Prosperity - Fish Lake

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Fish Lake porphyry copper-gold deposit, central British Columbia

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ABSTRACT

The Fish Lake porphyry copper-gold deposit is situated 130 km southwest of Williams Lake, British Columbia, near the southwestern edge of the Intermontane Belt. The deposit is spatially and genetically related to the Late Cretaceous Fish Lake Intrusive Complex. This Complex consists of the steeply-dipping, lenticular Fish Creek quartz diorite stock surrounded by an east-west swarm of subparallel quartz feldspar porphyry dikes. The greater part of the deposit, however, is hosted by adjacent andesite flows and volcaniclastic rocks of probable Early Cretaceous age.

The Fish Lake deposit contains a global geological reserve of 1148 million tonnes with an average grade of 0.22% Cu and 0.41 g/t Au. It is oval in plan and is 1500 m long, 800 m wide and extends to a maximum depth of 880 m. Potassium silicate alteration forms a central alteration zone co-extensive with the copper-gold mineralization. An irregular zone of phyllic alteration is developed at the boundary between the potassium silicate alteration zone and the surrounding propylitic altered rocks. Later sericite-iron carbonate-clay alteration forms numerous narrow zones throughout the deposit. Pyrite and chalcopyrite are the principal sulphide minerals within the deposit and bornite occurs widely in subordinate amounts. Native gold occurs as microscopic grains, as inclusions and along microfractures in chalcopyrite, tetrahedrite/tennantite and pyrite. An irregular pyrite halo several hundred metres wide surrounds the northern and eastern sides of the deposit, and is more or less co-extensive with the phyllic alteration zone.

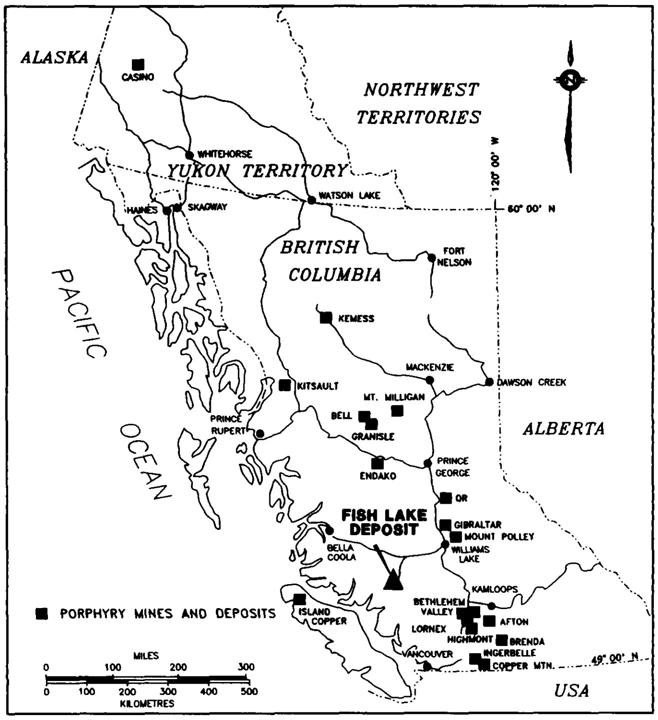

FIGURE 1. Location map in British Columbia.

Introduction

The Fish Lake deposit is situated 130 km southwest of Williams Lake in southwestern British Columbia at latitude 51°27′ North, longitude 123°37′ West, on NTS mapsheet 92O/5 (Fig. 1). The deposit lies at an elevation of 1450 m within gently rolling, forested terrain of the Fraser Plateau (Fig. 2), with the Coast Mountains rising abruptly to elevations of greater than 2500 m, 10 km to the southwest. The property is situated immediately north of Fish Lake, within the upper valley of Fish Creek, a tributary of the Taseko River (Fig. 3).

History

Prospectors E. Calep and C.M. Vick made the initial discovery at Fish Lake in the 1930s when they found copper showings in outcrop approximately 1 km east of the main deposit. Phelps Dodge Corporation recognized and drill tested the porphyry copper potential of these showings in 1960. Taseko Mines Limited acquired the property in 1966 and, after completing a small drill program, optioned the property, first to Nittetsu Mining Company Ltd. in 1970, and then to Quintana Minerals Corporation who drilled 4800 m in 24 holes in 1973 and 1974 (Wolfard, 1976). Bethlehem Copper Corporation optioned the property in 1979. In 1981, Bethlehem Copper amalgamated with Cominco Ltd. Together these companies completed 14 150 m of diamond drilling and 4800 m of percussion drilling (McMillan, 1983). Taseko Mines, under an exploration agreement with Cominco, drilled 7506 m of core in ten holes in 1991, and in 1992 completed approximately 60 000 m of HQ and NQ diamond drilling in 111 holes (Figs. 5 and 6). By the end of 1992, the Fish Lake deposit had been delineated. In 1993, Taseko Mines acquired Cominco's residual interest to hold 100% of the property.

Regional Geology

The Fish Lake property is situated within the western-most Intermontane Belt, about 50 km northeast of the Coast Plutonic Complex but within the boundary zone between the Coast and Intermontane morphogeological belts. The surrounding region is underlain by several poorly exposed lithotectonic assemblages of Late Palaeozoic to Cretaceous age, cut by mid-Cretaceous to Early Tertiary plutons.

The deposit is on the northeast side of the Yalakom Fault (Fig. 4), a major Eocene dextral strike-slip fault with postulated offsets of 80 km to 190 km (Tipper, 1969), 125 km to 175 km (Kleinspehn, 1985) or 115 km (Riddell et al., 1993).

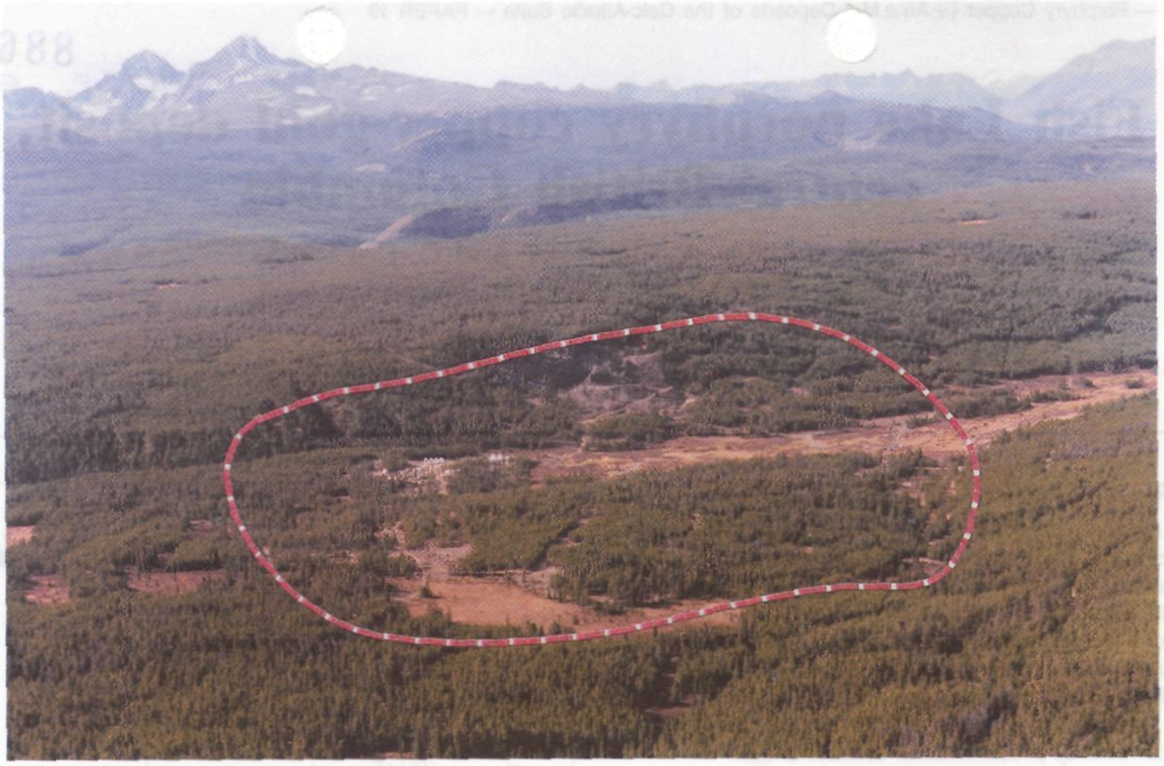

FIGURE 2. View looking west over the Fish Lake deposit (outlined) toward Mount Tatlow in the Coast Range mountains. Fish Creek flows to the right across the centre of the picture, and the Taseko River valley is visible in the middle distance.

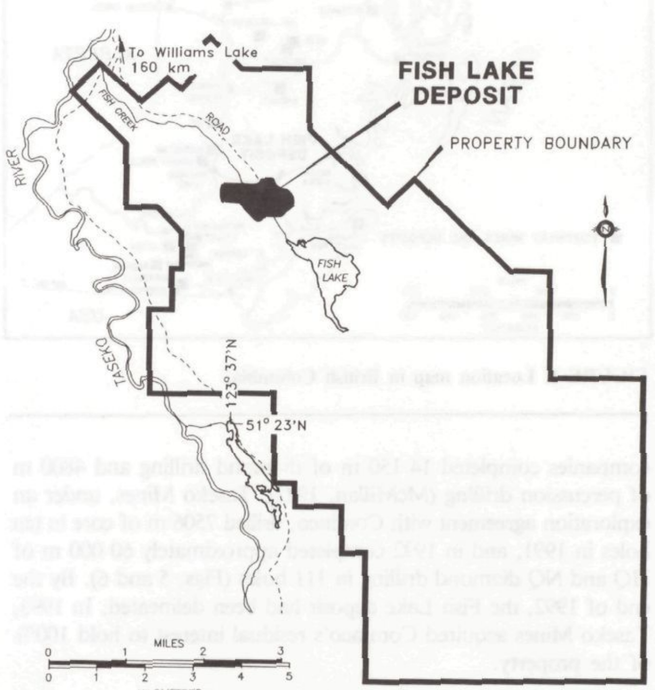

FIGURE 3. Property location map.

Most of the rocks exposed northeast of the Yalakom Fault are feldspathic lithic sandstones, conglomerates, and shales. The andesitic volcanic and volcaniclastic rocks which host the greater part of the Fish Lake deposit are poorly exposed. They may correlate with a succession of andesites, tuffaceous sandstones, argillites and siltstones that crops out near the mouth of Fish Creek. Tipper (1978) assigned both the sedimentary and volcanic rocks to the Upper Cretaceous Kingsvale Group. Riddell et al.(1993) and Schiarizza et al. (1993) correlated the sedimentary rocks with the Lower Cretaceous Jackass Mountain Group, but assigned the volcanic succession found near the mouth of Fish Creek to a separate unit, in fault contact with the adjacent sedimentary rocks. Fossils collected by Riddell et al. (1993), from argillite apparently intercalated with volcanic rocks near the mouth of Fish Creek, are Hauterivian (Early Cretaceous) in age. The sedimentary rocks that structurally underlie the Fish Lake deposit, and those that are encountered in drill holes to the south of the deposit, are also likely correlative with the nearby Hauterivian siltstones.

