + plagioclase + quartz + ilmenite mineral assemblage.

The alteration sequence in ultramafic rocks comprise of the distal tremolite-chlorite-olivine-phlogopite, intermediate diopside-tremolite-phlogopite and proximal quartz-tremolite-phlogopite-talc-calcite-dolomitediopside assemblages. Proximal alteration in mafic host rocks is characterised by a quartz-plagioclase-K-feldsparhornblende-biotite-diopside mineral assemblage. Arsenopyrite, pyrrhotite and pyrite are the dominant sulphide minerals related to the ore.

Hand specimen descriptions:

Sample	*Description*
108125	Ultramafic(?) host rock. According to Mueller (1995): `banded amphibole-biotite-quartz rock with pyrrhotite, arsenopyrite, scheelite and gold'. Minor scheelite in veins.
ML-1	Komatiite-hosted lode. Mainly quartz and diopside. Minor scheelite in veins.
ML-4	Komatiite. Quartz-diopside veins with minor scheelite, and proximal tremolite- phlogopite-pyrrhotite-arsenopyrite-calcite alteration.
ML-5	Komatiite. Boudinaged quartz-diopside veins with minor scheelite, and proximal tremolite-phlogopite-calcite alteration overprinted by retrograde chloritisation and, possibly, formation of fuchsite.

ML-6 Komatiite. Proximal tremolite-phlogopite-talc-arsenopyrite-pyrrhotite-calcite alteration and intermediate tremolite alteration with minor sulphides. Minor scheelite in veins.

ML-8 Komatiite. Folded tremolite-rich and diopside- and pyrrhotite-bearing band in phlogopite-altered rock. Minor scheelite in veins.

12.7 Fraser's

The major host rocks at the Fraser's gold deposit, Southern Cross, are komatiitic metavolcanic rocks. Metabasalts, metapelitic schists, feldspar-phyric granitoid and BIF form minor host rocks to the ore (Bloem 1994, Hay 1995). The host rocks have been metamorphosed and altered under mid-amphibolite facies PT conditions. Mineralisation is located in the Fraser's-Corinthia Shear Zone, which is 20-80 m wide, at least 20 km long and has a NW-SE trend (Hay 1995). Average Au content is 7 ppm, but best ore blocks may contain up to 220 ppm.

Unaltered BIF displays a grunerite + anthophyllite + quartz + magnetite mineral assemblage. During alteration, this assemblage is replaced by grunerite + anthophyllite + quartz + pyrrhotite ± chalcopyrite. Some remnant magnetite occurs within the altered BIF.

Unaltered komatiite has a tremolite + anthophyllite + talc + serpentine + biotite + epidote + magnetite + ilmenite mineral assemblage. During alteration, this assemblage is replaced by: 1) distal assemblage: tremolite + anthophyllite + talc + phlogopite + epidote + pyrrhotite + ilmenite ± calcite, 2) intermediate assemblage: talc + phlogopite + pyrrhotite + tremolite or calcite, anthophyllite and ilmenite, and 3) proximal assemblage: phlogopite + diopside or calcite + titanite + pyrrhotite + chlorite and scheelite (Bloem 1994). Intermediate and proximal alteration zones are commonly very restricted: Each zone is normally $^{<1}$ cm in width. The total lateral extent of the alteration halo around individual lodes is 2-10 m. The presence of plagioclase in the mafic rocks is the only apparent difference in alteration between mafic and ultramafic host rocks (Hay 1995).

The majority of the gold occurs as coarse grains of free gold and associated with sulphides, and is commonly visible to naked eye (Hay 1995). Free gold is commonly associated with the thin tremolite-actinolite selvages of the quartz veins.

Hand specimen descriptions

Sample *Description*

F-4 Ore in komatiite. Quartz veins with tremolite selvages and proximal diopside-tremolite-phlogopite-pyrrhotite alteration. Minor scheelite in the host rock.

13. Mafic host rocks

13.1 Bulletin

A set of hand specimens and polished thin sections from the Bulletin deposit and associated wallrocks are on display.

Bulletin is one of the Wiluna lode-gold deposits. It is in the northernmost part of the Norseman-Wiluna greenstone belt, approximately 5 km SE of the town of Wiluna. The mineralisation is hosted by tholeiitic lavas that have been metamorphosed and altered under sub-greenschist facies PT conditions (Hagemann 1992, Hagemann et al. 1992, 1994). Pillowed and massive lavas commonly host ore and occur within the alteration halo around the deposit.

Four major alteration zones, each varying from 2 cm to 50 m in width, occur at Bulletin. These are the distal chlorite-calcite, intermediate calcite-dolomite, proximal sericite and dolomite-sericite zones (Eilu 1996a, Chanter et al. 1997). In some areas, there is no dolomite in the alteration sequence, resulting in distal chlorite-calcite and proximal sericite alteration zones. All dolomite is Fe-bearing. XRD-analyses have not indicated ankerite as a major mineral at Bulletin. The chemical compositions of the host rocks are presented in Table 2.

Hand specimen descriptions

Sample *Description*

WD 138 180.66 Unaltered, fine-grained, pillow lava.
Mineral assemblage: actinolite-albite-epidote-titanite-chlorite-pyrite. Texture: pillow interiors are massive, intergranular to spherulitic; actinolite-rich pillow margins; inter-pillow matrix comprises epidote, chlorite, actinolite, quartz, calcite and pyrite. Veins: black chlorite-dominated and yellow-green epidote-dominated, both related to the early sub-seafloor alteration (spilitisation), as like as the mineral assemblage in the inter-pillow matrix.

WD 117 714.75 Distal alteration, epidote and titanite present, pillow lava.
Mineral assemblage: chlorite-calcite-albite-epidote-titanite-pyrite. Texture: pillow interiors are massive, intergranular to spherulitic; actinolite-rich pillow margins; inter-pillow matrix comprises epidote, quartz, calcite, chlorite and pyrite, formed during early sub-seafloor alteration (spilitisation). Veins: quartz-epidote, related to spilitisation; quartz-calcite, later.

WD 126 308.45 Distal alteration, epidote and titanite present, pillow lava.
Mineral assemblage: chlorite-calcite-albite-epidote-titanite-pyrite. Texture: massive, small plagioclase microphenocrysts and completely chloritised clinopyroxene and olivine(?) microphenocrysts, amygdales filled by epidote and plagioclase-chlorite-calcite. Veins: epidote- chlorite, related to the

early sub-seafloor alteration; quartz-calcite ± pyrite, later, gold mineralisation-related(?). Alteration: olivine and clinopyroxene completely replaced by chlorite + calcite, plagioclase replaced by albite + epidote, epidote partially replaced by chlorite + calcite.

WD 138 132.68 Distal alteration, epidote and titanite not present, massive lava.
Mineral assemblage: chlorite-calcite-albite-quartz-rutile-pyrite. Texture: massive, intergranular to granoblastic. Veins: quartz-calcite ± pyrite, chlorite.

WD126 464.86 Proximal sericite alteration, calcite absent.
Mineral assemblage: chlorite-sericite-dolomite-albite-quartz-rutile-pyrite. Texture: foliated, lepido-granoblastic. Veins: chlorite ± quartz, early; quartz-dolomite ± pyrite, late.

WD126 378.34 Proximal dolomite-sericite alteration. Gold content approx. 16 ppm.
Mineral assemblage: sericite-dolomite-albite-quartz-rutile-pyrite-arsenopyrite-telluride(?). Texture: foliated and brecciated, lepido-granoblastic, pyrite and arsenopyrite are idioblastic; up to 2 mm long rutile clusters suggest originally medium-grained rock. Alteration: chlorite and calcite are completely replaced by dolomite and quartz; albite is partially replaced by sericite + quartz.

Table 2. Bulletin, median chemical compositions of the alteration zones. Data from Eilu (1996a).

Alteration Zone	Unaltered rock	Distal		Intermed	Sericite		Dolomite-sericite
		Epidote Present	Epidote absent		Dolomite absent	Calcite and dolomite present	
SiO_2	49.4	46.9	46.0	44.3	46.4	45.0	41.2
TiO_2	1.06	1.04	0.96	1.01	0.92	0.93	0.75
Al_2O_3	13.65	13.50	12.60	13.00	11.95	12.40	11.00
Fe_2O_3*	13.88	12.86	11.91	12.75	12.00	12.09	10.97
MnO	0.22	0.21	0.19	0.19	0.18	0.19	0.17
MgO	6.46	5.30	5.45	5.15	5.34	5.71	4.65
CaO	9.52	9.90	10.12	9.64	9.20	8.63	11.67
Na_2O	2.11	2.15	2.11	1.77	0.45	0.57	0.95
K_2O	0.13	0.09	0.18	0.33	0.69	0.66	**1.00**
P_2O_5	0.09	0.08	0.08	0.08	0.08	0.07	0.04
LOI	3.20	9.01	9.84	11.59	9.29	12.06	**13.48**
sum	99.7	101.0	99.4	99.7	96.5	98.3	95.9
S	0.109	0.076	0.150	0.145	0.365	0.310	**3.570**
CO_2	0.73	6.23	7.26	8.18	7.17	9.57	**13.79**
Au	0.7	5.8	3.5	11	269	167	**5000**
Te	13	12	10	16	33	56	**930**
Ag	0.05	0.06	0.04	0.03	0.10	0.16	0.22
Se	0.41	0.39	0.38	0.23	0.21	0.35	0.25
Sb	3.3	5.2	3.1	7.8	7.7	6.0	**25.4**
As	56	97	76	148	341	305	**19200**
Bi	0.01	0.01	0.01	0.01	0.01	0.01	0.02
W	0.2	0.2	1.1	1.4	6.5	5.6	12.0
Rb	6.0	5.3	8.1	13.4	26.1	21.6	**40.6**
Ba	43	31	26	32	41	49	**104**
Sr	138	117	79	81	75	77	105
Pb	5	2	2	2	2.5	2	4
Cu	158	152	146	139	145	132	108
Zn	117	114	110	105	99	100	63
Ni	112	116	106	108	103	105	100
Nb	3.5	3.1	3.0	3.1	2.9	2.8	2.4
Y	27.8	24.2	21.1	11.5	13.1	10.9	**10.6**
V	263	273	255	257	251	252	231
Cr	147	137	126	133	125	130	119
Zr	70	64	62	64	58	60	47

Major components, LOI, CO_2 and S in weight-%, trace elements in ppm, except Au and Te in ppb. Analytical methods: major oxides, Cr and Zr by XRF; CO_2 and S by Leco; LOI by gravity; Au, Te, Ag, Se, As and Bi by GAAS; V by ICPOES and the other trace elements by ICPMS.
* total Fe as Fe_2O_3

13.2 Golden Kilometre

The Golden Kilometre deposit is located in the Mt. Pleasant area, 40 km NW from Kalgoorlie. It is hosted by a Fe-rich granophyre in a layered gabbro sill which has been metamorphosed under lower-greenschist facies PT conditions and altered under sub-greenschist PT conditions (Gebre-Mariam 1994). Unaltered rock has the mineral assemblage actinolite + albite + quartz + ilmenite + magnetite, distal alteration is characterised by chlorite + ankerite + albite + quartz + ilmenite + magnetite, intermediate alteration zone by ankerite + sericite + quartz + albite + ilmenite (Witt et al. 1997), while the proximal alteration assemblage is described below.

Hand specimen descriptions

Sample	*Description*
GK001	Quartz-carbonate breccia and proximal alteration in the host rock. Mineral assemblage present in the host rock: albite - quartz - sericite - ankerite - pyrite - rutile - arsenopyrite(- pyrrhotite in outer proximal areas).

13.3 Racetrack

The Racetrack gold deposit is hosted by porphyritic basalt of the Ora Banda Sequence in the Mt. Pleasant area, close to Golden Kilometre. Host rocks have been metamorphosed and altered at sub-greenschist to lowergreenschist facies PT conditions (Gebre-Mariam et al. 1993).

