The Gambier Island porphyry copper deposit, southwestern British Columbia

P.E. FOX, G.N. GOODALL
Fox Geological Consultants Ltd., Vancouver, British Columbia

R.M. DURFELD
Geological Consultant, Williams Lake, British Columbia

ABSTRACT

The Gambier Island porphyry copper deposit was discovered in 1979 and subsequently 114 million tonnes grading 0.29% Cu and 0.018% MoS_2 at a waste to ore ratio of 2.7:1 were outlined by 1980. Soil geochemistry and induced polarization surveys proved to be the most effective tools in delineating the reserve. The deposit, 750 m by 1000 m, consists of a well-developed stockwork of quartz veinlets containing variable amounts of chalcopyrite, pyrite and molybdenite in a quartz porphyry stock, of probable Cretaceous age, and hornfelsed volcanic rocks of the Gambier Group. The deposit is associated with intense sericite and quartz-altered rocks surrounded by a weakly developed halo of propylitic rock rich in pyrite and epidote.

Introduction

The Gambier Island porphyry copper deposit was discovered in 1979 by 20th Century Energy Corporation who drilled three prospect holes on a small outcrop of mineralized and altered Gambier Group volcanic rocks near Gambier Creek. These holes were mineralized throughout and eventually led to the development of a moderate-sized porphyry deposit to the north and east. Earlier work reported in assessment files of the British Columbia Ministry of Energy, Mines and Petroleum Resources pointed to the presence of a copper deposit near Gambier Creek, but its significance went unrecognized for many years.

This paper is presented as a brief overview of the deposit together with its history and geological setting.

The Gambier Island copper-molybdenum porphyry deposit (49°30′N, 123°25′W, NTS 92G/6) is situated in the coastal region of British Columbia near the north end of Gambier Island about 30 km northeast of Vancouver, British Columbia (Fig. 1). The prospect lies in Gambier Creek valley about 1.5 km from tidewater at Douglas Bay. The property is easily reached by boat from Horseshoe Bay or by aircraft from Vancouver.

The property comprises thickly wooded precipitous slopes that range from sea level at Douglas Bay to rocky summits that reach 1000 m in the central part of the island. The main showings on Gambier Creek are at an elevation of 157 m. Thick stands of mature cedar, hemlock and fir, usually with a thick undergrowth of salal and hemlock saplings, mantle the sides of Gambier Creek valley. Cottonwoods and alder are common along the valley bottom where thick glacial tills and varved clays comprise the valley fill. Much of the valley has been logged at various times and remnants of an extensive road system are present. These roads proved to be excellent supply routes and were utilized for access roads and drill sites during the exploration of the deposit. Bedrock exposures are common along the valley sides near the showings and in steep, subvertical bluffs covered with lichen, moss and tangle of dead-fall inland. Rainfall, particularly in winter months, is considerable, typically 300 cm per year.

History

A number of small copper showings have been known in the Douglas Bay area of Gambier Island for many years and much of the northeast corner of the island was staked by Gaylord Mines Ltd. in 1972. This company conducted extensive soil sampling, EM 16, and magnetometer surveys over most of the Gambier Creek valley. Two geochemical anomalies were outlined by Gaylord's sampling work, one near several old copper prospects about 1.5 km south of Douglas Bay, and a second, situated south of Gambier Creek at the site of the main porphyry deposit.

The prospect was staked by 20th Century Energy Corporation on February 7, 1978, who later expanded their holdings to 17 claims. J. McGoran (1978) prospected the area in February 1978, re-establishing part of Gaylord's grid system and confirming results of previous geochemical work (Hings, 1972). A camp was subsequently established at an elevation of 157 m and three diamond drill holes consisting of 692 m of BQ core were drilled between November 1978 and January 1979 under the supervision of A. F. Roberts (Roberts, 1979). In 1979 and 1980, the senior author of this paper directed an extensive drill program designed to evaluate the area north and east of the discovery (Fox and Durfeld, 1981). A total of 7958 m of BQ core was recovered from 33 drill holes.

Applied Exploration Techniques

Soil geochemical sampling, induced polarization surveys and drilling proved to be the key exploration techniques employed. Samples were collected from "B" horizon soils on a grid pattern every 30 m along lines spaced 120 m apart. Induced polarization surveys were conducted over the grid using a pole-dipole array with a 60 m electrode spacing. Diamond drilling was conducted over a 750 m by 1000 m area in a grid pattern with approximately 120 m spacing between holes. Most holes were vertical and drilled to an average depth of 200 m.

