Kanowna Belle gold mine

by

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History of exploration and mining

Exploration in the Kanowna district commenced in 1895 with the discovery of gold near the historic Kanowna townsite. About 0.5 million ounces of gold (Moz) was produced in the early part of the twentieth century, primarily from quartz reef (e.g. White Feather – Reward trend) and 'deep lead' palaeochannel deposits. Modern exploration for gold, nickel, and base metals (volcanogenic massive sulfides) commenced in the late 1970s. A series of widely spaced rotary airblast (RAB) drilling and soil sampling programs were carried out in the vicinity of the Kanowna Belle deposit between 1983 and 1989. These programs targeted the historic 'deep lead' deposits with the aim of locating a shallow supergene gold resource. 'Target 11' was a coincident gold anomaly in soils (350 m-diameter bullseye anomaly with a peak value of 150 ppb) and RAB drilling (2 m at 11 g/t Au from 52 m, 4 m at 3 g/t Au from 28 m) at the western edge of the target area. Follow-up reverse circulation (RC) drilling of this anomaly in late 1989 revealed economic mineralization beneath a 40 m-deep zone of gold-depleted saprolite. By September 1991, a resource of 11.2 Mt at 5.2 g/t had been determined by RC and diamond drilling, and openpit feasibility studies had commenced. By 1993, drilling on 80 × 80 m spacings had been completed to a depth of 1000 m, and proved a pre-mining resource of 21.4 Mt at 5.7 g/t Au (4 Moz) for the Kanowna Belle deposit. Openpit mining was completed in 1998 to a depth of 220 m, with a total production of 8.87 Mt at 4.4 g/t Au. Mining of the decline commenced in 1995, with underground production beginning in July 1998. Total gold production from Kanowna Belle to 31 December 2003 totals 2.6 Moz. The remaining resources and reserves are listed in Table 1.

Kanowna Belle and the Golden Mile are the only known refractory pyritic orebodies in the Yilgarn Craton where arsenopyrite is not a major sulfide phase. Gold in the Kanowna Belle deposit occurs mostly as fine grained (<10 μm) inclusions in pyrite or as invisible gold located in arsenic-rich growth zones in pyrite (Guest, 2002; typical ore assemblage contains 0.5–1.5% S and 40 ppm As). Processing is by jaw crushing, primary semi-autogenous grinding (SAG) milling, and secondary ball milling, followed by sulfide flotation. The pyrite and arsenopyrite concentrate is treated by roasting followed by carbon-in-leach (CIL) to extract the gold. The nameplate capacity of the Kanowna Belle plant is 1.35 Mtpa, but it is currently operating at 1.85 Mtpa. Mill feed is in excess of the mine production (1.3 Mtpa) and is supplemented from openpit stockpiles. The average gold recovery in 2003 was 89.3%.

Geological and structural setting

The following section is extracted from Davis (2000). Kanowna Belle occurs in the Boorara Domain subdivision of the Kalgoorlie Terrane, Eastern Goldfields. Mineralization is hosted in a sequence of conglomeratic and felsic volcaniclastic rocks (2668 Ma), which have been intruded by a porphyritic granodiorite (Kanowna Belle Porphyry; 2655 Ma) and minor felsic intrusions (Fig. 1). An intense zone of structural disruption separates the deposit into hanging- and footwall structural domains, and has a close spatial association with mineralization (Figs 1 and 2).

Initial deformation that controlled deposit architecture occurred in response to northerly directed thrusting during north–south shortening. This produced a mylonitic fabric (Fitzroy mylonite), variation in the strike of rocks in the foot- and hangingwalls, and was instrumental in localizing

Table 1. December 2003 resource and reserve statement for Kanowna Belle

	Mt	*Au g/t*	*Million oz*
Reserves	15.7	4.5	2.25
Additional resources (M+I)	11.1	4.5	1.59
Total reserves + resources	26.8	4.5	3.84