Hand specimen descriptions

Sample	*Description*
RT	Quartz breccia with mineralised fragments of host rock. Ore minerals: pyrite, arsenopyrite, tetrahedrite and freibergite. White, thin, cross-cutting, post-mineralisation(?) quartz-carbonate veins.

13.4 Mt. Charlotte

Mineralisation at Mt. Charlotte, Kalgoorlie, comprises a series of broadly stratabound vein arrays that form pipe-like to irregular orebodies situated predominantly within the footwalls of major dextral faults. Veins include coarsely crystalline to massive quartz, scheelite, ankerite and sulphide minerals along with late calcite and chlorite. Vein walls are commonly overgrown by early selvages dominated by albite, rare sericite, ankerite, pyrite, scheelite and quartz. These veins are enveloped by alteration haloes that can extend up to 3-4 m from the quartz veins. Gold is commonly associated with pyrite and, to a lesser extent, pyrrhotite within the innermost bleached proximal alteration zones within these haloes. Free gold in quartz veins represents a relatively minor percentage of total gold grade. Mikucki and Heinrich (1993)

Mapping has shown that there are three distinct types of alteration haloes present at Mt. Charlotte based on differences in the sequence of mineralogical zoning. Alteration halo types are clearly zoned at the mine scale, with zones of contrasting alteration types surrounding the veins forming a series of concentric shells. Pyrrhotiterich, Type II & III alteration haloes dominate the deeper and more central portions of the orebodies whereas pyrite-only, Type I alteration haloes form the peripheral edges and shallow levels of the ores. Mikucki and Heinrich (1993)

Hand specimen descriptions

Sample	*Description*
Type III	Proximal type III alteration around pyrite-quartz veins. Mineral assemblage: albite-quartz-ankerite-pyrite-muscovite-rutile.

13.5 Golden Mile

Most of the gold mineralisation at Golden Mile, Kalgoorlie, is hosted by the tholeiitic, differentiated, Golden Mile Dolerite sill (GMD) (Phillips et al. 1996). Rocks are metamorphosed and altered under low- or midgreenschist facies conditions (e.g. Phillips 1990). Immediately below the GMD, the Paringa Basalt sequence and the interflow metasedimentary units near the basalt-dolerite contact also form significant hosts to ore. Three major styles of mineralisation occur at Golden Mile: the Charlotte (described in section 5.2.5), Golden Mile and Oroya style.

The Golden Mile-style is pyrite-gold mineralisation within steeply dipping shear zones which are confined mainly to the GMD, but, in places, extend into the Paring Basalt. The mineralised structures typically consist of a siliceous pyritic core with variable amounts of quartz±ankerite veining. All economically significant mineralisation is in this pyritic zone with the diagnostic mineral assemblage of ankerite-sericite-pyrite. Surrounding the pyritic core is a carbonate zone (ankerite ± siderite) without pyrite, commonly termed bleached dolerite. The periphery of the mineralised structure is marked by a broad, unbleached, chlorite-calcite alteration halo. Unaltered host rock is typified by the mineral assemblage actinolite-albite.

Oroya-style mineralisation is developed at the closure of the Brownhill syncline. It occurs mainly in shear or breccia zones in Paringa Basalt adjacent to carbonaceous metasedimentary rocks on the GMD-Paringa Basalt contact, but is also present in flat-lying faults on the GMD-Paringa Basalt contact or within the GMD. Mineralisation is characterised by a complex mineralogy, including quartz, ankerite, muscovite, V- and Ti-bearing minerals, chalcopyrite, sphalerite, arsenopyrite, pyrrhotite, pyrite, anhydrite, haematite, gold and tellurides.

Hand specimen description

Golden Mile-style

Sample	*Description*
94464	Perseverance mine, 10110 south drive. Strongly silicified lode material with pyritic and bleached Golden Mile Dolerite unit 7 (GMD7).
94470	Perseverance mine, 355 south drive. Sample shows transition from unbleached through partially bleached (pale green) to strongly bleached (pinkish) GMD7. This transition reflects the change in mineral assemblage from albite-quartz-chlorite-ankerite-rutile-pyrite to albite-quartz-sericite-ankeriterutile-pyrite.
94488	Perseverance mine, 1194 south drive. Weakly to moderately bleached, pinkish GMD7 with sulphide stringers.
94504	Perseverance mine, 568 north drive. Moderately bleached GMD7; quartz veins.
94505	Perseverance mine, 568 north drive. Completely bleached GMD7 with pyrite dissemination.
97488	Lake View mine, 461 south drive. Intensely foliated, distal chlorite-carbonate alteration in GMD9.
97500	Perseverance mine, 6100 C+F. Intensely foliated and bleached, pyrite-rich GMD8.
97521	Lake View mine, 979 C+F. Silicified pyritic lode in GMD9. Mineral assemblage quartz-sericiteankerite-albite-pyrite.
97522	Lake View mine, 979 C+F. Intensely bleached GMD9 50 cm away from the lode presented by the sample 97521.
97540	Lake View mine, 10133 east cross-cut. Intensely foliated and bleached, pyrite-rich GMD8. Mineral assemblage: quartz, albite, sericite, ankerite, rutile, pyrite. Quartz-carbonate veins.
97541	Lake View mine, 10133 east cross-cut. Mylonitic GMD8 from the centre of the shear zone.

Oroya-style

Sample	*Description*
97308	Paringa mine, 7 level, 809/1 stope. Lode hosted by carbonaceous metasedimentary rock. Gold, tellurides, chalcopyrite, sphalerite, Ti- and V- oxides, V-chlorite, pyrite present.
97314	Paringa mine, 8 level, west drive south of Lewis stope. Mineralised breccia with massive sulphide matrix (pyrite : chalcopyrite, sphalerite). Hosted by Paringa Basalt.
97328	Paringa mine, 3A level, Oroya shoot. Lode hosted by Paringa Basalt. Gold occurs in fractured pyrite. Mineral assemblage in host rock: quartz-albite-chlorite-carbonate-pyrite-arsenopyrite. The fibrous carbonate-quartz vein has a narrow chlorite selvage and contains thin slivers of altered host rock. Arsenopyrite is related to the quartz vein selvage and thin carbonate-chlorite veinlets.
97336	Paringa mine, 7 level, OHW lode. Green leader ore. Green colour is due to the presence of V-mica.

13.6 North Kalgurli

According to Sang (1991), the North Kalgurli mineralisation at Golden Mile formed under low-greenschist facies conditions. Both Golden Mile-style and Oroya-style mineralisation occur within the deposit.

Hand specimen description

Sample	*Description*
N.KAL-1	Ore hosted by Paringa basalt. Proximal alteration with mineral assemblage sericite-pyrite-quartz-albite and, locally, remnants of chlorite. Intense foliation.

13.7 Ora Banda

One sample from the Ora Banda gold deposit, about 50 km NW from Kalgoorlie, is on display. The gold mineralisation is hosted by porphyritic tholeiitic metabasalts which are metamorphosed and altered under mid-greenschist facies PT conditions (Witt et al. 1997). Proximal mineral assemblage is described below; distal alteration is characterised by chlorite + calcite + rutile or titanite + pyrrhotite + epidote, and unaltered rock by actinolite + albite + epidote + ilmenite (Witt et al. 1997).

Hand specimen description

Sample	*Description*
Ora Banda, Gimlet South	Proximal alteration with mineral assemblage sericite - pyrite - ankerite - quartz - albite - rutile - arsenopyrite - tourmaline enveloping auriferous quartz veins. Intense foliation.

13.8 Golden Crown

Hand specimens are on display from Golden Crown deposit, 5 km S of Cue, in the Murchison Greenstone Belt. Gold mineralisation is mainly hosted by a differentiated dolerite which has been metamorphosed and altered under mid- to upper-greenschist facies PT conditions. The alteration sequence comprises (T. Uemoto, pers. comm. 1996):

1) unaltered assemblage: albite-actinolite-epidote-magnetite,
2) distal assemblage: albite-chlorite-calcite-magnetite ± epidote,
3) intermediate assemblage: albite-chlorite-calcite-ankerite,
4) proximal assemblage: muscovite-ankerite-quartz-ilmenite in the upper parts and biotite-chlorite-calcite-ankerite-quartz-ilmenite in deeper parts of the deposit.

Hand specimen description

Sample	*Description*
Main reef -1	Sample from upper parts of the deposit. Vein material: quartz + pyrite, pyrrhotite, galena, arsenopyrite, and ankerite. Minor slivers of host rock (sericite + albite + arsenopyrite) in the vein.

13.9 Sons of Gwalia

The Sons of Gwalia deposit is located within the Sons of Gwalia Shear Zone (SGSZ), marginal to the Raeside Batholith, Leonora. Mineralisation is confined to a shallow south-easterly dipping section of the SGSZ within a package of highly deformed high-Mg metabasalts and high-Mg tholeiitic metabasalts. The ore body comprises a series of high grade lenses or "shoots" (>4 g/t) that are confined to the plane of the foliation. These are surrounded by lower grade envelopes, giving the ore body a pipe-like appearance. The down dip persistence of the Sons of Gwalia lode system was confirmed by diamond drilling to depths of at least 1300 m below the surface. A. Smith, pers. comm. (1996)

The general alteration features at Sons of Gwalia are broadly consistent with the alteration styles documented in other Archaean lode-gold mesothermal lode-gold deposits, that are hosted in mid-upper greenschist facies mafic rocks. All alteration zones are characterised by an increase in volume during metasomatism, ranging from approximately 22% in the distal zones to as much as 40% in the proximal alteration zones. Increasing alteration intensity is also marked by: (I) an increase in the number of mobile elements in proximal zones; (II) an increase in the amount of veining towards lode zones; (III) an increase in the intensity of the shear-fabric (IV) increase in the amount of sulphides; (V) an increase in the degree of carbonation/hydration of the rocks and pronounced K-metasomatism. A. Smith, pers. comm. (1996)

An unique feature of alteration at Sons of Gwalia is the presence of a two-fold asymmetry with respect to biotite. In particular: (I) the presence of biotite in the footwall alteration assemblages in shallow levels (<700 m) of the lode system only and (II) a significant increase in the modal abundance of biotite with depth. Within the shallow levels, biotite is only present in the intermediate alteration assemblage, whereas in the deeper levels (>900 m) of the lode system, its stability increases to include both distal and intermediate alteration zones.

Hand specimen descriptions

Sample	*Description*
SOG-1	Main Lode. Proximal alteration and gold mineralisation from the upper parts of the deposit. Mineral assemblage: quartz-albite-sericite-ankerite-pyrite-rutile.

SOG-2 Main Lode. Similar to SOG-1, but less quartz veins and weaker sulphidation and gold mineralisation.

13.10 Bronzewing

The Bronzewing deposit is located about 500 km north from Kalgoorlie, in the Yandal greenstone belt, which is commonly included into the Norseman-Wiluna Belt forming its NE portion. Ore is hosted by tholeiitic metavolcanic rocks which are metamorphosed and altered under upper greenschist facies PT conditions (Dugdale 1996, Eilu et al. 2001). The Bronzewing deposit consists of two main ore zones which are localised at the intersection of heterogeneous, large-scale conjugate, brittle-ductile shear system (Dugdale et al. 1997). Gold mineralisation occurs in quartz veins within the shear zones. The veins are enveloped by a concentric sequence of alteration zones. In the upper levels of the deposit, the dominant alteration sequence, from distal to proximal zone, is: chlorite-calcite, chlorite-muscovite-ankerite, and muscovite-ankerite zones (Eilu et al. 2001). Biotite locally replaces muscovite in the upper levels and more extensively in the deeper levels of the deposit. Visible alteration haloes extend laterally 10-50 m away from the mineralised structures at Bronzewing (Eilu et al. 2001).

Hand specimen descriptions

Sample	*Description*
Bronzewing	Visible gold in a quartz vein and its selvages to altered tholeiitic metabasalt. Mineral assemblage in the host rock: albite-quartz-sericite-pyrite-rutile + locally chlorite (the darker areas).