Regional Geology

Most of Gambier Island is underlain by basic volcanic strata and associated sedimentary rocks of the Gambier Group (Fig. 1) of Lower Cretaceous age (Roddick and Woodsworth, 1979). Granitic rocks of the Coast Plutonic Complex underlie the southern part of Gambier Island between Halkett Point and the island's west coast. Volcanic strata generally strike northwest and dip steeply northeast. Most summits in the vicinity of Gambier Creek valley consist of andesitic volcanics locally intruded by swarms of granitic dikes.

Property Geology

A geological plan of the deposit is given in Figure 2 and a cross section in Figure 3. Lithologic boundaries, major faults and

K-silicate alteration has not been d[illegible]nstrated. The Tirad Cu-Au porphyry (Trudu and Bloom, 198[illegible]) contains all three alteration stages, which represent a change from magma-dominated to meteoric-dominated fluids with time. Gold and copper precipitation occurred throughout the life of the hydrothermal system, but was dependent upon an abundant, long-lived magmatic source.

Similarities in physical characteristics between Kerr and some Philippine deposits suggests similar evolutionary histories. K-silicate alteration is, therefore, assumed to have been the initial alteration stage at Kerr, which developed as a high level hydrothermal system with abundant meteoric water input.

In conclusion, the Kerr deposit is associated with porphyritic monzonitic intrusions within a northerly trending structural zone in Stuhini volcaniclastic and sedimentary rocks. Cupola-like copper-gold porphyry mineralization with widespread K-silicate alteration was probably associated with one or more of these early intrusive phases. Significant local remobilization of original porphyry mineralization has taken place. The timing of many of these events and the nature of the original porphyry system still pose many questions.

Acknowledgments

The authors would like to acknowledge the support of Placer Dome Canada Limited, and the invaluable contributions made by those Placer Dome geologists who have worked on the project. Financial support for Bridge was provided by the Mineral Deposits Research Unit (MDRU) at The University of British Columbia, and Colin Godwin directed much of his research. Technical discussions with MDRU staff, primarily James Macdonald and Peter Lewis, are greatly appreciated. Geological Survey of Canada personnel, particularly Bruce Ballantyne and Don Harris, were most helpful in their (repeated) efforts to supply the authors with their lithogeochemical data. The authors would also like to thank D. Alldrick, S. Gardiner, C. Godwin, the late R. Hewton, E. Kimura and R. Pease for reviewing the manuscript.

REFERENCES

ANDERSON, R.G., 1989. A stratigraphic, plutonic, and structural framework for the Iskut River map area, northwestern British Columbia. *In* Current Research, Part E. Geological Survey of Canada, Paper 89-1E, p. 145-154.

ANDERSON, R.G. and THORKELSON, D.J., 1990. Mesozoic stratigraphy and setting for some mineral deposits in Iskut River map area, northwestern British Columbia. *In* Current Research, Part E. Geological Survey of Canada, Paper 90-1F, p. 131-139.

BRIDGE, D.A., 199[illegible] The Kerr poly-deformed copper-gold porphyry deposit, Sulphur[illegible] [illegible]old camp. Mineral Deposit Research Unit Iskut River project, annual technical report, Year 2, p. 9.1-9.9.

BRIDGE, D.A. and GODWIN, C.I., 1992. Preliminary geology of the Kerr copper-(gold) deposit, northwestern British Columbia (104B/8). *In* Geological Fieldwork 1991. British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1992-1, p. 513-516.

BRIDGE, D.A., 1993. The deformed early Jurassic Kerr porphyry Cu(-Au) deposit, Sulphurets gold camp, northwestern British Columbia — An update. Mineral Deposit Research Unit Iskut River metallogeny project, Annual report, Year 3, p. 2.1-2.13.

HENDERSON, J.R., KIRKHAM, R.V., HENDERSON, M.N., PAYNE, J.G., WRIGHT, T.O. and WRIGHT, R.L., 1992. Stratigraphy and structure of the Sulphurets area, British Columbia. *In* Current Research, Part A. Geological Survey of Canada, Paper 92-1A, p. 323-335.

LEWIS, P.D., 1992. Structural evolution of the Iskut River area: Preliminary results. Mineral Deposit Research Unit Iskut River project, Annual technical report, Year 2, p. 2.1-2.23.

LEWIS, P.D., 1993. Stratigraphic and structural setting of the Iskut River area. Mineral Deposit Research Unit Iskut River metallogeny project, Annual report, Year 3, p. 1.1-1.5.

MACDONALD, A.J., LEWIS, P.D., THOMPSON, J.F.H., NADARAJU, G., BARTSCH, R.D., RHYS, D.A., ROTH, T., KAIP, A. and SINCLAIR, A.J., 1993. The Iskut River area, northwestern British Columbia Canada: An application of research in metallogenesis to enhance exploration success. Mineral Deposit Research Unit Iskut River metallogeny project, Annual report, Year 3, p. 7.1-7.37.