Subhorizontal Miocene plateau basalts and non-marine sediments of the Chilcotin Group form an extensive cover in the immediate area.

Geology of the Deposit

Andesite flows and volcaniclastic rocks host the greater part of the Fish Lake deposit. These rocks are underlain at depth, below the low-angle Fish Lake Fault, by clastic sedimentary rocks. The deposit is spatially and genetically related to the Fish Lake Intrusive Complex that consists of a small, steeply dipping body of quartz diorite (the Fish Creek stock) surrounded by an east-west elongate complex of subparallel quartz feldspar porphyry dikes (Figs. 7 and 8).

Volcanic and Sedimentary Rocks

An andesite sequence consisting largely of coarse-grained ash tuff with subordinate lapilli tuff, laminated tuff and flows hosts the lower eastern portion of the deposit. Thick, uniform andesite flows predominate in the west, around the western border of the Fish Creek stock. A sequence of thick, more coarsely porphyritic flows and subvolcanic bodies hosts the upper eastern portion of the deposit. The clastic sedimentary rocks that underlie the host andesite sequence below the Fish Lake Fault, and those found to the south, are probably correlative.

Andesite tuffs are most often coarse-grained crystal tuffs with minor lapilli-sized clasts. They are most often unbedded or show indistinct bedding marked by subtle grain-size variation; less often, sharp bordered units of different grain size are interbedded on a

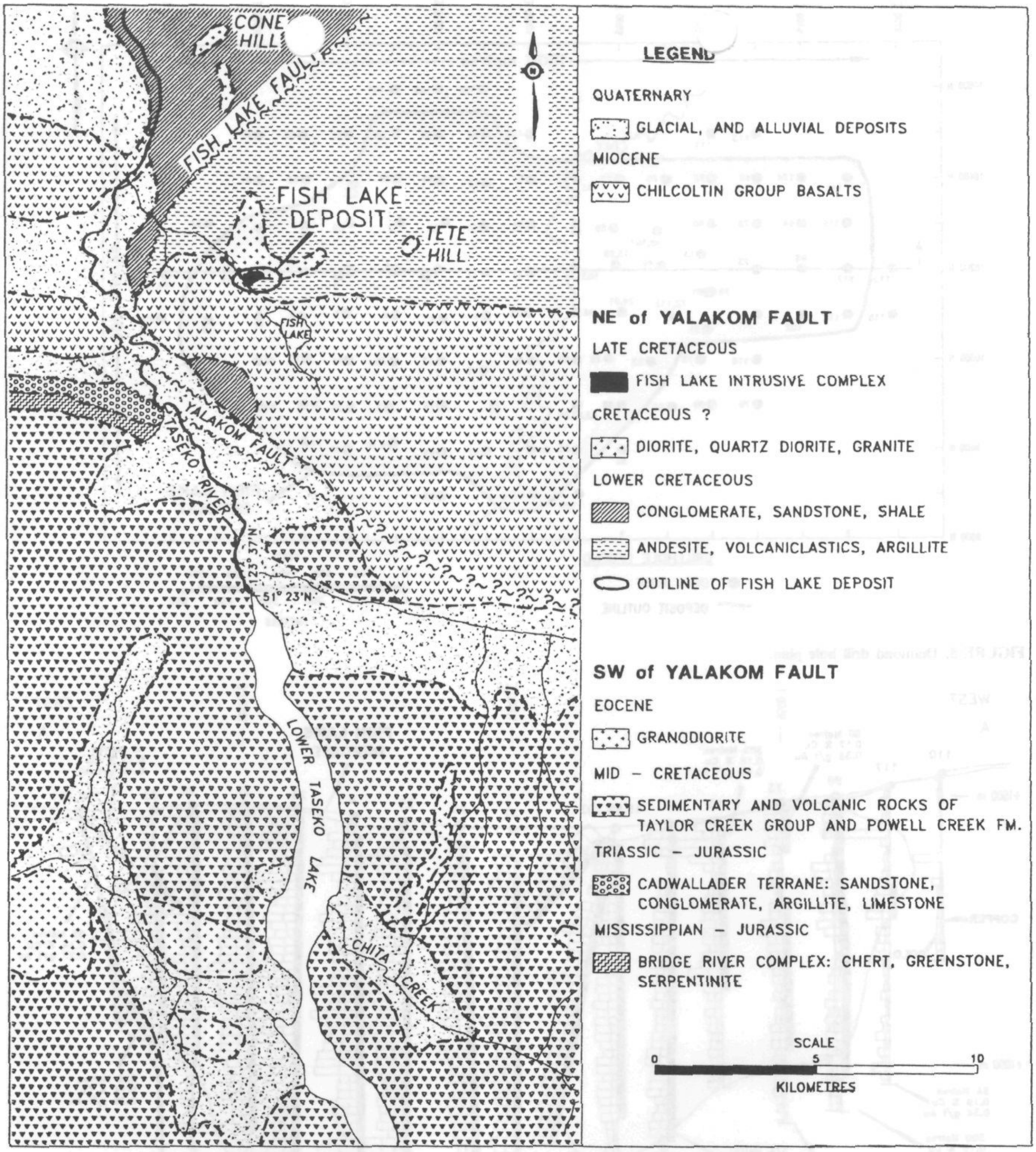

FIGURE 4. Regional geology (modified after Riddell et al., 1993).

scale of a few millimetres to a few centimetres. Volcanic wackes, with up to 25% detrital quartz grains, occur sparsely within the northern part of the deposit.

Andesite lapilli tuff contains isolated to packed, subrounded to subangular clasts ranging up to several centimetres in size; the more clast-rich variants would most aptly be termed lapilli stones. The heterolithic constituent clasts are mostly of andesite, although intrusive clasts also occur. Clasts often show strongly altered, variably destroyed borders, which may be the result of either synvolcanic, or later synmineral alteration. Andesite lapilli tuff forms units, ranging from tens of centimetres to several tens of metres thick, interbedded with andesite tuff.

Laminated andesite tuff is a fine-grained, pale, siliceous tuff with millimetre-scale planar laminae, marked by colour banding and locally, by the alignment of chloritic alteration aggregates. The tuff forms units ranging from several metres to several tens of metres in thickness, often interbedded with units of coarser plagioclase crystal tuff.

Andesite flows are interbedded with tuffs within the lower eastern part of the deposit and also form distinctive, thick units which host the upper eastern part of the deposit and a large portion west of Fish Creek. In general, flows are porphyritic, with plagioclase and hornblende phenocrysts in a fine-grained to aphanitic groundmass that locally shows a well developed trachytic tex-

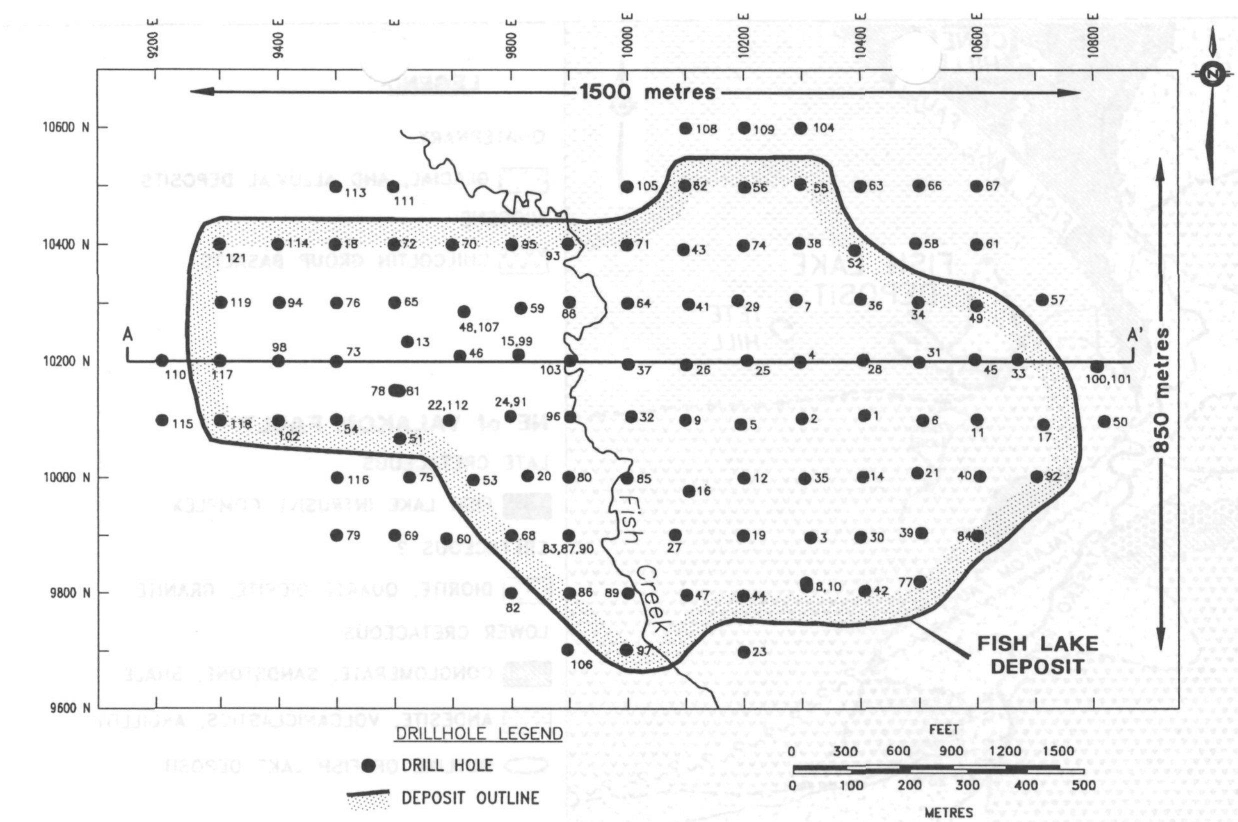

FIGURE 5. Diamond drill hole plan.