13.11 Harlequin, Norseman

The Harlequin deposit at Norseman is hosted by metadolerite and metabasalts which are metamorphosed and altered under PT conditions close to the transition from greenschist to amphibolite facies. Most of gold is in subhorizontal veins which are up to 1.5 m thick. Their Au content is generally 10-30 ppm. Subvertical tension veins occur commonly around the lode-veins; also the tension veins may, locally, carry some gold. Biotitic (±sericite) alteration extends laterally up to 12 m and carbonation (calcite only) 20-25 m from the lode-veins. Inconsistent gold mineralisation also occurs within the biotitised alteration zone.

Hand specimen descriptions

Sample	*Description*
HQ-1	Quartz reef with abundant arsenopyrite, pyrrhotite and chalcopyrite. Sulphides are chiefly in or next to host rock slivers within the vein.
HQ-2	Quartz reef with minor calcite and proximal alteration (biotite-calcite-sericitearsenopyrite-ilmenite-rutile-chlorite) in the host rock. Sulphides are chiefly in or next to host rock slivers within the vein.
HQ-3	Quartz reef with abundant arsenopyrite and actinolite and some pyrrhotite in the altered host rock.

13.12 Hunt

The Hunt mine is located on the SW flank of the Kambalda dome, where a 5 km thick sequence of mainly mafic to ultramafic metavolcanic rocks with a central granitoid core, is flanked by metasedimentary and felsic metavolcanic rocks. The Hunt mine is located within a tholeiitic basalt sequence which underlies a sequence of ultramafic flows hosting Fe-Ni-Cu sulphide mineralisation. Gold mineralisation is hosted by a 10-20 m wide, steeply dipping shear zone in metabasalt, immediately below a Fe-Ni-Cu sulphide ore horizon at the maficultramafic rock contact (Neall and Phillips 1987).

According to Neall and Phillips (1987), the host rocks have been metamorphosed and altered under PT conditions close to the transition from greenschist to amphibolite facies. Orebodies are comprised of arrays of quartz veins with albite-ankerite margins and associated wallrock alteration. The veins are near-vertical and are *en echelon* along the shear zone more than 10 m below the mafic-ultramafic rock contact. In contrast the veins form complex conjugate sets, 5-10 m from the contact. Veining is more intense and results in a breccia of host rock fragments in a quartz matrix closer to the contact.

The alteration sequence enveloping quartz veins consists of, from vein margin outwards: 1) pyrite-biotiteankerite-chlorite zone, 2) pyrrhotite-biotite-ankerite-chlorite ± pyrite and magnetite zone, 3) biotite-ankeritechlorite-magnetite zone, 4) chlorite-ankerite-magnetite zone, and 5) chlorite-calcite-magnetite zone. Unaltered metabasalt is characterised by a hornblende-plagioclase mineral assemblage.

Gold occurs in quartz veins and in the most proximal pyrite alteration zone. Gold grades are considerably higher towards the mafic-ultramafic rock contact. The quartz veins contain gold as small nuggets and thin films on fractures nearer the mafic-ultramafic contact.

Hand specimen descriptions:

(all samples are from the Hunt shoot)

Sample	*Description*
95883	Gold-bearing quartz vein. Proximal alteration in the host rock. 0.5 m from the main vein.
95938	Tellurides in quartz vein hosted by altered metabasalt below the mafic-Ni sulphide contact. Mineral assemblage in intensely foliated host rock: quartz, biotite, calcite, ilmenite, rutile. Veins: mainly quartz, close to margins also calcite, albite, biotite, chlorite, pyrrhotite, pyrite, tellurides(?), pentlandite, chalcopyrite and gold. One free gold grain occurs associated with quartz.
95945	Proximal alteration in metabasalt 0.5 m below the mafic-Ni sulphide contact.

13.13 Victory

Two hand specimens from the Victory ore body, Kambalda, are on display. The basaltic host rocks have been metamorphosed and altered under PT conditions close to the transition from greenschist to amphibolite facies.

Hand specimen description

Sample	*Description*
VICTORY	Two samples containing proximal, biotite-sericite altered basalt and quartz veins. The dominant sulphide is pyrite.

13.14 Kings Cross

Kings Cross is one of the Coolgardie lode-gold deposits. It is in the Norseman-Wiluna greenstone belt, approximately 40 km SW from Kalgoorlie. The Kings Cross ore body is within Mg-tholeiitic basalts of the lower part of the stratigraphic succession (Knight et al. 1993, Knight 1994, Eilu 1996c). The host rocks were metamorphosed at lower-amphibolite facies PT conditions (510-520±50°C and 2-4 kbar, Knight 1994). The mineralisation is sited within a NNE-striking, steeply E-dipping (about 70°), brittle-ductile shear zone called the Kings Cross Fault (KXF). A moderate to intense foliation fabric is developed within the shear zone, and the width of the KXF, 5-20 m, is determined by the extent of this fabric. The shear zone offsets its adjacent wallrocks for about 10-15 m in a dextral sense, and hosts a continuous, laminated quartz reef that extends for about 400 m along strike, at least 250 m down dip, and varies in thickness from <10 cm to up to 3 m. The gold-mineralised reef is boudinaged along strike and down dip and parallels the steeply dipping foliation (Knight et al. 1993, Knight 1994).

Unaltered basalts are dark grey-green in colour and largely unstained. Pillowed flows are dominant, but completely massive and partly massive flows are also common. Grain size varies from 0.03 to 2 mm. Pillow margins are marked by 0.5–3 cm wide, pale grey, epidote-rich and green hornblende-rich bands, and flow margins by up to 50 cm wide zones comprising green hornblende and grey epidote-quartz-calcite bands. Subophitic and intergranular textures are dominant, but porphyritic, spherulitic and serrate textures are also common in the most fine-grained rock types, especially in pillow interiors close to the epidote- or amphibole-rich pillow margins. In addition, hornblende porphyroblasts, 1–2 mm in length, commonly occur in massive units and pillow interiors. The typical mineral assemblage is hornblende-plagioclase-ilmenite-titanite (Eilu 1996c).

Wallrock alteration comprises a sequence of two 1 mm – 3 m wide zones, the distal biotite and the proximal biotite-calcite zones. In addition, monomineralic actinolite selvages separate the biotite-calcite zone and the quartz veins that host most of the gold. The chemical compositions of the host rock in the alteration zones are presented in Table 3.

Alteration is most prominent in the KXF. Laminated quartz veins that form the quartz reef contain variable amounts of actinolite, pyrrhotite, arsenopyrite and gold, and are enveloped by the alteration halo. Within the 0.5–5 m wide core of the KXF, a series of parallel, 1 cm – 2 m wide quartz veins are closely spaced, and the quartz veins, the enveloping actinolite selvages and the most proximal, originally very biotite-rich parts of the biotite-calcite zones, combined, form 80–100% of the rock volume. Adjacent to the centre of the KXF, and up to 10 m from the centre of the KXF, biotite and biotite-calcite zones, locally intercalated with quartz veins, form domains up to 8 m wide. Retrograde chloritisation of biotite is locally developed and characterised by change in rock colour, from brown to dark green. Eilu (1996c)

Outside the KXF, in areas from 5 m to >100 m from the shear zone, the rocks are dominantly unaltered. Here, the 3 cm – 3 m wide, altered and weakly foliated domains comprise approximately 3-10% of the rock volume. Complete alteration-zoning profiles containing actinolite selvages and proximal parts of the biotite-calcite zones are uncommon, while alteration is mainly biotitisation at pillow margins and a few cm wide bands.

Hand specimen descriptions

Sample	*Description*
KXD 177 119.98	Narrow biotite alteration halo around a quartz vein in otherwise unaltered metabasalt, laterally about 20 m away from the KXF and ore. Mineral assemblages: hornblende - plagioclase - ilmenite - titanite -> hornblende - biotite - plagioclase - quartz - ilmenite - titanite. Texture: nematoblastic, massive, hornblende porphyroblasts. Veins: Quartz + traces of calcite and pyrrhotite, with actinolite selvages: typical gold-related quartz vein at Kings Cross. Alteration: intensity of biotitisation increases gradually towards the quartz vein.
KXD 187 219.41	Proximal biotite-calcite alteration in the central parts of the KXF. Mineral assemblage: biotite-hornblende-plagioclase-K feldspar-quartz-calcite-pyrrhotite. Visible gold in vein margins (numerous small grains visible on one surface of the sample). Texture: lepidoblastic, foliated. Veins: Quartz + calcite, K feldspar, pyrrhotite, arsenopyrite, gold, with green actinolite selvages.

Table 3. Kings Cross, median chemical compositions of the host rocks. Data from Eilu (1996c).

Zone	Unaltered rock	Biotite zone	Biotite-calcite zone	Potential ore zone = the most proximal alteration and quartz veins
SiO_2	49.9	48.7	47.8	**62.4**
TiO_2	0.69	0.69	0.68	0.40
Al_2O_3	14.6	14.6	14.3	8.57
Fe_2O_3*	11.8	11.4	11.2	7.21
MnO	0.20	0.18	0.21	0.12
MgO	7.74	7.13	6.67	4.10
CaO	11.9	11.6	12.0	8.17
Na_2O	1.83	1.81	1.80	0.92
K_2O	0.13	0.81	0.83	**1.35**
P_2O_5	0.050	0.050	0.054	0.041
SO_3**	0.14	0.20	0.12	0.39
LOI	0.99	2.54	3.64	**5.44**
sum	99.8	99.3	99.2	99.1
CO_2	0.13	0.59	**1.98**	1.59
S	0.067	0.080	0.091	**0.34**
Au	4.0	9.3	37.9	**650**
Te	16	37	27	**69**
Ag	0.06	0.07	0.10	0.15
Se	0.20	0.73	0.19	0.68
As	11	47	48	**531**
Sb	**0.4**	0.3	0.2	0.2
Bi	0.01	0.03	0.02	0.08
W	0.7	2.8	1.6	**5.9**
Rb	2.9	23.5	28.8	**37.2**
Ba	20	99	124	**176**
Sr	121	141	107	88
Cu	117	160	103	85
Zn	84	83	71	58
Ni	129	133	121	79
Nb	1.8	1.9	2.2	1.3
Y	15.3	15.7	15.4	10.2
V	222	222	217	150
Cr	328	336	322	190
Zr	42	41	37	22

Major components, LOI, CO_2 and S in weight-%, trace elements in ppm, except Au and Te in ppb. Analytical methods: major oxides, SO_3, Cr and Zr by XRF; CO_2 and S by Leco; LOI by gravity; Au, Te, Ag, Se, As and Bi by GAAS; V by ICPOES and the other trace elements by ICPMS.
* total Fe as Fe_2O_3
* * Sulphur not included in LOI

13.15 Lindsays

Host rocks, metamorphic grade and alteration conditions in the Lindsays gold deposit, Coolgardie, are similar to those at Kings Cross (see above, and Knight et al. 1993).

<u>Hand specimen description</u>

Sample	*Description*
Lindsays-2	Quartz-scheelite vein and proximal biotite-calcite-arsenopyrite alteration.
Lindsays-3	Quartz vein with minor arsenopyrite, scheelite and gold. Queens reef. Gold is near vein margins and in actinolite selvages of the vein. A block of basaltic host rock in the vein: proximal alteration is partially overprinted by retrograde, post-mineralisation chloritisation and sericitisation or prehnitisation.

13.16 Corinthia

The Corinthia gold deposit is in the Southern Cross Greenstone Belt. It is chiefly hosted by tholeiitic basalts which have been metamorphosed and altered under low-amphibolite facies PT conditions (Mueller and Groves 1991, Bloem 1994).

Hand specimen description

Sample	*Description*
Corinthia	Quartz-pyrrhotite vein from East Lode; with traces of chalcopyrite and calcite.