PEARCE, T.H., 1990. Getting the most from your data: Applications of Pearce element ratio analysis. *In* Theory and application of Pearce element ratios to geochemical data analysis. *Edited by* J.K. Russell and C. R. Stanley. Geological Association of Canada, short course notes No. 8, p. 99-130.

SILLITOE, R.H. and CICERON, A.A., 1985. Geological characteristics and evolution of a gold-rich porphyry copper deposit at Guinaoang, Luzon, Philippines. *In* Asian Mining '85. Institute of Mining and Metallurgy, p. 15-26.

SILLITOE, R.H. and GAPPE, I.M., 1984. Philippine porphyry copper deposits: Geologic setting and characteristics. CCOP technical publication 14, 89 p.

STANLEY, C.R. and RUSSELL, J.K., 1989. Petrologic hypotheses testing with Pearce element ratio diagrams: Derivation of diagram axes. Contributions to mineralogy and petrology, 103, p. 78-89.

TRUDU, A.G. and BLOOM, M.S., 1988. A genetic model for the origin of hypogene gold in porphyry copper systems: The Tirad porphyry copper-gold deposit (Guinaoang, NW Luzon, Philippines). Bicentennial Gold 88, Melbourne, p. 211-216.

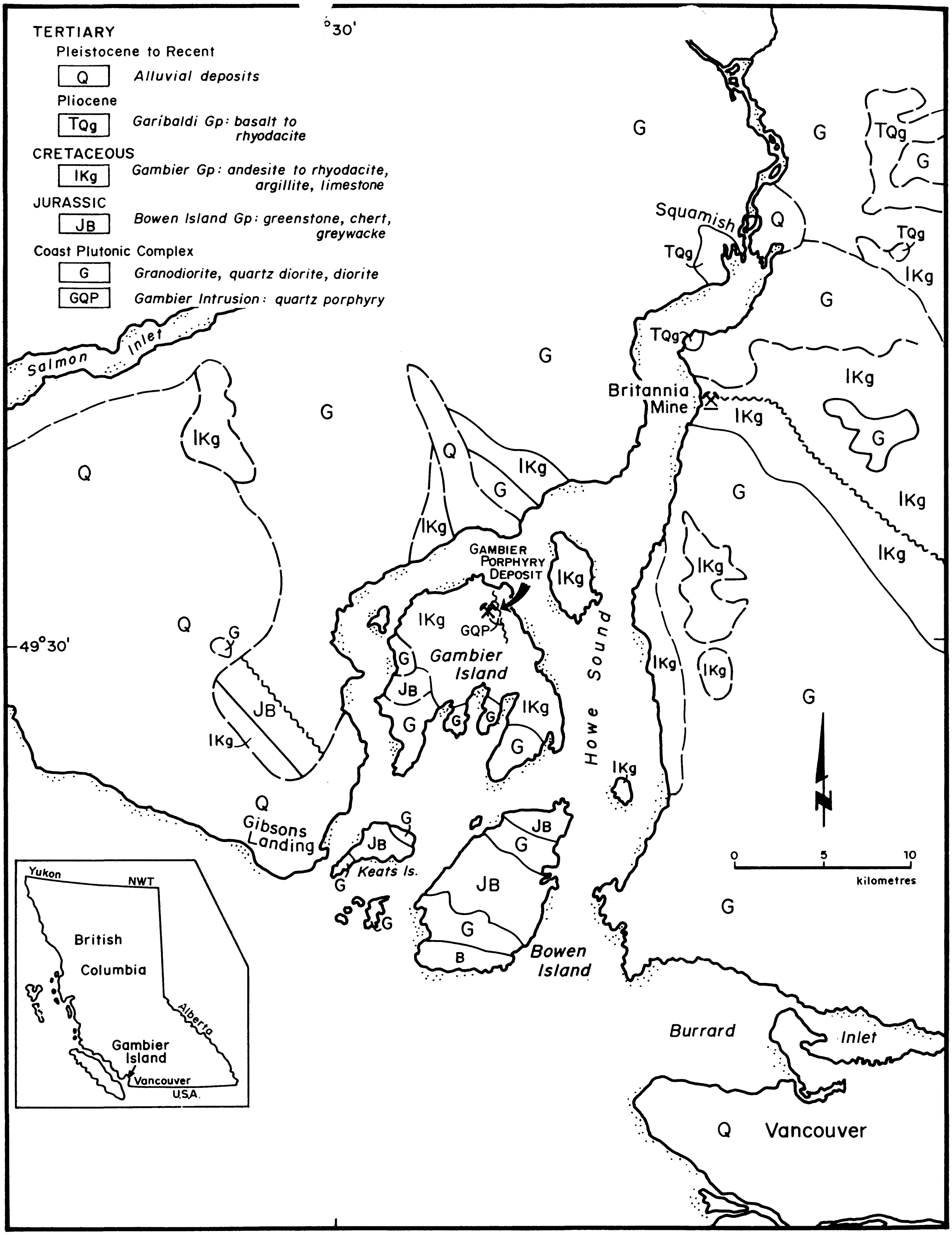

FIGURE 1. Location plan and regional geology. Geology after Roddick and Woodsworth, 1979.