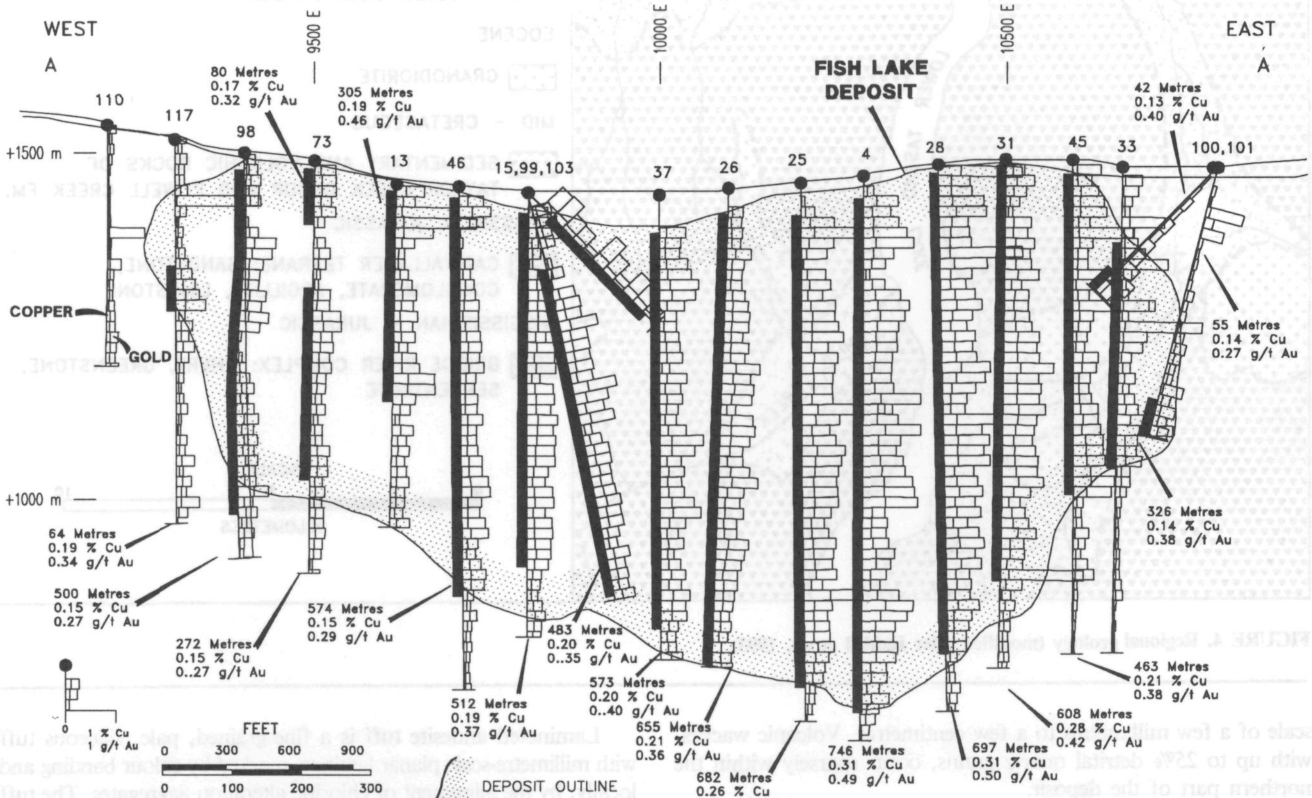

FIGURE 6. Longitudinal Section 10200 N (looking north).

ture. Homogeneous, coarse-grained, sharp-bordered andesite units likely represent synvolcanic dikes or sills. The extensive andesite flows west of Fish Creek show a similar, though more uniform lithology and commonly contain distinctive amoeboid quartz amygdules a few millimetres in size.

The porphyritic andesite that hosts the upper eastern part of the Fish Lake deposit (Figs. 7 and 8) forms a shallow easterly dipping body up to 500 m thick. It extends to the north and east well beyond the deposit. The unit typically contains 45% to 65% uniform sized plagioclase phenocrysts, mostly 1 mm to 2 mm in length;

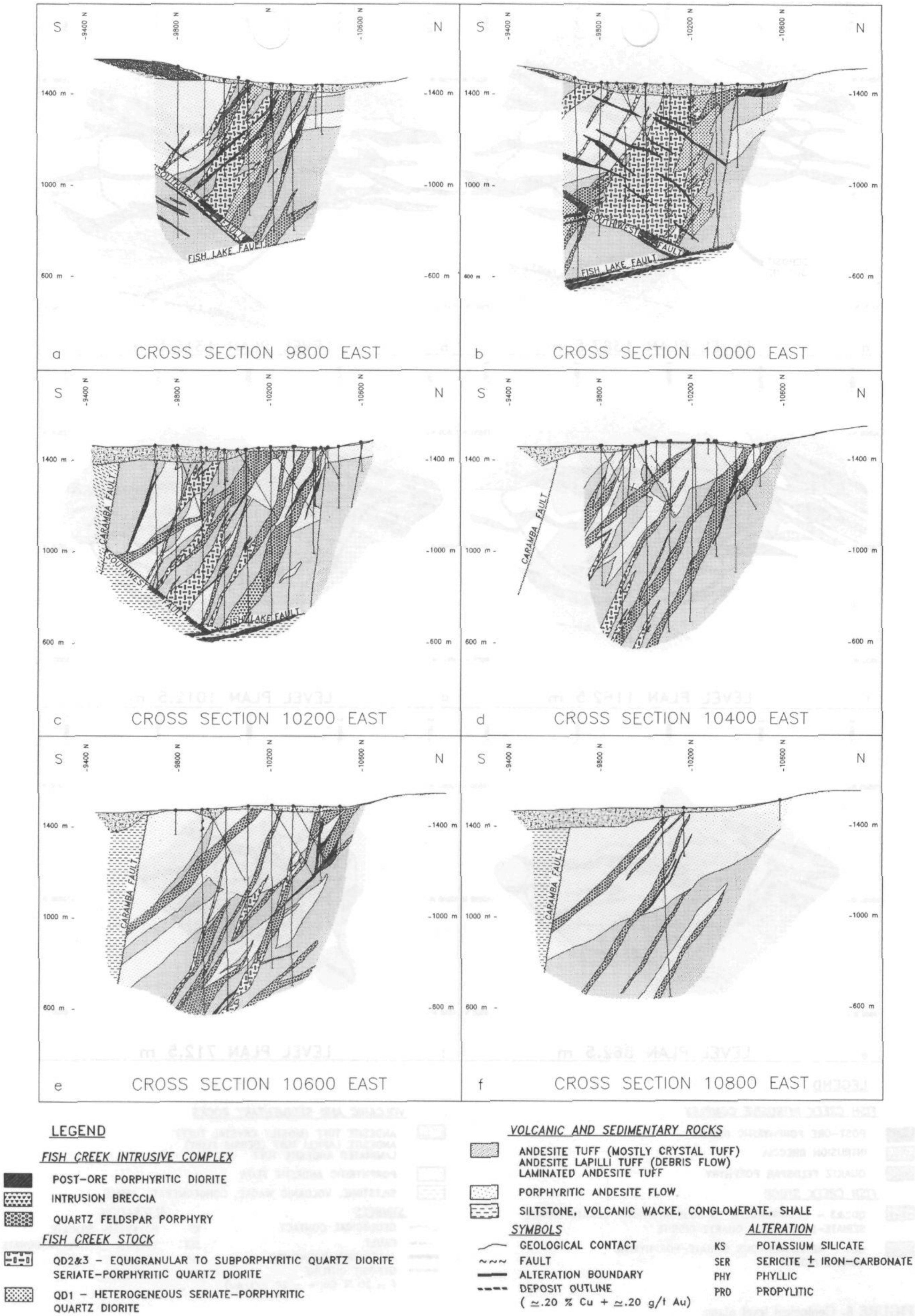

FIGURE 7. Geological cross-sections (looking west).

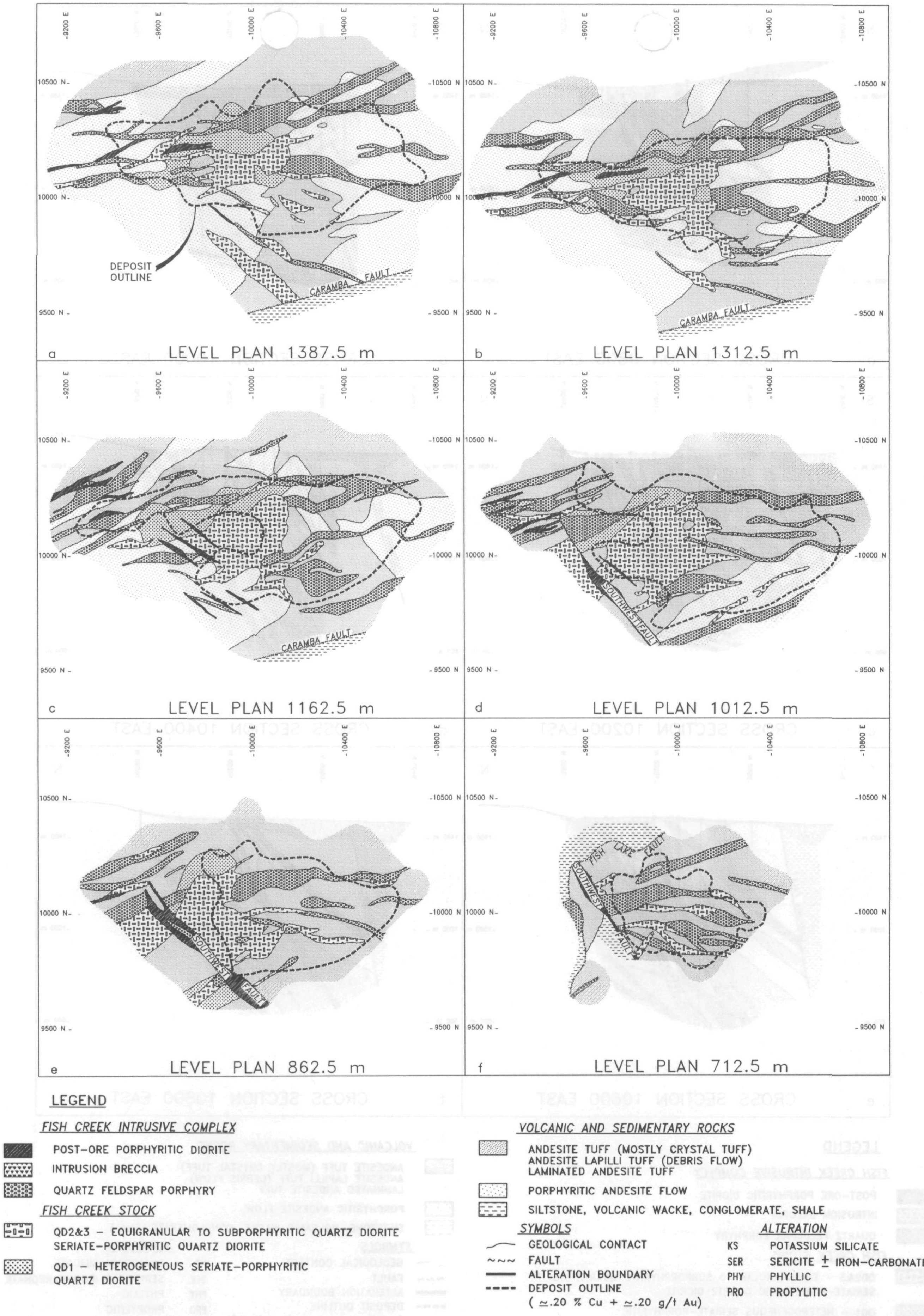

FIGURE 8. Geological level plans.

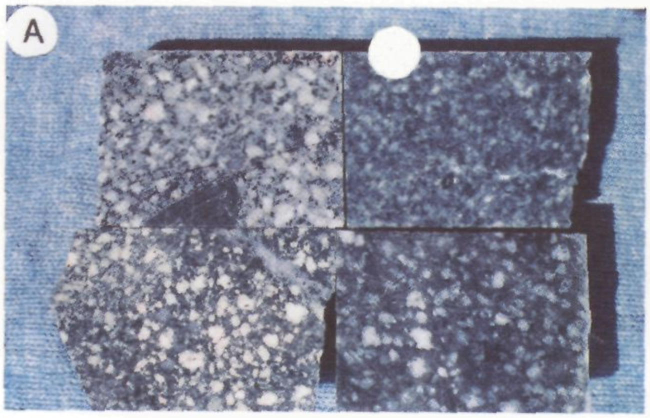

FIGURE 9a. Fish Lake intrusive complex. Clockwise from top right: post-mineral porphyritic diorite (PD), quartz feldspar porphyry (QFP), Fish Creek stock (phases QD2 and QD3).