13.17 Edward's Find

Two samples are on display from the Edward's Find gold deposit, Southern Cross Greenstone Belt . The deposit is chiefly hosted by basaltic rocks. Locally, metasedimentary rocks also host gold mineralisation. The host rocks have been metamorphosed and altered under mid-amphibolite facies PT conditions (Schwebel et al. 1995). Alteration around the mineralised veins comprises mostly biotite and diopside. The alteration halo extends generally for 1.5-3 m and contains, on average, 1 ppm Au. Most of gold occurs in quartz veins, with the Main Lode (0.8 m wide) averaging 23 ppm and the West Lode 29 ppm (0.3-0.4 m wide) (Schwebel et al. 1995). There is no apparent systematic relationship between gold grade and lode width.

Hand specimen description

Sample	*Description*
EF-1	Quartz lode with minor amounts of calcite, diopside, arsenopyrite and gold.
EF-2	Proximal alteration in mafic host rock with mineral assemblage hornblende + diopside(?) + calcite + biotite + pyrrhotite + arsenopyrite.

13.18 Polaris South

The Polaris South gold deposit, Southern Cross Greenstone Belt, is chiefly hosted by basaltic, but, locally, also by komatiitic metavolcanic rocks. The host rocks metamorphosed and altered under mid-amphibolite facies PT conditions (Bloem 1994). Alteration sequence in mafic rocks is from the unaltered mineral assemblage hornblende-plagioclase-ilmenite through distal hornblende-plagioclase-ilmenite-biotite and intermediate hornblende-biotiterutile-titanite to proximal diopside-calcite-quartz-titanite-pyrrhotite. Alteration in ultramafic rocks is from unaltered mineral assemblage olivine-tremolite-anthophyllite-talc-chlorite through distal tremolite-anthophyllitetalc-biotite and intermediate tremolite-talc-biotite-pyrrhotite-calcite-quartz to proximal diopside-calcite-quartztitanite-pyrrhotite, i.e. the proximal alteration zones have the same major minerals present in both host rock types (Bloem 1994).

Hand specimen description

Sample	*Description*
PS-1	Proximal diopside-quartz-calcite-pyrrhotite alteration enveloping quartz veins in mafic host rock.

14. Intermediate and felsic igneous host rocks

14.1 Granny Smith

A set of hand specimens and polished thin sections from Granny Smith are on display. Of these, samples from the granitoid host-rock are described in this section, while metasedimentary rock-hosted samples are presented in Section 15.2.

The Granny Smith gold deposits, which include Goanna, Granny, Granny Deeps and Windich, are situated 250 km NE from Kalgoorlie and 20 km S from Laverton, in the NE Eastern Goldfields, along the Laverton lineament. Most of the samples presented here are from the Granny Deeps deposit and its wallrocks.

According to Ojala et al. (1993) and Ojala (1995), the main gold-mineralised zone at Granny Smith extends for at least 3 km in a N-S direction, <100 - >400m in an E-W direction, and varies in thickness from 3 to 40 m. It is metamorphosed and altered under low-greenschist facies PT conditions. The gold mineralisation largely follows the contact between the Granny Smith Granodiorite and metasedimentary rocks. The mineralisation is in the contact zone where the contact dips at low angles (<50°E). However, where the dip is greater, mineralisation is either in the granitoid or roughly follows bedding in the metasedimentary rocks. In addition, discontinuous 0.1-3 m thick zones of low-grade gold mineralisation occur within the metasedimentary sequence, up to 150 m above the granodiorite-metasedimentary rock contact and the main mineralised zone (Ojala et al. 1993, Ojala 1995).

The gold mineralisation stage at Granny Smith is characterised by a sequence of four alteration zones (Eilu 1996b). These are, from the most distal to the most proximal: the calcite, calcite-dolomite, dolomite and sericite-pyrite zones, and they occur in all host rock types. The alteration is concentrated in the main mineralised zone at the granodiorite-metasedimentary rock contact, and may extend for 2-30 m from the contact. In the granodiorite, a downwards weakening network of bleached, 1-20 cm wide alteration haloes occurs around single quartz-dolomite-pyrite veins, below the main mineralised zone. Close to the main mineralised zone in the granodiorite, distal and intermediate alteration tend to occupy areas between the bleached haloes. The bleached haloes have been identified up to 70 m below the main mineralised zone. The chemical composition of the granodiorite is presented in Table 4.

Hand specimen descriptions

Sample	*Description*
GSD178 206.20	Dominantly unaltered granitoid + two veins and bleached haloes related to mineralisation. Mineral assemblage: plagioclase - K-feldspar - quartz - hornblende - biotite - sericite - epidote - titanite - magnetite. Texture: massive, hypidiomorphic. Veins: quartz-dolomite-calcite-pyrite.
GSD282 273.4	Dominantly distal calcite alteration in granitoid + a few veins with narrow bleached haloes. Mineral assemblage: plagioclase - K-feldspar - quartz - chlorite - biotite - calcite - sericite - rutile - magnetite. Texture: massive, hypidiomorphic. Veins: quartzdolomite-calcite(?)-pyrite.
GSD178 186.7	Dominantly intermediate calcite-dolomite alteration in granitoid + a few veins with very narrow bleached haloes. Mineral assemblage: plagioclase - K-feldspar - quartz - chlorite - biotite - calcite - sericite - rutile - magnetite. Texture: massive, hypidiomorphic. Veins: quartz-dolomite-pyrite.
GSD282 253.2	Dominantly intermediate dolomite alteration in granitoid + a set of veins with narrow bleached haloes. Mineral assemblage: plagioclase - K-feldspar - quartz - chlorite - biotite - dolomite - sericite - rutile - magnetite. Texture: massive, hypidiomorphic. Veins: quartz-dolomite-pyrite.
Granny Smith ore and GSD178 176.20	Proximal sericite-pyrite alteration in granitoid. Mineral assemblage: albite - quartz - dolomite - sericite - K-feldspar(?) - pyrite – rutile. Texture: massive, originally hypidiomorphic, now brecciated and granoblastic. Veins: a network of dolomite-quartz-pyrite veins.

Table 4. Granny Smith, median chemical compositions of the granodiorite. Data from Eilu (1996b).

Zone	Unaltered	Calcite	Calcite-dolomite	Dolomite	Sericite-pyrite
SiO_2	64.1	63.0	59.6	59.7	60.1
TiO_2	0.49	0.47	0.56	0.45	0.43
Al_2O_3	16.3	15.7	16.1	15.2	14.6
Fe_2O_3*	4.14	4.12	4.78	3.86	3.86
MnO	0.06	0.06	0.07	0.06	0.06
MgO	2.23	2.11	2.43	1.98	1.78
CaO	4.01	4.07	4.25	3.72	3.59
Na_2O	4.88	4.99	4.94	4.99	**6.41**
K_2O	2.72	2.98	3.08	3.51	2.85
P_2O_5	0.33	0.33	0.39	0.31	0.26
LOI	1.16	2.33	2.08	3.90	**4.24**
Sum	100.3	100.2	98.2	97.6	98.2
CO_2	0.61	1.69	1.65	3.67	**4.55**
S	0.05	0.07	0.08	0.12	**1.30**
Au	25.1	134	82.6	181	**3940**
Te	10	23	15	26	**616**
Ag	0.07	0.08	0.05	0.09	**1.31**
Se	<0.01	0.03	<0.01	0.03	**0.22**
As	6	3	4	4	3
Sb	0.4	0.6	0.8	0.7	**1.0**
Bi	0.14	0.19	0.14	0.15	**1.42**
W	3.0	9.2	12.0	17.5	**50.8**
Rb	103	**113**	**113**	103	62
Ba	998	998	**1019**	950	710
Sr	1008	872	**1021**	953	708
Pb	21	21	22	17	15
Cu	21	25	25	31	12
Zn	70	67	75	49	42
Ni	36	31	39	40	30
Nb	6.6	6.4	7.6	6.0	4.8
Y	12.5	12.4	15.0	9.9	**9.6**
V	65	63	78	69	**30**
Cr	39	36	31	33	30
Zr	157	162	169	154	142

Major components, LOI, CO_2 and S in weight-%, trace elements in ppm, except Au and Te in ppb. Analytical methods: major oxides, Cr and Zr by XRF; CO_2 and S by Leco; LOI by gravity; Au, Te, Ag, Se, As and Bi by GAAS; V by ICPOES and the other trace elements by ICPMS.
* total Fe as Fe_2O_3

14.2 Sunrise Dam-Cleo

For general description of the Sunrise Dam deposit, see Section 12.3.

Hand specimen description

Sample	*Description*
CD215 435.5	Unaltered intermediate dolerite ('microdiorite'). Mineral assemblage albite - chlorite - epidote - quartz - titanite. Texture is massive, hypidiomorphic to subophitic. Early, pre-gold, quartz-epidotechlorite veins with minor chalcopyrite and a narrow epidotised halo.
CD215 444.3	Distal alteration in dolerite. Mineral assemblage albite - chlorite - calcite - quartz - rutile and remains of titanite. Calcite veins (related to gold mineralisation). Entirely brittle deformation.
CD215 387.5	Distal alteration in dolerite. Mineral assemblage albite - chlorite - calcite - quartz - rutile. Early chlorite veins and syn-gold calcite-quartz-tourmaline veins. Dominantly brittle deformation. Original grain size about 1 mm.
CD215 393.0	Outer intermediate alteration in dolerite. Mineral assemblage albite - chlorite - calcite - ankeritequartz - rutile. The pale-brown, disseminated mineral is rutile (leucoxene). Quartz-calcite-ankerite veins,

gold-related, with minor pyrite. Brittle-ductile deformation; rock is, probably, originally medium-grained.

CD215 399.5 Inner intermediate, partially bleached alteration in dolerite. Mineral assemblage albite - chlorite - sericite - ankerite - quartz - rutile. Dominantly brittle deformation with minor ductile component. Quartz-ankerite-haematite veins, syn-gold, with a narrow bleached (intensely sericitised) halo.

CD215 411.9 Proximal alteration in dolerite; brittle deformation. Mineral assemblage sericite - ankerite - quartz - albite - rutile - pyrite; some chlorite left near the pyrite grains. Brecciated by ankerite-quartz-pyrite veins.

CD296 333.2 Inner intermediate, partially bleached alteration in a felsic porphyry. Mineral assemblage albite - chlorite - sericite - ankerite - quartz - rutile with minor pyrite. The primary porphyritic texture is well-preserved. Phenocrysts: quartz, albite (orig. plagioclase), chlorite+sericite+rutile (orig. biotite).

14.3 Lady Bountiful

According to Cassidy (1992) and Cassidy and Bennet (1993), the Lady Bountiful granitoid-hosted lode gold deposit, located in the mid-greenschist facies metamorphosed Ora Banda greenstone sequence, 36 km NW from Kalgoorlie, is predominantly hosted by the late-tectonic Liberty Granodiorite. Gold mineralisation is localised along quartz-veined, sinistral, brittle-ductile fault zone(s) that transect the boundary between the granodiorite and Mt. Pleasant Sill. Ore minerals include pyrite, chalcopyrite, pyrrhotite, galena, sphalerite, Au-Ag-Bi-Pb tellurides and native gold.

Alteration related to gold mineralisation has taken place under mid-greenschist facies PT conditions and characterised by narrow discrete haloes enveloping quartz veins. Alteration sequence in the granodiorite is (Cassidy and Bennet 1993):

1) unaltered assemblage quartz + oligoclase + K-feldspar + biotite + hornblende + titanite,
2) distal assemblage quartz + oligoclase + albite + K-feldspar + biotite + chlorite + calcite + rutile,
3) proximal assemblage quartz + albite + K-feldspar + chlorite + sericite (phengite) + calcite + rutile + pyrite + pyrrhotite.

Hand specimen description

Sample	*Description*
N1-lode	Quartz vein: traces of pyrite, dolomite, calcite. Host rock: intense proximal alteration with mineral assemblage quartz-albite-sericite-calcite-dolomite.
N1-lode	Proximal alteration in granodiorite: albite, quartz, sericite, pyrite, calcite, dolomite.

14.4 New Celebration

One sample from the New Celebration gold deposit, located in the Jubilee area in the Norseman-Wiluna greenstone belt, is on display. The gold deposit is hosted by felsic porphyry, komatiites and gabbro, and metamorphosed and altered under upper-greenschist facies PT conditions (Norris 1990).