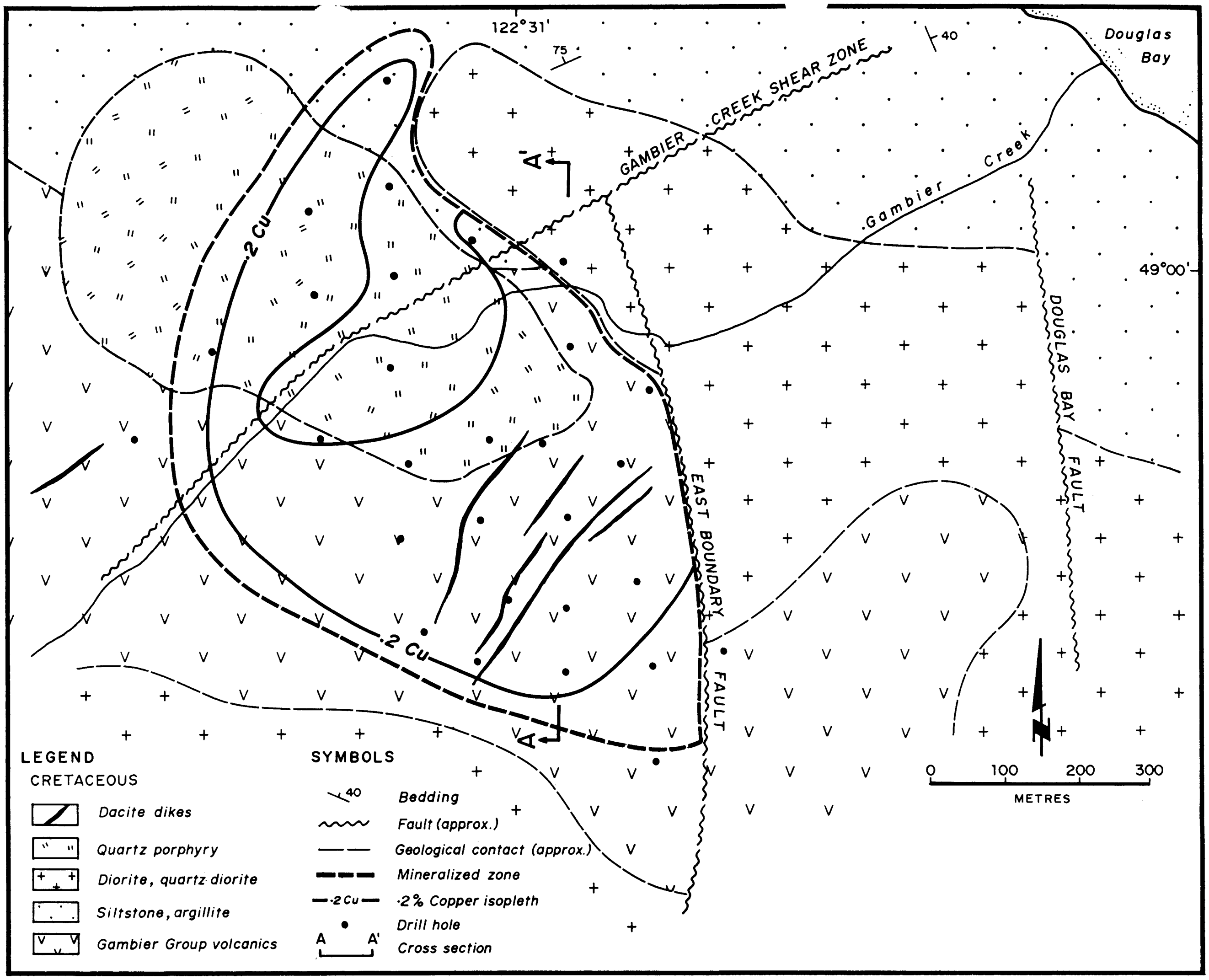

FIGURE 2. Geological plan.

approximate boundaries of the mineralized zone (inferred 0.2% Cu equivalent isopleth) are shown.