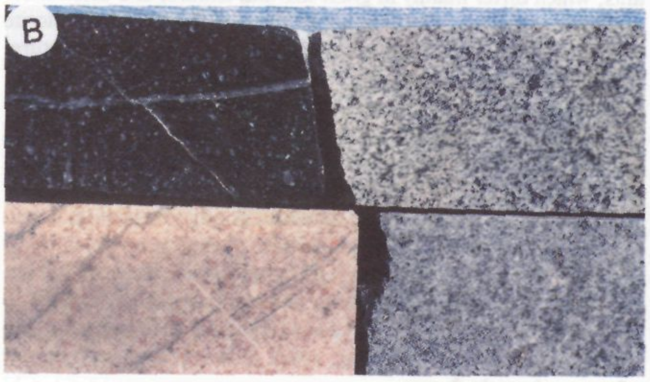

FIGURE 9b. Alteration types. Clockwise from top right: propylitic, pervasive phyllic, sericite-iron carbonate-clay, potassium silicate (with abundant hydrothermal biotite).

FIGURE 9c. Secondary K-spar along veinlets and fractures within QD2 and QD3 units (K-spar stained yellow by sodium cobaltinitrite).

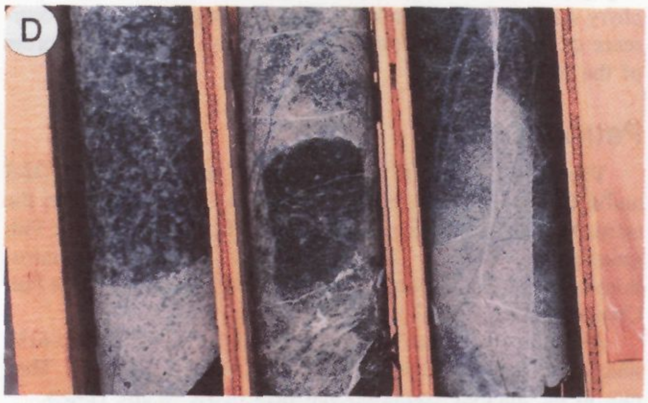

FIGURE 9d. Abundant, irregularly distributed, black hydrothermal biotite within altered andesite flow and porphyritic andesite.

FIGURE 9e. Chlorite alteration aggregates along bedding and margins of veinlets in altered andesite tuff.

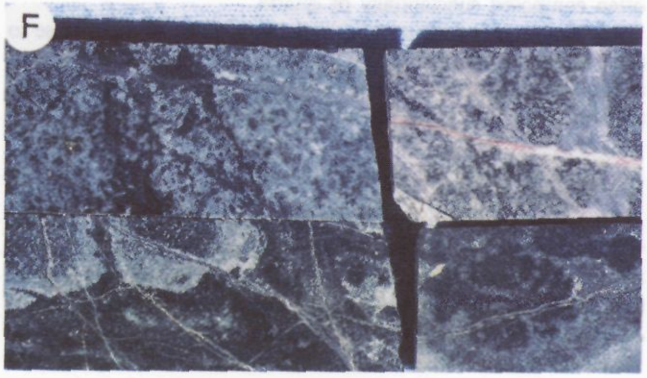

FIGURE 9f. Closely spaced quartz-sulphide veins with phyllic alteration envelopes.

FIGURE 9g. Sharp borders between dark potassium silicate alteration (with abundant hydrothermal biotite) and later, pale sericite-iron carbonate-clay alteration; several borders are coincident with quartz veinlets.

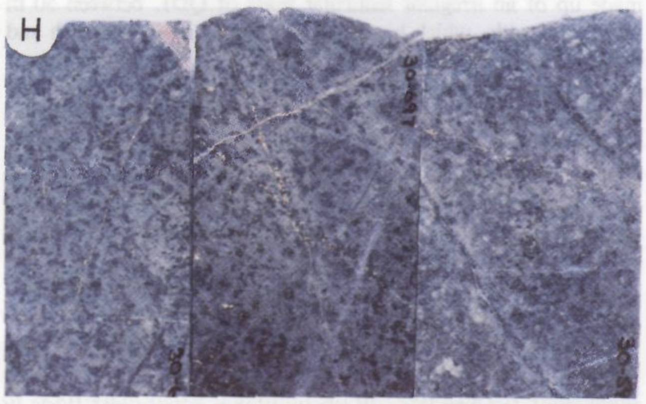

FIGURE 9h. Quartz diorite with disseminated and fracture-fill pyrite and chalcopyrite grading approximately 1.0 g/t Au and 0.60% Cu.

more or less evenly disseminated, within the groundmass of the Fish Lake Intrusive Complex rocks, where it averages 5% and occasionally exceeds 10% in abundance.

Quartz Feldspar Porphyry Dikes

Quartz feldspar porphyry dikes typically contain between 25% and 35% subhedral to euhedral plagioclase phenocrysts and 2% to 5% subhedral quartz phenocrysts in a siliceous aphanitic groundmass (Fig. 9a). Both plagioclase and quartz phenocrysts are relatively uniform in size compared to those seen in QD1, QD2 and QD3. Plagioclase phenocrysts are mostly 3 mm to 4 mm in length, occasionally up to 7 mm. Quartz phenocrysts are typically 2 mm to 3 mm in size. Quartz feldspar porphyry contains hornblende phenocrysts 1 mm to 3 mm long and, where less altered, up to 1% black, euhedral biotite books. The groundmass closely resembles that of the quartz diorite although it is typically finer grained, with an average grain size of a few hundredths of a millimetre, and is often composed substantially of quartz.

Several quartz feldspar porphyry dikes, most of them close to the margins of the Fish Creek stock, show a greater abundance and more seriate size distribution of plagioclase phenocrysts, defining an overall lithology transitional to that of both QD2 and QD3.

Igneous Breccias

Intrusion and subordinate magmatic-hydrothermal breccias occur within the Fish Lake deposit. Bodies of intrusion breccia occur along the borders of the Fish Creek stock. They range in thickness up to a few tens of metres, and contain angular to subrounded clasts of andesite flow and tuff in an igneous matrix.

Rare magmatic-hydrothermal breccias occur as irregular, discordant, dike-like bodies within and along the margins of quartz feldspar porphyry dikes. These breccias contain well-rounded, heterolithic clasts, including many of quartz feldspar porphyry and mineralized vein quartz, in a fine-grained "rock flour" matrix which commonly contains abundant magnetite.

Post-ore Porphyritic Diorite Dikes

Post-ore porphyritic diorite dikes show a considerable variation in texture. Plagioclase phenocrysts range in size from 1 mm to 3 mm, and comprise 15% to 45% of total rock volume, but generally less than 30%. Hornblende phenocrysts range in size from 1 mm to 4 mm, and comprise 12% to 15% rock volume. Locally, up to 2% quartz eyes are present. The groundmass is fine-grained, but typically phaneritic.

Nature of the Fish Lake Intrusive Complex

The Fish Creek stock is a steep southerly dipping lenticular to cylindrical body up to 300 m wide and 700 m long, with highly irregular borders. The northern and western parts of the stock are made up of an irregular lenticular mass of QD1, between 50 m and 150 m wide, which has been intruded along its southern and eastern sides by a composite QD2-QD3 body, which forms approximately three-quarters of the total volume of the stock. The Fish Creek stock appears to "root" to the southeast, although geological relationships at depth are obscured by displacement along the 10% to 15% hornblende phenocrysts; and sparse quartz eyes, in a very fine-grained groundmass. This andesite body is probably a sequence of thick, coarser, more porphyritic flows. It may be, in part, subvolcanic sills and dikes.

Clastic sedimentary rocks interbedded with variable minor volcanic rocks underlie the Fish Lake Fault and subcrop to the south of the deposit. This unit includes conglomerate, greywacke, arkose, mudstone and local volcanic wacke. Relationships between dominantly volcanic rocks to the north and sedimentary rocks to the south are obscured by intrusions and alteration. The alteration is not accompanied by significant mineralization.

Fish Lake Intrusive Complex

The deposit is spatially and genetically related to the Fish Lake Intrusive Complex, one of several intermediate porphyritic stocks and dike complexes in the area. A Lower Cretaceous age of intrusion for the Fish Lake Complex is indicated by a U-Pb date of around 80 Ma. This age is based on four fractions of zircons from the Fish Creek stock, (Gabites, pers. comm., 1994). A whole rock K-Ar date of 77.2 Ma was obtained from a sample of biotite-rich hornfels (Wolfard, 1976).

The Fish Lake Intrusive Complex consists of a steeply-dipping, composite, lenticular to cylindrical body of quartz diorite, the Fish Creek stock, which is surrounded by an east-west elongate lenticular complex of subparallel quartz feldspar porphyry dikes.

Fish Creek Stock

The Fish Creek stock is made up of three quartz diorite variants, which differ mainly in grain size and texture, and often show gradational borders. Heterogeneous fine porphyritic quartz diorite (QD1) is fine-grained with a crowded, seriate porphyritic texture. Plagioclase phenocrysts, which vary in abundance from 45% to 60%, average from 1 mm to 2 mm in size. QD1 in places shows conspicuous heterogeneity, particularly in grain size, on a scale of a few centimetres to tens of centimetres. Coarse seriate porphyritic quartz diorite (QD2) (Fig. 9a) is coarser grained than QD1 and is characterized by a more seriate, crowded porphyritic texture; it contains between 35% and 55% plagioclase phenocrysts, which range in length from 1 mm to 7 mm. QD2 grades, with increasing abundance of plagioclase phenocrysts and corresponding decrease in abundance of groundmass, into coarse equigranular to subporphyritic quartz diorite (QD3) (Fig. 9a), which shows an average grain size of approximately 3 mm.

These three quartz diorite variants all contain subhedral quartz grains, typically between 3% and 6%, but ranging in abundance from trace to 10%; QD3, however, locally contains up to 15% coarse quartz. Quartz phenocrysts in the relatively coarse variants QD2 and QD3 are generally 3 mm to 5 mm in size, but range up to 8 mm. The matrix of the quartz diorite is typically a granular plagioclase-quartz mosaic with an average grain size of a few hundredths to a few tenths of a millimetre, containing minor altered mafic and opaque minerals. Primary magmatic orthoclase occurs, Fish Lake Fault. Several units of QD2 and QD3, characterized by relatively low copper and gold grades, form part of the western core of the Fish Lake stock below the 1100 m level. These units may represent poorly defined late intramineral intrusions.

The quartz feldspar porphyry occurs as an east trending, steeply south-dipping swarm of subparallel dikes. Most dikes are a few tens of metres thick, but they locally exceed 100 m in thickness. These dikes appear to be very close in age to the Fish Creek stock. They crosscut and largely postdate the QD1 phase, but are truncated by and appear as inclusions within the QD2-QD3 phase, which they largely predate. The contemporaneity of the quartz feldspar porphyry dikes and Fish Creek stock is also suggested by the occurrence of some units of transitional lithology, close to the border of the stock.