Hand specimen description

Sample	*Description*
HBC 1200-11203 m	Proximal alteration in porphyry. Sericitisation, weak pyritisation, visible gold(?), quartz vein stockwork.

14.5 Jupiter

The Jupiter deposit, located in the NE Eastern Goldfields, is hosted by a red syenite which is intruded into a metabasaltic rock. Some gold is also hosted by the basalt, but the syenite forms the main host to ore, as it is the locally most competent rock type (Duuring et al. 2000).

Hand specimen description

Sample	*Description*
Jupiter	Ore. Dark grey metabasaltic rock intruded by red syenite.

15. Clastic metasedimentary host rocks

15.1 Kanowna

The Kanowna deposits are approximately 20 km NE from Kalgoorlie, and are metamorphosed and altered under low-greenschist facies PT conditions and hosted by polymictic conglomerates, a doleritic sill and felsic porphyries (Ho 1984, Heithersay et al. 1994, Beckett 1996).

The Kanowna Main Reef is a quartz vein system which is confined to polymictic conglomerate, and forms a moderately steeply dipping arcuate zone, about 3 km long, within a dextral shear zone. Mineralisation consists of anastomosing veins and associated wallrock alteration. Veins are formed by massive quartz and quartz with chlorite-talc-ankerite-calcite laminations. Felsic clasts in the conglomerate are predominantly carbonated, mafic clasts altered to muscovite-carbonate-quartz-pyrite assemblage and ultramafic clasts to fuchsite-carbonate-quartz assemblage. Mineralisation, commonly formed by free gold, is largely restricted to quartz veins, particularly to laminated sections of the veins.

At Kanowna Belle, gold mineralisation is chiefly in a felsic to intermediate porphyry and polymictic conglomerate, and alteration related to mineralisation is characterised by distal sericite-carbonate to carbonate-chlorite, intermediate sericite-carbonate-pyrite, and proximal pyrite-albite-quartz alteration zones (Heithersay et al. 1994, Beckett 1996).

Hand specimen descriptions:

Main Reef

Sample	*Description*
92269	Intensely altered polymictic conglomerate, now fuchsite-sericite-quartz-ankerite-pyrite rock. Both ultramafic (green) and felsic (yellow-brown) clasts present.

Kanowna Belle

Sample	*Description*
KB-2	Proximal alteration, sericitisation and carbonation, and ore in dacitic porphyry. Minor scheelite in host rock or in tiny veins.
KB-3	"Grit", Troy deposit, proximal alteration, visible gold within the domain of abundant, diffuse quartz veins and intense sericitisation of the host rock. Quartz phenocrysts common throughout the rock, locally also plagioclase phenocrysts. Mineral assemblage: quartz, albite, sericite, rutile, carbonate, pyrite, gold and tellurides. Also, traces of scheelite in host rock. Pyrite, gold and tellurides occur both in the host rock and veins.
KB-4, KB-5	"Rudite" = volcanogenic, polymictic conglomerate, proximal alteration with abundant sericite (green fuchsite in ultramafic clasts) and ore. Rock fragments: variably sericitised, plagioclase-phyric, felsic to intermediate metavolcanic rock that has a albite - quartz - sericite - carbonate - rutile groundmass. Matrix: larger quartz and albite fragments and very fine-grained quartz, albite, sericite, carbonate, pyrite, rutile, chalcopyrite, sphalerite.

15.2 Granny Smith

For general description of the Granny Smith deposit, see Section 14.1. For chemical composition of the meta-sedimentary rock, see Table 5 below.

Hand specimen descriptions

Sample	*Description*
GSD282 180.50	Unaltered rock. Mineral assemblage: albite - quartz - chlorite - biotite - sericite - pyrrhotite - graphite - ilmenite. Texture: massive, granoblastic, medium-grey arenitic and dark-grey argillic layers.
GSD250 210.50	Unaltered rock. Mineral assemblage: albite - quartz - chlorite - biotite - sericite - pyrrhotite - graphite - ilmenite. Texture: massive, granoblastic meta-argillite. Veins: quartz-calcite ± pyrite.
GSD282 200.70	Distal calcite alteration in metasedimentary rock. Mineral assemblage: albite - quartz - chlorite - biotite - sericite - calcite - pyrrhotite - graphite(?) - ilmenite - rutile(?). Texture: massive, granoblastic. Veins: quartz-calcite ± pyrrhotite.
GSD241279.04	Intermediate calcite-dolomite alteration in metasedimentary rock. Mineral assemblage: albite - quartz - chlorite - calcite - dolomite - biotite - sericite - pyrrhotite - graphite(?) - ilmenite - rutile. Texture: massive, granoblastic, weakly brecciated. Veins: quartz-calcite-dolomite ± pyrite.
GSD241 210.29	Intermediate dolomite alteration in metasedimentary rock. Mineral assemblage: dolomite - albite - quartz - chlorite - sericite - pyrrhotite - rutile - ilmenite. Texture: massive, granoblastic, brecciated. Veins: earlier quartz-dolomite ± albite; later quartz-dolomite ± pyrrhotite.

GSD 178168.60 Dominantly proximal sericite-pyrite alteration in metasedimentary rock, minor parts of the sample represent unbleached dolomite zone.
Mineral assemblage: dolomite - albite - quartz - sericite - pyrite - rutile - chlorite - pyrrhotite(?) - graphite(?).
Texture: granoblastic, foliated and intensely brecciated.
Veins: quartz-dolomite ± albite.

Table 5. Granny Smith, median chemical composition of the metasedimentary rock. Data from Eilu (1996b).

Zone	Unaltered	Calcite zone	Calcite-dolomite zone	Dolomite zone	Sericite-pyrite zone
SiO_2	61.4	59.5	58.0	57.9	52.7
TiO_2	0.80	0.83	0.83	0.82	0.69
Al_2O_3	16.2	16.2	16.1	16.3	13.9
Fe_2O_3*	8.47	8.43	8.94	8.80	8.30
MnO	0.12	0.09	0.13	0.11	0.12
MgO	2.37	2.44	2.47	2.49	2.28
CaO	2.04	3.64	3.12	2.89	3.94
Na_2O	2.53	2.53	2.51	2.78	**4.86**
K_2O	2.05	1.83	2.23	2.44	**3.52**
P_2O_5	0.11	0.10	0.10	0.10	0.10
LOI	3.40	3.47	4.30	5.04	**6.18**
Sum	99.5	99.1	98.7	99.6	96.6
CO_2	2.82	2.09	3.85	4.71	**7.92**
S	1.24	0.86	1.12	1.10	**2.32**
Au	0.8	16.4	3.5	15.9	**747**
Te	93	113	79	104	**337**
Ag	0.13	0.11	0.09	0.14	**0.32**
Se	0.64	0.52	0.65	0.58	**0.87**
As	22	27	**70**	53	68
Sb	0.6	0.7	1.3	1.3	1.4
Bi	**0.18**	0.14	0.14	0.14	0.11
W	0.8	2.8	2.6	11.8	**36.8**
Rb	67	65	83	96	**100**
Ba	377	315	374	332	337
Sr	164	170	170	171	**340**
Pb	11	9	10	11	15
Cu	87	91	96	86	89
Zn	201	197	205	165	103
Ni	97	99	110	96	110
Nb	6.1	5.1	5.5	5.3	4.0
Y	16.1	14.1	12.6	12.3	9.5
V	159	167	168	157	**105**
Cr	157	174	179	162	134
Zr	132	116	120	119	93

Major components, LOI, CO_2 and S in weight-%, trace elements in ppm, except Au and Te in ppb. Analytical methods: major oxides, Cr and Zr by XRF; CO_2 and S by Leco; LOI by gravity; Au, Te, Ag, Se, As and Bi by GAAS; V by ICPOES and the other trace elements by ICPMS.
* total Fe as Fe_2O_3

15.3 Sunrise Dam-Cleo

For general description of the Sunrise Dam deposit, see Section 12.3.

Hand specimen description

Sample	*Description*
Crystal tuffite	(volcanogenic metasedimentary rock):
CD215 270.5	Intermediate alteration in crystal tuffite. Plagioclase phenocrysts. Mineral assemblage quartz albite - sericite - chlorite - sericite - rutile. Ankerite-quartz veins.

CD215 239.3 Intermediate alteration in crystal tuffite. Plagioclase phenocrysts. The dark spots are mafic to ultramafic lapilli and/or altered and deformed mafic phenocrysts. Mineral assemblage quartz - albite - sericite - chlorite - sericite - rutile - magnetite. Pre-deformation chlorite veins and syndeformation ankerite veins.

CD272 159.7 Intermediate to proximal alteration in crystal tuffite. Plagioclase phenocrysts(?). The dark spots are mafic to ultramafic lapilli and/or altered and deformed mafic phenocrysts. Mineral assemblage quartz - albite - sericite - chlorite - sericite - rutile - pyrite. Syn- and post-ductile deformation quartz-ankerite+pyrite veins.

CLEO WSZ Grab sample: proximal alteration in crystal tuffite. Pyrite dissemination.

Volcanogenic polymictic conglomerate:

CD272 668.7 Unaltered polymictic, volcanogenic conglomerate. Blastoclastic texture. At least, three types of clasts: crystal tuff or andesite, felsic porphyry or rhyolite, and intermediate tuffite. Mineral assemblage chlorite - albite - quartz - actinolite - epidote - titanite. Minor retrograde sericite, locally also calcite present, chiefly around calcite veins related to weak brittle deformation.

CD272 124.5 Inner intermediate alteration in granoblastic, intermediate, crystal tuffite in the USZ. Mineral assemblage: albite - quartz - sericite - chlorite - ankerite - rutile. Original clinopyroxene(?) phenocrysts(?) now as chlorite pseudomorphs and visible as dark-green dots in the hand specimen.

CD272 114.8 Proximal alteration and brecciation of conglomerate in the USZ. Clasts consists of, at least, fine-grained volcanogenic metasedimentary rock (tuffite) and metakomatiite. Mineral assemblage: albite - quartz - sericite - ankerite - rutile - pyrite and, in the ultramafic clasts, bright-green fuchsite. Brecciated by ankerite-quartz-pyrite veins.

CD272 145.7 Intensely deformed polymictic conglomerate with proximal alteration in the USZ. Clasts mostly komatiitic and intermediate in composition. Mineral assemblage: albite - quartz - sericite/fuchsite - chlorite - ankerite - rutile - pyrite.

The brittle fracture zones at Sunrise-Cleo:

CD265 223.3 Distal part of the Western Shear Zone (WSZ), volcanogenic metasedimentary rock (= intermediate tuffite). Typical open-space filling with ankerite margin and quartz interior of the vein. Bleaching is only partial, but sulphidation of the host rock still intense. Mineral assemblage in the host rock chlorite - sericite - quartz - albite - ankerite - rutile - pyrite - arsenopyrite.

CD265 217.9 Interior of the WSZ, volcanogenic metasedimentary rock (= intermediate tuffite), high-grade ore with visible gold. Intense and multiple brecciation accompanied with ductile deformation, proximal alteration and intense sulphidation. Mineral assemblage quartz - albite - sericite - pyrite - arsenopyrite - futile - gold. Breccia veins consist, in decreasing abundance, of quartz-ankeritepyrite-arsenopyrite-gold-telluride(s). Although the rock is totally sericitised, the degree of bleaching is low, because the sulphide content is high.

CD291 240.5 A narrow brittle fracture zone in volcanogenic metasedimentary rock with intermediate to proximal alteration and visible gold in veins. Mineral assemblage quartz - albite - sericite - chlorite - pyrite - arsenopyrite - rutile.

15.4 Lancefield

The Lancefield gold deposit is approximately 8 km N from Laverton in the north eastern part of the Eastern Goldfields province.

