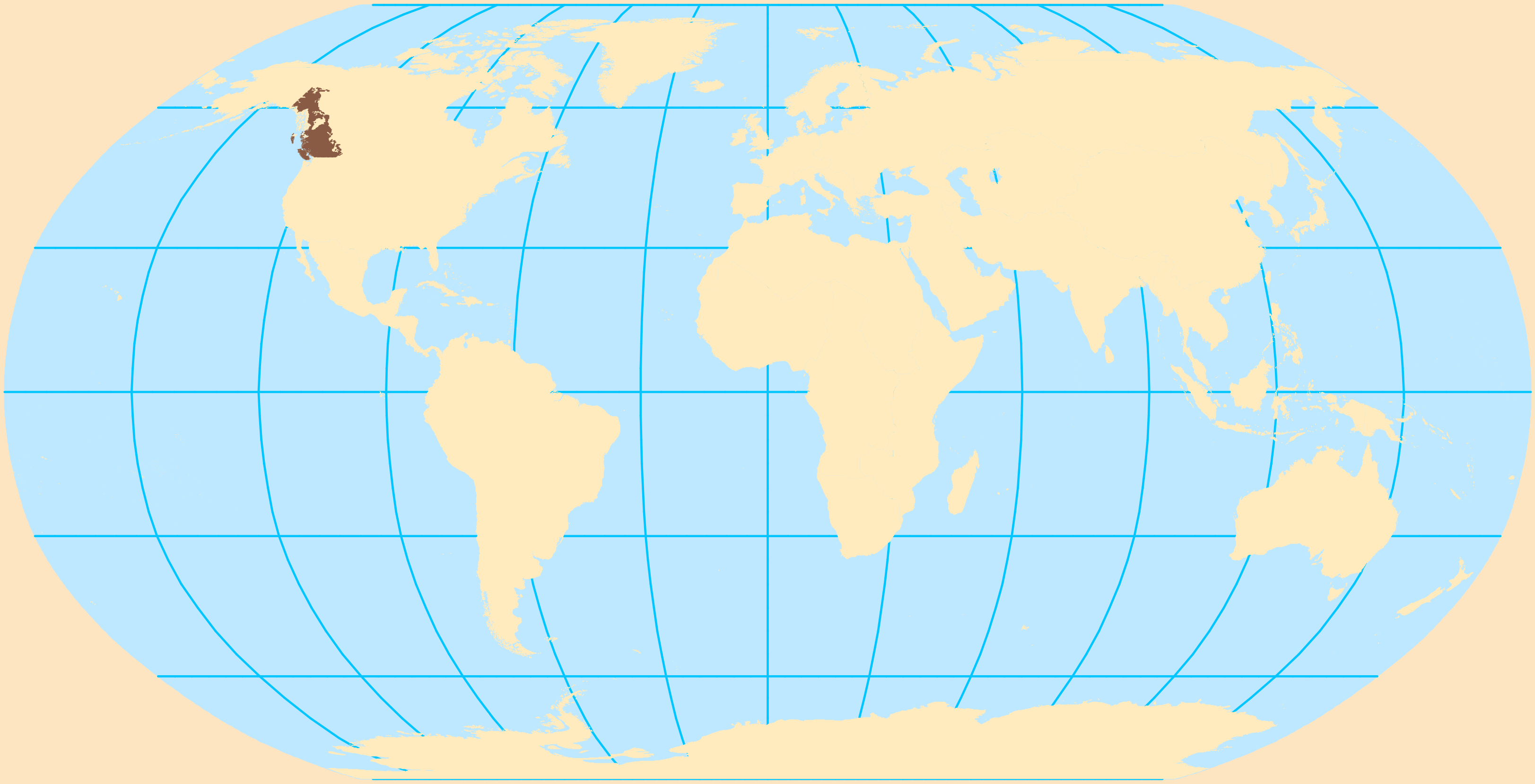
Global Mineral Resource Assessment

Porphyry Copper Assessment of British Columbia and Yukon Territory, Canada



Prepared in cooperation with the British Columbia Geological Survey, Yukon Geological Survey, and XDM Geological Consultants, Inc.

Scientific Investigations Report 2010–5090–C

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Michael L. Zientek and Jane M. Hammarstrom, editors

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By Mark J. Mihalasky, Arthur A. Bookstrom, Thomas P. Frost, and
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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
yard (yd)	0.9144	meter (m)
	Area	
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Mass	
ounce, avoirdupois (oz)	28.35	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	megagram (Mg) or metric ton
ton, long (2,240 lb)	1.016	megagram (Mg) or metric ton

SI to Inch/Pound

Multiply	**By**	**To obtain**
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
hectare (ha)	2.471	acre
square hectometer (hm^2)	2.471	acre
square kilometer (km^2)	247.1	acre
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
megagram (Mg) or metric ton	1.102	ton, short (2,000 lb)
megagram (Mg) or metric ton	0.9842	ton, long (2,240 lb)

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Porphyry Copper Assessment of British Columbia and Yukon Territory, Canada

By Mark J. Mihalasky[1] , Arthur A. Bookstrom[2] , Thomas P. Frost[3] , and Steve Ludington[4], with contributions from James M. Logan[5] , Andre Panteleyev[6] , and Grant Abbott[7]

Abstract

The U.S. Geological Survey does regional, national, and global assessments of resources (mineral, energy, water, biologic) to provide science in support of land management and decision making. Mineral resource assessments provide a synthesis of available information about where mineral deposits are known and suspected to be in the Earth's crust, which commodities may be present, and estimates of amounts of resources that may be present in undiscovered deposits.

Canada is an important source of copper, consistently ranking as one of the top 10 world producers during the past decade (2000-2010). The preponderance of this production has been from porphyry-copper-type deposits in the western Canadian Cordillera. A probabilistic mineral resource assessment of undiscovered resources associated with porphyry copper deposits in western Canada was completed as part of a global mineral resource assessment. The purpose of the assessment was to (1) compile a database of known deposits and significant prospects, (2) delineate permissive areas (tracts) for undiscovered porphyry copper deposits that may be present in the upper kilometer (minimally) of the Earth's crust, and (3) provide probabilistic estimates of amounts of copper (Cu), molybdenum (Mo), gold (Au), and silver (Ag) that could be contained in undiscovered porphyry copper deposits in the tracts. The study was done by the U.S. Geological Survey (USGS) in collaboration with geologists from the British Columbia Geological Survey, Yukon Geological Survey, and industry consultants.

The database of known deposits and significant prospects includes an inventory of mineral resources in 89 known porphyry copper (and 2 related copper-bearing polymetallic vein) ore zones, representing 50 porphyry copper deposits, and lists key characteristics of 280 additional porphyry copper and related copper-bearing prospects, as indicated by currently available exploration results, which also are summarized. Resource and exploration and development activity are updated with information current through April 2010.

The delineation of permissive tracts and probabilistic estimation of resources in undiscovered deposits were done using the USGS three-part mineral resource assessment approach. Permissive tracts are defined in accordance with descriptive models for porphyry copper deposits to include igneous rocks and known deposits and prospects within magmatic arcs related to convergent plate-margin boundary zones. Frequency distributions of total tonnages and average grades of thoroughly explored deposits were used as models for undiscovered deposits and include a new grade and tonnage model for calc-alkaline porphyry Cu±Mo±Au deposits in western Canada.

Five permissive tracts for the occurrence of porphyry copper deposits were delineated: 2 island-arc tracts, 1 tract of transitional, mixed island-arc and continental arc affinities, and 2 continental arc tracts.

In permissive tract 003pCu2001, calc-alkaline igneous rocks of Middle Triassic to Late Jurassic age in accreted island-arc terranes of the Intermontane belt are assessed for calc-alkaline porphyry Cu±Mo±Au deposits. The area of this tract is 175,250 km^2. In 12 known deposits, the total reported tonnage of ore is 8,100 million metric tons (Mt) containing 24.6 Mt copper. An estimated 6.9 undiscovered deposits contain a calculated mean of 8.9 Mt copper and a median of 6.9 Mt copper. The spatial density for the 18.9 known plus estimated undiscovered deposits in this tract is approximately 11 deposits per 100,000 km^2.

In permissive tract 003pCu2002, alkaline igneous rocks of Middle Triassic to Late Jurassic age within the Intermontane accreted island-arc terranes are assessed for alkaline porphyry Cu-Au deposits. The area of this tract is 109,290 km^2. In 12 known deposits the total reported tonnage of ore is 6,440

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Mt, containing 20.9 Mt copper. An estimated 7 undiscovered deposits contain a calculated mean of 22 Mt copper and a median of 13 Mt copper. The spatial density for the 19 known plus estimated undiscovered deposits in this tract is approximately 17 deposits per 100,000 km^2.

In permissive tract 003pCu2003, calc-alkaline igneous rocks of Late Triassic to Early Cretaceous age within the accreted Insular terranes of mixed island-arc and continental arc affinities are assessed for calc-alkaline porphyry Cu±Mo±Au deposits. The area of this tract is 58,360 km^2. The total tonnage of ore reported in the 2 known deposits is 1,160 Mt containing 3.17 Mt copper. An estimated 2.3 undiscovered deposits contain a calculated mean of 3 Mt copper and a median of 1.9 Mt copper. The spatial density for the 4.3 known plus estimated undiscovered deposits in this tract is approximately 7 deposits per 100,000 km^2.

In permissive tract 003pCu2004, calc-alkaline igneous rocks in continental magmatic arcs of Jurassic to Eocene age are assessed for porphyry Cu±Mo±Au deposits. The area of this tract is 639,500 km^2. The total tonnage of ore reported for the 23 known deposits is 6,520 Mt containing 17.9 Mt copper. An estimated 9.6 undiscovered deposits contain a calculated mean of 13 Mt copper and a median of 11 Mt copper. The spatial density for the 32.6 known deposits plus the estimated undiscovered deposits in this tract is approximately 5 deposits per 100,000 km^2.

In permissive tract 003pCu2005, calc-alkaline igneous rocks in continental magmatic arcs of Oligocene to Pliocene age are assessed for porphyry Cu±Mo±Au deposits. The area of this tract is 32,840 km^2. The total tonnage of ore reported for the 1 known deposit is 44.8 Mt containing 0.224 Mt copper. An estimated 1.4 undiscovered deposits contain a calculated mean of 1.8 Mt copper and a median of 0.72 Mt copper. The spatial density for the 2.4 known plus estimated undiscovered deposits in this permissive tract is approximately 7 deposits per 100,000 km^2.

Western Canada has been thoroughly explored for porphyry copper deposits. The total estimated copper contained in known deposits is about 66.8 Mt (based on 2010 data), as compared to a 49 Mt mean of estimated copper in undiscovered deposits and a 34 Mt median of estimated copper in undiscovered deposits. The copper contained in known porphyry copper deposits represents about 58 percent of the total of known and undiscovered porphyry copper deposits (based on mean values). About 86 percent of the increase in estimated copper resources between 1993 and 2009 resulted from the discovery of extensions to known deposits. Nevertheless, exploration for undiscovered deposits continues, especially in and around significant prospects and in parts of permissive tracts that are mostly hidden beneath younger volcanic, sedimentary, or vegetated surficial cover.

Introduction

Porphyry copper deposits are the most important source of copper (Cu) in the world. The primary (hypogene) ore mineral in porphyry copper deposits is chalcopyrite (copper-iron-sulfide, $CuFeS_2$). This and other copper-bearing minerals occur in and around stockworks of intersecting veinlets in hydrothermally altered porphyritic igneous intrusions and their host rocks. In some deposits, supergene processes alter the original copper minerals and make chalcocite (Cu_2S) the most important ore mineral. Molybdenum (Mo), silver (Ag), and gold (Au) are important byproducts in many deposits.

The U.S. Geological Survey (USGS) does national and global assessments of resources (mineral, energy, water, biologic) to provide science in support of decision making. Mineral resource assessments provide a synthesis of available information about where mineral deposits are known and suspected to be in the Earth's crust, which commodities may be present, and estimates of amounts of resources that may be present in undiscovered deposits.

A probabilistic mineral resource assessment of undiscovered resources associated with porphyry copper deposits in western Canada was done as part of a global mineral resource assessment (GMRAP) (Briskey and others, 2001). This global assessment provides a consistent, comprehensive analysis of current information about global, nonfuel mineral resources of platinum-group elements, copper, and potash in selected types of mineral deposits. These commodities were chosen partly for their economic importance, but also as prototypes for estimation of resources in other orthomagmatic, magmatic-hydrothermal, sediment-hosted hydrothermal, and evaporitic deposit types.

The purpose of the assessment for western Canada was to (1) compile a database of known deposits with identified minerals inventory, (2) delineate permissive areas (or tracts of land) for undiscovered porphyry copper deposits that may be present in the upper kilometer of the Earth's crust, (3) estimate numbers of undiscovered porphyry copper deposits within the permissive tracts, and (4) provide probabilistic estimates of amounts of copper, molybdenum, gold, and silver that could be contained in undiscovered porphyry copper deposits in the tracts.

Results of the assessment are provided at a scale of 1:1,000,000 and could be used to:

- Evaluate known and undiscovered copper resources,
- Design and evaluate new mineral-exploration programs,
- Anticipate economic, environmental, and social impacts of mineral development, and
- Provide information for aiding in land-use decisions where competing, or mutually exclusive uses or environmental issues may coincide.

The study was done by the USGS in collaboration with geologists from the British Columbia Geological Survey (BCGS), the Yukon Geological Survey (YGS), and XDM Geological Consultants of Vancouver, British Columbia.

Terminology

The terminology used in this study follows the definitions used in the 1998 assessment of undiscovered deposits of gold, silver, copper, lead, and zinc in the United States (U.S. Geological Survey National Mineral Resource Assessment Team, 2000; U.S. Bureau of Mines and U.S. Geological Survey, 1980; Bates and Jackson, 1997). The terminology is intended to represent standard definitions and general usage by the minerals industry and the resource-assessment community. Some countries in the world recently have adopted more rigorous definitions of terms for estimating mineral resources and mineral reserves and for reporting exploration information to comply with legal mandates (Committee for Mineral Reserves International Reporting Standards, 2004).

Mineral deposit. A mineral concentration of sufficient size and grade that it might, under the most favorable of circumstances, be considered to have potential for economic development.

Undiscovered mineral deposit. A mineral deposit believed to exist 1 km or less below the surface of the ground, or an incompletely explored mineral occurrence or prospect that could have sufficient size and grade to be classified as a deposit.

Descriptive mineral deposit model. A set of data in a convenient, standardized form that describes a group of mineral deposits having similar characteristics.

Grade and tonnage model. Frequency distributions of the grades and sizes of thoroughly explored, and(or) completely mined out, individual mineral deposits that are classified by a descriptive mineral deposit model.

Permissive tract. The surface projection of a volume of rock where the geology permits the existence of a mineral deposit of a specified type. The probability of deposits of the type being studied occurring outside the tract is negligible.

Resource. A mineral concentration of sufficient size and grade, and in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.

Identified resources. Resources whose location, grade, quality, and quantity are known or can be estimated from specific geologic evidence. For this assessment, identified resources are the deposits that constitute the grade and tonnage models used in the assessment (which can include measured, indicated, and inferred mineral resources at the lowest available cut-off grade). In addition, deposits that are not included in the models used for the assessment may be considered as identified resources if they are characterized well enough by deposit type, grade, and tonnage to meet U.S. Securities and Exchange Commission or CRIRSCO[8] reporting guidelines.

Undiscovered resources. Resources in undiscovered mineral deposits whose existence is postulated on the basis of indirect geologic evidence. These include undiscovered resources in known types of mineral deposits postulated to exist in permissive geologic settings. Undiscovered resources may include active mines if the resource is delineated incompletely. For example, a deposit that is explored only partially and reported as "open to the west or open at depth" could be counted as an undiscovered deposit. Undiscovered resources in extensions to identified resources are not addressed explicitly in the assessment process.