Petrochemistry

The rocks of the Fish Lake Intrusive Complex (QD1, QD2-3 and QFP), when unaltered, are distinct in composition from the extrusive and subvolcanic rocks that host a large portion of the Fish Lake deposit (Table 1). The older andesites and subvolcanic intrusions contain more magnesium and iron and less silica than the Fish Creek Intrusive Complex.

Andesites and subvolcanic rocks contain between 53% and 61% silica (averaging 57.85%). Some variation is due to alteration. They plot in the andesite compositional field of Le Maitre (1989).

The three texturally distinct units of the Fish Lake Intrusive Complex have similar major element compositions (Table 1). The quartz feldspar porphyry dikes (QFP) are slightly less mafic, and contain more silica (64% and 67%). T are dacite in composition.

Phosphorous and titanium, elements that are relatively incompatible in igneous fractionation and less mobile in hydrothermal fluids, are plotted in Figure 10. This plot shows that the two groups of rocks fit on different trends indicating different magmatic origins.

All the Fish Lake intrusive rocks fit a linear trend showing they may be co-sanguinous. The QFP has slightly lower absolute amounts of phosphorous and titanium. It may be a more evolved product from that same magma (Fig. 10).

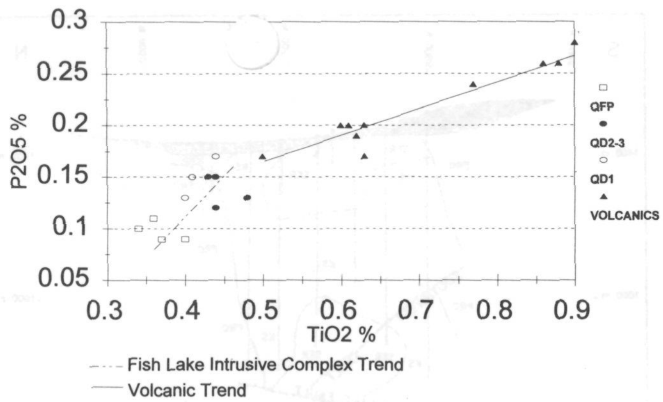

FIGURE 10. Immobile element plot – P_2O_5 vs $T.O_2$.

Chilcotin Group Cover

Chilcotin Group basalt flows and unconsolidated sediments up to 90 m thick cover the southwest corner of the deposit. Dark grey to black, variably vesicular, microporphyritic basalt flows are commonly separated by narrow rubble zones and by paleotalus. These flows are underlain by unconsolidated, locally well-bedded conglomerates, sedimentary breccias and sandstones, which may represent both fanglomerates and fluvial sediments. The coarser Chilcotin Group sedimentary rocks contain abundant brick-red iron oxide, a product of lateritic paleoweathering.

Alteration

Six main types of alteration have been identified within the Fish Lake deposit area. These are: potassium silicate, propylitic, phyllic, albite-silica, sericite-iron carbonate-clay and argillic.

Potassium silicate alteration is the most widespread alteration developed in the deposit area, forming a large oval central zone co-extensive with significant copper-gold mineralization (≈.20% Cu and ≈.20 g/t Au) (Figs. 11, 12, 13, and 14). The potassium silicate zone is surrounded by propylitically altered rocks which extend outward, for several hundred metres. Along the northern and eastern margins of the deposit a highly irregular zone of phyllic alteration, up to 300 m wide, is developed at the transition between potassium silicate and propylitic alteration. Texture destructive albitization and silicification occurs irregularly within the northern part of the deposit. Late sericite-iron carbonate-clay alteration occurs in numerous, irregular zones which are most abundant at higher elevations and overprint earlier alteration assemblages. Late clay alteration is localized along fault zones.

Potassium Silicate

Potassium silicate alteration is characterized by the replacement of the original mafic minerals by biotite (or chlorite) and by subordinate secondary orthoclase.

Potassium silicate altered intrusive rocks and andesite porphyry flows typically contain black and, less often, brown biotite in fine-grained aggregates pseudomorphing hornblende phenocrysts and weakly to moderately sericitized plagioclase (Figs. 9b, d and f). Biotite is often altered to chlorite in envelopes, ranging from a few centimetres to several tens of metres in width, enclosing later fractures. Secondary orthoclase is restricted to the Fish Creek stock and adjacent rocks where it occurs along microfractures, as quartz-orthoclase veinlets, and as disseminated grains within narrow veinlet envelopes (Fig. 9c).

Abundant fine-grained secondary black biotite locally forms more than 30% of altered rock over intervals of several tens of metres within and along the west side of the Fish Creek stock. Zones of abundant secondary biotite also occur as remnants within the porphyritic andesite body, along the east side of the deposit.

Potassium silicate altered tuffs show ubiquitous secondary alteration textures, although it is not clear to what degree these textures are due to synvolcanic rather than synmineral alteration. Mafic minerals are mainly chlorite which, relative to biotite, is more abundant in altered tuffs than in altered intrusive rocks and flows. Chlorite and biotite are commonly concentrated in subcircular alteration aggregates, 5 mm to 10 mm in diameter, which are often aligned along lamination planes, and to a lesser extent, along veinlets and fractures (Fig. 9e). Acicular to thin prismatic actinolite pseudomorphs, of chlorite and less often brown biotite, are widely distributed within altered tuff throughout the deposit. They are most abundant close to quartz feldspar porphyry dike contacts.

Propylitic

Propylitic altered rocks are characterized by sericitization of plagioclase phenocrysts and chloritization of mafic minerals with good preservation of primary textures (Fig. 9e). Abundant disseminated calcite and 1% to 3% pyrite also occur. Epidote is rare in propylitic rocks in the immediate vicinity of the deposit, but is a widespread alteration product of plagioclase and hornblende several kilometres outside the deposit. Accessory magnetite and radiating aggregates of zeolites were deposited on late fractures that clearly postdate sulphide introduction. The rocks along the western and southwestern borders of the deposit are only weakly altered. Hornblende phenocrysts are chloritized and plagioclase phenocrysts are weakly sericitized.

Phyllic

Phyllic alteration occurs both as wide zones of pervasive alteration peripheral to significant copper-gold mineralization, and in widespread but sparse envelopes surrounding quartz-sulphide veins. Rocks affected by pervasive phyllic alteration are altered mainly to quartz and fine-grained colourless phyllosilicates (sericite), and contain 3% to 5% pyrite (Figs. 9b and 9g). Variable destruction of primary texture is common.

Phyllic alteration also occurs in envelopes bordering quartz-sulphide veins and veinlets which occur throughout the deposit, but are most abundant toward its northern and eastern borders. Phyllic envelopes are typically 5 mm to 30 mm wide, show sharp borders, and are composed of a fine-grained, grey, texture destructive quartz-sericite-pyrite aggregate.

Albitization and Silicification

Pale coloured, hard, texture destructive alteration is fairly widespread, mainly in tuffs, within the northern part of the deposit and represents both albitization and silicification. X-ray diffraction analyses of several samples showed abundant plagioclase, of probable secondary origin.

Sericite-Iron Carbonate-Clay

Sericite-iron carbonate-clay altered rocks are typically competent, of medium hardness and usually show good preservation of primary texture, but can occur as zones where tecture destruction makes lithology determination difficult. Drill core darkens over a period of months to a buff to medium orange-brown, due to the weathering

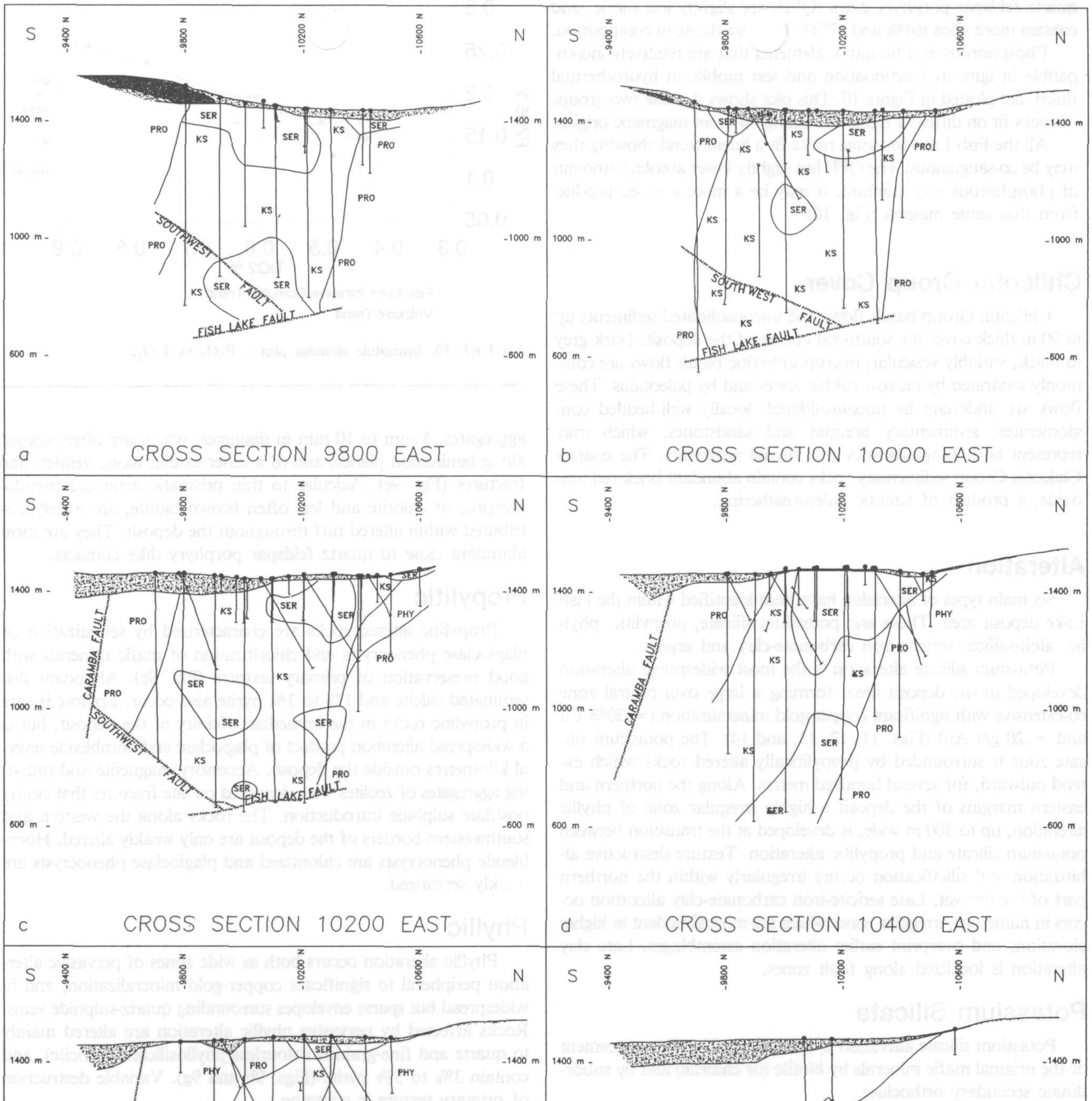

FIGURE 11. Alteration cross sections.