According to Hronsky (1990, 1993) the gold mineralisation at Lancefield is hosted by two shear zones that are predominantly localised within carbonaceous schist (metamorphosed black shale). The host rocks have been metamorphosed and altered under low-greenschist facies PT conditions. Two alteration zones, distal and proximal, can be distinguished, the former is characterised by the mineral assemblage quartz-pyrrhotite-chlorite-calcitepyrite-muscovite, and the latter by quartz-pyrrhotite-dolomite-pyrite-chlorite-arsenopyrite-calcite-muscovite. Most of gold is `invisible' within arsenopyrite; remainder occurs as free grains in quartz veins and associated with sulphide grain boundaries.

<u>Hand specimen descriptions</u>

Sample *Description*

LA 114546 Pyrrhotite-rich black schist with cherty interlayers. Mineral assemblage: chlorite-muscovite-quartz-calcite-dolomite-pyrrhotite.

LA 114593 Ore sample dominated by auriferous quartz veins in black schist. Mineral assemblage in the host rock: quartz-dolomite-muscovite-calcite-pyrite-chlorite-pyrrhotite-arsenopyrite.

15.5 Twin Peaks

The Twin Peaks deposit is about 5 km west from Lake Rebecca and 100 km NE from Kalgoorlie. It is one of the numerous gold deposits within or close to the >200 km long, 5-10 km wide, NW-SE trending Keith-Kilkenny lineament in the Norseman-Wiluna greenstone belt. The deposit is in the SW margin of the Keith-Kilkenny lineament, in a shear zone called the Monty-Twin Peaks shear, and is hosted by intermediate volcaniclastic metasedimentary rocks containing both arenitic and argillic beds , the formed type being dominant, and is metamorphosed and altered probably under mid-greenschist facies conditions (Longworth 1996).

The host rocks can be divided into unaltered rocks and three alteration zones, according to diagnostic minerals (Eilu 1996d). These alteration zones are 1 mm - 40 m wide and form a continuous sequence that includes, from the most distal to the most proximal zone, the calcite, dolomite-arsenopyrite and sericite zones. Median chemical compositions of unaltered host rock and the alteration zones are presented in Table 6.

Deformation related to alteration and gold mineralisation is brittle-ductile, brittle deformation being the dominant style (Eilu 1996d). Alteration and deformation styles are similar in all host rocks, with one exception. In calcite alteration zones, calcite is dominantly disseminated in the arenitic layers, but is almost exclusively in quartz-carbonate veins in the argillic layers (Eilu 1996d). This difference is most probably caused by the difference in grain size and permeability between arenite and argillite. A weak post-kinematic, post-alteration, brittle deformation stage has followed the gold mineralisation. It is indicated by the occurrence of minor quartz-calcite veins throughout the area.

Hand specimen descriptions

Sample	*Description*
J122 236.25	Unaltered rock, arenitic type. Mineral assemblage: albite-quartz-K-feldspar-chlorite-sericite-biotite-dolomite-ilmenitepyrrhotite-chalcopyrite. Texture: blastoclastic, weak foliation, clasts: quartz and feldspars, matrix: all minerals. Veins: quartz-carbonate ± pyrrhotite.
JDDH001 119.3	Distal calcite alteration, arenitic type. Mineral assemblage: albite - quartz - K-feldspar(?) - chlorite - sericite - biotite - calcite - dolomite - ilmenite - pyrrhotite - chalcopyrite - rutile. Texture: blastoclastic, weak foliation, biotite is micro-porphyroblastic, possibly replacing chlorite and sericite. Veins: quartz-calcite ± ilmenite, pyrite, chalcopyrite.
JDDH001 107.85	Distal calcite to proximal sericite alteration, arenitic type. Mineral assemblage; from distal : albite - quartz - K-feldspar(?) - chlorite - sericite - biotite - calcite - dolomite - ilmenite - pyrrhotite - chalcopyrite - rutile to proximal: sericite - albite - quartz - dolomite - arsenopyrite - rutile - biotite - pyrite - chalcopyrite - tourmaline. Texture: blastoclastic, weak to intense foliation, biotite is micro-porphyroblastic, possibly replacing chlorite and sericite. Veins: quartz-calcite ± ilmenite, pyrite, chalcopyrite.
JDDH001 104.43	Intermediate dolomite-arsenopyrite alteration, arenitic type. Mineral assemblage: albite - quartz - K-feldspar - sericite - biotite - dolomite - chlorite - ilmenite - rutile - pyrite - arsenopyrite. Texture: blastoclastic, foliated, arsenopyrite porphyroblasts locally. Rutile-ilmenite-rich bands: possibly, sedimentary heavy-mineral layers. Veins: early, boudinaged and banded, quartz ± dolomite, calcite veins, and later, quartz ± dolomite, calcite, pyrrhotite, chalcopyrite veins. Proximal alteration: completely bleached slices of host rock within the veins.
JDDH001 101.16	Proximal sericite alteration, arenitic type. Mineral assemblage: sericite - albite - quartz - dolomite - K-feldspar(?) - arsenopyrite - rutile - biotite - pyrite - chalcopyrite - tourmaline. Texture: blastoclastic, foliated and brecciated, idioblastic arsenopyrite porphyroblasts are very common. Veins: quartz ± arsenopyrite, dolomite, biotite, chalcopyrite and pyrite. Alteration: pervasive and intense sericitisation and carbonation; weak biotitisation around some veins.

Table 6. Twin Peaks, median chemical composition of the metasedimentary host rock. Data from Eilu (1996d).

Zone	Unaltered	Calcite	Dolomite-arsenopyrite	Sericite
SiO_2	61.9	62.8	62.0	61.4
TiO_2	0.55	0.54	0.55	0.51
Al_2O_3	14.8	14.8	15.0	14.3
Fe_2O_3*	5.81	5.56	5.81	5.43
MnO	0.08	0.08	0.08	0.08
MgO	3.10	3.07	3.21	2.89
CaO	2.61	2.63	2.44	2.93
Na_2O	3.92	3.78	3.54	3.15
K_2O	1.93	2.17	2.42	**2.70**
P_2O_5	0.14	0.14	0.14	0.14
SO_3**	0.63	0.71	0.57	**0.80**
LOI	4.05	3.71	4.52	**4.60**
Sum	99.5	99.9	100.3	98.9
CO_2	2.93	2.07	2.93	**3.96**
S	0.19	0.24	0.23	**0.54**
Au	2.3	2.7	7.9	**1785**
Te	24	21	16	20
Ag	0.07	0.08	0.09	**0.33**
Se	0.14	0.12	0.11	**0.24**
Sb	0.5	0.6	0.5	0.6
As	13	17	36	**171**
Bi	0.14	0.15	0.13	**0.18**
W	2.8	3.1	5.2	**7.0**
Rb	64.1	70.8	81.6	**86.5**
Ba	495	580	630	**756**
Sr	348	350	379	**425**
Pb	7	7	7	8.0
Cu	40	41	42	42
Zn	82	80	82	72
Ni	86	80	84	73
Nb	5.2	5.4	5.4	4.5
Y	10.1	10.5	10.4	**9.2**
V	101	105	105	90
Cr	178	169	167	160
Zr	123	121	123	120

Major components, LOI, CO_2 and S in weight-%, trace elements in ppm, except Au and Te in ppb. Analytical methods: major oxides, Cr and Zr by XRF; CO_2 and S by Leco; LOI by gravity; Au, Te, Ag, Se, As and Bi by GAAS; V by ICPOES and the other trace elements by ICPMS.
* total Fe as Fe_2O_3
** Sulphur not included in LOI

15.6 Union Reefs

The Union Reefs gold deposit is in the Northern Territory of Australia, about 185 km SSE of Darwin and 20 km NNW from the town of Pine Creek, within the Palaeoproterozoic Pine Creek Inlier (Ahmad 1998). It is hosted by 2.0-1.87 Ga turbiditic greywacke with interlayered pelitic and psammitic units metamorphosed and mineralised at mid- or upper-greenschist facies PT conditions (Newton et al. 1998a).

The deposit is one of the large number of gold mineralisations within the Pine Creek area and is hosted by the Pine Creek Shear Zone. Presently (1998) it is under an open-pit operation by the Acacia Resources Ltd. The known mineralisation is subvertical, 3.5 km long, 400 m wide and open at depth of 300 m and the preferred host rock psammitic metaturbidite (Newton et al. 1998a). Average grade (mill feed) is 1.6-2.0 ppm (Don Hall, pers. comm. 15/6/1998).

Hand specimen description

Sample	*Description*
UR-1	Unaltered or distally altered metaturbidite from the Pine Creek Shear Zone. Mineral assemblage quartz - chlorite - muscovite - albite - magnetite.
UR-2	Proximal alteration and intense carbonation in psammite. Abundant quartz-ankerite veins and ankerite porphyroblasts.
UR-3	Proximal alteration in metaturbidite. Mineral assemblage quartz - chlorite - muscovite - arsenopyrite - dolomite. The volume of arsenopyrite porphyroblasts increases towards a mineralised quartz vein which is not present in this sample.
UR-4	Intermediate to proximal alteration in metapelite. Note the weakly bleached proximal halo enveloping a narrow quartz vein in the central part of the sample.
UR-5	An unusually arsenopyrite-rich quartz vein from high-grade ore. Small amount of pyrite.

15.7 Cosmo Howley

The Cosmo Howley gold deposit is in the Northern Territory of Australia, about 130 km SSE of Darwin, within the Palaeoproterozoic Pine Creek Inlier. It is hosted by 2.0-1.87 Ga turbiditic pelites metamorphosed and mineralised at upper-greenschist facies PT conditions (Ahmad 1998) or formed during contact metamorphism (T = 550-620°C, p = 2 kbar) related to the intrusion of a synorogenic granitoid (Matthäi et al. 1995). The most recent studies favour the `mesothermal' genesis for the deposit (Simon Mottram, pers. comm. 17/6/1998). The favoured host rocks are the most Fe-rich units in the metasedimentary sequence and the age of mineralisation is, apparently, ca. 1800 Ma (Partington and McNaughton 1997).

Hand specimen description

Sample	*Description*
COH- l	Unaltered, Fe-rich metaturbidite. Mineral assemblage chlorite - garnet - quartz - biotite - plagioclase - haematite.
COH-2	Unaltered, C-rich and pyrite-bearing metaturbidite. Mineral assemblage chlorite - quartz - biotite - plagioclase(?) - graphite - synsedimentary(?) pyrite. Conformable, syn-gold(?) quartz-pyrite veins
COH-3	Drill-core sample of ore: proximal alteration of host rock enveloping a quartz-carbonate-pyrite vein. Both arsenopyrite and pyrite porphyroblasts in the host rock.
COH-4	Massive pyrite-quartz vein from ore.
COH-5	Laminated, pyrite-bearing quartz vein from ore. Slightly weathered sample. Slices of graphitic pelite in the vein.
COH-6	Laminated, arsenopyrite- and pyrite-bearing quartz vein and intensely altered host rock, ore.

15.8 Yilgarn Star

Three hand specimens form the Yilgarn Star gold deposit, located 40 km SE from Southern Cross, are on display during this workshop.

According to Crookes and Schaus (1995), the Yilgarn Star gold deposit is located in the brittle-ductile Yilgarn Star Shear Zone. This shear zone occurs along the contact between a mafic-ultramafic metavolcanic sequence and a metasedimentary sequence, on the SSE flank of the Ghooli Dome. The footwall of the ore zone consists of high-Mg basalts and the hangingwall consists of argillic and arenitic metasedimentary rocks. The host rocks are metamorphosed and altered under upper-greenschist facies or greenschist-amphibolite facies transition PT conditions.

Hand specimen description

Sample	*Description*
YS-1	Intensely deformed and altered metapelite brecciated by quartz veins. Abundant pyrrhotite. Mineral assemblage in the host rock is probably quartz-muscovite-biotite-albite-tremolite(?)-pyrrhotitearsenopyrite-gold.
YS-2	Mineralisation and quartz-carbonate veining in high-Mg basalt.
YS-3	Mineralisation and quartz±pyrrhotite veining in intensely biotitised metasedimentary rock.