Lithology

The grid area is underlain by rocks of the Gambier Group, dioritic rocks of the Coast Range batholith, granitic rocks of possible Tertiary age and isolated, postmineral dacite porphyry dikes. Gambier Group rocks comprise a northwest trending package of argillite, volcanic wacke and breccia, propylitically-altered volcanic rocks and massive andesitic rocks and related breccias that underlie most of the southwestern part of the grid area. Abroad zone of hydrothermally-altered hornfelsed rock extends along the southwest part of the grid. Within this zone, andesitic rocks have been converted to a granoblastic assemblage of quartz, sericite, biotite, chlorite and epidote; a result of complex multistage overprinting of biotite hornfels by phyllic and propylitic mineral assemblages.

Dioritic rocks resemble medium- to coarse-grained heterogeneous rocks of the Coast Range batholith. Equigranular hornblende diorite and quartz diorite are the most common rock types, usually containing abundant zenoliths and chloritic schlieren. Others are massive, homogeneous, fine- to medium-grained diorite. These rocks are barren except for small amounts of pyrite, and consist of saussuritized plagioclase, 10% clinopyroxene, 20% fibrous green amphibole, chlorite, epidote, magnetite, and small amounts of interstitial quartz.

A heterogeneous assemblage of quartz porphyry, breccia and subporphyritic granitic rock forms a northwest trending, oval-shaped stock approximately 500 m in diameter north and south of Gambier Creek. Quartz forms conspicuous phenocrysts up to 2 cm enclosed by altered feldspar phenocrysts and anhedral aggregates of chlorite, sericite and quartz. Much of the stock, particularly along its southern perimeter, is intensely altered to quartz, sericite and lesser amounts of chlorite.

Dacite porphyry dikes are the youngest rocks on the prospect. They intrude the quartz porphyry unit and enclosing volcanic strata. The dikes strike northeast, are subvertical and commonly fill fault zones. The dikes range from 20 cm to 3 m thick, have fine-grained chilled margins and grade inward to medium-grained quartz feldspar porphyry. The dikes are notably barren and locally contain inclusions of mineralized wall rock.

A broad, arcuate mineralized zone several hundred metres wide, is concordant to the south and west contact of the porphyry stock and encloses a low-grade core zone rich in quartz veinlets. Elsewhere, quartz veinlets ranging from a few isolated veins to intense stockworks are common throughout the porphyry body and enclosing volcanic rocks. Most veinlets trend northwesterly and form a south-closing arcuate stockwork zone within the porphyry mass and the peripheral altered and mineralized volcanic rocks. The veinlets are selvage-free and generally contain small amounts of pyrite, molybdenite and chalcopyrite, but many are barren.