Calc-alkaline, calc-alkalic; alkaline, alkalic. These terms are used in a general, non-rigorous manner to refer to plutonic igneous rocks of granitoid composition (calc-alkaline or calc-alkalic) and of syenitoid through dioritoid to gabbroid composition (alkaline or alkalic), and their volcanic equivalents (see Le Maitre and others, 2002, provisional field classifications, figs. 2.10 and 2.19). In the igneous literature, the "-alkaline" and "-alkalic" terms are defined and used in multiple and inconsistent ways (see Arculus, 2003). For this assessment, the term calc-alkalic is used synonymously for calc-alkaline, and alkalic synonymously for alkaline, as well as for their associated deposits, which are classified as calc-alkaline (or calc-alkalic) Cu±Mo±Au or alkaline (or alkalic) porphyry copper subtypes.

NI 43-101. National Instrument 43-101. A Canadian mineral resource classification scheme and set of rules and regulations for how publicly traded companies report and display scientific and technical information about mineral projects. The purpose of NI 43-101 is to protect investors and other interested parties from erroneous, misleading, unproven, or otherwise fraudulent information and promotional materials. For additional information, see http://www.cim.org, http://www.ni43-101.net, http://www.osc.gov.on.ca, or http://en.wikipedia.org/wiki/National_Instrument_43-101.

Assessment Methods

The assessment of undiscovered porphyry copper deposits in western Canada was done using the three-part form of mineral-resource assessment based on mineral deposit models (Singer, 1993, 2007a, b). This form of mineral resource assessment provides internally consistent estimates of undiscovered resources that can be evaluated using economic filters and other tools for economic, environmental, and policy analysis. Assessments are based on analogy, that is, that undiscovered resources will be like those that already have been discovered.

In applying the three-part form of mineral resource assessment, (1) permissive tracts are delineated according to

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[8] Committee for Mineral Reserves International Reporting Standards (2006) (http://www.crirsco.com/welcome.asp).

the types of deposits permitted by the geology, (2) the amount of metal in typical deposits is estimated by using grade and tonnage models, and (3) the number of undiscovered deposits of each type is estimated by using a variety of subjective methods (Singer, 2007a).

Descriptive mineral deposit models provide criteria for delineating permissive tracts for undiscovered deposits by highlighting features of deposit types that are obtained readily from geologic maps, such as tectonic setting and host-rock lithology (Singer, 2007a; Singer and Berger, 2007). Mineral occurrence databases are used to plot the spatial distribution of known deposits and prospects. Based on published geologic maps, areas that include permissive geology for the deposit type, as well as any known deposits are outlined as permissive tracts. Permissive tracts delineate typical fundamental geologic features, or units, that characterize the deposit type, such as magmatic arcs for porphyry copper deposits.

A permissive tract for porphyry copper deposits is delineated as a geographic area that includes volcanic and intrusive rocks of a specified age range that are part of a magmatic arc related to convergent plate margin boundary zones. The tract generally is bounded by the outline of the magmatic arc, as depicted on the scale of the maps available for tract delineation, and also should include known porphyry copper deposits and prospects of that age range. The tract also may include areas suspected to include similar geology, but covered by younger or structurally overlying materials that are less than 1 km thick.

Frequency distributions of pre-mining tonnages and average grades of thoroughly explored deposits of a given type are used as models for grades and tonnages of undiscovered deposits (Singer, 1993). Models are constructed from average grades and tonnage based on the total production, reserves, and resources at the lowest possible cutoff grade, as described in Singer and others (2008) for porphyry copper deposits.

Numbers of undiscovered deposits at various quantiles (degrees of belief) are estimated by an assessment team of experts using a variety of strategies, such as density models or counting and assigning probabilities to anomalies (Singer, 2007b). Probable amounts of undiscovered resources are estimated by combining estimates of numbers of undiscovered deposits with grade and tonnage models by using a Monte Carlo simulation (Root and others, 1992; Bawiec and Spanski, in press). Results are reported as estimates of the mean expected number of undiscovered deposits along with the associated standard deviation and variance, cumulative probability graphs, and associated data tables showing the amounts of the commodities predicted by the estimates, all based on the team's consensus estimates for each permissive tract.

Guidelines for porphyry copper assessment in the GMRAP project are summarized and discussed in Hammarstrom and others (in press) and references therein. For more detailed descriptions of the three-part form of mineral resource assessment, see Singer (1993, 2007a, b), Singer and Berger (2007), and Menzie (2005a, b).

Report Format

This report includes an overview of the regional geologic setting of porphyry copper deposits in western Canada and a summary of results. The assessment data and results for each permissive tract are presented in a standardized format in appendixes A through E. Appendix F is an Excel workbook containing information about the porphyry copper deposits and prospects included in this study. Descriptive and grade and tonnage models used or developed for this particular assessment region are described below. A new grade and tonnage model for calc-alkaline-porphyry Cu±Mo±Au deposits of the Canadian Cordillera is included as appendix G.

Permissive tract boundaries and information about deposits and significant prospects are included in appendix H as ESRI geographic information system (GIS) files (geodatabase format) that accompany this report. Political boundaries are based on U.S. Department of State (2009).

Permissive Tract Descriptions

Appendixes A through E contain summary information for each permissive tract. Each permissive tract is assigned three identifiers: (1) a unique 10-character "Coded_ID" number, (2) a descriptive tract name, and (3) a user-defined "Tract_ID" number. The Coded_ID tract identifier is constructed to serve as a key field for lookup tables within the global GIS. The Coded_Id designates the United Nations geographical region[9] (003 for North America), a deposit type abbreviation (pCu for porphyry copper), and a unique 4-digit number for each permissive tract (2001 through 2005 for this assessment). The descriptive tract name references a readily identifiable geographical or geological feature. The optional user-defined Tract_ID is convenient shorthand used by the authors to refer to tracts (for example, CA01PC, CA02PC) throughout the text and summary tables. The assessment for each permissive tract includes the following:

- Coded_ID, Tract name (User_ID), authorship, and author affiliation,
- Information and references for the deposit type assessed,
- Information about the tract location and the geologic feature assessed,
- Summary table of selected resource assessment results for the tract,
- Rationale for tract delineation,
- Geologic criteria,

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[9] UNdata, 2009, United Nations Statistics Division (http://unstats.un.org/unsd/methods/m49/m49alpha.htm).

- Known deposits (table),
- Significant prospects, mineral occurrences, and related deposit types (table),
- Exploration history,
- Sources of information,
- Rationale for grade and tonnage model selection,
- Estimate of the number of undiscovered deposits,
- Rationale for the estimate,
- Probabilistic assessment simulation results,
- References,
- Page-size tract map, and
- Cumulative frequency plot of simulation results.

Porphyry Copper Assessment of Western Canada

Porphyry Copper Deposits and Prospects of Western Canada

According to Singer and others (2008), the western Canadian provinces of British Columbia and the Yukon Territory contain 54 known porphyry copper deposits. By comparison, the much larger total area of the rest of Canada contains only five known porphyry copper deposits (see Singer and others, 2008). Recognizing this, and given a limited time to complete this study, we concentrated on porphyry-copper potential of British Columbia and Yukon. Appendix F lists characteristic attributes of about 350 porphyry copper deposits and prospects in the western Canadian study area. MINFILE databases of the British Columbia (MINFILE BC, 2009) and Yukon geological surveys (MINFILE YT, 2009), which are available on the Internet, contain records for more than 600 porphyry copper deposits, prospects and showings. The MINFILE record for each site lists its name, location (latitude, longitude), commodities, ore minerals, alteration types, deposit types, host terranes, types and ages of host rocks, associated igneous intrusions, sample intervals, and interval assay results. Most records also contain an inventory of assay data, a narrative description of the geology of the site and its history of exploration, and a list of references.

For major mines and developed prospects, we compiled information from descriptive articles in Special Volume 15 of the Canadian Institute of Mining and Metallurgy, edited by A. Sutherland Brown (1976), and Special Volume 46 of the Canadian Institute of Mining, Metallurgy and Petroleum, edited by T. Schroeter (1995). For recently active exploration projects, we compiled information from British Columbia Mining and Mineral Exploration Overviews (Schroeter and others 2006, 2007; DeGrace and others, 2008, 2009). These sources led us to Web sites of minerals-exploration companies, where we found up-to-date project summaries and technical reports.

Porphyry Copper Deposits in the Context of Physiographic Belts and Accreted Terranes

The Canadian Cordilleran region trends northwesterly along the western margin of North American. Maps by Jackson (1976) and by Wheeler and others (1991) show the boundaries of five parallel tectonic belts that comprise the Canadian Cordillera. From inland to coastal, these are the Foreland, Omineca, Intermontane, Coast, and Insular belts. A map by Pilcher and others (1976) shows the distribution of porphyry copper deposits and prospects in relation to the general geology and tectonic belts mapped by Jackson (1976). Ney and Hollister (1976), Dawson and others (1991) and McMillan (1991) described the distribution of Canadian Cordilleran porphyry copper deposits in the context of these belts, as illustrated in figure 1 and summarized below.

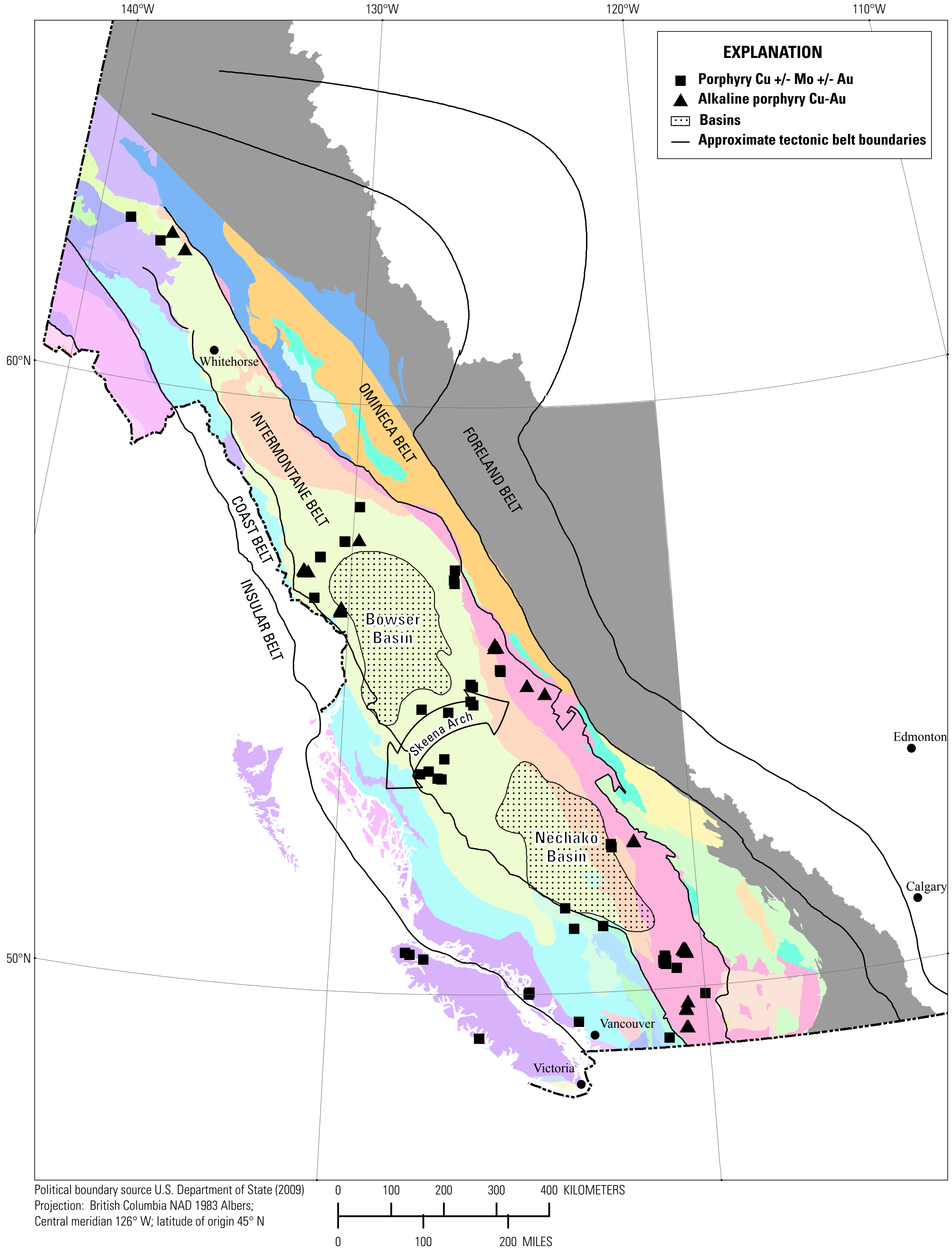
The ***Foreland (or Eastern Marginal belt)*** consists of folded and northeastward thrust-faulted sedimentary strata. The Foreland belt contains few igneous rocks and no known porphyry copper deposits.

The ***Omineca belt*** consists of metasedimentary, metavolcanic, and metaplutonic rocks that were metamorphosed during Jurassic to Paleocene orogenic crustal thickening. The Omineca belt contains few porphyry copper prospects. Uplifted metamorphic core complexes in its southern part expose plutons that probably are eroded too deeply for preservation of any porphyry copper deposits that may have existed before uplift and erosion.

The ***Intermontane belt*** lies between the mountainous Omineca and Coast belts. It generally corresponds to the Intermontane superterrane, which includes the Quesnel and Stikine island-arc terranes and the Cache Creek ocean-floor terrane. These terranes were accreted to North America in Jurassic time (between about 186 and 170 Ma). The Quesnel and Stikine island-arc terranes contain both pre-accretionary and post-accretionary porphyry copper deposits of both calc-alkaline porphyry Cu±Mo±Au and alkaline porphyry Cu-Au subtypes. The Cache Creek ocean-floor terrane, however, contains only post-accretionary porphyry copper deposits.

In northern British Columbia, much of Stikinia is overlain by Middle Jurassic to Cretaceous sedimentary strata of the Bowser Basin. Rickets and others (1992) interpreted the Bowser Basin as a fore-deep basin. They suggested that thrust loading of the Cache Creek terrane on Stikinia initiated subsidence of the Bowser Basin. This began in early Middle Jurassic time (from about 178 to 174 Ma), after accretion of Quesnellia and during closure of the Cache Creek ocean, but before accretion of Stikinia. In southern British Columbia, much of Stikinia is covered by Cretaceous to Eocene volcanic and epiclastic rocks and Miocene plateau basalts.

The ***Coast belt*** consists mostly of a composite granitoid batholith of Late Jurassic to Miocene age, which parallels the coast. Inclusions of highly metamorphosed rocks of the Insular belt are common in the western and central parts of the batholith. Inclusions of less metamorphosed rocks of the Intermontane belt are common along its eastern margin. Inland



Political boundary source U.S. Department of State (2009)
Projection: British Columbia NAD 1983 Albers;
Central meridian 126° W; latitude of origin 45° N

Figure 1. Map showing the distribution of porphyry copper deposits relative to generalized tectonic belts and major terranes of the Canadian Cordillera (derived from McMillan, 1991; Wheeler and McFeely, 1991; Wheeler and others, 1991; Gordey and Makepeace, 1999; Massey and others, 2005). The terranes are represented as a collage of pastel colors (for terrane names and geologic characteristics, see Wheeler and McFeely, 1991, and Wheeler and others, 1991). Also shown are the Bowser Basin, the Skeena arch, and the Nechako basin, after Gabrielse and others (1991).

from the exposed part of the batholith, satellite plutons intrude co-magmatic volcanic rocks. Most porphyry copper prospects in the Coast belt are near the upper-eastern margin of the batholith, or near later intrusions of Oligocene-Miocene age.