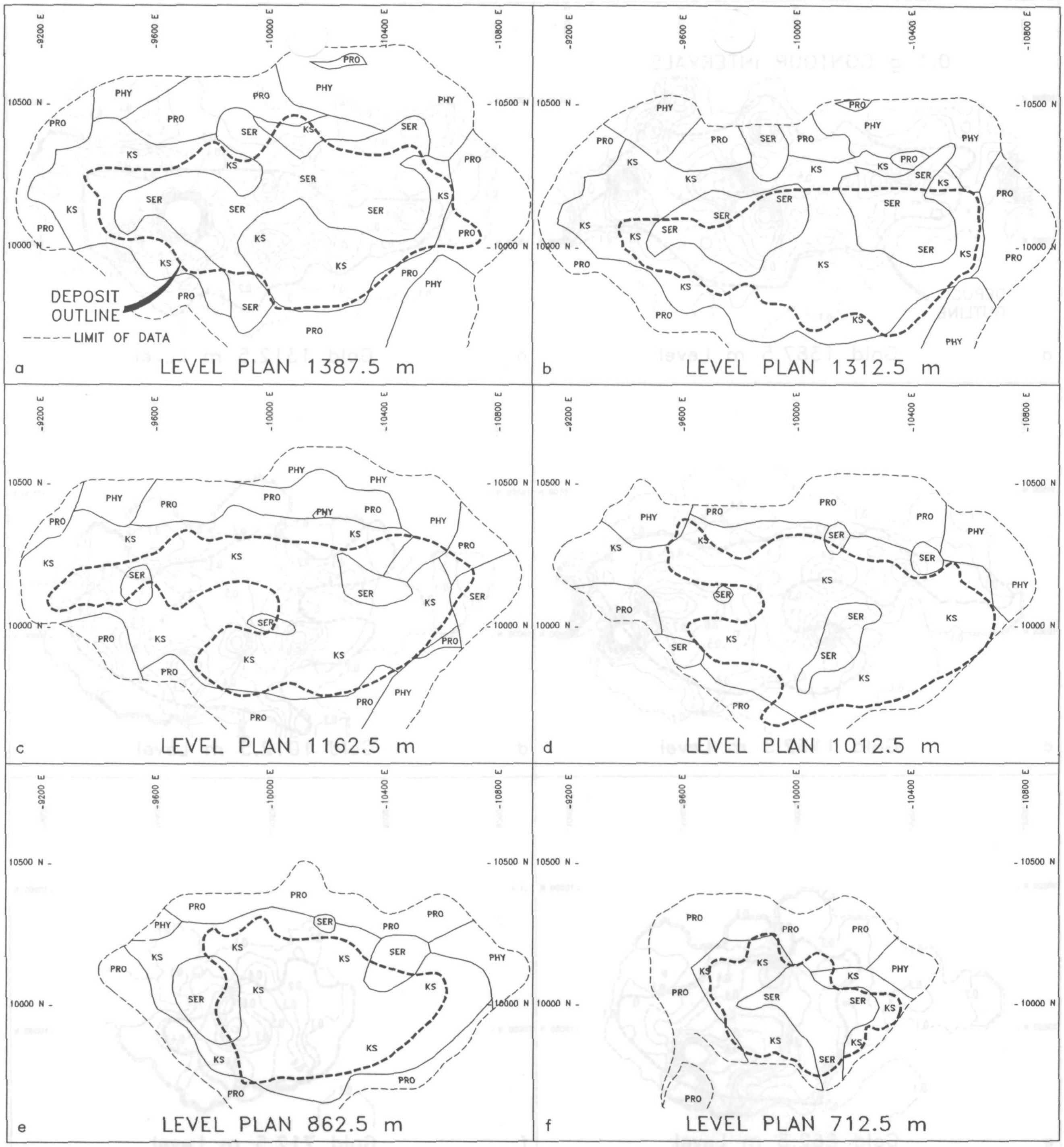

FIGURE 12. Alteration level plans.

of iron carbonate altered mafic pseudomorphs (Fig. 9b). Sericite-iron carbonate-clay altered intrusive rocks and andesite flows form uniformly-altered, abruptly-bordered intervals. The andesite tuffs, however, show less sharply defined intervals with more gradational borders.

In sericite-iron carbonate-clay altered intrusive rocks and andesite flows, plagioclase phenocrysts are altered to a soft, white sericite-clay mixture containing minor carbonate; mafic phenocrysts are pseudomorphed by aggregates of iron carbonates intermixed with kaolinite and sericite. The groundmass comprises fine-grained quartz and sericitized plagioclase. Sericite-iron carbonate-clay altered andesite tuffs contain abundant quartz, plagioclase (moderately to strongly altered to sericite), iron-carbonate and kaolinite. Magnetite within sericite-iron carbonate-clay altered rocks is altered to hematite. Sulphide minerals occur in the same abundance as in adjacent potassium silicate and propylitic altered rocks.

Argillic

Soft, pale coloured, texture destructive clay alteration occurs locally within fault zones, most often within quartz feldspar porphyry dikes.

Distribution of Alteration

The central potassium silicate alteration zone is fairly distinctly, although in detail irregularly, limited by both phyllic and propylitic altered rocks along the northern and eastern borders of the deposit (Figs. 11 and 12). Peripheral propylitic alteration is generally easily distinguished from potassium silicate alteration because it contains

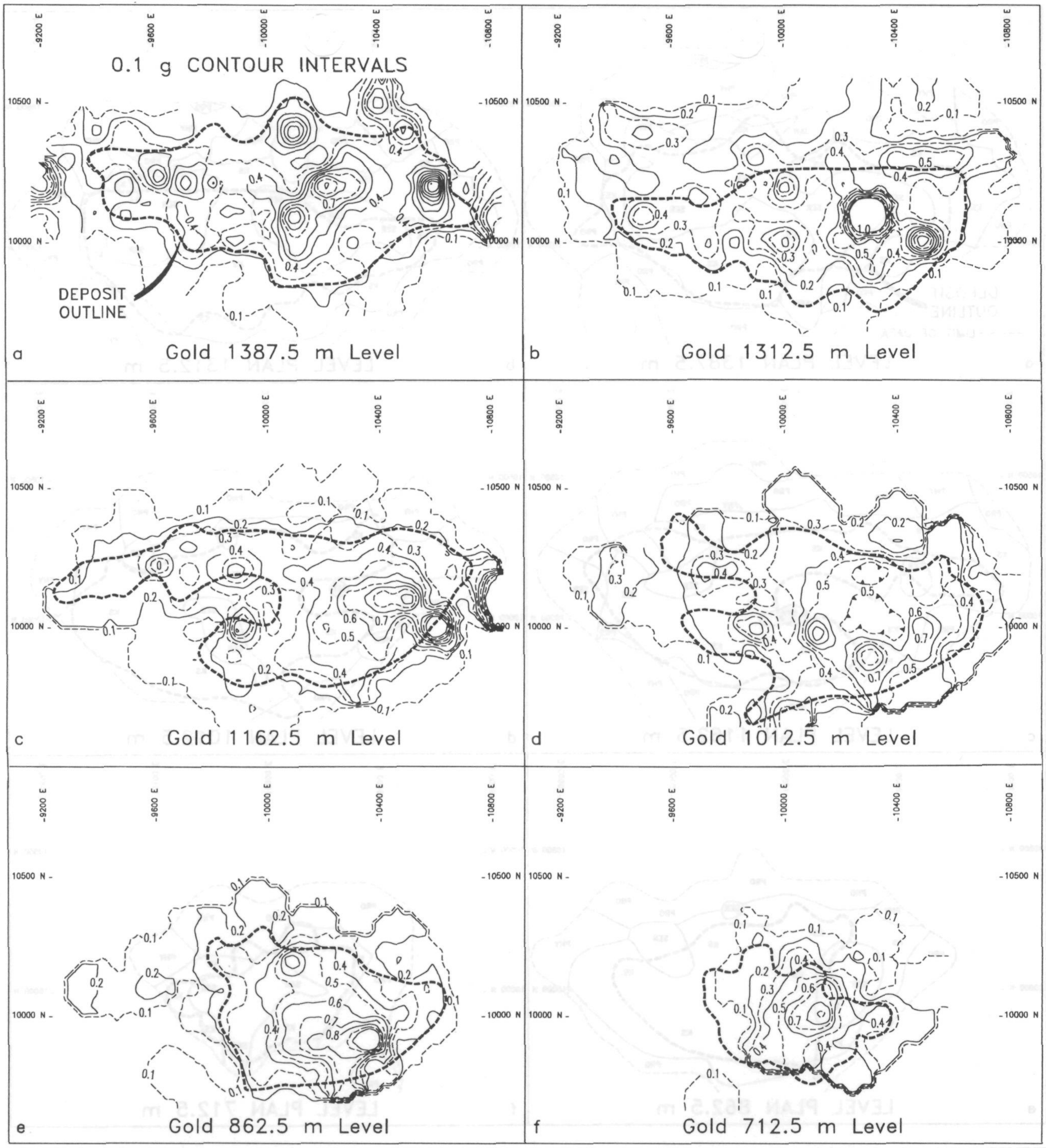

FIGURE 13. Contoured gold concentrations — level plans.

strongly sericitized plagioclase and abundant disseminated calcite. However, the southern and southwestern borders of the potassium silicate zone are less distinct, because potassium silicate altered rocks containing unaltered plagioclase pass outward into weakly propylitic altered rocks, which also contain unaltered plagioclase, as well as sparse calcite.

Pervasive phyllic altered rocks are more abundant at elevations above 1100 m and they form several irregular lenticular bodies up to several hundred metres in width along the northern and eastern periphery of the deposit, essentially forming an incomplete half-annulus. These phyllic zones, at the northern and eastern border of the potassium silicate alteration zone, are generally isolated within the surrounding propylitic alteration, but may be intercalated with propylitic and, less commonly, potassium silicate altered rock.

Sericite-iron carbonate-clay alteration likely postdates phyllic alteration. Throughout the deposit it forms intervals a few tens of centimetres to several tens of metres in width which host about one-fifth of the mineralization. These intervals often envelope faults and post-ore porphyritic diorite dikes. Sericite-iron carbonate-clay alteration is more widespread within the central potassium silicate alteration zone than within the surrounding propylitic and phyllic zones, and is most abundant within the upper part of the deposit, where it has overprinted more than one-third of the potassium silicate alteration zone above an elevation of 1250 m.