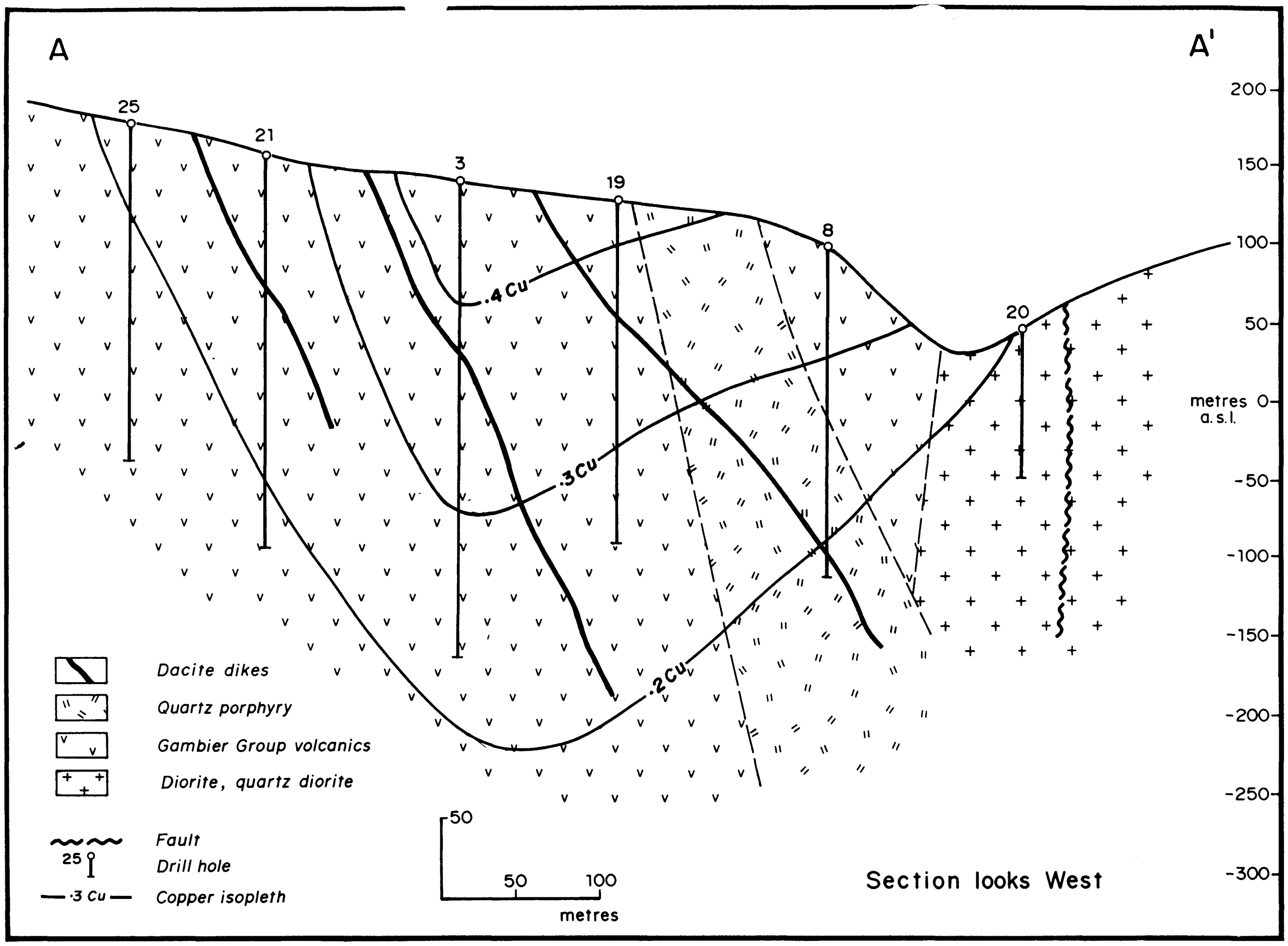

FIGURE 3. Cross-section A-A[1].

Structure

Important fault zones are believed to be the Gambier Creek shear zone, the East Boundary Fault and the Douglas Bay Fault. The Gambier Creek shear zone (Fig. 2) is thought to be a broad, northeasterly trending cataclastic zone that passes through the north part of the mineralized zone, the quartz porphyry unit and much of the enclosing volcanic and sedimentary strata. Many of the rocks north of Gambier Creek are intensely brecciated and sheared and form a broad zone of cataclastic rock along the valley of Gambier Creek. The East Boundary Fault separates most (but possibly not all) of the mineralized volcanic rocks to the west from barren, dioritic rocks to the east. The Douglas Bay Fault is a parallel fault along which the north contact of the diorite body has been displaced southward.

Mineralization and Alteration

A compilation plan outlining the geochemical anomaly, I.P. chargeability, and mineralized zone is shown in Figure 4. Mineralized rocks of the quartz porphyry stock and elements of the enclosing volcanic strata form a broad, west-closing arcuate zone 1200 m long and 200 m wide within the quartz porphyry body and extending for 100 m to 400 m outward from its south and west contact. Barren to low-grade pyritic rocks, locally containing small veins rich in sphalerite, galena, and chalcopyrite, crop out north, west and south of the grid area more or less concentric to the porphyry stock. Fracture coatings, veinlets, and finely disseminated aggregates of pyrite, chalcopyrite and molybdenite occur in altered volcanic rocks and within porphyritic rocks of the quartz porphyry stock. The best grade material occurs in altered volcanic rocks close to the south contact of the quartz porphyry and in a narrow extension of the deposit north of Gambier Creek. This zone is shown as the 0.2% Cu isopleth line in Figure 2. Chalcopyrite, pyrite and rare bornite occur as widely dispersed, fine-grained disseminated aggregates and fracture coatings within this zone. Molybdenite forms small rosettes in quartz stringers and coatings on fracture surfaces. Copper grades generally decrease with depth; the 0.2% Cu isopleth is about 300 m from surface at its deepest point (Fig. 3).

Reserves

Reserves estimates were prepared at the IREM-MERI facility in Montreal, Quebec, under the supervision of Professor M. David and Dr. P. Diehl. Computations were based on the overall deposit outline indicated by geological work and results of the drill program. Estimates were prepared from surface to the 90 m elevation utilizing 15 m bench composites and 60 m by 60 m blocks. Grade estimates were calculated from drill hole assays using standard geostatistical methods.

Computations comprised preparation of assay histograms and bench composites, testing for vertical grade continuity, preparation of horizontal and vertical variograms for both copper and molybdenite (15 m bench composites), calculation of block grades by kriging and estimation of recoverable reserves both bench by bench and over-all by utilizing log normal methods. Copper and molybdenite assays are log normally distributed and only weakly correlated (correlation coefficient = .48). Correlation between copper and copper equivalent is high (.94, Cu equivalent used = %Cu + 8 × % MoS_2).