The ***Insular belt*** includes Vancouver Island, the Queen Charlotte Islands, and many other islands that generally constitute a chain of islands between the mainland and the open Pacific Ocean. The Insular belt corresponds to the Insular superterrane, which consists of the Wrangellia and Alexander island-arc terranes, which were accreted to North America by Cretaceous time. Wrangellia contains both pre- and post-accretionary porphyry copper occurrences.

Major Tectonic Features and Igneous Assemblages of the Canadian Cordillera

In the Canadian Cordillera, major paleogeographic elements of the western margin of ancient North America (Laurentia) include the Mackenzie platform, the Lower Paleozoic Selwyn black-shale basin, the Cassiar terrane, the Cambrian Kootenay arc (a carbonate shelf), the Late Proterozoic Windermere rift, the Mesoproterozoic Belt-Purcell intracratonic basin, and the Yukon-Tanana terrane. The Yukon-Tanana terrane (fig. 2) is a far-traveled pericratonic terrane. It probably represents a rifted fragment of Laurentia, upon which an oceanic island-arc was superimposed (Nelson and others, 2006; Colpron and others, 2007; Nelson and Colpron, 2007).

Major accreted terranes of ocean-floor affinity include the Slide Mountain and Cache Creek terranes. The Slide Mountain terrane represents a closed marginal ocean between the Laurentian margin and the Yukon-Tanana terrane. It probably formed in response to back-arc extension, caused by rollback of subduction beneath the Yukon-Tanana terrane (Nelson and others, 2006). The Quesnel and Stikine island-arc terranes envelop the east, north, and west margins of the exotic and far-traveled Cache Creek oceanic terrane (fig. 2). According to Mihalynuk and others (1994), counterclockwise oroclinal rotation of the Stikine and Nisling terranes in the Late Triassic to Early Jurassic caused enclosure of the Cache Creek terrane.

Major accreted oceanic island-arc terranes include Quesnellia and Stikinia (of the Intermontane superterrane), as well as Wrangellia and the southern Alexander terrane (of the Insular superterrane). The northern Alexander terrane is a pericratonic fragment with affinities to the Farewell terrane of central Alaska (JoAnne Nelson, written commun., 2010). The younger and relatively minor Chugach (CG) and Yakutat (YT) terranes are in southeastern Alaska and are, therefore, not included in this study.

The whole collage of accreted terranes generally is bounded on the east by the Northern Rocky Mountain and Tintina fault systems, which are physiographically expressed as the Northern Rocky Mountain Trench in British Columbia and the Tintina Trench in Yukon. The western boundary, excluding the Wrangellia, Alexander, and other terranes outboard of the Coast belt, is formed by the Denali fault system and other fault systems to the south. These transcurrent fault systems have accommodated several hundred kilometers of mainly right-lateral strike-slip motion since the middle Cretaceous (Gabrielse, 1985). These post-accretion strike-slip faults have thus modified the spatial relationships of the accreted terranes of the western North America.

Regional igneous assemblages include: (1) Triassic and Early to Middle Jurassic volcanic and intrusive igneous rocks related to subduction beneath the Quesnel, Stikine, and Yukon-Tanana island arcs; (2a) Late Jurassic to mid-Cretaceous intrusions of the discontinuous Omineca batholith (mostly in the Selwyn Basin and Cassiar terrane, but also in the Quesnel and Yukon-Tanana terranes); (2b) Late Jurassic to mid-Cretaceous intrusions of the Coast Plutonic Complex; (3) Late Cretaceous to early Tertiary volcanic and plutonic rocks in and around the Coast Plutonic complex, including Eocene volcanic and plutonic rocks that extend east across the Intermontane Belt and into the Omineca Belt in southern and northern British Columbia and central Yukon; (4) igneous rocks of the Oligocene to Holocene Cascade-Garibaldi-Pemberton magmatic arc; and (5) flood basalts of Miocene-Pliocene age in southern British Columbia.

Probabilistic Assessment of Undiscovered Mineral Resources

Descriptive Models for Canadian Cordilleran Porphyry Copper

USGS descriptive models for porphyry copper deposits and their various subtypes include general porphyry copper models by Cox (1986a) and Berger and others (2008). A global porphyry copper database by Singer and others (2008) also contains tabular descriptive information along with grade and tonnage data. USGS descriptive models for subtypes of porphyry copper deposits include those for skarn-related porphyry copper, porphyry Cu-Au, and porphyry Cu-Mo deposits by Cox (1986b, c, d).

McMillan (1991) described two types of Canadian Cordilleran porphyry copper deposits—porphyry copper deposits associated with calc-alkaline igneous rocks, and porphyry Cu-Au deposits associated with alkaline igneous rocks.

Panteleyev (1995a) wrote a descriptive model for calc-alkaline porphyry Cu±Mo±Au deposits associated with porphyritic intrusions of quartz diorite, granodiorite, or quartz monzonite. The ore bodies are in, or adjoin, these intrusions and consist of large zones of mineralized quartz veins and veinlets, closely spaced fractures, stockworks, and breccia bodies that are economically bulk-mineable for their copper, molybdenum, and gold. Zones of disseminated sulfide mineralization are also present, but generally in subordinate amounts. Ore minerals consist of pyrite and chalcopyrite with lesser molybdenite, bornite, and magnetite (see Panteleyev, 1995a, for full description).

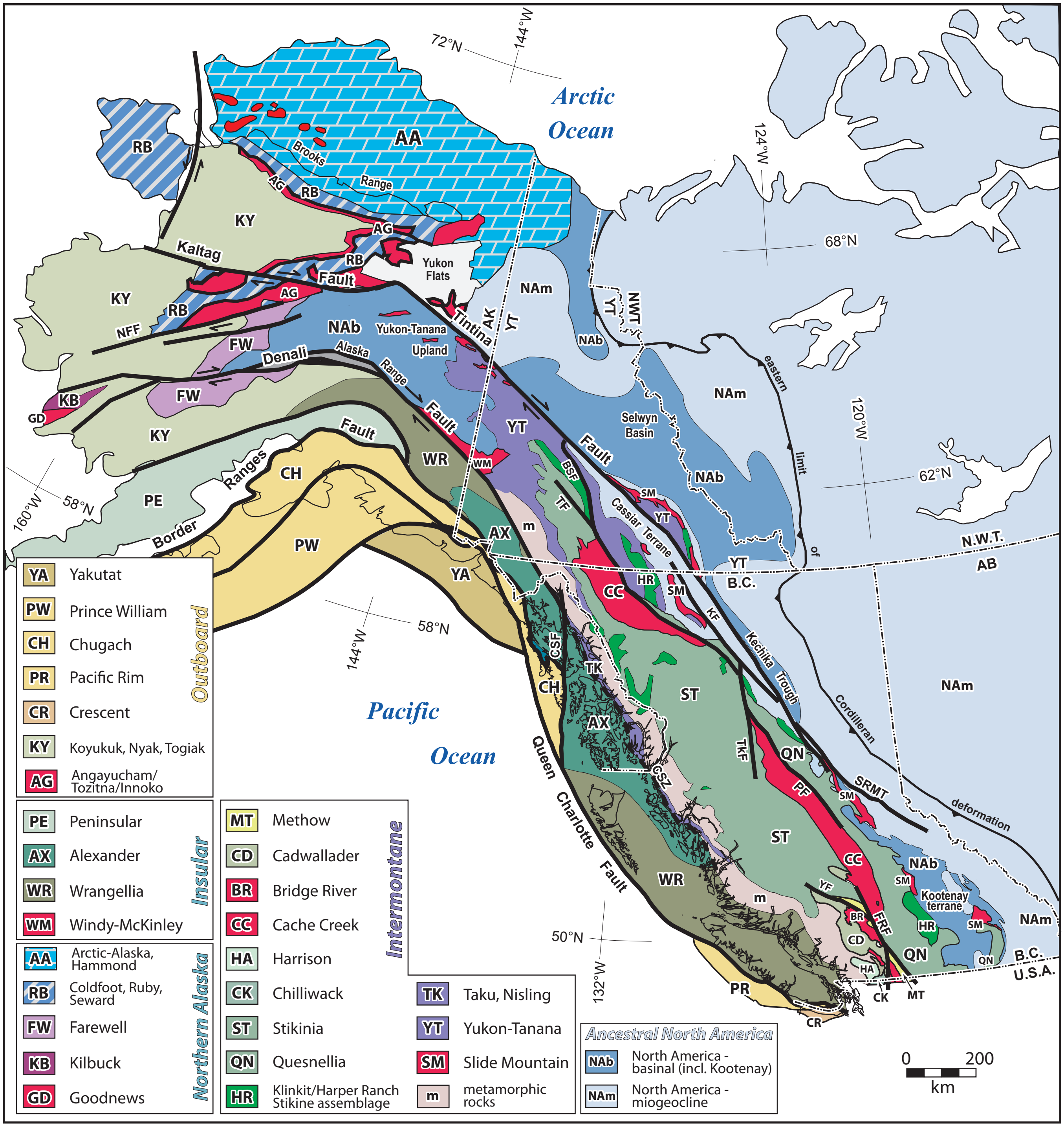


Figure 2. Map showing major terranes and superterranes of the Canadian Cordillera (from Nelson and Colpron, 2007). Fault abbreviations: BSF – Big Salmon fault; CSF – Chatham Strait fault; CSZ – Coast shear zone; FRF – Fraser River fault; KF – Kechika fault; NFF – Nixon Fork-Iditarod fault; PF – Pinchi fault; SMRT – southern Rocky Mountain trench; TkF – Takla-Finlay-Ingenika fault system; YK – Yalakom fault. Other abbreviations: AB – Alberta; AK – Alaska; BC – British Columbia; NWT – Northwest Territories; YT – Yukon Territory.

Panteleyev (1995b) also wrote a descriptive model for alkalic porphyry Cu-Au deposits associated with porphyritic intrusions of dioritic to syenitic composition. The ore bodies consist of zones of fractured and mineralized rocks and mineralized breccias that are economically bulk-mineable for their contained copper and gold. Ore consists of stockworks of intersecting veinlets and disseminations of chalcopyrite, pyrite, magnetite, bornite and chalcocite±rare galena, sphalerite, tellurides, tetrahedrite, gold, and silver±traces of platinum group elements (see Panteleyev, 1995b, for full description).

Panteleyev's models best describe the porphyry copper deposits of the Canadian Cordillera (Panteleyev, 1995a, b). Plutonic, classic (stock-related, cylindrical porphyritic intrusions), and volcanic subtypes of these models describe geologic characteristics of deposits formed at respectively deep, moderate, and shallow levels of the upper crust.

Permissive Tracts for Porphyry Copper

Areas where the geology permits the existence of mineral deposits of a specified type are called permissive tracts. Criteria for identification of permissive tracts are derived from descriptive models, which are based on studies of known deposits. According to Singer (2007a), permissive boundaries are defined such that the probability of deposits of the type delineated occurring outside the boundary are negligible (specifically, tracts are drawn such that the probability of a deposit occurring outside the boundary is less than 1 in 100,000 to 1,000,000). According to M.L. Zientek and J.M. Hammarstrom (written commun., 2007):

> The fundamental unit for delineation of a permissive tract for porphyry copper is a subduction-related magmatic arc of a given age-range [subsequently this definition was expanded to also include post-collisional and post-subduction magmatic belts]. Porphyry copper deposits form as hydrothermal systems associated with relatively shallowly emplaced porphyritic stocks in volcano-plutonic arcs. Each permissive tract for porphyry copper deposits is outlined by delineating a geographic area on a geologic map that includes volcanic and plutonic rocks of a magmatic arc of a specified age range. The tract may include known porphyry copper deposits and prospects of that age range, and it may overlap with tracts for deposits of other age ranges. A permissive tract may also include areas covered by younger materials, where estimated depths to underlying permissive rocks are less than about 1 km.

To define magmatic episodes associated with porphyry copper deposits, we consulted histograms of age determinations on igneous rocks and porphyry copper deposits by Christopher and Carter (1976) and Dawson and others (1991). Then we made similar histograms based on up-to-date compilations of isotopic age determinations (fig. 3). We plotted age data for igneous rocks from Breitsprecher and Mortensen (2004a, b). We compiled and plotted age data for porphyry copper deposits in western Canada from McMillan and others (1995), Mortensen and others (1995), Sinclair (2007), Singer and others (2008), and records in the MINFILE databases.

From the compiled histograms, we recognized five sets of porphyry copper deposits and prospects, defined on the basis of their subtypes, ages and host terranes (relative to pre- or post-accretionary intrusions). Each of these five sets of porphyry copper occurrences is associated with a tract of plutonic and volcanic rocks. Thus, we defined and delineated five permissive tracts, constrained by the ages and compositions of igneous rocks associated with either calc-alkaline porphyry Cu±Mo±Au deposits or alkaline porphyry Cu-Au deposits in the Canadian Cordillera.

The first two (oldest) tracts are co-extensive with island-arc terranes, in which porphyry copper deposits formed before their accretion to North America. The third tract is co-extensive with island-arc terranes superimposed on fragments of continental crust, in which porphyry copper deposits formed in a transitional tectonic setting between island arc and continental arc magmatism during accretion of island arc terranes to the Cordilleran continental margin. The last two (youngest) tracts are co-extensive with continental magmatic arcs and accreted island-arc and oceanic terranes, in which porphyry copper deposits formed after accretion to North America.

Table 1 lists and briefly describes each of these five permissive tracts in terms of age range, magmatic-arc type and porphyry copper subtype. The geologic feature assessed is identified for each tract. Table 2 lists types of intrusive and volcanic rocks in each tract and gives interpretive remarks about the tectonic settings and origins of the igneous rocks in each tract.

We delineated permissive tracts by selecting map units representing igneous rocks of appropriate age and composition from digital geologic maps of British Columbia and Yukon. These maps were compiled from geologic maps (scale 1:250,000) for presentation at a scale of 1:1,000,000. First, we selected all map units representing lithologic assemblages containing igneous rocks. From those maps, we selected map units representing rocks of age ranges appropriate to each tract and then, selected map units representing lithologic assemblages containing rocks of compositions appropriate to each tract (table 2). For map units including rocks with ages appropriate to more than one tract, location was considered to determine the proper tract assignment, which could include assignment to more than one tract. In the GIS map attribute table of all igneous units, we recorded a reason for including or excluding any map unit from each tract.