NOTES: M+I = Measured and Indicated Ore Reserves

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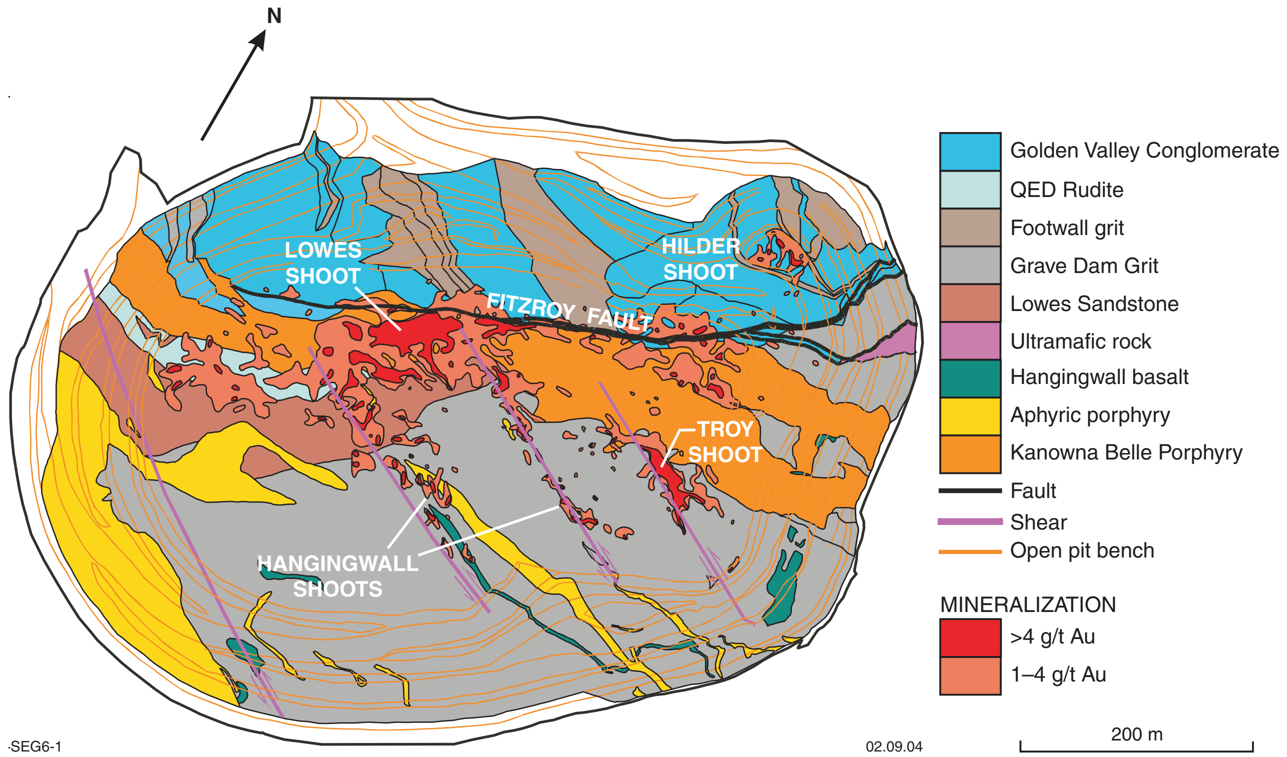

Figure 1. **Geology of the Kanowna Belle openpit (map is orientated on KB mine grid; mine grid north = 330° TN; centre of pit is located at about MGA 363514E 6612745N)**