15.9 Kundana

According to Warden (1996), the host rocks at Kundana, located 25 km NW from Kalgoorlie, have been metamorphosed under greenschist-amphibolite facies transition PT conditions. Alteration has taken place under upper-greenschist facies or greenschist-amphibolite facies transition PT conditions. The mineralisation occurs within the NS-trending Zuleika Shear Zone, in a 10 m wide unit of graphitic schists of sedimentary origin and within the contact zone between felsic volcaniclastic rocks and a quartz dolerite. Gold is dominantly free and occurs in greyish-white quartz veins which are 0.15-2 m wide. Other minerals occurring in the auriferous quartz veins are calcite, tourmaline, arsenopyrite, galena, sphalerite, chalcopyrite, unidentified tellurides and aurostibite (Warden 1996).

Hand specimen description

Sample	*Description*
KU-STRZ	Sample from the Strzelecki lode. Laminated quartz vein within sericitised and pyritised wallrocks. In addition to quartz, contains gold, galena, arsenopyrite and ankerite or siderite, possibly also calcite, tourmaline and sphalerite.

15.10 Chalice

The Chalice gold deposit is in the southern part of the Norseman-Wiluna Greenstone Belt, about 40 km north of Norseman. The deposit is hosted by metasedimentary rocks metamorphosed and altered under mid- or upper-amphibolite facies PT conditions (Thompson 1994, Witt and VanderHor 1998). Ore minerals detected are, in decreasing order, pyrrhotite, pyrite, loellingite, arsenopyrite and native gold (Witt and VanderHor 1998).

Hand specimen description

Sample	*Description*
Chalice	Ore: proximal alteration enveloping diopside-quartz-pyrrhotite-calcite vein. Mineral assemblage in the host rock: hornblende - diopside - plagioclase - K feldspar - titanite - quartz - pyrrhotite - pyrite.

15.11 Griffins Find

The Griffins Find gold deposit is located about 300 km SE from Perth. According to Fare and McNaughton (1990) and Mueller and Groves (1991), the Griffins Find deposit is in a ductile shear zone in sedimentary and mafic volcanic rocks which have been metamorphosed and altered under low-granulite facies PT conditions. Unaltered metasedimentary garnet granulites, which form the main host to the ore, have a mineral assemblage of plagioclase + quartz + biotite + garnet + hypersthene. Unaltered mafic rocks at Griffins Find have a mineral assemblage of microcline + hypersthene + quartz + titanite. The alteration sequence in the metasedimentary rocks is (Fare and McNaughton 1990):

1) distal assemblage plagioclase + quartz + biotite + hypersthene,

2) intermediate assemblage quartz + biotite + hypersthene + diopside, and

3) proximal assemblage quartz + diopside + pyrrhotite + arsenopyrite + loellingite + garnet.

Proximal alteration in mafic rocks is characterised by a mineral assemblage of microcline + quartz + diopside + titanite + pyrrhotite + arsenopyrite + loellingite. Gold occurs almost exclusively as free grains within composite arsenopyrite-loellingite grains. No gold is associated with pyrrhotite or silicates (Fare and McNaughton 1990).

Sample descriptions

Sample	*Description*
GF-1	Garnet-rich proximal alteration and diopside-dominated bands in metasedimentary rock. Low pyrrhotite, arsenopyrite and loellingite content. Minor scheelite in the quartz veins.
GF-2	Metasedimentary rock-hosted ore with quartz veins. Abundant pyrrhotite, arsenopyrite and loellingite. Sulphides and diopside occur also in the veins.

16. Banded iron formation (BIF) host rocks

16.1 Sunrise Dam-Cleo

For general description of the Sunrise Dam deposit, see Section 12.3.

Hand specimen description

Sample	*Description*
CD215 570.0	Unaltered BIF interlayered with tuff. Mineral assemblage quartz - albite - magnetite - chlorite - metamorphic sericite - epidote. Note that the sericite is probably metamorphic, unrelated to any alteration in the area. Calcite-chlorite veins with no apparent alteration halo are associated with weak brittle deformation.

CD261 449.3	Distal alteration in BIF interlayered with tuff. Mineral assemblage quartz - magnetite - chlorite - calcite - haematite - rutile ± pyrite. The presence of albite is unclear. Quartz-calcite±pyrite±chlorite veins. Note that deformation is dominantly brittle in the more compact BIF layers and dominantly ductile in the less compact tuff layers.
CD215 339.8	Distal alteration in mafic tuff interlayered with BIF. Mineral assemblage quartz - albite - metamorphic sericite - magnetite - chlorite - calcite - epidote - rutile. Early, layer-parallel quartzmagnetite-haematite-titanite-sericite-calcite veins and later, cross-cutting, calcitechlorite±haematite veins.
CD272 484.3	Outer intermediate alteration in BIF and chert interlayered with tuff. Mineral assemblage quartz - albite - metamorphic sericite - magnetite - chlorite - ankerite - calcite - epidote - rutile - pyrite - haematite. The epidote present is, probably, Fe-rich pistasite. Carbonate veins and vein-parallel shearing.
CD215 537.1	Intermediate alteration in BIF interlayered with tuff. Mineral assemblage magnetite - quartz - albite - metamorphic(?) sericite - ankerite - chlorite - haematite - rutile - pyrite. Ankerite veins with minor quartz, chlorite and haematite.
CD215 538.3	Intermediate to proximal alteration in mafic tuff interlayered with minor BIF. Mineral assemblage magnetite - quartz - albite - metamorphic sericite - ankerite - chlorite - haematite - pyrite. Quartz-ankerite veins with minor pyrite and chalcopyrite and a bleached halo of proximal alteration.
CD280 392.9	Intermediate to proximal alteration in mafic tuff interlayered with BIF. Mineral assemblage magnetite - quartz - albite - metamorphic sericite - ankerite - chlorite - haematite - pyrite. Quartzankerite-chlorite veins with minor pyrite and a bleached halo of proximal alteration. Note that bleaching is more widespread in the tuffite layers than in the BIF layers: chlorite is replaced more easily than magnetite.
CD215 327.6	Proximal alteration in BIF interlayered with minor tuff, in the SSZ. Mineral assemblage Quartz - ankerite - siderite - haematite - pyrite - sericite. In the weathered surface, siderite is dark red-brown while ankerite is much paler brown. Quartz-siderite veins with minor pyrite and haematite. Earlier brittle-ductile and later brittle deformation.
CLEO-2	Gold mineralisation in BIF. Sulphidation in host rock; banded quartz vein.

16.2 Randalls

The Randalls gold deposit is about 100 km E from Kalgoorlie, in BIFs that have been altered and metamorphosed under low-amphibolite facies PT conditions (Newton et al. 1996).

<u>Hand specimen descriptions</u>

Sample	*Description*
R-1	Sulphidised BIF. Mineral assemblage: quartz, hornblende, pyrrhotite, arsenopyrite, chlorite, carbonate, biotite, chalcopyrite. A cross-cutting quartz vein and remains of cross-cutting pyrrhotite veins. Massive green bands are dominantly chlorite.
R-2	Sulphidised BIF. Abundant, large-grained, idiomorphic arsenopyrite. Intensely brecciated, visible gold occurring chiefly with chlorite. Free and inclusion gold is also related to arsenopyrite. Mineral assemblage: quartz, chlorite, arsenopyrite, hornblende, carbonate, biotite, pyrrhotite, gold, ilmenite. Massive green domains are dominantly chlorite.
R-3, R-4	Sulphidised BIF. Large arsenopyrite porphyroblasts, abundant pyrrhotite. Visible gold occurring chiefly with chlorite. Massive green bands are dominantly chlorite.

16.3 Copperhead

The Copperhead gold deposit is located about 40 km NW of Southern Cross. According to Bloem (1994) and Mayers and Warriner (1995), the Copperhead deposit is hosted chiefly by BIF, while mafic and ultramafic volcanic rocks form minor hosts to the ore. The host rocks have been metamorphosed and altered under low-amphibolite facies PT conditions (Bloem 1994). Gold is associated with pyrite and pyrrhotite in quartz veins and all host rocks. <u>Alteration</u> in the BIF is characterised by replacement of magnetite by pyrite and pyrrhotite, and the formation of a quartz + actinolite + pyrite + chlorite mineral assemblage. In mafic host rocks, the visible proximal alteration zones have actinolite + plagioclase + calcite + biotite + chlorite + pyrite mineral assemblages.

<u>Hand specimen descriptions</u>

Sample	*Description*
CH-1	BIF lode. Abundant relict magnetite.

CH-2 Dolerite lode. Chiefly quartz vein material with host rock slivers displaying proximal alteration. Quartz + small volumes of actinolite, calcite, pyrrhotite, chalcopyrite and galena in the veins. Actinolite, biotite, plagioclase, calcite and pyrrhotite in the host rock.

16.4 Fraser's

The major host rocks at the Fraser's gold deposit, Southern Cross, are komatiitic metavolcanic rocks (Bloem 1994, Hay 1995). These are discussed in Section 1.5, above. BIF forms a minor host to the ore at Fraser's. The host rocks have been metamorphosed and altered under mid-amphibolite facies PT conditions.

Unaltered BIF displays a grunerite + anthophyllite + quartz + magnetite mineral assemblage. During alteration, this assemblage is replaced by grunerite + anthophyllite + quartz + pyrrhotite ± chalcopyrite. Some remnant magnetite occurs within the altered BIF.

Hand specimen descriptions

Sample	*Description*
F-1 and F-2	Brecciated BIF-hosted ore. Abundant quartz veins and pyrrhotite. Other minerals present are grunerite, antophyllite and chalcopyrite. Gold content in this lode is approximately 90 ppm.

16.5 Golden Pig

Golden Pig mineralisation, near the Fraser's and Polaris South deposits in the Southern Cross Greenstone Belt, is hosted by BIF. The host rocks have probably been metamorphosed and altered under similar conditions as at Fraser's, i.e. under mid-amphibolite facies PT conditions.

Hand specimen descriptions

Sample	*Description*
Golden Pig	Gold mineralisation in partially weathered BIF.
GP-2	Pyrrhotite-rich quartz vein from the main lode
GP-3	Ore from level 180.

16.6 Nevoria

The major host rock at the Nevoria gold deposit is BIF. The deposit is located 45 km SE of Southern Cross. Komatiitic and basaltic metavolcanic rocks form minor hosts to the ore (Mueller 1990b, Mueller and Groves 1991). The host rocks have been metamorphosed and altered under mid- to upper amphibolite facies PT conditions. Unaltered BIF has a grunerite-quartz-magnetite mineral assemblage. During gold-related alteration, this assemblage is replaced by distal quartz-actinolite-hornblende-magnetite and proximal quartz-actinolite or hedenbergite-pyrrhotite-almandine garnet ± calcite assemblage (Cullen et al. 1990, Mueller 1990b).

Hand specimen descriptions

Sample	*Description*
108077	Diopside-dominated proximal alteration in ultramafic host rock.
NEV-1	Brecciated BIF-hosted lode. Quartz veins, abundant pyrrhotite. Mineral assemblage: diopside and tremolite with minor quartz, calcite, pyrrhotite, pentlandite, magnetite and ilmenite.
NEV-2	Cross-cutting quartz vein in sulphidised BIF. Green hedenbergite in silicate- dominated bands.
NEV-4	Cross-cutting quartz veins in intensely sulphidised (pyrrhotite) BIF. Green hedenbergite is silicate-dominated bands. A garnet-dominated band next to the quartz veins.
NEV-5	Intensely brecciated and altered (carbonated and pyritised) BIF. Host rock: quartz, carbonate, pyrite ± chlorite, pyrrhotite, chalcopyrite. Carbonate has nearly completely replaced Fe-Mg silicates, only locally there is chlorite left. Veins: quartz, carbonate, pyrite.
NEV-6	Intensely brecciated and altered BIF: abundant and coarse-grained pyrrhotite, amphibole (grunerite?) and garnet.