After selecting permissive map units, we added a 10-km buffer zone around intrusive rocks and a 2-km buffer zone around bodies of volcanic rocks. This buffer expanded the area of the permissive tract to include all significant porphyry copper prospects and to include unexposed permissive rocks and porphyry copper deposits proximal to mapped permissive

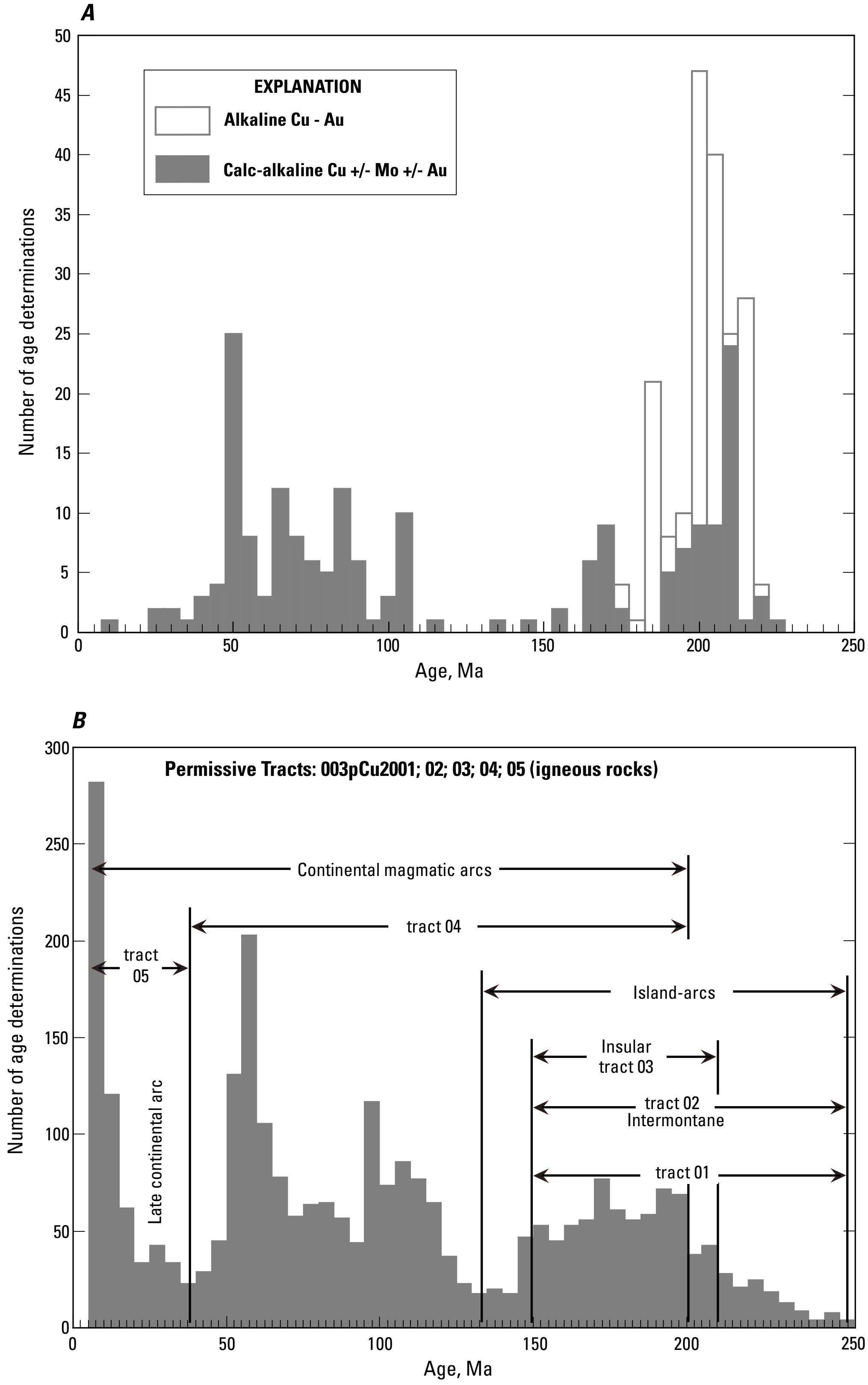


Figure 3. Ages of porphyry copper deposits and igneous rocks in western Canada. *A*, Histogram showing frequency distribution of ages of Canadian porphyry copper deposits. *B*, Histogram showing frequency distribution of isotopic age determinations on igneous rocks of the Canadian Cordillera. (See text for explanation and data sources.)

Table 1. Permissive tracts for porphyry copper deposits in the Canadian Cordillera.

Coded_ID	User_ID	Tract name and deposit type	Porphyry Cu age range (Ma)	Geologic feature assessed	Permissive map units, geologic age range	Permissive map units, age range (Ma)
003pCu2001	CA01	Intermontane Island-Arc Porphyry Cu	222-168	Porphyry Cu systems associated with calc-alkaline igneous rocks of the Quesnel and Stikine accreted island-arc terranes	Middle Triassic to Late Jurassic	245-146
003pCu2002	CA02	Intermontane Island-Arc Porphyry Cu-Au	212-183	Porphyry Cu-Au systems associated with alkaline igneous rocks of the Quesnel and Stikine accreted island-arc terranes	Middle Triassic to Late Jurassic	245-146
003pCu2003	CA03	Insular Mixed Island- and Continental Arc Porphyry Cu	173-154	Porphyry Cu systems associated with calc-alkaline igneous rocks of Wrangellia and the Alexander mixed island-arc and continental-arc terranes	Triassic to Cretaceous	251-65
003pCu2004	CA04	Cordilleran Continental Arc Porphyry Cu	134-35	Porphyry Cu systems associated with predominantly calc-alkaline igneous rocks of post-accretionary continental magmatic arcs	Jurassic to Eocene	200-35
003pCu2005	CA05	Late Continental Arc Porphyry Cu	29-7	Porphyry Cu systems associated with predominantly calc-alkaline igneous rocks of the Cascades-Garibaldi-Pemberton continental magmatic arc	Oligocene to Pliocene	34-1.8

Table 2. Tectonic settings and characteristic igneous rocks of permissive tracts for Canadian Cordilleran porphyry copper deposits.

Coded_ID	User_ID	Tectonic setting	Characteristic intrusive rocks	Characteristic volcanic rocks	Interpretation
003pCu2001	CA01	island arc	quartz diorite, tonalite, granodiorite, granite	andesite, dacite, rhyodacite, rhyolite	Calc-alkaline igneous rocks generated by subduction beneath island arcs
003pCu2002	CA02	island arc	gabbro, diorite, monzonite, syenite	basalt, basaltic andesite, latite, trachyte, phonolite	Alkalic igneous rocks generated by subduction beneath island arcs
003pCu2003	CA03	mixed, island arcs and continental arcs	quartz diorite, tonalite, granodiorite, granite	andesite, dacite, rhyodacite, rhyolite	Calc-alkaline igneous rocks generated by subduction beneath composite island arcs during their accretion to the Cordilleran continental margin
003pCu2004	CA04	continental arc	quartz diorite, tonalite, granodiorite, granite	andesite, dacite, rhyodacite, rhyolite	Mostly calc-alkaline igneous rocks generated by subduction beneath the Cordilleran continental margin
003pCu2005	CA05	continental arc	quartz diorite, tonalite, granodiorite, granite	andesite, dacite, rhyodacite, rhyolite	Calc-alkaline igneous rocks generated by subduction beneath the Cordilleran continental margin

rocks. The buffers allow for possible downward expansion of intrusions below their surface expressions (subsurface satellite cupolas of intrusions and unmapped parts of plutons), and for extensions of intrusive and extrusive units beneath overlapping cover materials (mineral occurrences that are covered by younger materials, such as basalt flows, glacial till, colluvium, alluvium, or basin-fill sediments less than 1 km thick). The rationale for buffering, and in particular for choosing 10-km and 2-km buffers, is derived from a number of factors:

- Uncertainty related to the true, on-the-ground location of the mapped igneous rock contacts, as represented on geologic maps compiled from a number of scales from a number of sources.
- Intrusion contacts commonly slope outwards, and porphyry copper deposits, which can form peripherally to intrusive bodies, can have alteration areas as extensive as 10 km (Singer and others, 2008).
- Bodies of permissive volcanic rocks may have relatively thin edges, which might be discontinuous, covered, or otherwise not mapped at the scale of the source geologic maps used for the assessment.
- Proximity analysis of volcanic rock-hosted epithermal gold and silver deposits in Nevada indicate that the majority of significant occurrences lie within 10 km of a plutonic body, as mapped at 1:500,000 scale (for additional details, see Mihalasky, 2001, p. 75-76).
- Ten kilometers is a subjective, expert-based estimate representing the nominal extent of a mining lease, which may or may not include peripheral “backyard” claims, prospects, or other exploration areas.
- A radius of 10 km around a pluton may be a fair approximation for the extent of (or at least encompasses) the potentially mineralizing system (that is, the extent of district or local-scale hydrothermal circulation; see Nesbitt and Muehlenbachs, 1989; Sillitoe and Bonham, 1990).
- A radius of 2 km around volcanic map units (as opposed to 10 km around plutonic map units) represents an expert-based judgment that related or concealed intrusions in those map units are likely to be much smaller and limited in extent (Hammarstrom and others, in press).
- Accepted precedent for the use of buffers around igneous map units to delineate permissive tracts in previous USGS mineral resource assessments, including Singer (1996) and Wallace and others (2004).

Although these buffers may not be appropriate in all instances—10 km may be an overstatement with regard to small igneous bodies or an understatement for extensive, long-lived bodies—but, for all practical purposes, it is considered reasonable for including permissive areas of interest within the tectonic environment being assessed (for more detailed discussion, see Wallace and others, 2004, p. 105; 125-126; 131).

We then adjusted tract boundaries to include aeromagnetic anomalies (Natural Resources Canada, 2008a, b) interpreted to represent subsurface intrusions related to the tract, but extending beyond its buffered margins. We also looked for copper anomalies associated with molybdenum, lead, or zinc anomalies (National Resources Canada, 2008c), as possible indicators of porphyry copper systems to be included in permissive tracts. In the Quesnel and Stikine terranes, we considered large areas of high copper and nickel concentrations to be permissive for alkaline porphyry Cu-Au deposits, and we included them in tract 003pC2002 (CA02).

Next, we used a spatial modeling algorithm to smooth the boundaries of the permissive tracts (see the metadata associated with the tracts for additional details). We then trimmed the buffered and smoothed tracts so as not to extend across major strike-slip faults and terrane boundaries. We also cut out and excluded areas of plutons that are younger than the time span of the magmatic arc represented by the permissive tract. Finally, we checked to see that every known porphyry copper deposit and significant prospect is within its assigned tract.

Although the tracts are delineated so as to include all areas considered to have potential for undiscovered porphyry copper deposits, the following caveats should be kept in mind. The tracts were drawn on the basis of geologic maps at scales no larger than 1:250,000, and small intrusions, such as dikes, may not be represented on maps of such scales. Similarly, areas of hydrothermally altered rocks are not indicated on most small scale bedrock geologic maps. Furthermore, some important deposits have been discovered in areas where mineralized rocks may be covered and hidden by basalt flows or deposits of unconsolidated surficial materials, such as glacial till, colluvium, or alluvium. These cover materials may be opaque to most currently available (and affordable) exploration methods, even where cover material is much less than 1 km thick.

Assignment of Deposits and Prospects to Permissive Tracts

Assignment of each deposit and prospect to its proper permissive tract (and grade and tonnage model) required each to be classified as either a calc-alkaline porphyry Cu±Mo±Au, or an alkaline porphyry Cu-Au subtype. This is reported in most MINFILE records for porphyry copper deposits and prospects. Assignment to permissive tracts also required an estimation of the age of each deposit and prospect in terms of millions of years before the present (Ma).

We compiled and plotted age data for porphyry copper deposits from McMillan and others (1995), Mortensen and others (1995), Sinclair (2007), Singer and others (2008), and from MINFILE records. These records list available isotopic age determinations, as well as geologic ages of oldest and youngest host rocks. For deposits and prospects for which there was only relative geologic age information available, we assigned numerical ages according to the following procedures.

For undated deposits and prospects in a group or cluster with one or more dated deposits, we assigned the mid-range age of the dated deposit or deposits to the undated ones. Otherwise, we assigned a numerical age based on the geologic age of the youngest host rock. For example, if the youngest host rocks were Eocene in age, we assigned a mid-Eocene age of 45 Ma. However, if the youngest host rocks were Late Cretaceous to Tertiary in age, we assigned the age of the Late Cretaceous-Tertiary boundary (65 Ma). In this way, we assigned estimated numerical ages to all of the deposits and prospects in the table included in appendix F, and assigned them accordingly to permissive tracts. Appendix F lists age constraints for each isotopic age determination or estimated numerical age.

Grade and Tonnage Models

Frequency distributions of metal grades and ore tonnages from well-explored deposits are employed as models to estimate the grades and tonnages of undiscovered deposits that are of the same type and occur in geologically similar settings (Singer 1993, 2007a). Grade and tonnage models based on porphyry copper deposits of the world have been developed by Singer and others (2008) and include data from deposits that are classified by Cox and Singer (1986) into three deposit subtypes: (1) porphyry copper deposits (model 17), (2) porphyry Cu-Au (model 20c), and (3) porphyry Cu-Mo deposits (model 21a).

Our assessment uses the Singer and others (2008) grade and tonnage models as a starting point, but rather than using the Cox and Singer (1986) deposit classification scheme above, we adopt an alternate classification scheme specifically developed for Canadian Cordillera deposits by Panteleyev (2005a, b), which groups deposits into calc-alkalic Cu-Mo-Au and alkalic Cu-Au subtypes. In order to determine whether the Singer and others (2008) models are appropriate for estimating the grade and tonnage of undiscovered Canadian Cordillera deposits, statistical tests were performed.

Statistical Testing

Using well-explored Canadian Cordillera deposits in our assessment area, we performed statistical tests to determine if their mean values of grade and tonnage are significantly different from the corresponding means of the Singer and others (2008) grade and tonnage models. The spreads or variabilities of grades and tonnages were also evaluated. The two-sample t-test is used to make these comparisons (Trochim, 2006). In a t-test, the means and distributions of two sets of observations are compared to test if they may come from the same population, or if they represent distinct populations (additional discussion of the test methodology is included in appendix G).

Menzie and Singer (1993) developed a grade and tonnage model for porphyry copper deposits in British Columbia and Alaska. They found that, as a group, these deposits have significantly smaller tonnages and significantly lower copper grades than those of the general porphyry copper model by Singer and others (1986). Assuming similar results for our assessment area, we tested separately Canadian calc-alkaline and alkaline deposit subtype grades and tonnages against Singer and others' (2008) general porphyry copper model (364 deposits, including models 17, 20c, and 21a), porphyry copper model (231 deposits, porphyry copper model only), porphyry Cu-Au model (92 deposits, model 20c only), and porphyry Cu-Mo model (41 deposits, model 21a only) (see appendix G, table G2). Prior to performing the tests, the Canadian deposits in the Singer and others (2008) database were removed.

For tonnage of ore, these t-tests indicated that the mean in either type (calc-alkaline Cu±Mo±Au or alkaline Cu-Au) of Canadian Cordilleran porphyry copper deposit is not different statistically from the mean of tonnages of the deposits in the respective porphyry copper models of Singer and others (2008). Furthermore, the mean of copper grade of Canadian alkalic porphyry Cu-Au deposits is not different statistically from that of porphyry copper deposits in the Cu-Au model of Singer and others (2008).

For copper grade, however, the mean of Canadian Cordillera calc-alkaline porphyry Cu±Mo±Au deposits statistically is lower than that of copper grades for the deposits in the general model of Singer and others (2008). This difference required us to make a new grade and tonnage model for calc-alkaline porphyry Cu±Mo±Au deposits of the Canadian Cordillera, which is included in appendix G of this assessment.

Starting with the data of Singer and others (2008), we searched for recently updated estimates of total resources of known porphyry copper deposits in the Canadian Cordillera. During the past few years, record amounts of exploration and infill drilling have been done in the Canadian Cordillera. Tens of thousands of meters have been drilled at many properties in order to extend known resources of operating mines, revive shut-down past producers, or extend and improve estimated resources of previously sub-economic deposits. James Logan (BCGS) contributed new estimates of tonnages and grades of many deposits that have undergone such recent exploration.

Annual Exploration Overviews for 2005 through 2009, published by the British Columbia Ministry of Energy, Mines and Petroleum Resources, list and describe active exploration projects and name the companies involved in this work. Most of these companies have Web sites on which they describe their projects and post drilling results and technical reports with up-to-date estimates of tonnages and grades, reported in accordance with *Standards for Disclosure for Mineral Projects in Canada*, as set forth in National Instrument 43-101 (British Columbia Securities Commission, 2005).

According to Singer and others (2008, p. 4), data gathered for each deposit should include average grade of each metal or mineral commodity of possible economic interest and the associated tonnage of ore based on the total production, reserves, and resources at the lowest possible cutoff grade. According to a consensus of USGS grade and tonnage modelers, estimated resources should include all proven and probable reserves, or measured and indicated resources, and also inferred resources. These terms are defined and explained in standards and guidelines adopted by the Canadian Institute of Mining, Metallurgy, and Petroleum (Committee for Mineral Reserves International Reporting Standards, 2004).