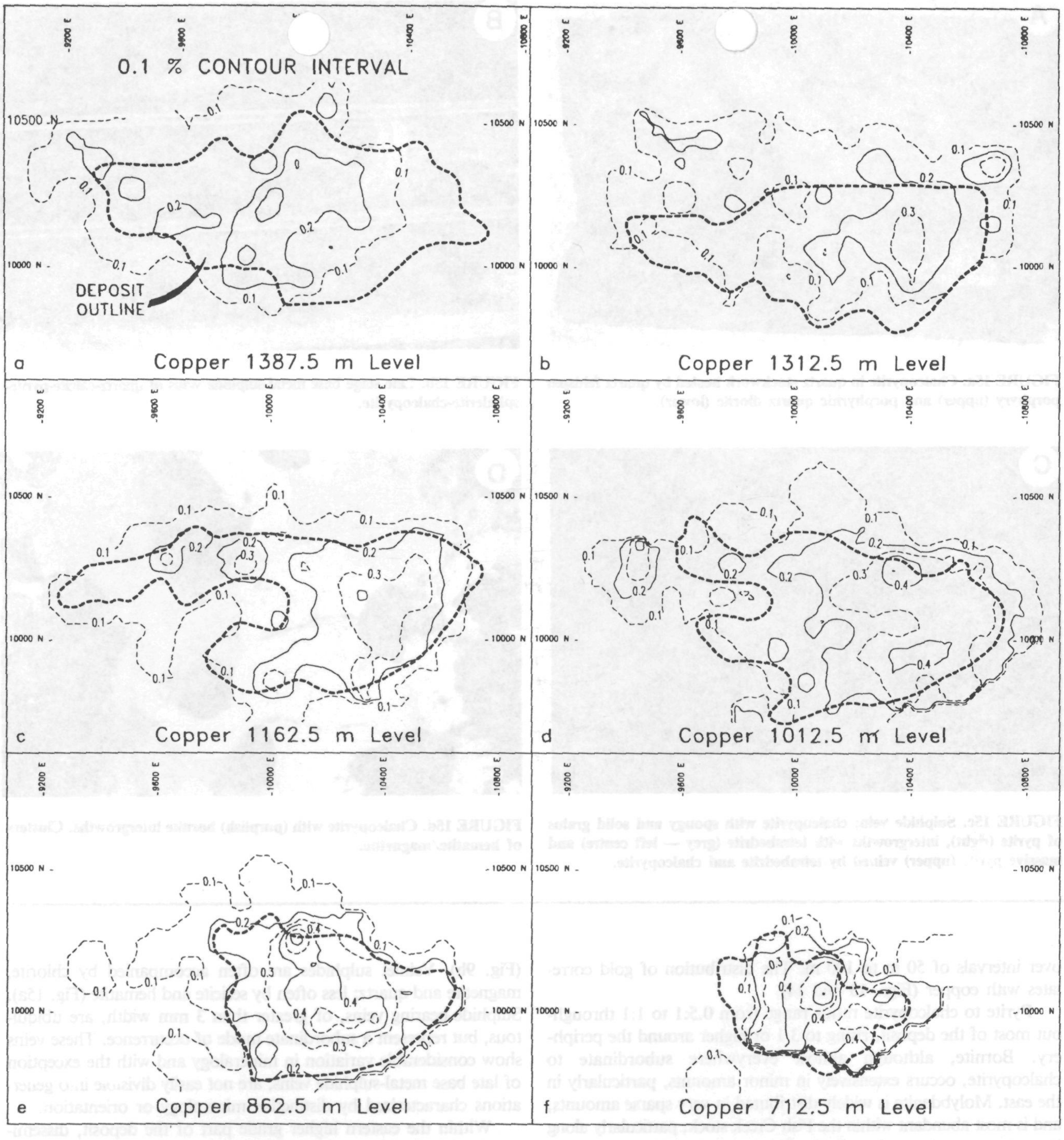

FIGURE 14. Contoured copper concentrations — level plans.

Mineralization

The Fish Lake deposit is oval in plan and is 1.5 km long, up to 800 m wide, and locally extends to a depth of 880 m. Its long axis parallels the east-west trend of the Fish Lake Intrusive Complex, which trends at 075° and dips 55° to 75° to the southeast. The deposit is essentially co-extensive with the potassium silicate alteration zone, and mineralization is almost entirely developed within rocks affected by potassium silicate and superimposed sericite-iron carbonate-clay alteration. An irregular barren pyrite halo several hundred metres wide surrounds the northern and eastern sides of the deposit, and is more or less co-extensive with the phyllic alteration zone. The major low-angle Fish Lake Fault terminates the deposit at depths of between 680 m and 880 m.

Pyrite and chalcopyrite are the principal sulphide minerals, accompanied by widespread bornite, sparse tetrahedrite-tennantite and molybdenite (Figs. 15c, 15d and 15e). Rare sphalerite, pyrrhotite, digenite, covellite, chalcocite, galena, marcasite and enargite also occur. Native gold occurs as inclusions and along microfractures most abundantly in association with copper minerals and pyrite.

Distribution of Sulphides and Metal Values

Both pyrite and chalcopyrite, and hence copper values, are relatively uniformly distributed in comparison to many other porphyry deposits. Copper concentrations are higher overall within the eastern part of the deposit where volcanic rocks predominate. Copper is often distinctly enriched within intervals of a few, to a few tens of metres in width, enveloping quartz feldspar porphyry dikes. Copper values fall off relatively abruptly along the margin of the deposit,

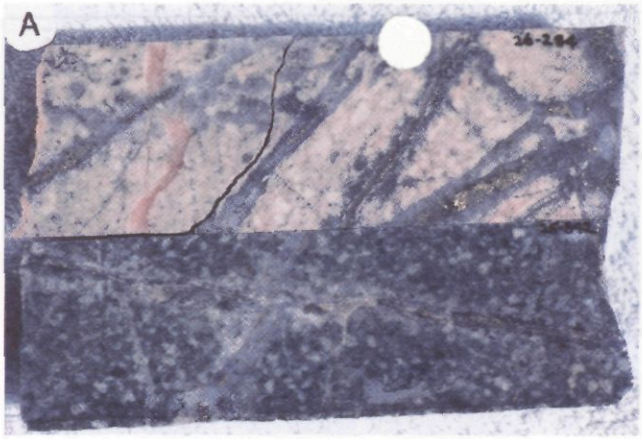

FIGURE 15a. Chalcopyrite in quartz stockwork hosted by quartz feldspar porphyry (upper) and porphyritic quartz diorite (lower).

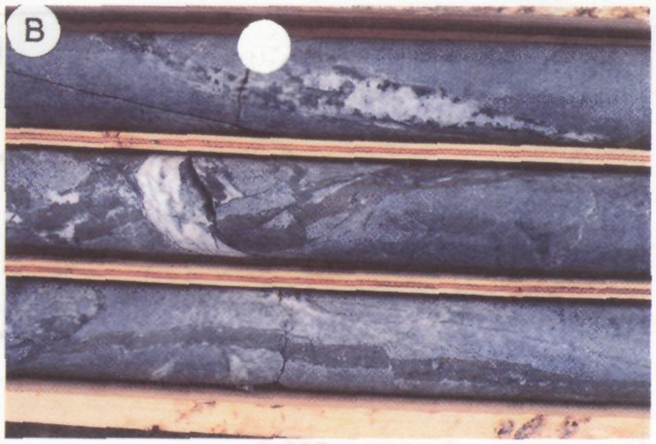

FIGURE 15b. Late stage base metal-sulphide veins of quartz-calcite-pyrite-sphalerite-chalcopyrite.

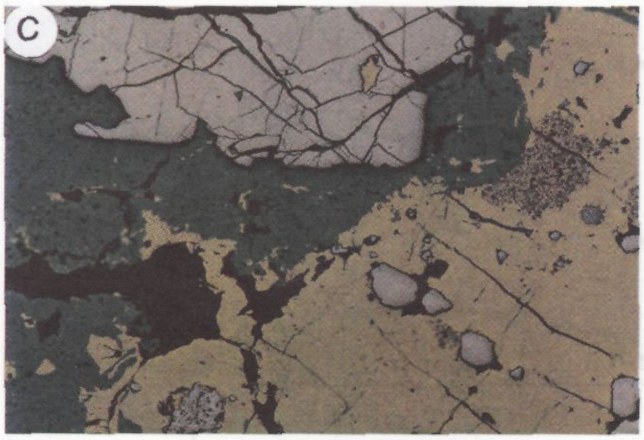

FIGURE 15c. Sulphide vein; chalcopyrite with spongy and solid grains of pyrite (right), intergrowths with tetrahedrite (grey — left centre) and massive pyrite (upper) veined by tetrahedrite and chalcopyrite.

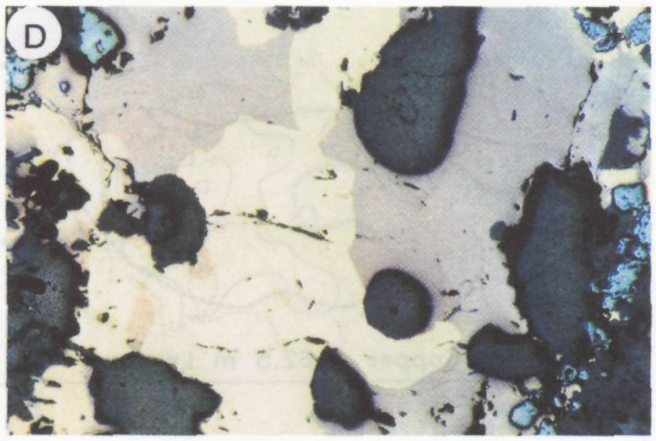

FIGURE 15d. Chalcopyrite with (purplish) bornite intergrowths. Clusters of hematite/magnetite.

over intervals of 50 m to 100 m. The distribution of gold correlates with copper (Figs. 13 and 14).

Pyrite to chalcopyrite ratios range from 0.5:1 to 1:1 throughout most of the deposit, rising to 3:1 or higher around the periphery. Bornite, although almost everywhere subordinate to chalcopyrite, occurs extensively in minor amounts, particularly in the east. Molybdenite is widely distributed in very sparse amounts, and is most abundant within the Fish Creek stock, particularly along its eastern margin, and at depth. The northern and eastern margins of the deposit are surrounded by a distinct though irregular pyrite halo, typically containing between 3% and 5% pyrite, and generally extending outward for more than 200 m. The pyrite halo is poorly developed along the south and southwest borders of the deposit, where pyrite abundance outside the limits of significant copper mineralization is mostly in the range of 1% to 3%. The pyrite halo is very broadly co-extensive with the zone of peripheral phyllic alteration although abundant pyrite occurs also in both phyllic and propylitic rocks.

Mode of Occurrence of Sulphides

Sulphide minerals show the thoroughly dispersed mode of occurrence characteristic of porphyry copper deposits. Disseminated sulphides are associated with, or occur as replacements, of mafic minerals. There is a continuum in mode of occurrence between incomplete, 'hairline' sulphide coatings along discontinuous microfractures (fracture-fill) and thicker, more through-going, sulphide veinlets (Fig. 9h). Veinlet sulphides are often accompanied by chlorite, magnetite and quartz; less often by sericite and hematite (Fig. 15a). Sulphide-bearing veins, of greater than 3 mm width, are ubiquitous, but represent a subordinate mode of occurrence. These veins show considerable variation in mineralogy and with the exception of late base metal-sulphide veins, are not easily divisible into generations characterized by distinctive mineralogy or orientation.

Within the eastern higher grade part of the deposit, disseminated sulphide, fracture-fill and veinlet sulphide, occur in subequal proportions. Further west, where mineralization is hosted in large part by the Fish Creek stock, fracture-fill, veinlet and vein sulphides together substantially exceed truly disseminated sulphides in abundance. Mineralized quartz stockwork occurs in zones up to 250 m wide in the west, most frequently within and immediately adjacent to the Fish Creek Stock.