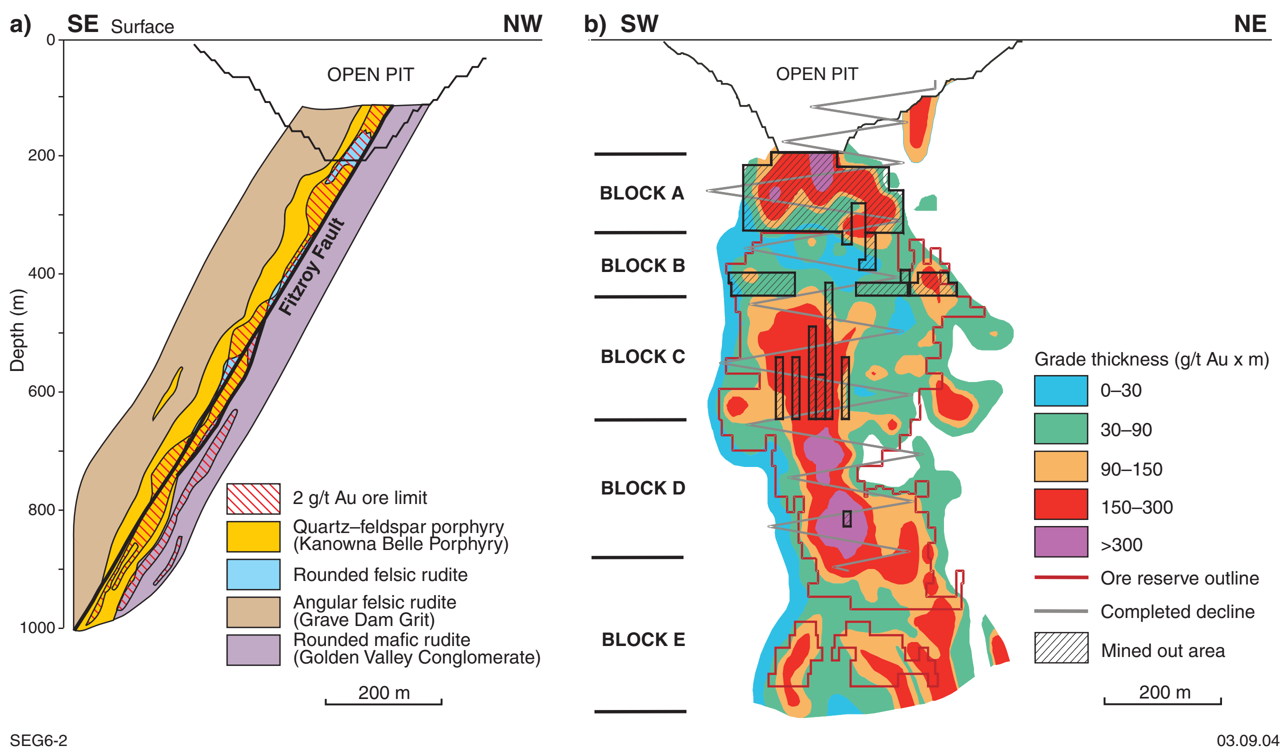

Figure 2. **Sections through Kanowna Belle gold mine. a) northwest–southeast cross section (looking west). b) long section (looking northwest in the plane of the Fitzroy Shear Zone)**

Table 2. Kanowna Belle alteration stages

Timing	*Proximal assemblage*	*Distal assemblage*
Early	Ankerite–sericite	Ankerite–sericite along regional structures, hematite alteration of porphyry intrusions
Late (gold-bearing hydrothermal fluids)	Alkali feldspar–dolomite Phengite–dolomite–pyrite	Muscovite–ankerite–pyrite

subsequent emplacement of the tabular Kanowna Belle porphyry. A short tectonic hiatus is inferred during emplacement of the Kanowna Belle porphyry, followed by resumption of north–south shortening. This resulted in the formation of an extensive zone of brittle–ductile deformation, characterized by fault splays that bound zones of intense foliation, all of which have accommodated steeply directed reverse movement. This zone is termed the Fitzroy Shear Zone. The Fitzroy mylonite and Fitzroy Shear Zone are interpreted to have formed during regional D_1.