In compiling these data, we have encountered many ambiguities and inconsistencies. For example, some production records list only the amounts of metals produced and do not include the average grade of the ore mined, or the tonnage of the ore milled. Operating mines may not differentiate clearly between originally estimated resources, remaining resources, and resources added as a result of exploration during mining. Some reports list proven and probable reserves, and others list measured and indicated resources, but many do not list inferred resources. Therefore, we included inferred resources only if they were available.

Singer (1993) also mentioned that resource estimates used in grade and tonnage models should be based on the lowest cutoff grades of possible economic interest. He also noted that cutoff grades commonly are near the median grade within the deposits, but that exceptions may exist where production costs are relatively high (as in underground mines in ores that require milling) or relatively low (as in open-pit mines in ores amenable to heap leaching). We found great variability in the availability of cutoff grades to accompany estimates of tonnage and grade.

Clusters of Relatively Closely Spaced Porphyry Copper Deposits and Prospects

Porphyry copper deposits and prospects commonly occur in clusters. We use the term "cluster" to describe a set of deposits or prospects that are relatively closely spaced, as compared to the spacing of deposits or prospects outside the cluster. Thus, we use cluster as a relative term that does not imply a specified distance between the clustered deposits or prospects. Where clusters of similar deposits or prospects are cospatial with the same or similar bodies of igneous rocks, it is reasonable to suppose that they formed by similar processes that occurred during similar time intervals. If isotopic age determinations are available for one or more of the deposits of a cluster, we estimated the ages of similar but undated deposits of the cluster to be that of the mid-range of the available age determinations.

Groups of Porphyry Copper Deposits and Prospects (Aggregated According to the 2-km Rule)

For grade and tonnage models to be internally consistent there must be a spatial limit that determines how to group together deposits and prospects near to one other for the purposes of grade and tonnage modeling and deposit endowment estimation. The 2-km rule states that, "deposits that have mineralization or alteration separated by less than an arbitrary but consistent distance—2 km for porphyry copper deposits—are combined into one deposit" (Singer and others, 2005b, p. 491). This rule also applies to deposit-density models because they must be consistent with tonnage and grade models.

We use the term "group" to describe that part of a cluster in which the deposits and prospects are sufficiently close together that they are within the spacing required by the 2-km rule for porphyry copper deposits. However, for the 2-km rule to be rigorously applied for sites with noncircular zones of mineralization and alteration, the relative orientations of the long and short axes of the neighboring sites must be known. Singer and others (2008) listed the lengths of the long and short axes of alteration zones associated with 21 Canadian Cordilleran porphyry copper deposits. As shown in table 3, the average length of the long axes is 5 km, and the average length of the short axes is 2 km. However, we do not know the directional orientations of the long and short axes of these deposits, and we do not know the shapes, sizes, or orientations of other clustered deposits and prospects included in this assessment. Therefore, we could not apply the 2-km rule rigorously as it is defined.

Figure 4 illustrates how we applied a modified 2-km deposit-grouping rule with the limited information available in the time allowed for this assessment. Rotation of the long axis through 360 degrees describes a circle with the diameter of the long axis. Such a circle around each of the points representing a neighboring deposit or prospect covers all possible orientations of the long axes of the neighboring zones of mineralization and alteration of the neighboring deposits. Based on the 21 sites in table 3, the mean diameter of such a circle is about 5 km, so its radius is 2.5 km. Thus, the center points of average neighboring alteration zones would be less than 7 km (2.5+2.5+2 km) apart. Therefore, for compilation of the grade and tonnage information, we grouped deposits and prospects represented by points that are less than about 7 km apart. This is the equivalent of buffering all deposit and prospect points using a 2.5 km radius, then grouping together those points whose buffer zones lie within 2 km of one another.

For purposes of estimation of undiscovered deposits, any prospect within a group is considered as a possible extension to the known resources of the group, rather than as an undiscovered deposit. In order for a prospect to be counted as a possible undiscovered deposit, it must be outside of a group that includes a known deposit (see example, fig. 4). Nevertheless, our tables of known deposits include estimated tonnages and grades of individual deposits within groups, as well as total tonnages and average grades for the aggregated resources of the group.

Table 3. Dimensions of zones of mineralized and altered rocks of Canadian Cordilleran porphyry copper deposits.

Deposit name	Subtype	Tract	Zone of altered rocks	
			Long axis (km)	Short axis (km)
Eaglehead	Calc-alkalic Cu±Mo±Au	003pCu2001 (CA01)	5.6	1.5
Gnat Lake	Calc-alkalic Cu±Mo±Au	003pCu2001 (CA01)	4	2
Red Bluff	Calc-alkalic Cu±Mo±Au	003pCu2001 (CA01)	6	4
Schaft Creek	Calc-alkalic Cu±Mo±Au	003pCu2001 (CA01)	3.1	1.3
Chuchi	Alkaline Cu-Au	003pCu2002 (CA02)	10	2
Dorothy	Alkaline Cu-Au	003pCu2002 (CA02)	2.3	1.8
Mt. Milligan	Alkaline Cu-Au	003pCu2002 (CA02)	5.5	4.5
Mt. Polly	Alkaline Cu-Au	003pCu2002 (CA02)	3.6	2
Red Chris	Alkaline Cu-Au	003pCu2002 (CA02)	5	1.5
Sulphurets	Alkaline Cu-Au	003pCu2002 (CA02)	6	3
Hushamu	Calc-alkalic Cu±Mo±Au	003pCu2003 (CA03)	6	3
Island Copper	Calc-alkalic Cu±Mo±Au	003pCu2003 (CA03)	5.2	1.1
Bell Copper	Calc-alkalic Cu±Mo±Au	003pCu2004 (CA04)	3.2	2.6
Granisle	Calc-alkalic Cu±Mo±Au	003pCu2004 (CA04)	3.2	2.2
Huckleberry	Calc-alkalic Cu±Mo±Au	003pCu2004 (CA04)	5	2.5
Kemess North	Calc-alkalic Cu±Mo±Au	003pCu2004 (CA04)	6.7	2.6
Louise Lake	Calc-alkalic Cu±Mo±Au	003pCu2004 (CA04)	4	1
Ox Lake	Calc-alkalic Cu±Mo±Au	003pCu2004 (CA04)	1.3	1.3
Pine	Calc-alkalic Cu±Mo±Au	003pCu2004 (CA04)	4.5	2
Poplar	Calc-alkalic Cu±Mo±Au	003pCu2004 (CA04)	2	0.9
Taseko	Calc-alkalic Cu±Mo±Au	003pCu2004 (CA04)	5	1.5
		Means of axes of zones of altered rocks	5	2
		Plus 2-km between zones of altered rocks	2	
		Maximum distance between grouped sites	7	

Development of New Grade and Tonnage Models for Canadian Cu±Mo±Au Porphyry Copper Deposits

T-tests using updated grade and tonnage data indicated that the mean copper grade of the Canadian calc-alkaline porphyry Cu±Mo±Au deposits statistically is lower than that of the non-Canadian deposits in the general model (models 17, 20c, and 21a) dataset of Singer and others (2008).We therefore constructed new grade and tonnage models for Canadian Cordilleran deposits of the calc-alkaline porphyry Cu±Mo±Au subtype (appendix G). In the new models, we included only resource estimates that we considered reasonably well constrained and substantiated. Nevertheless, preliminary estimates of incompletely known deposits and not fully substantiated estimates from press releases are included in tables of known deposits in permissive tracts. Although such deposits are excluded from the grade and tonnage models, they are included in calculations of spatial densities of known and undiscovered deposits in permissive tracts.

One explanation for relatively low copper grades in Canadian porphyry Cu±Mo±Au deposits, as compared to the general model, is that significant zones of supergene Cu-enrichment are uncommon in porphyry copper deposits of Canada. Supergene enrichment occurs when the original sulfide minerals are oxidized in the near-surface environment by meteoric waters, and the metals are leached and reprecipitated at, or near the top of, the existing water table. According to Ney and others (1976) zones of supergene enrichment may have formed before continental-scale glaciations during Pleistocene time, but most were removed by glacial erosion. Nevertheless, zones of oxidation and supergene enrichment are preserved in deposits that were not glaciated, or were covered by younger materials that protected them from glacial erosion, or underwent post-glacial oxidation and weak to moderate supergene enrichment.

Much of the Yukon interior was not glaciated. According to Froese and others (2009), it was cold enough to support permafrost, but it was too dry to support glaciers. Therefore, oxidized and leached caps, as well as supergene-enriched zones, which formed in earlier times of greater warmth and moisture, are preserved in Yukon at the Casino and Williams Creek deposits.

In southern British Columbia, Tertiary volcanic and sedimentary cover strata protected supergene-enriched zones

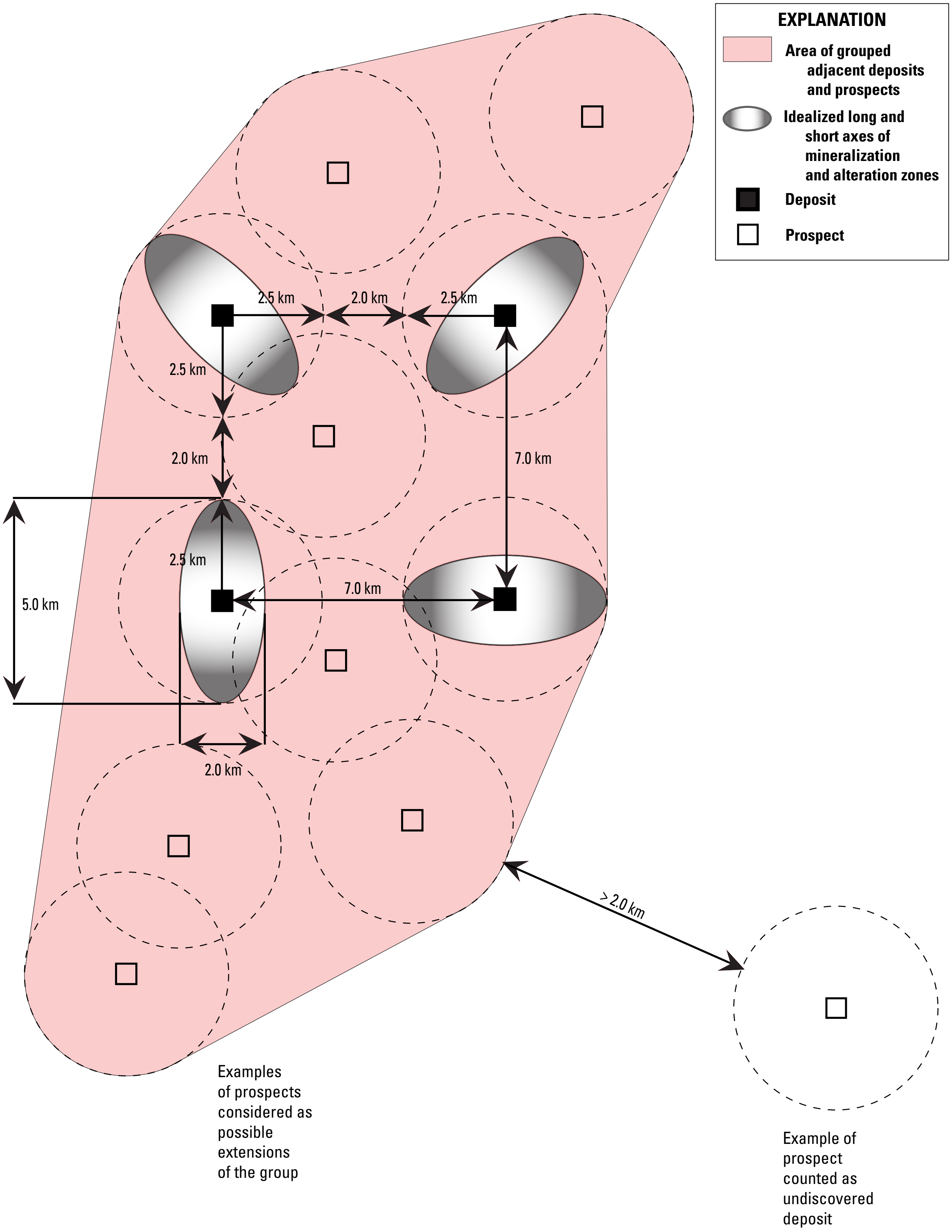


Figure 4. Diagram illustrating application of the 2-km rule for grouping adjacent deposits and prospects. Sites less than about 7 km apart were grouped. (See text for explanation of rationale for grouping.)

Table 4. Compilation of published resource estimates through time for Canadian Cordilleran porphyry copper deposits.

[Cu, copper; Mo, molybdenum; Au, gold; Ag, silver; g-t, grade and tonnage; Mt, million metric tons; deposit names in caps are grouped (GP); -, no data. See report text for sources of data. These estimates represent those that were available through 2009. They have not been updated with resource estimates made to the deposits or prospects listed in appendix F in 2010.]

Deposit name	First g-t estimate	Discovery year	1976 (Mt Cu)	1993 (Mt Cu)	1995 (Mt Cu)	2008 (Mt Cu)	2009 (Mt Cu)
AFTON-AJAX GP	1976	1971	0.31	0.67	0.83	1.14	2.95
AXE-PRIMER GP	1976	1973	0.08	0.33	0.39	0.55	0.55
Bell Copper	1976	1963	0.56	0.56	0.56	1.78	1.78
Berg	1976	1963	1.6	1.6	1.6	0.95	1.85
DOROTHY-NAK GP	1976	1976	0.1	0.11	0.11	0.12	0.62
GALORE CREEK	1976	1956	1.33	3.01	4.06	3.57	6.25
GIBRALTAR GP	1976	1968	1.21	1.21	1.21	3.69	3.97
Gnat Lake (Gnat Pass)	1976	1960	0.12	0.11	0.11	0.12	0.12
HIGHLAND VALLEY GP	1976	1954	6.94	10.07	7.35	9.77	12.48
HUCKLEBERRY GP	1976	1961	0.42	0.35	0.35	0.85	0.9
Kwanika (Swan)	1976	1974	0.07	0.07	0.07	0.07	0.59
LORRAINE GP	1976	1931	0.07	0.09	0.09	0.21	0.27
Maggie	1976	1970	0.51	0.51	0.51	0.51	0.51
Minto	1976	1973	0.12	0.12	0.14	0.15	0.41
Morrison (Hearne Hill)	1976	1963	0.36	0.36	0.36	1.03	0.7
New Nanik (Nanika)	1976	1973	0.07	0.07	0.07	0.07	0.07
OK GP	1976	1965	0.2	0.2	0.2	0.34	0.61
POLLEY GP	1976	1970	0.12	0.12	0.19	0.67	0.69
Red Chris	1976	1974	0.23	0.23	0.58	1.83	2.54
SULPHURETS GP	1976	1960	1.32	0.78	1.43	1.55	3.83
1976 Subtotal:			15.74	20.57	20.21	28.97	41.69
Big Onion (Cimbria)	1993	1977	-	0.07	0.4	0.4	0.4
Brenda	1993	1947	-	0.36	0.29	0.36	0.36
Bronson Slope	1993	1988	-	0.14	0.14	0.24	0.21
Cash	1993	1976	-	0.1	0.1	0.1	0.1
Casino	1993	1969	-	1.29	0.29	2.12	2.12
Catface	1993	1960	-	0.6	0.57	1.14	1.14
COPPER MTN GP	1993	1957	-	0.93	1.31	1.53	1.83
Fish Lake (Prosperity)	1993	1960	-	2.52	2.53	2.53	2.53
Gambier Island	1993	1978	-	0.3	0.33	0.33	0.33
Granisle	1993	1955	-	0.37	0.37	0.37	0.7
HED	1993	1981	-	0.04	0.04	0.04	0.04
Hi-Mars	1993	1978	-	0.25	0.25	0.25	0.25
Island Copper	1993	1966	-	1.35	1.46	1.55	1.55
KEMESS GP	1993	1983	-	0.65	1.2	1.79	1.45
Mount Milligan	1993	1987	-	0.92	1.35	0.96	1.16
Poison Mountain	1993	1966	-	0.49	1.87	1.94	1.94
Rey Lake	1993	1973	-	0.08	0.08	0.08	0.08
SCHAFT CREEK GP	1993	1958	-	2.72	2.9	3.59	3.79
Williams Creek (Carmacks)	1993	1970	-	0.16	0.16	0.16	0.18
1993 Subtotal:				13.34	15.64	19.48	20.16
Eaglehead	1995	1981	-	-	0.18	0.12	0.32
GIANT COPPER GP	1995	1930	-	-	0.15	0.66	0.22
Jean	1995	1995	-	-	0.08	0.08	0.08
Lexington-Lone Star	1995	1968	-	-	0	0	0.11
Louise Lake	1995	1992	-	-	0.15	0.15	0.36
Pine	1995	1968	-	-	0.06	0.06	0.11
Poplar	1995	1974	-	-	0.87	0.87	0.87
Taseko	1995	1988	-	-	0.12	0.08	0.08
1995 Subtotal:					1.61	2.02	2.15
HUSHAMU GP	2008	1967	-	-	-	1.6	1.6
KINASKAN GP	2008	2006	-	-	-	0.59	0.83
2008 Subtotal:						2.19	2.43
Chuchi	2009	1991	-	-	-	-	0.11
2009 Subtotal:							0.11
Grand Total:			15.74	33.91	37.46	52.66	66.54

at the Afton, Gibraltar and Krain deposits. In west-central British Columbia, the Berg deposit has a blanket of mildly supergene-enriched ore that probably formed after Pleistocene glaciation. Small amounts of post-glacial supergene minerals also are present at many other Canadian Cordilleran deposits. Nevertheless, “no supergene zones have been found in Canada that compare in size and grade with the major examples in the southwestern United States, or Central or South America” (Ney and others, 1976, p. 77).