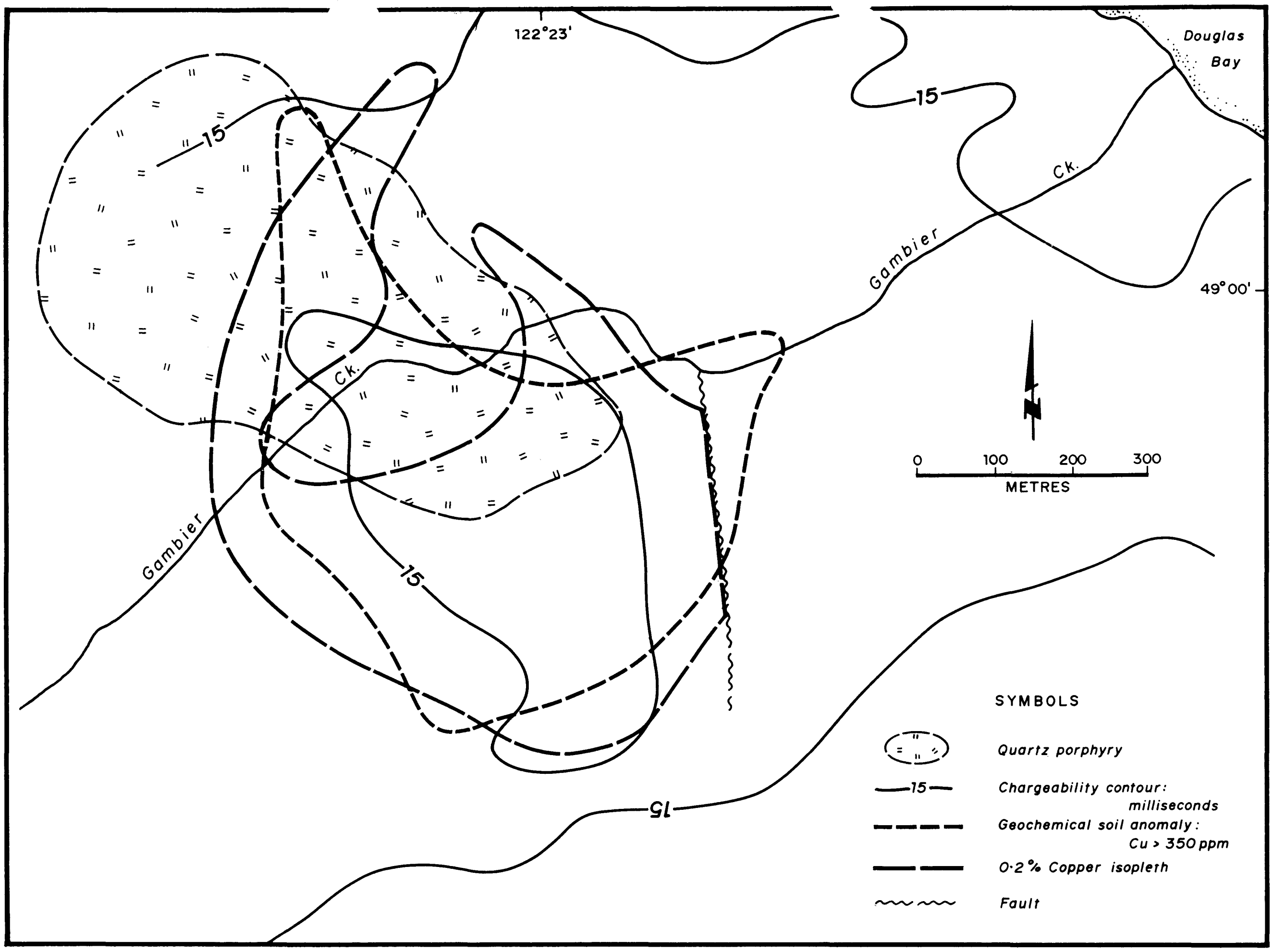

FIGURE 4. Summary map showing quartz porphyry body, induced polarization response (15 milliseconds), geochemical soil anomaly (>350 ppm Cu) and mineralized zone (0.2% Cu isopleth).

Variography studies indicated that the deposit has both zonal and geometric anisotropy. Horizontal variograms of copper and molybdenite have ranges of 500 m and 400 m, respectively, whereas vertical variograms have ranges of 100 m and 80 m. All variograms have little or no nugget effect.