A switch in far-field stress axes to an east-northeasterly–west-northwesterly orientation caused sinistral reactivation of the Fitzroy Shear Zone. This imparted sigmoidal geometries to pre-existing Fitzroy Shear Zone structures, and produced a shallow lineation on pre-existing structures in response to subhorizontally directed shearing. Emplacement of mineralization is interpreted to have been contemporaneous with sinistral reactivation of the Fitzroy Shear Zone (c. 2650 Ma), and is hosted by carbonate breccias, carbonate vein stockworks, quartz–carbonate veins, siliceous breccias, and sulfide–quartz–carbonate veinlets (stringers) and sheeted vein arrays. A synchronously developed, steep, northwesterly trending foliation has locally controlled emplacement of mineralization. Fitzroy Shear Zone reactivation, cleavage formation, and emplacement of mineralization are all interpreted to have been synchronous with the regional D_2 deformation event.

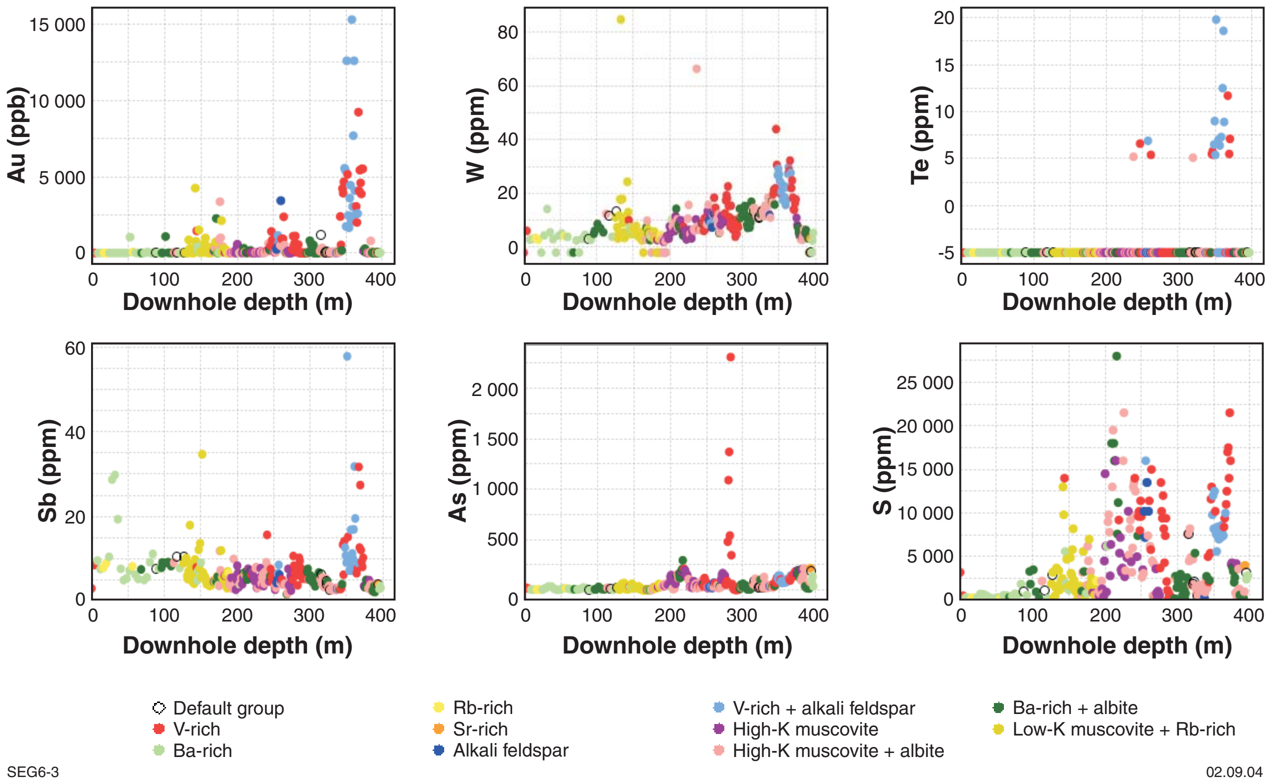

Figure 3. Distribution of pathfinder elements in diamond drillhole GDD438 (Lowes shoot). Downhole geology: 0–95 m = quartz grit; 95–130 m = felsic intrusion; 130–270 m = quartz grit and quartz–feldspar porphyry; 270–375 m = Kanowna Belle porphyry; 375 m = Fitzroy Fault; 375–398 m = polymict conglomerate