Socioeconomic and geographic factors also allow for exploration and development of lower grade porphyry copper deposits in western Canada, which has access to inexpensive hydroelectric power, and geographically is well-situated to sell and ship copper concentrates to Pacific-Rim countries. The government of British Columbia has mining and exploration investment tax credit programs, and the British Columbia and Yukon geological surveys provide geoscience databases and a Web-based mineral tenure system (DeGrace and others, 2009). In addition, major mining companies and junior exploration companies are able to raise capital for exploration and development on the Vancouver and Toronto stock exchanges. In times of high gold prices, Canadian porphyry Cu-Au targets have been particularly attractive to investors.

Exploration History and Status

Mustard (1976) tabulated dates of original lode discovery, porphyry copper discovery, beginning of exploration and development, and mining startup for 24 Canadian Cordilleran porphyry copper systems. Before 1950, two-thirds of these deposits had been discovered as veins or other types of deposits, but only the Lorraine and Brenda deposits had been recognized as porphyry copper deposit types. Although potential for large, low-grade copper deposits had been recognized in the Highland Valley area in 1917, it was not until 1954 that the Bethlehem deposit was recognized as a porphyry copper deposit. Production began there in 1962. Four other porphyry copper deposits were discovered in the 1950s—Krain (in the Highland Valley group), Schaft Creek, Granisle, and Galore Creek.

From 1960 to 1971, 24 additional porphyry copper ore bodies were discovered in the Canadian Cordillera. Four of these are in the Highland Valley group, and four are in the Gibraltar group, but 16 others are individual deposits. By 1971, the total of known Canadian porphyry copper ore bodies was 32, but as grouped by the 2-km rule of Singer and others (2005a), the total was 24 because 6 of these are in the Highland Valley group and 4 are in the Gibraltar group.

According to Mustard (1976) the boom in exploration activities in the early 1960s, which led to the first peak in discovery rates, was based on the combination of a number of factors, including (1) recognition that low-grade porphyry copper deposits could support economically viable mining operations; (2) emergence of Japan as a major market for concentrate; (3) an investment climate that encouraged and supported mineral development with favorable tax laws, adequate land tenure, and developing transportation systems and power sources; (4) excellent geographic and geologic databases; (5) technological developments (such as geochemical and geophysical methods for minerals exploration, and helicopter support); and (6) a proliferation of exploration-oriented companies and professional societies. Although the global economy has fluctuated widely, these same factors also supported the most recent boom in exploration and discovery, which probably ended with the world recession of 2009.

By 1995, the total number of known Canadian porphyry copper deposits (as grouped by the 2-km rule) had increased from 24 to 31 deposits. These deposits, and four additional prospects were described in CIM Special Volume 46 (Schroeter, 1995). Thus, seven porphyry copper discoveries were added in the 24 years between 1971 and 1995.

Singer and others (2008) were able to compile tonnages and grades for 54 western Canadian porphyry copper ore bodies. However, four of these ore bodies belong to the Highland Valley group, and two belong to the Kemess group. Therefore, the total number of Canadian porphyry copper deposits in 2008 was 50, which represents an increase of 19 deposits in 13 years.

Graphs of minerals-exploration expenditures in western Canada by Mustard (1976) and DeGrace and others (2009) indicate cyclical fluctuations with increasingly higher peaks through time. Starting at about $5M/yr in 1950, annual expenditures increased to about $40M/yr by 1970, spiked to nearly $200M/yr in 1980, and spiked again from 1988 to 1990 to about $250M/yr. After that, exploration expenditures dropped to less than $50M/yr from about 1999 to 2004, and then spiked again to a record $400M/yr in 2006. Since 2004, about a quarter to a third of these exploration expenditures have been for porphyry copper exploration. Most of that money was spent to increase and improve the estimated resources of previously discovered deposits. As previously discovered deposits become increasingly well constrained, the proportion of exploration efforts directed at discovery of undiscovered deposits probably will increase again.

Estimated Copper Resources versus Exploration History

Estimated total tonnage of copper contained in Canadian Cordilleran porphyry copper deposits has more than quadrupled since 1976. It has increased from about 15.7 Mt copper in 1976 to about 66.5 Mt copper[10] in 2009 (table 4 and fig. 5). However, this increase applies only to estimated total resources and does not take into account the progressive depletion of known resources by mining.

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[10] Note that this value and the exploration history analysis presented in this section are based upon resource estimates that were available through the end of 2009, and do not reflect updated estimates for 2010 as listed in table 7 or the appendixes. Using table 7 data, the total would be about 66.8 Mt copper for 2010.

Early grade and tonnage models based on Canadian Cordilleran porphyry copper deposits by Menzie and Singer (1993) and Grunsky (1995) indicated that the Canadian deposits were significantly smaller than those of the general porphyry copper model by Singer and others (1986). Since then, however, estimated tonnages of the Canadian deposits have increased according to a series of more recent grade and tonnage models (Singer and others, 2002, 2005a, 2008) and the data presented in appendixes F and G of this report. As a result, presently estimated tonnages of Canadian Cordilleran porphyry copper deposits are indistinguishable statistically from those of the global grade and tonnage model by Singer and others (2008).

Before about 1992, copper resources were added mostly by discovery of previously unknown deposits. Since then, however, copper resources have been added mostly by discovery of extensions to previously known deposits. This change occurred as the Canadian Cordillera became increasingly well-explored. As numbers of known and partially known deposits increased, new discoveries became harder to find, exploration efforts turned increasingly to extensions of known resources. This trend was accentuated during the period from about 2003

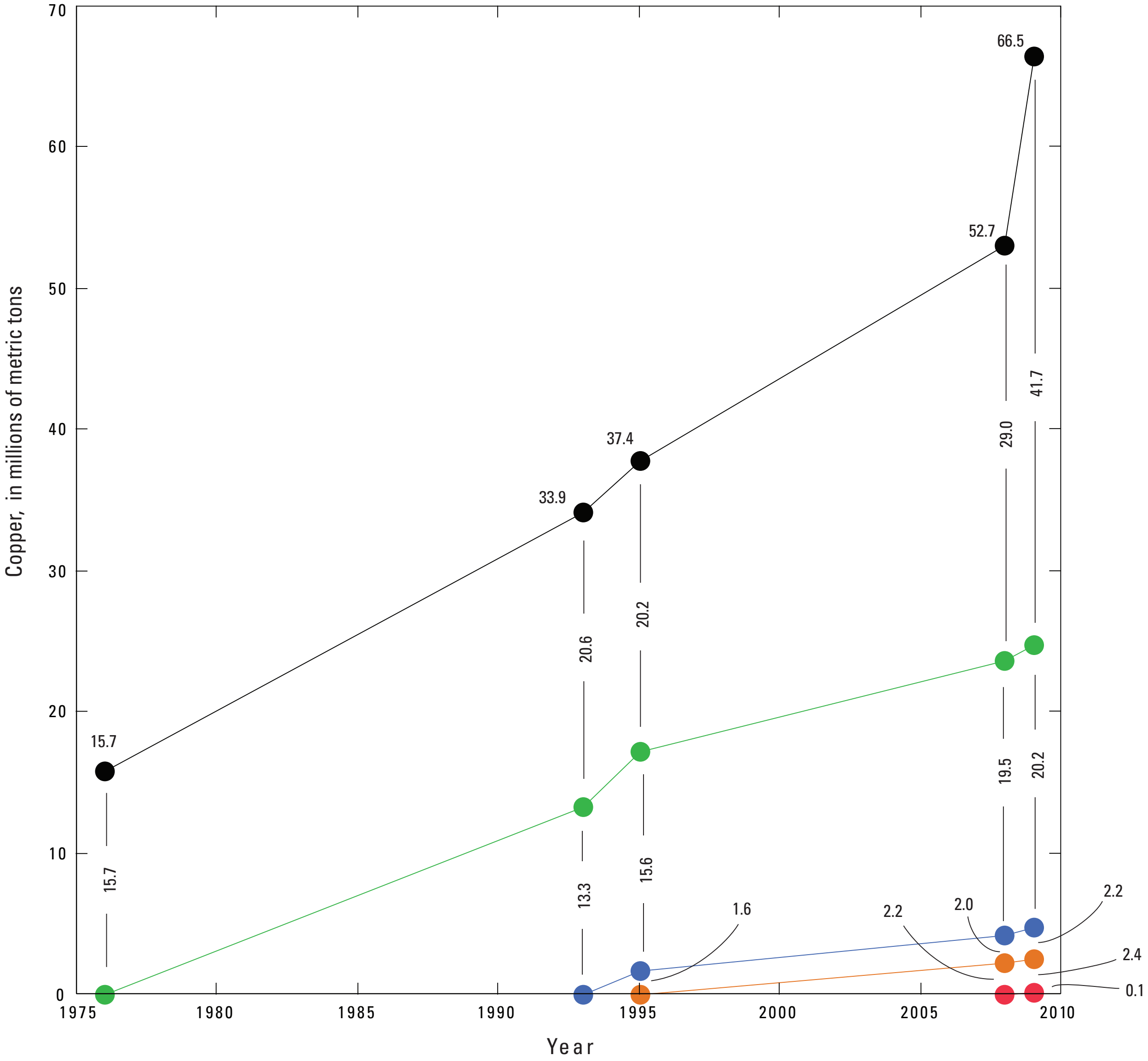

Figure 5. Graph showing the proportion contributed to total estimated copper (in millions of metric tons, Mt) from the start of each of five sequential resource-reporting time intervals: (1) discovered deposits as of, and after, 1975 (black line), (2) new discoveries since 1975 (green line), (3) since 1993 (blue line), (4) since 1995 (orange line), and (5) since 2008 (red line). (See report text for sources of data.)

to 2008, as metal prices rose, and the economic potential of previously subeconomic parts of known deposits gained economic favorability. This drove a record amount of drilling in and around known deposits from 2003 to 2008.

Figure 5 summarizes the history of discovery and successive published estimates of total contained copper for Canadian porphyry copper deposits from initial to current estimates. The resource-reporting time intervals for which data were available for this compilation include pre-1976, 1976-1993, 1993-1995, 1995-2008, and 2008-2009. Data for table 4 and figure 5 are from Sutherland Brown (1976), Mustard (1976), MINFILE BC (2009), MINFILE YT (2009), Menzie and Singer (1993), Singer and others (2008), and references specific to each deposit, as cited in appendix F. The data for 1995 are from articles in Schroeter (1995). A comparable data set, compiled by Grunsky (1995), also is available. Resource estimates available in 2008-2009 have not been updated to include information added to appendix F in 2010.

As enumerated in table 4 and graphically represented in figure 5, between 1976 and 2009, reported resources for deposits known in 1976 had grown from 15.7 Mt to 41.7 Mt, an increase of 26.0 Mt (see fig. 5, the tonnage interval between the green and black lines). Between 1993 and 2009, reported resources for deposits known in 1993 had grown from 13.3 Mt to 20.2 Mt, an increase of 6.9 Mt (see fig. 5, the tonnage interval between the blue and green lines). Thus, the earliest known deposits have grown the most through addition of extensions (an increase in 26.0 Mt between 1976 and 2009 versus an increase in 6.9 Mt between 1993 and 2009). For example, from 1975 to 1993, the total resource base had increased from 15.7 Mt to 33.9 Mt, of which 13.3 Mt were added from new discoveries, while only 4.9 Mt were added by discoveries of extensions of known deposits (20.6 Mt–15.7 Mt=4.9 Mt). In contrast, between 1993 and 2009, the total resource base had increased by 32.6 Mt (66.5 Mt–33.9 Mt=32.6 Mt), of which 4.7 Mt were added from new discoveries (0.1 Mt+2.4 Mt+2.2 Mt=4.7 Mt), and 27.9 Mt were added owing to discoveries of extensions of known deposits (32.6 Mt–4.7 Mt=27.9 Mt). As such, for the latter resource-reporting time interval between 1993 and 2009, about 86 percent of the increase in estimated copper resources resulted from the discovery of extensions to known deposits, while about 14 percent resulted from newly discovered deposits.

The total of the mean estimates of copper resources contained in undiscovered deposits (table 5) from our study (about 48.7 Mt at depths less than about 1 km) plus the total presently known copper resources (about 66.8 Mt, using the updated 2010 resource estimates; see footnote 10 on page 18) is 115.5 Mt of copper (tables 6 and 7). Based upon these estimates, the copper contained in known porphyry copper deposits represents about 58 percent of the total of known and undiscovered porphyry copper deposits at depths of 1 km or less. Similarly, the estimated copper contents of undiscovered porphyry copper deposits amount to about 42 percent of the total copper resources in the Canadian Cordillera at depths of 1 km or less. During the recent surge in exploration activity, most of the effort was directed toward increasing the resources of known deposits. As the limits of known deposits are approached, exploration efforts likely will shift back toward finding undiscovered deposits. This probably will involve target identification by further study of favorable prospects and exploration for hidden porphyry-copper occurrences by a variety of traditional and novel geological, geochemical, geophysical, remote-sensing, and geospatial methods. Target testing will continue to require abundant drilling, sampling, assaying, record-keeping, and thoughtful interpretation.

Estimation of Undiscovered Resources

According to Singer (1993), estimates of the number of undiscovered deposits in a permissive tract explicitly represent the subjective probability (at a given level of confidence, or degree of belief) that some fixed but unknown number of undiscovered deposits exists within the delineated tract. We held an estimation workshop in early February 2009 to estimate numbers of undiscovered porphyry copper deposits in the Canadian Cordillera. Participants in the workshop (see appendix I) were USGS geologists Art Bookstrom, Tom Frost, Steve Ludington, and Mark Mihalasky. Our panel also included three Canadian geologists with career-long experience and knowledge of the geology and mineral resources of the Canadian Cordillera: Grant Abbott (YGS), James Logan (BCGS), and Andre Panteleyev, author of descriptive models for Canadian Cordilleran calc-alkaline porphyry Cu±Mo±Au deposits and alkaline porphyry Cu-Au deposits.