Kriging computations were done over a large volume (1200 m by 960 m by 320 m) comprising some 6852 blocks. A search field of 350 m by 350 m by 50 m was used for each block, resulting in the utilization of 10 to 20 samples per block. Estimation errors are relatively large (20% to 50%) because of the large drill hole spacing (120 m). Sample values from barren dikes were included in the sample sets, hence they are regarded as a dilution component.

Selection of recoverable reserves was based on copper equivalent cutoff grades utilizing established log normal techniques (David, 1977). Copper equivalent cutoff grades were used rather than copper and molybdenite because of the poor correlation between copper and molybdenite assays. The tonnage factor used was 2.75 tonnes per m^3. The deposit has a geologic reserve of 114 million tonnes having an average grade of 0.29% Cu and 0.018% MoS_2 at a waste to ore ratio of 2.7.

Metallurgy

A series of metallurgical tests were performed by Lakefield Research of Canada Limited on several drill core composites. Mineralized rocks require grinding to 80% minus 64 microns to produce a rougher flotation concentrate containing approximately 90% of the copper and molybdenite values. The rougher concentrate requires a regrind to 96% minus 37 microns and two cleaning cycles. Microscopic examination of test products indicated that 90% of the chalcopyrite was liberated from gangue materials. Overall test results indicate that a copper recovery of 87% can be attained and a copper concentrate produced that contains at least 25% Cu.

Discussion

The Gambier Island porphyry deposit is similar to the OK porphyry Cu-Mo deposit near Powell River, British Columbia (Meyer et al., 1976) where a reserve of some 68 million tonnes grading 0.30% Cu and 0.016% MoS_2 was established by drilling between 1972 and 1974. Like the Gambier Island deposit, the OK porphyry deposit comprises widespread copper and molybdenite mineralization associated with a well-developed quartz stockwork peripheral to a body of leucogranodiorite. The mineral zone at the OK deposit is associated with a poorly developed phyllic zone that grades outward to propylitic rocks surrounding the deposit. Other copper prospects similar to the OK and Gambier deposits are known near Powell River and farther east in the Jervis Inlet area.

Conclusions

The Gambier Island deposit is a typical calc-alkaline porphyry deposit conforming to the standard Lowell and Guilbert model (Lowell and Guilbert, 1970) and the Plutonic Porphyry Model of Sutherland Brown (1976). The Gambier Island deposit is one of several deposits and prospects lying along the suture zone between the Coast Plutonic Complex to the east and the Insular Belt to the west.

Acknowledgments

The authors wish to acknowledge the cooperation of 20th Century Energy Corporation in supplying some of the information contained herein.

REFERENCES

DAVID, M., 1977. Geostatistical Ore Reserve Estimation. Elsevier, New York.

FOX, P.E. and DURFELD, R.M., 1981. An evaluation of the Gambier Island Porphyry Copper Prospect, British Columbia. Unpublished company report, 20th Century Energy Corporation, Vancouver, British Columbia, p. 1-26.

HINGS, D.L., 1972. Geophysics Report Number 72-212, Geophysical and geochemical surveys over A, B, and C areas for Gaylord Mines Limited, Gambier Island, B.C. British Columbia Ministry of Energy, Mines and Petroleum Resources, Assessment Report 3908.

LAKEFIELD RESEARCH OF CANADA LTD., 1980. An investigation of the recovery of copper-molybdenum from drill core reject samples, Project Number LR2248. Unpublished company report, 20th Century Energy Corporation, Vancouver, British Columbia.

LOWELL, J.D. and GUI .T, J.M., 1970. Lateral and vertical alteration-mineralization zoning in porphyry ore deposits. Economic Geology, 65, p. 373-408.

McGORAN, J., 1978. Prospecting report on the Daybreak claim, Gambier Island, B.C. Unpublished company report, 20th Century Energy Corporation, Vancouver, British Columbia.

MEYER, W., GALE, R.E. and RANDALL, A.W., 1976. O.K., *In* Porphyry Deposits of the Canadian Cordillera. *Edited by* A. Sutherland Brown. Canadian Institute of Mining and Metallurgy, Special Volume 15, p. 311-316.

ROBERTS, A.F., 1979. Report on diamond drill holes 791, 792, Daybreak Property, Gambier Island, B.C. Unpublished company report, 20th Century Energy Corporation, Vancouver, British Columbia.

RODDICK, J.A. and WOODSWORTH, G.J., 1979. Geology of Vancouver west half and mainland part of Alberni. Geological Survey of Canada, Open File 611.

SUTHERLAND BROWN, A., 1976. Morphology and classification. *In* Porphyry Deposits of the Canadian Cordillera. *Edited by* A. Sutherland Brown. Canadian Institute of Mining and Metallurgy. Special Volume 15, p. 44-51.