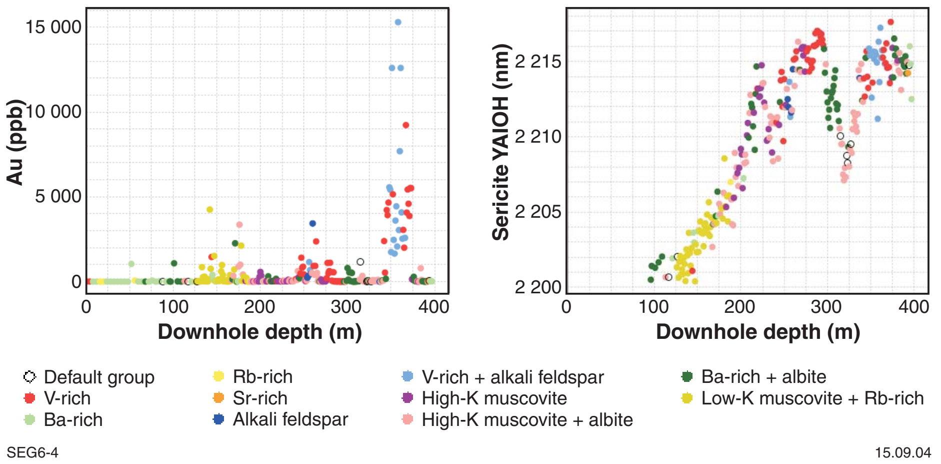

Figure 4. **Gold grade and sericite infrared absorption wavelength (measured using PIMA, a portable infrared multispectral analyser) versus downhole depth for diamond drillhole GDD438. Downhole geology as for Figure 3**