Before our estimation workshop, we made preliminary versions of five permissive tracts. We compiled a preliminary table of known porphyry copper deposits (based on MINFILE records), and we made preliminary assignments of deposits and prospects to tracts. James Bliss (USGS) did preliminary statistical testing of the tonnages and grades of Canadian Cordilleran porphyry copper deposits versus other deposits in the tonnage and grade models for porphyry copper deposits of the world by Singer and others (2008). Tom Frost made a preliminary version of the tonnage and grade models for calc-alkaline porphyry Cu±Mo±Au deposits, based on the Canadian Cordilleran subset of the global models by Singer and others (2008).

Michael Zientek (USGS; Global Mineral Resource Assessment Project Co-Chief) began our workshop with an introduction to the goals of the project and the three-part method for estimation of undiscovered mineral resources. Tom Frost described statistical testing of tonnage and grade models and his preliminary version of the tonnage and grade models for Canadian Cordilleran porphyry Cu±Mo±Au deposits. We then discussed the tracts sequentially. For each tract, we discussed the geology of the permissive tract. We reviewed the list of known porphyry copper deposits and prospects in the

Table 5. Estimates of numbers of undiscovered deposits, porphyry copper assessment of British Columbia and Yukon Territory, Canada.

[Cu, copper; Au, gold; Nxx, estimated number of deposits associated with the xxth percentile; N_{und}, expected number of undiscovered deposits; s, standard deviation; Cv%, coefficient of variance; N_{known}, number of known deposits in the tract with identified resources; N_{total}, total of expected number of deposits plus known deposits; area, area of permissive tract in square kilometers; density, deposit density reported as the total number of deposits per km²; N_{und}, s, and Cv% are calculated using a regression equation (Singer and Menzie, 2005).]

Coded_ID	User_ID	Tract name and deposit type	Consensus estimates of numbers of undiscovered deposits					Summary statistics					Tract area (km²)	Deposit density (N_{total}/km²)
			N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
003pCu2001	CA01	Intermontane Island-Arc Porphyry Cu	3	5	14	14	14	6.9	4.3	62	12	18.9	175,250	0.00011
003pCu2002	CA02	Intermontane Island-Arc Porphyry Cu-Au	3	6	13	13	13	7	3.8	54	12	19	109,290	0.00017
003pCu2003	CA03	Insular Mixed Island- and Continental Arc Porphyry Cu	1	2	4	5	6	2.3	1.5	66	2	4.3	58,360	0.00007
003pCu2004	CA04	Cordilleran Continental Arc Porphyry Cu	3	8	19	19	19	9.6	5.9	61	23	32.6	639,500	0.00005
003pCu2005	CA05	Late Continental Arc Porphyry Cu	0	1	3	4	4	1.4	1.4	99	1	2.4	32,840	0.00007
							Total	27.2			50	77.2		

Table 6. Summary of probabilistic assessment results, porphyry copper assessment of British Columbia and Yukon Territory, Canada.

[Cu, copper; Mo, molybdenum; Au, gold; Ag, silver; t, metric tons; Mt, million metric tons]

Coded_ID	User_ID	Tract name and deposit type	Mean expected amounts of metal and rock				Rock (Mt)
			Cu (t)	Mo (t)	Au (t)	Ag (t)	
003pCu2001	CA01	Intermontane Island-Arc Porphyry Cu	8,900,000	370,000	460	3,100	3,300
003pCu2002	CA02	Intermontane Island-Arc Porphyry Cu-Au	22,000,000	130,000	1,600	7,400	4,400
003pCu2003	CA03	Insular Mixed Island- and Continental Arc Porphyry Cu	3,000,000	130,000	160	1,100	1,100
003pCu2004	CA04	Cordilleran Continental Arc Porphyry Cu	13,000,000	530,000	640	4,400	4,700
003pCu2005	CA05	Late Continental Arc Porphyry Cu	1,800,000	76,000	92	660	680
		Total	48,700,000	1,236,000	2,952	16,660	14,180

Table 7. Identified resources in known porphyry copper deposits listed by permissive tract, porphyry copper assessment of British Columbia and Yukon Territory, Canada.

[Cu, copper; Mo, molybdenum; Au, gold; Ag, silver; t, metric tons; Mt, million metric tons; -, no data; *, deposit with unsubstantiated grade and tonnage estimate, based on a press release to a newsletter. Such deposits are listed here but are not included in the grade and tonnage model.**, deposit is known to be open in one or more directions, so that the presently estimated tonnage and grade probably do not represent the entire deposit. Such deposits are listed here, but are not included in the grade and tonnage model. Resource estimates are through 2009 but include updates for 2010 when available.]

Coded_ID	User_ID	Deposit or Group	Tonnage (Mt)	Contained Cu (t)	Contained Mo (t)	Contained Au (t)	Contained Ag (t)
		Intermontane Island-Arc Porphyry Cu					
003pCu2001	CA01	HIGHLAND VALLEY GROUP					
003pCu2001	CA01	Ann (included in Highmont)	43.4	117,000	-	-	-
003pCu2001	CA01	Bethlehem	677	3,050,000	108,320	3.4	271
003pCu2001	CA01	Getty South (Trojan)	36	169,000	-	-	-
003pCu2001	CA01	Highland Valley Copper (Valley Cu)	1,356	5,020,000	81,336	8.1	1,323
003pCu2001	CA01	Highmont	265	705,000	108,650	1.1	239
003pCu2001	CA01	IDE-AM (included in Highmont)	11.5	31,000	575	-	-
003pCu2001	CA01	JA	260	1,120,000	44,200	-	-
003pCu2001	CA01	Krain (Getty North)	72.1	224,000	8,652	-	-
003pCu2001	CA01	Lornex	514	2,190,000	77,100	3.1	617
		HIGHLAND VALLEY TOTAL	3,179.7	12,500,000	413,361	15.9	2,448
003pCu2001	CA01	GIBRALTER GROUP					
003pCu2001	CA01	Gibraltar	1,297	3,800,000	77,790	-	105
003pCu2001	CA01	Sawmill	68.5	167,000	-	-	-
		GIBRALTAR TOTAL	1,365	3,970,000	81,900	-	105
003pCu2001	CA01	KEMESS GROUP					
003pCu2001	CA01	Kemess North	719.2	1,080,000	-	107.9	-
003pCu2001	CA01	Kemess South	228.8	375,000	-	101.8	-
		KEMESS TOTAL	948	1,460,000	-	209.5	-
003pCu2001	CA01	KINASKAN GROUP					
003pCu2001	CA01	Goat	71.2	283,000	-	28.3	157
003pCu2001	CA01	Kinaskan	176	528,000	-	63.5	-
		KINASKAN TOTAL	247.2	811,000		92	157
		KWANIKA GROUP					
003pCu2001	CA01	Kwanika Central	182.6	530,000	-	52	-
003pCu2001	CA01	Kwanika (South Central)	129.1	387,000	12,900	11.6	227
		KWANIKA TOTAL	311.7	917,000	12,900	63.7	227
		SCHAFT CREEK GROUP					
003pCu2001	CA01	NABS	90.7	306,000	42,629	-	-
003pCu2001	CA01	Schaft Creek	1,393.3	3,480,000	264,727	250.8	2,160
		SCHAFT CREEK TOTAL	1,484	3,790,000	311,640	250.8	-
003pCu2001	CA01	INDIVIDUAL DEPOSITS					
003pCu2001	CA01	Brenda	227	363,000	88,530	3	143
003pCu2001	CA01	Bronson Slope - Red Bluff	129.8	208,000	10,384	57.1	317
003pCu2001	CA01	Eaglehead**	79.5	321,000	3,975	3.5	43
003pCu2001	CA01	Gnat Lake (Gnat Pass)	30.4	119,000	-	-	-
003pCu2001	CA01	HED*	23	37,000	9,200	-	-
003pCu2001	CA01	Pine	70	105,000	-	39.9	-
		Tract Total	8,095	24,601,000			

Coded_ID	User_ID	Deposit or Group	Tonnage (Mt)	Contained Cu (t)	Contained Mo (t)	Contained Au (t)	Contained Ag (t)
		(Intermontane Island-Arc Porphyry Cu-Au)					
003pCu2002	CA02	AFTON-AJAX GROUP					
003pCu2002	CA02	Afton (old pit + new block-cave)	96.8	981,958	-	68.6	300
003pCu2002	CA02	Ajax area (JV)	523	1,510,000	5,230	96.8	-
003pCu2002	CA02	Big Onion (Afton)	3.3	23,200	-	1.5	-
003pCu2002	CA02	DM-Audra-Crescent	108.8	221,000	-	10.9	-
003pCu2002	CA02	Galaxy	5.4	31,900	-	1.1	-
003pCu2002	CA02	Iron Mask	2.4	20,200	-	1	-
003pCu2002	CA02	Rainbow	30.7	162,000	-	3.7	-
		AFTON-AJAX TOTAL	770.4	2,950,000	-	183.4	300
003pCu2002	CA02	AXE-PRIMER GROUP					
003pCu2002	CA02	Axe	116.7	501,810	14,004	-	-
003pCu2002	CA02	Axe - South zone (included in Axe)	37.2	179,000	-	-	-
003pCu2002	CA02	Axe - West zone (included in Axe)	5.8	27,000	-	-	-
003pCu2002	CA02	Primer - North zone	23	161,000	-	-	-
		AXE-PRIMER TOTAL	139.7	663,000	13,970		
003pCu2002	CA02	COPPER MTN GROUP				0	0
003pCu2002	CA02	Alabama	29	102,000	-	4.6	
003pCu2002	CA02	Copper Mountain (Similco-Ingerbelle)	455.7	1,730,000	4,557	118.5	1,393
		COPPER MTN TOTAL	484.7	1,830,000	4,847	123.1	1,393
003pCu2002	CA02	POLLEY GROUP					
003pCu2002	CA02	Lloyd-Nordik	7.2	22,300	-	1.7	-
003pCu2002	CA02	Mount Polley (Cariboo-Bell)	204.8	664,000	-	63.5	-
		POLLEY TOTAL	212.5	686,000	-	65.2	-

Table 7. Identified resources in known porphyry copper deposits listed by permissive tract, porphyry copper assessment of British Columbia and Yukon Territory, Canada.—Continued

Coded_ID	User_ID	Deposit or Group	Tonnage (Mt)	Contained Cu (t)	Contained Mo (t)	Contained Au (t)	Contained Ag (t)
		(Intermontane Island-Arc Porphyry Cu-Au)					
003pCu2002	CA02	LORRAINE GROUP					
003pCu2002	CA02	Jajay (Lorraine)	31.9	210,000	-	5.4	150
003pCu2002	CA02	Misty	3	18,000	-	-	-
003pCu2002	CA02	TAM	7.2	39,600	-	-	30
		LORRAINE TOTAL	42.2	268,000	-	5.4	180
003pCu2002	CA02	GALORE CREEK GROUP					
003pCu2002	CA02	Galore - C, J, NJ, SW, WFG	1,382.6	5,670,000	-	304.2	5,543
003pCu2002	CA02	Galore - Central (included in Galore)	233.9	1,570,000	-	81.9	1,637
003pCu2002	CA02	Galore - Copper Canyon	164.8	575,000	-	89	1,178
003pCu2002	CA02	Galore - Junction (included in Galore)	101.6	567,000	-	33	382
003pCu2002	CA02	Galore - North Junction (included in Galore)	7.7	116,000	-	-	-
003pCu2002	CA02	Galore - Southwest (included in Galore)	170.6	595,000	-	108	424
003pCu2002	CA02	Galore - West Fork Glacier (included in Galore)	60.8	301,000	-	21.2	299
		GALORE CREEK TOTAL	1,547	6,250,000	-	393	6,722
003pCu2002	CA02	SULPHURETS GROUP					
003pCu2002	CA02	Kerr	225.3	924,000	-	51.8	-
003pCu2002	CA02	Mitchell	1,509.9	2,720,000	-	966.3	-
003pCu2002	CA02	Sulphurets Gold	87.3	236,000	-	62.9	-
		SULPHURETS TOTAL	1,822.5	3,880,000	72,900	1080.7	3,827
003pCu2002	CA02	INDIVIDUAL DEPOSITS					
003pCu2002	CA02	Chuchi	50	105,000	-	10.5	-
003pCu2002	CA02	Minto	34.4	408,000	-	11.1	143
003pCu2002	CA02	Mount Milligan	602.7	1,160,000	-	210.3	-
003pCu2002	CA02	Red Chris	714.8	2,540,000	-	200.9	1,072
003pCu2002	CA02	Williams Creek (Carmacks)	15.5	157,000	-	7.5	72
		Tract Total	6,437	20,897,000			
		Insular Mixed Island- and Continental Arc Porphyry Cu					
003pCu2003	CA03	HUSHAMU GROUP					
003pCu2003	CA03	Hushamu	735.4	1,460,000	80,894	181.6	-
003pCu2003	CA03	Red Dog	45	158,000	2,700	19.8	-
		HUSHAMU TOTAL	780.4	1,620,000	85,844	201.3	-
003pCu2003	CA03	INDIVIDUAL DEPOSIT					
003pCu2003	CA03	Island Copper	377	1,550,000	64,090	71.6	528
		Tract Total	1,157	3,170,000			
		Cordilleran Continental Arc Porphyry Cu					
003pCu2004	CA04	DOROTHY-NAK GROUP					
003pCu2004	CA04	Dorothy	45	117,000	4,500	-	-
003pCu2004	CA04	NAK	271	499,000	-	36	-
		DOROTHY-NAK TOTAL	316	616,000	-	36	-
003pCu2004	CA04	HUCKLEBERRY GROUP					
003pCu2004	CA04	Huckleberry	177.5	831,000	24,850	4.1	150
003pCu2004	CA04	Ox Lake	21.4	72,800	1,712	-	-
		HUCKLEBERRY TOTAL	198.9	904,000	25,857	4.2	150
003pCu2004	CA04	OK GROUP					
003pCu2004	CA04	OK	143	343,000	12,870	-	-
003pCu2004	CA04	Okeover	86.8	269,000	12,152	-	-
		OK TOTAL	230	612,000	25,300	-	-
003pCu2004	CA04	INDIVIDUAL DEPOSITS					
003pCu2004	CA04	Bell Copper	495	1,780,000	24,750	79.2	495
003pCu2004	CA04	Berg	650.6	1,850,000	234,216	11.7	2,342
003pCu2004	CA04	Big Onion (Cimbria)	94.4	396,000	18,880	6	94
003pCu2004	CA04	Cash	36	101,000	7,560	6.1	-
003pCu2004	CA04	Casino	964	2,120,000	192,800	231.4	1,735
003pCu2004	CA04	Catface	308	1,140,000	21,560	15.4	
003pCu2004	CA04	Fish Lake (Prosperity)	1,150	2,530,000	23,000	471.5	2,645
003pCu2004	CA04	Gambier Island	114	331,000	20,520	3.4	148
003pCu2004	CA04	Granisle	171.2	488,000	-	24.7	68
003pCu2004	CA04	Hi-Mars*	82	246,000	-	-	-
003pCu2004	CA04	Jean**	27	81,000	4,050	-	-
003pCu2004	CA04	Lexington-Lone Star	19.5	109,000	-	10.7	-
003pCu2004	CA04	Louise Lake	151	359,000	12,080	34.4	-
003pCu2004	CA04	Maggie	181.4	508,000	52,606		-
003pCu2004	CA04	Morrison (Hearne Hill)	206.9	697,000	8,276	36.6	-
003pCu2004	CA04	New Nanik (Nanika)	16.5	71,900	-	-	-
003pCu2004	CA04	Poison Mountain	808	1,940,000	64,640	97	2,424
003pCu2004	CA04	Poplar	236	873,000	-	-	-
003pCu2004	CA04	Rey Lake	46.9	80,000	8,442	-	-
003pCu2004	CA04	Taseko	15	79,500	1,800	8	-
		Tract Total	6,518	17,912,400			

Table 7. Identified resources in known porphyry copper deposits listed by permissive tract, porphyry copper assessment of British Columbia and Yukon Territory, Canada.—Continued

Coded_ID	User_ID	Deposit or Group	Tonnage (Mt)	Contained Cu (t)	Contained Mo (t)	Contained Au (t)	Contained Ag (t)
Late Continental Arc Porphyry Cu							
003pCu2005	CA05	GIANT COPPER GROUP					
003pCu2005	CA05	Giant Copper (AM Breccia)	29.5	192,000	2,065	0.3	11
003pCu2005	CA05	Invermay	15.3	32,200		5.8	121
		GIANT COPPER TOTAL	44.8	224,200	2,240	6.1	132
		Tract Total	44.8	224,200			
		Tracts Grand Total	22,253	66,804,600			

tract under discussion and invited comments and discussion about significant prospects. During such discussions, our Canadian experts offered many helpful corrections and suggestions regarding tract definition, tract delineation, preliminary assignments of deposits and prospects to tracts, and relative merits of various prospects in each tract.