17. Iron oxide-copper-gold deposits

17.1 Osborne, Mt Isa Inlier, Queensland

Hand specimen descriptions

Sample	*Description*
OSB Lower Fe	Ore. Massive magnetite rock with chalcopyrite.
OSB Upper Fe	Ore. Banded magnetite-quartz rock with chalcopyrite and pyrite

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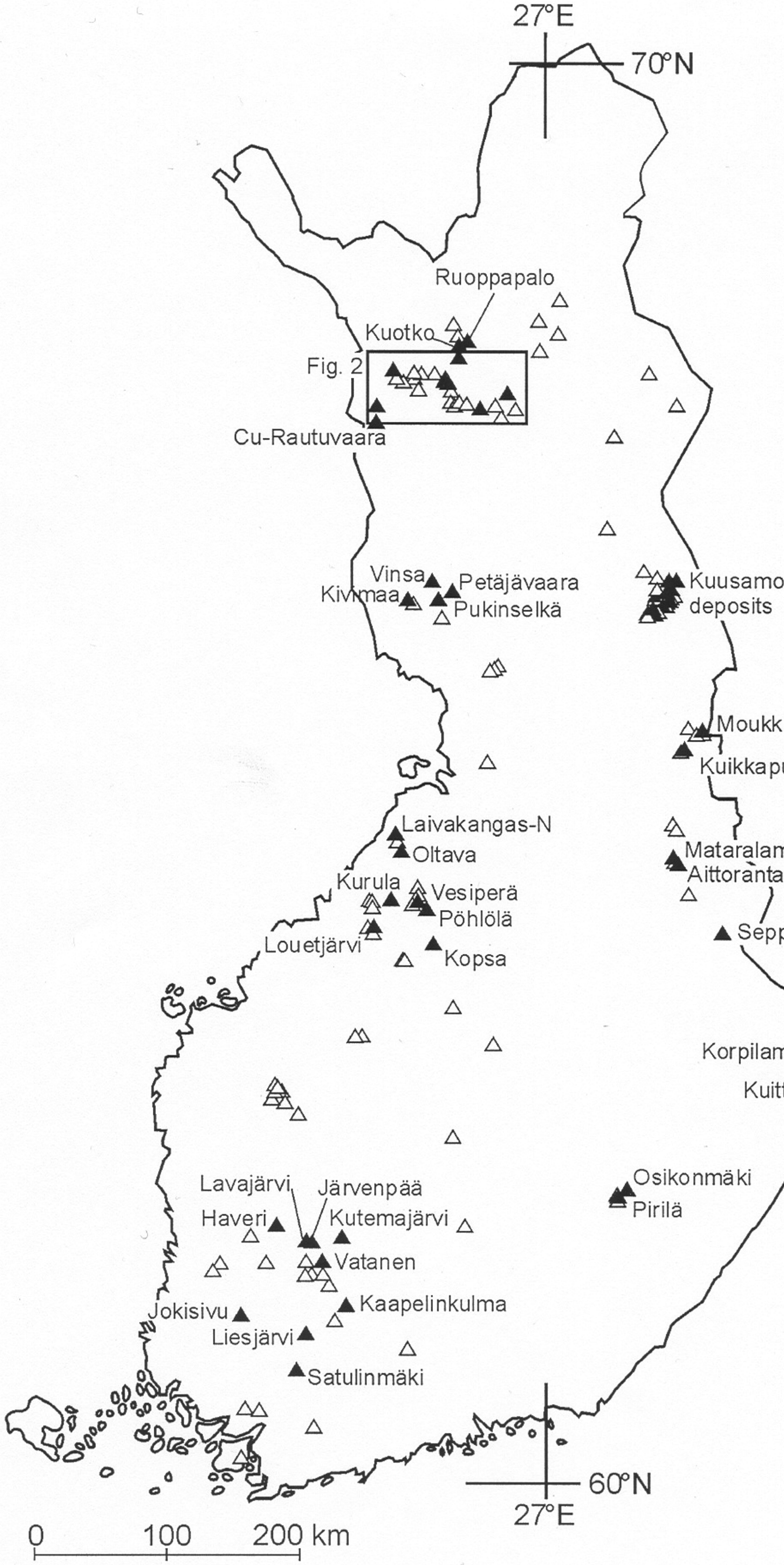
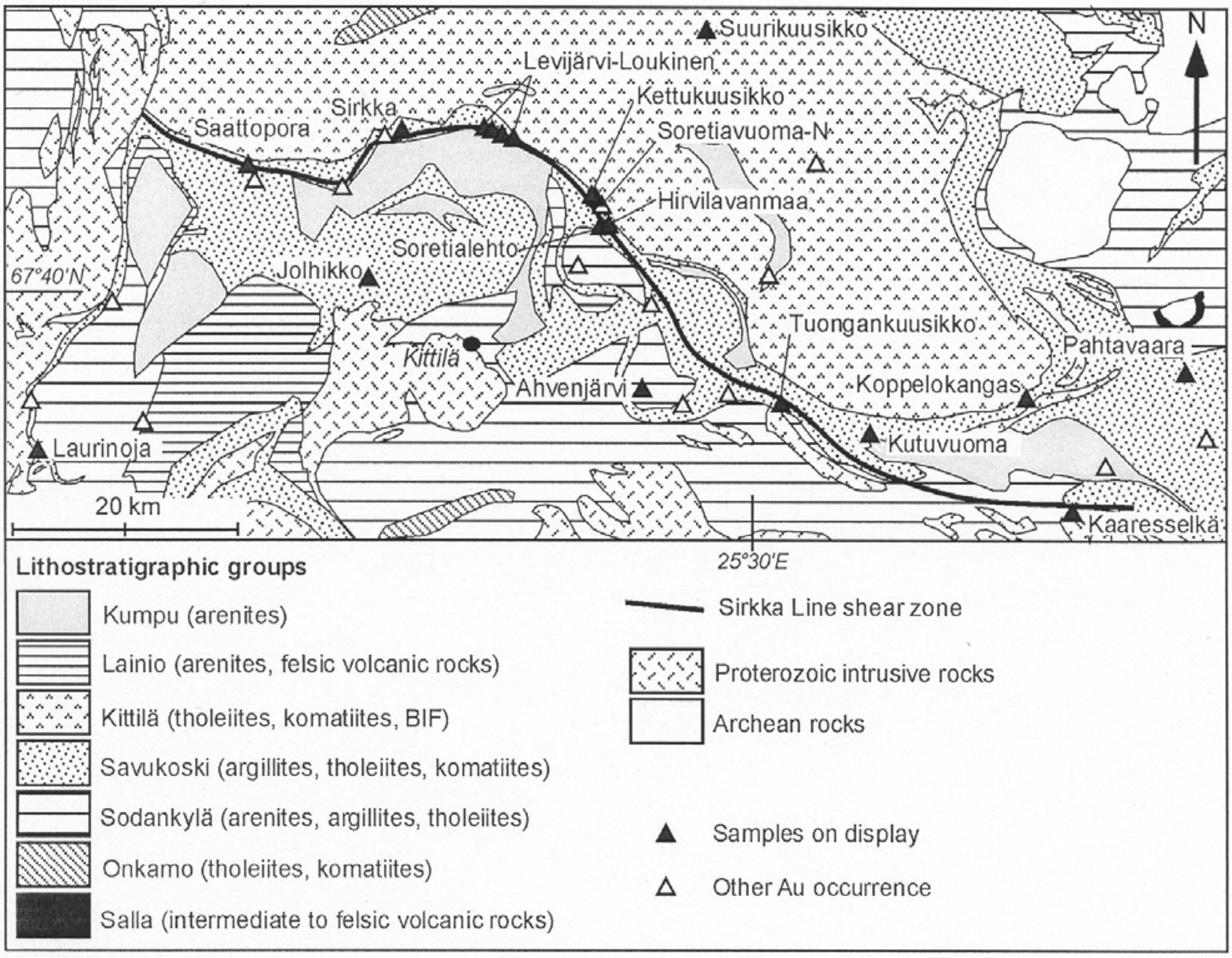
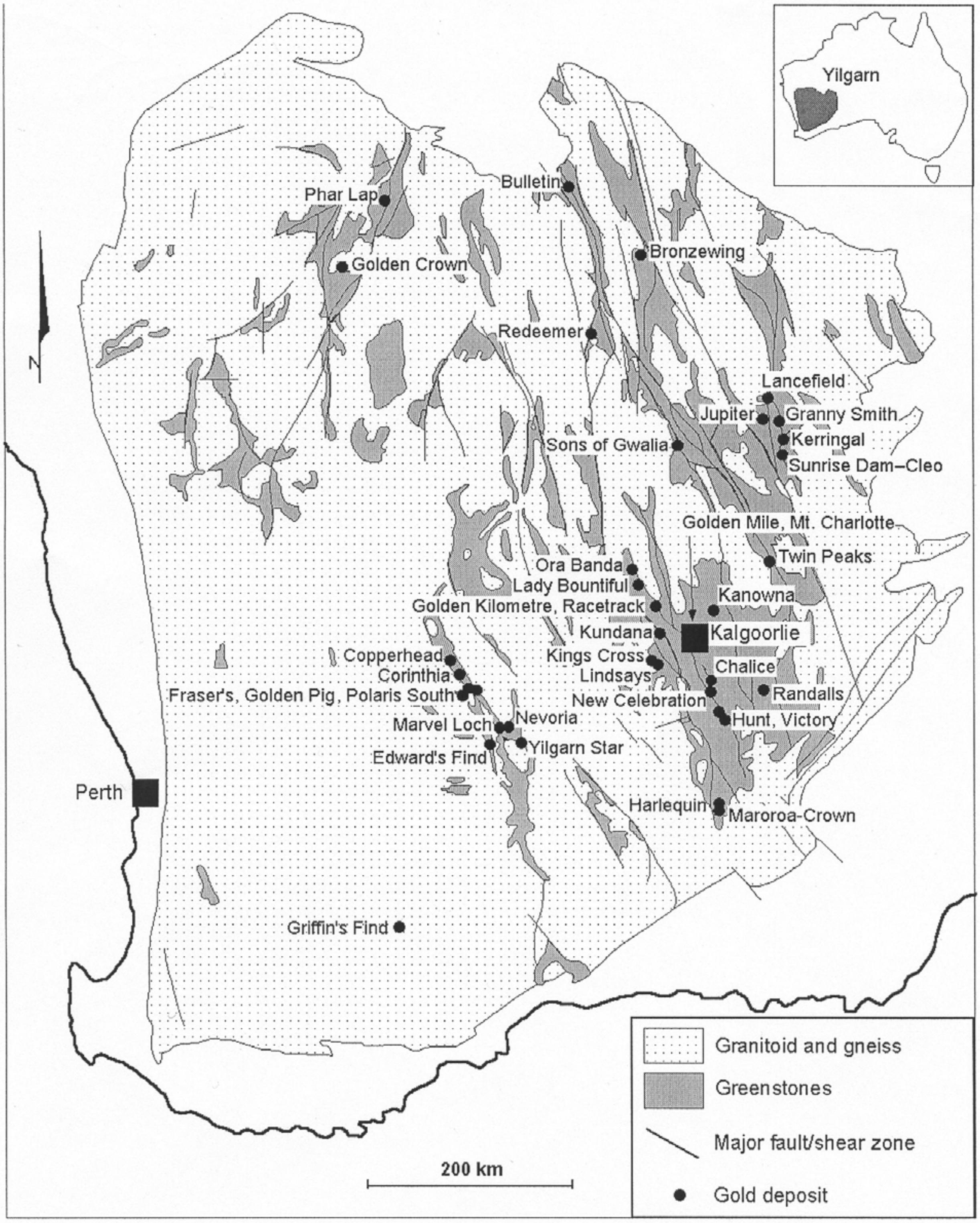


Finland. Black triangle: Deposit or occurrence mentioned in this report. White triangle: other gold deposit or occurrence.



Central Lapland. Black triangle: Deposit or occurrence mentioned in this report. White triangle: other gold deposit or occurrence.



Western Australia, Yilgarn Block: Deposits mentioned in this report.