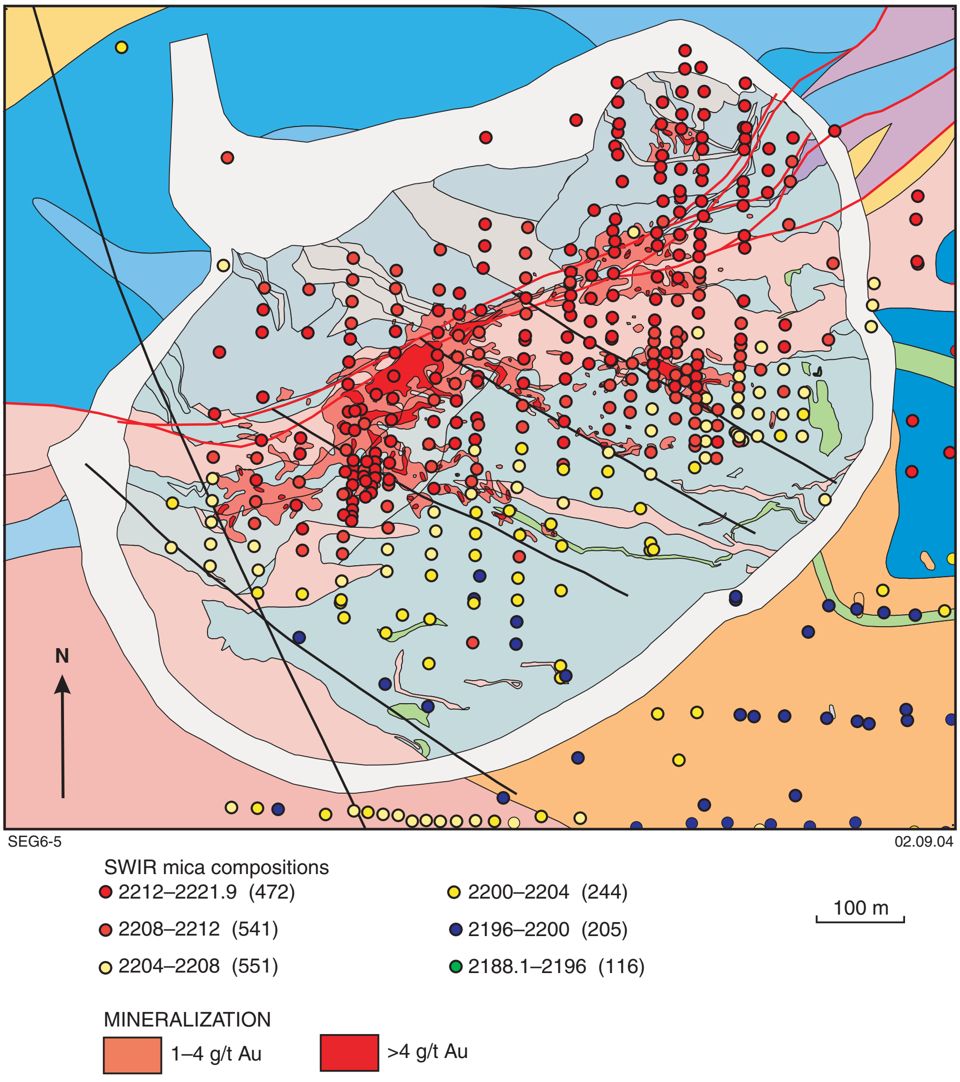

Figure 5. **Results of PIMA survey of SWIR white mica compositions across the Kanowna Belle pit. Note correlation of high wavelength micas and gold grade shells**

Hydrothermal alteration and gold mineralization

Two temporally and mineralogically distinct styles of gold mineralization are recognized at Kanowna Belle, corresponding to stages III and IV of the vein emplacement history (Aaltonen, 1997). The first, volumetrically minor, style of gold mineralization is represented by a telluride-associated mineralogy, and is restricted to crustiform carbonate(–quartz) veins and breccias (type III veins) near the Fitzroy Shear Zone. Veins show structural overprinting relationships consistent with emplacement synchronous with regional D_2. Telluride–gold mineralization occurs as microfracture and microvug infill. Free gold is associated with altaite, coloradoite, and melonite with rare hessite. No gold tellurides have been noted.

The second style of gold emplacement comprises the bulk of economic mineralization and overprints the telluride-associated style. It is a telluride-absent mineralization phase that displays a strong D_2 control on lode geometry. Gold occurs within pyrite–sericite–quartz–carbonate 'stringers' (type IV veins), which comprise stockwork geometries close to the Fitzroy Shear Zone but become more regularly aligned with the regional S_2 fabric away from the shear zone. Gold forms as inclusions, is located in arsenic-rich growth zones in pyrite, or both. Subordinate free gold occupies D_2 extensional sites adjacent to pyrite crystals.

Several stages of hydrothermal alteration have been recognized at Kanowna Belle (Table 2). The proximal alteration footprint associated with gold mineralization hosted by sedimentary rocks (footwall lodes) and porphyry (Lowes shoot) includes W, Mo, Bi, Te, As, and Sb (Fig. 3). The W halo around Lowes shoot is about 150 m wide and shows a systematic increase towards gold mineralization. Both sedimentary- and porphyry-hosted mineralization styles have alkali halos (K, Na, Rb, and Ba) that are well developed and characterized by alkali feldspar (albite–K-feldspar) altered rocks with a sericite overprint.

Gold in Lowes shoot is mainly found within V-bearing phengite domains, which are characterized by high AlOH short wavelength infrared (SWIR) absorption, near the transition to Ba-rich muscovite, which is characterized by low AlOH absorption wavelengths (Fig. 4). The correlation between gold and white mica gradients is evident at all scales across Kanowna Belle (Fig. 5). The transition from V-rich phengite (oxidized) associated with ore to Ba-rich (reduced) muscovite implies that a redox gradient influenced the composition of the white micas. This gradient is consistent with that inferred from the distribution of sulfur isotope values in ore-related and regional pyrite. The redox gradient observed at Kanowna Belle is interpreted to have resulted from multiple and contrasting fluid types that overlapped temporally and spatially during gold deposition.

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