Late Base Metal Sulphide Veins

Late stage base-metal sulphide veins, often several centimetres in width, are most abundant within the uppermost eastern portion of the deposit. These veins contain pyrite, accompanied by one or more of the minerals chalcopyrite, galena, sphalerite, tetrahedrite and tennantite, in a gangue of quartz and calcite (Fig. 14b). Pyrite-arsenopyrite veins, locally accompanied by pyrrhotite, host gold in the Albert zone, 1 km east of the eastern border of the deposit. Quartz-pyrite-chalcopyrite-sphalerite-arsenopyrite veins occur in the Renner zone, 1.25 km northeast of the deposit.

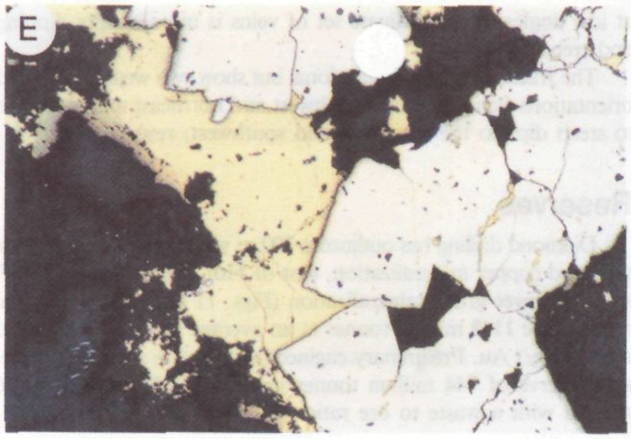

FIGURE 15e. Chalcopyrite interstitial to pyrite in a composite vein.

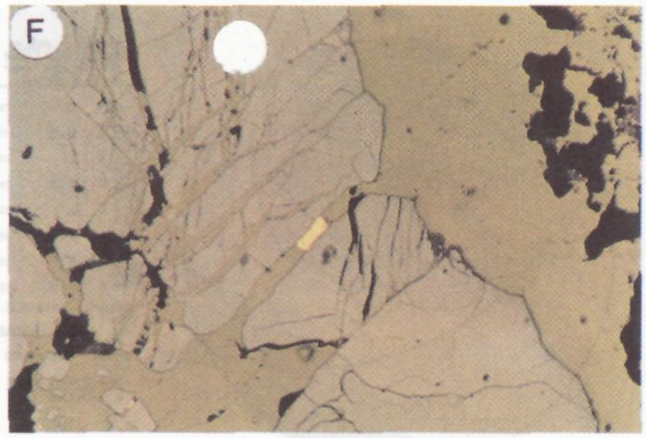

FIGURE 15f. Pyrite with interstitial and microveinlets of chalcopyrite. A 0.03 mm grain of gold occurs in a chalcopyrite veinlet cutting pyrite.

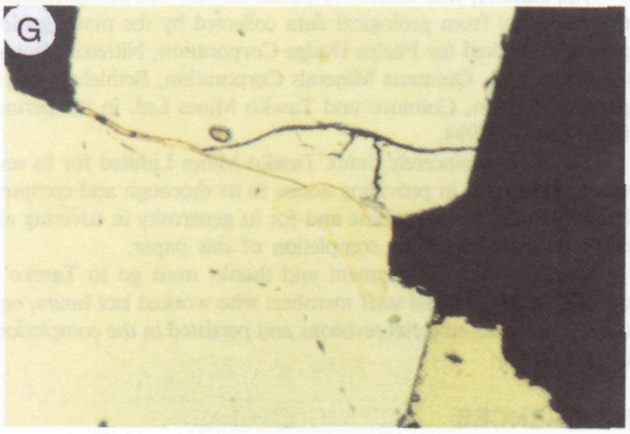

FIGURE 15g. Pyrite grain containing a 0.01 mm grain of gold and a microveinlet of gold (centre) and associated chalcopyrite (lower right).

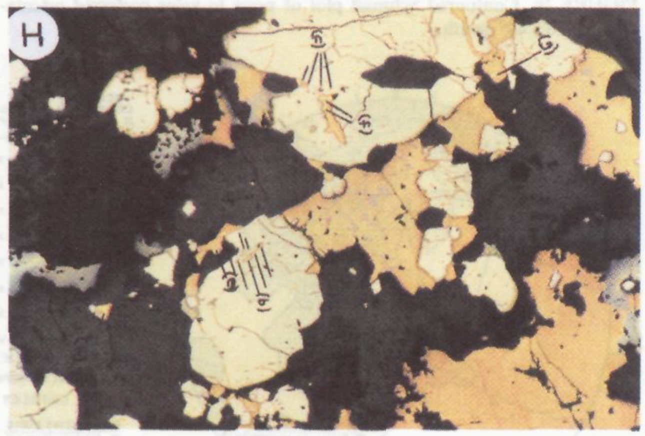

FIGURE 15h. Gold grains associated with pyrite (pale) and chalcopyrite (yellow) are indicated by the arrows.

Gold

Native gold occurs in grains which typically range in size from 2 microns to 30 microns, but locally exceed 100 microns. Gold occurs both as isolated grains, and in microveinlets, within both sulphides, and quartz-carbonate (Figs. 15f, 15g, and 15h). It occurs most abundantly in association with copper minerals, particularly where tetrahedrite and tennantite are present.

Oxide and Sulphate Minerals

Magnetite occurs throughout the deposit as disseminated small gains and as thin, discontinuous, often sinuous veinlets commonly accompanied by quartz and less frequently by sulphide. Magnetite is largely or entirely altered to hematite in zones of sericite-iron-carbonate-clay alteration, without any obvious change in overall iron-oxide abundance which ranges up to 5%.

Anhydrite and gypsum are ubiquitous in the deposit below the zone of weathering. Anhydrite occurs both as disseminated small grains (identifiable only in thin section) and as visible purple aggregates in quartz veins. Gypsum veinlets are ubiquitous in a 100 m to 200 m wide subhorizontal zone with a sharp upper border, the "Gypsum Line", marking the lower limit of gypsum dissolution by groundwater. The depth of the Gypsum Line averages 150 m below surface but varies irregularly as a result of varying permeability. Locally it exceeds 300 m below surface. The gypsum line separates a near surface broken zone of strongly broken rock from underlying more competent rock. Gypsum veins are narrow, generally only a few millimetres wide and often follow older, reopened sulphide bearing veins, sometimes incorporating minor wall rock sulphide. The spacing of gypsum veins is often as dense as one per few centimetres and in the more densely veined intervals gypsum often forms at least 5% of the rock. Gypsum veins generally show a shallow orientation in marked contrast to the steep orientation of most sulphide veins.

Structure

Bedded rocks in the region dip between 20° and 30° to the north. In the vicinity of the Fish Lake Intrusive Complex, the host rocks dip between 60° and 75° to the south, subparallel to the causative intrusive complex. Many low-angle and high-angle faults were intersected in drill holes, but in many cases their correlation between holes is uncertain.

Low-angle Faults

An important low-angle fault, the Fish Lake Fault, trends northeasterly and dips 20° to 25° to the southeast (Fig. 10). The 40 m and 50 m thick Fish Lake Fault is characterized by sheeted fracturing, mylonitic foliation and brecciated iron carbonate veining in post-ore dikes sealing the fault. The Fish Lake Fault marks the stratigraphic contact between the hangingwall tuffaceous andesitic volcanic rocks and the footwall clastic sedimentary rocks. This structure has been traced for a dip length of 800 m from east to west, rising from an elevation of 500 m in the east to an elevation of 700 m in the west.

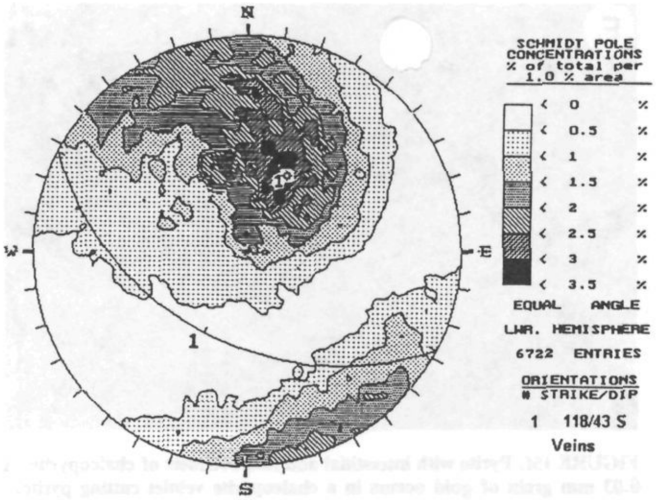

FIGURE 16. Contoured Schmidt plot of poles to veins preferred orientation is 118°/43° south.

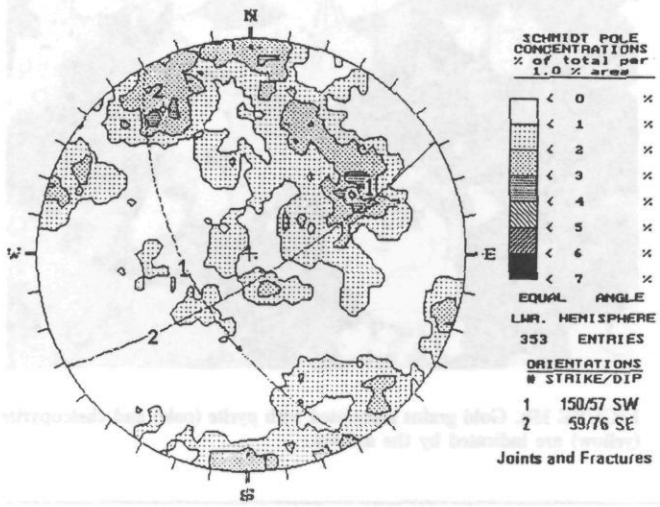

FIGURE 17. Contoured Schmidt plot of poles to joints and fractures. Two weakly preferred orientations at 150°/57° southwest and 59°/76° southeast.

High-angle Faults

An important high-angle fault, the Southwest Fault, trends at 323° and dips 55° to the northeast. It ranges between 5 m to 30 m in width and it is everywhere infilled by post-ore diorite dikes. The fault cuts the southwestern portion of the deposit, below the 1100 m elevation, displacing the western extension of the stock 200 m to the northwest (Fig. 7). Cross-cutting relationships suggest that the Southwest Fault predated the Fish Lake Fault. Brecciation and local gouge development along the contacts and within the post-ore dikes indicate post-intrusion reactivation.

Data gathered from oriented core in five drill holes are shown in Figures 16 and 17 as contoured Schmidt plots of poles to veins and fractures, respectively. The veins show a well defined preferred orientation that trends east-southeast and dips to the south, intersecting the general orientation of the Fish Lake Intrusive Complex at low angles. A subordinate set of veins is more steeply dipping and trends east-west.

The fractures are multidirectional but show two weakly preferred orientations trending south-southwest and northeast and moderate to steep dips to the southeast and southwest, respectively.

Reserves

Diamond drilling has outlined a 700 m wide core of higher grade gold and copper mineralization, east of Fish Creek, flanked on all sides by lower grade mineralization (Figs. 11 and 12). Geological reserves are 1148 million tonnes at an average grade of 0.22% Cu and 0.41 g/t Au. Preliminary engineering indicates a possible mineable reserve of 744 million tonnes grading 0.23% Cu and 0.446 g/t Au with a waste to ore ratio of 1.57:1.

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