After the presentation and discussion of each tract and its known deposits and prospects, Steve Ludington asked each participant to write estimations of the numbers of undiscovered deposits expected at three levels of subjective probability—90-, 50- and 10-percent (or for 50-, 10-, and 5-percent levels if the number of undiscovered deposits was thought to be zero at the 90-percent level, or for 10-, 5-, and 1-percent levels if the number of undiscovered deposits was thought to be zero at the 90- and 50-percent levels). The results were posted and each participant's estimates discussed. To help the group evaluate these results and guide us to consensus estimates, we calculated deposit densities and the mean expected number of deposits for alternative sets of estimates. The density of deposits (per 10,000 km^2) and the area of each assessment tract were calculated and compared to similar control areas (tracts) from around the world (see Singer and Menzie, 2005, and Singer and others, 2005b).

The mean expected number of deposits (λ) and the standard deviation of the estimates (s_x) were calculated using equations developed by Singer and Menzie (2005):

$$\lambda = 0.233\ N_{90} + 0.4\ N_{50} + 0.225\ N_{10} + 0.045\ N_{05} + 0.03\ N_{01}$$

$$s_x = 0.121 - 0.237\ N_{90} - 0.093\ N_{50} + 0.183\ N_{10} + 0.073\ N_{05} + 0.123\ N_{01}$$

where N_z is the estimated number of deposits associated with the Zth probability level. These equations require a minimum of three sequential non-zero estimates to produce a probably distribution for calculating quantities of contained metal (90-50-10 or 50-10-5 or 10-5-1 probability levels; see Root and others, 1992). An estimate of zero is acceptable for the 90- or the 90- and 50-percent levels provided that non-zero estimates are made for at least three of the lower percent levels. In instances where the 5- and(or) 1-percent levels are not estimated, the method requires that the value of the lowest estimated level be used to "backfill" the other lower values (for example, the N_{10} value is used for the N_{05} and N_{01} levels if they are not estimated, or the N_{05} value is used for the N_{01} level if N_{90} is believed to be zero and estimates are made only for N_{50}, N_{10}, and N_{05}). During and after these discussions, we negotiated consensus for a best set of estimates for numbers of undiscovered deposits at three levels of subjective probability.

After the assessment workshop, we ranked deposits and prospects on the basis of known resources and exploration results. Such ranking has helped us organize lists of deposits and significant prospects for each tract. It also lends support to our estimates of numbers of undiscovered deposits in each tract. Our criteria for such ranking are as follows:

- Rank 0 is for prospects that are not primarily porphyry copper prospects but may be related to an undiscovered porphyry copper system.
- Rank 1 is for porphyry copper deposits estimated to contain more than 16,000 t copper (the tonnage of copper contained in the smallest deposit included in the global grade and tonnage model for porphyry copper deposits by Singer and others, 2008).
- Rank 2 is for incompletely explored porphyry copper prospects with estimated resources containing less than 16,000 t copper.
- Rank 3 is for porphyry copper prospects with intercepts of at least 20 m of mineralized rock, containing at least 0.2 percent copper.
- Rank 4 is for porphyry copper prospects with samples containing more than 0.1 percent of copper, but less than 20 m of 0.2 percent copper.
- Rank 4.5 is for porphyry Mo-Cu prospects with average molybdenum grade more than three times higher than average copper grade.
- Rank 5 is for porphyry copper prospects with no assay data.
- Rank 6 is for copper showings or anomalies that have been explored with negative results.

Prospects of ranks 5 and 6 are not considered significant and are not included in the tables of significant prospects that accompany the descriptions of permissive tracts.

Summary of Probabilistic Assessment Results

Appendixes A through E contain descriptions of permissive tracts with maps, tables of resources in known deposits, character of significant prospects, and locations and types of recent exploration activity. Also included are maps of permissive tracts with locations of deposits and significant prospects, and graphed results of probabilistic estimation of tonnages of copper, molybdenum, gold, silver, and rock likely to be contained in undiscovered porphyry copper deposits. Assessment results are summarized in tables 5 and 6.

Considerations for Users of this Assessment

GMRAP products represent a synthesis of current, readily available information. Ideally, assessments are done on a recurring basis, at a variety of scales, because available data change over time. This assessment is based on the descriptive and grade and tonnage data contained in published mineral deposit models. Data in the models represent average grades of each commodity of possible economic interest and tonnages based on the total of production, reserves, and resources at the lowest cutoff grade for which data were available when the model was constructed. The present-day economic viability of the deposits used to construct the models varies widely, so care must be exercised when using the results of this assessment to answer questions that involve economics. Furthermore, these estimates are of numbers of deposits that are likely to exist, not necessarily those likely to be discovered (Singer, 2007a, b). In some cases, the assessment team was aware of prospects, revealed by past or current exploration efforts, that are believed to be significant deposits, but that do not yet have a citable grade and tonnage. These probable deposits are treated here as undiscovered deposits, albeit ones with a high degree of certainty of existence.

The mineral industry explores for extensions of identified resources, as well for greenfields projects in new exploration areas. Extensions to identified resources are not estimated in this assessment, although they are commonly a substantial part of newly discovered copper resources each year. This assessment considers the potential for concealed deposits within 1 km of the surface. However, exploration for, and exploitation of, such deposits may be so expensive that deposits, if present, may not be discovered in the near term. If they are discovered, the costs and logistics related to mining a deeply buried porphyry deposit might prohibit their development into mines given current or near-term metal prices and technology. Nevertheless, ore bodies throughout the world are mined at depths exceeding 1 km.

The estimated numbers of undiscovered deposits reported here may be conservative. We estimated numbers of undiscovered deposits before we formally ranked them. Thus, we may not have been sufficiently aware of the relative qualities of some prospects when the estimates were made. Also, our use of the average of long axes of alteration zones in application of the 2-km rule imposed a conservative influence on our estimation of undiscovered deposits. Had we known the shape and orientation of the zone of mineralized and hydrothermally altered rocks associated with each deposit, we could have rigorously applied the 2-km rule to each deposit. This would have allowed more prospects around known deposits to be classified as possible undiscovered deposits, rather than as possible extensions to identified resources, which are not estimated in this assessment.

Permissive tracts are based on geology, irrespective of political boundaries. Therefore, tracts may cross international boundaries or include lands that already have been developed for other uses, or withdrawn from mineral development as protected areas.

The permissive tracts are presented at a scale of 1:1,000,000 and are not intended for use at larger scales. For additional information about proper usage of the tracts, see the completeness and accuracy statements in the metadata of the accompanying GIS files.

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Appendixes A–I

Appendix A. Porphyry Copper Assessment for Tract 003pCu2001 (CA01), Intermontane Island-Arc—British Columbia and Yukon Territory, Canada

By Mark J. Mihalasky[1], Arthur A. Bookstrom[2], Thomas P. Frost[3], and Steve Ludington[4], with contributions from James M. Logan[5], Andre Panteleyev[6], and Grant Abbott[7]

Deposit Type Assessed: Porphyry copper

Descriptive model: Porphyry copper (Cox, 1986a; Berger and others, 2008), porphyry Cu-Mo (Cox, 1986b), porphyry Cu-Au (Cox, 1986c), porphyry Cu±Mo±Au (Panteleyev, 1995)
Grade and tonnage model: Canadian Cordillera Porphyry Cu±Mo±Au (appendix G)
(Table A1 summarizes selected assessment results)

Table A1. Summary of selected resource assessment results for tract 003pCu2001 (CA01), Intermontane Island-Arc—British Columbia and Yukon Territory, Canada.
[km, kilometers; km², square kilometers; t, metric tons]

Date of assessment	Assessment depth (km)	Tract area (km²)	Known copper resources (t)	Mean estimate of undiscovered copper resources (t)	Median estimate of undiscovered copper resources (t)
2009	1	175,250	24,600,000	8,900,000	6,900,000

Location

This tract is in the Cordilleran region of western Canada. It includes the plateaus, hills, and valleys of the Intermontane belt, which is between the Coast Mountains and the inland Rocky Mountains in British Columbia and Yukon (figs. 1, A1).

Geologic Feature Assessed

Calc-alkaline igneous rocks of Middle Triassic to Late Jurassic age in preaccretionary island-arc terranes of the Intermontane belt.

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Delineation of the Permissive Tract

Geologic Criteria

The fundamental units for delineation of this permissive tract are subduction-related magmatic arcs of Middle Triassic to Late Jurassic age that gave rise to the Quesnel and Stikine oceanic island-arc terranes before they were accreted to the continental margin. Geologic units that define this permissive tract are preaccretionary calc-alkaline igneous rocks of the Triassic-Jurassic Quesnel and Stikine terranes. Porphyry copper deposits and prospects that are preaccretionary with respect to Quesnellia and Stikinia range in age from Late Triassic to Middle Jurassic (222 to 168 Ma). Map units that include rocks of this age-span also may include older or younger rocks. This permissive tract, therefore, includes calc-alkaline igneous components of lithologic assemblages represented by map units including rocks as old as earliest Middle Triassic (245 Ma) or as young as latest Late Jurassic (146 Ma).

Criteria for consideration of rock types as permissive for the occurrence of calc-alkaline porphyry Cu±Mo±Au deposits are from descriptive models for porphyry copper and Cu-Mo deposits by Cox (1986b) and for calc-alkaline porphyry Cu±Mo±Au deposits of British Columbia by Panteleyev (1995). Phaneritic to porphyritic rock types classified as permissive for the occurrence of such deposits include quartz diorite, tonalite, granodiorite, quartz monzonite, monzogranite, and granite of calc-alkaline affinity. Porphyro-aphanitic equivalents are quartz-andesite, dacite, rhyodacite, quartz-latite, and rhyolite porphyries of calc-alkaline affinity (see table A2).

According to McMillan (1991) igneous assemblages associated with copper deposits of the calc-alkaline subtype consist of I-type igneous rocks, differentiated from magmas formed by partial melting of igneous source materials. Such calc-alkaline assemblages commonly contain either hornblende or biotite (or both). However, they do not contain primary muscovite, which is characteristic of peraluminous S-type granites, derived from sedimentary source rocks. Relatively low initial ^{87}Sr/ ^{86}Sr ratios of 0.704 to 0.706 indicate derivation from mafic source materials with low rubidium contents. With increasing proportions of silica, plagioclase is increasingly sodic, and proportions of K-feldspar and biotite generally increase. Nevertheless, plagioclase generally exceeds K-feldspar, and soda generally exceeds potash. Although most of these rocks contain primary igneous quartz, they generally contain less than 70 weight percent of silica. Accessory magnetite in calc-alkaline rocks indicates crystallization under relatively oxidizing conditions.

Although porphyry copper deposits commonly are associated with epizonal porphyritic intrusions, some are associated with predominantly phaneritic plutons, and some are associated with predominantly aphanitic subvolcanic intrusions and breccias. We classify calc-alkaline igneous rocks as permissive for calc-alkaline porphyry Cu±Mo±Au deposits, whether they are plutonic, subvolcanic, volcanic, or volcaniclastic.

This permissive tract includes calc-alkaline igneous rocks that formed within the Quesnel and Stikine island arcs before, during, and shortly after their amalgamation and accretion to the continental margin. As shown in tables A3 and A4, ages of known preaccretionary calc-alkaline porphyry Cu±Mo±Au deposits in these terranes range from 222 Ma (Late Triassic) to 168 Ma (Middle Jurassic). However, many geologic map units that include such rocks also include older and younger rocks. Therefore, calc-alkaline rocks included in this tract may belong to map units that contain rocks as old as earliest Middle Triassic (245 Ma) or as young as latest Late Jurassic (146 Ma).

According to Monger and others (1991), much of Quesnellia is characterized by island-arc volcanic rocks of the Late Triassic to Early Jurassic Nicola Group in southern British Columbia and the coeval Takla Group to the north. Calc-alkaline volcanic rocks of the Nicola and Takla Groups are intruded by comagmatic calc-alkaline plutons. Some of these plutons produced calc-alkaline porphyry Cu±Mo±Au deposits. The Highland Valley and Gibraltar Cu±Mo±Au deposits are examples of the plutonic style and are hosted in batholiths (see Panteleyev, 1995, for description of deposit subtype styles). The Brenda Cu-Mo deposit, of the classic style, is peripheral to a stock, emplaced into a batholith. The Kemess deposit is of the volcanic style, and is hosted in volcanic rocks of the Takla and Hazelton groups, intruded by intermediate to felsic intrusions of Early Jurassic age (Rebagliati and others, 1995). We therefore classified calc-alkaline volcanic rocks of the Nicola and Takla Groups and associated calc-alkaline intrusions as permissive for the occurrence of calc-alkaline porphyry Cu±Mo±Au deposits in Quesnellia.

Similarly, much of Stikinia is characterized by island-arc volcanic rocks of the Late Triassic to Early Jurassic Takla and Stuhini Groups (Monger and others, 1991). Such rocks in the Stikine terrane are separated from similar rocks of Quesnellia by the oceanic Cache Creek terrane (Nelson and Colpron, 2007). In Stikinia, volcanic rocks of the Takla and Stuhini Groups are intruded by many preaccretionary calc-alkaline plutons, some of which produced calc-alkaline porphyry Cu±Mo±Au deposits, such as the Schaft Creek deposit (Scott and others, 2008). We classified calc-alkaline volcanic rocks of the Takla and Stuhini Groups and associated calc-alkaline intrusions as permissive for the occurrence of calc-alkaline porphyry Cu±Mo±Au deposits in Stikinia.

The Kemess porphyry Cu-Au deposit is related to calc-alkaline porphyries that intrude the volcanic and sedimentary rocks of the Lower to Middle Jurassic Hazelton Group. Calc-alkaline volcanic, volcaniclastic, and epiclastic strata of the Hazelton Group overlie strata of the Takla and Stuhini Groups in much of Stikinia. We include calc-alkaline volcanic and volcaniclastic rocks of the Hazelton Group in this permissive tract because they are subduction-related calc-alkaline volcanic rocks, and they host the Kemess deposit. We also include rocks of the Toodoggone volcanics because they are similar to, and probably correlative with, those of the Hazelton Group. Felsic rocks of the Cold Fish volcanics could belong to a bimodal volcanic assemblage (though none have been identified). Nevertheless, we regard them as products of the Stikine magmatic-arc, and we include them in this permissive tract for porphyry Cu±Mo±Au deposits of Quesnellia and Stikinia.

Tract Delineation Process

We used digital tectonic-assemblage maps by Wheeler and McFeely (1991) and by Journeay and Williams (1995) to identify the areas of the Quesnel and Stikine terranes. We used digital geologic maps of British Columbia by Massey and others (2005) and of the Yukon Territory by Gordey and Makepeace (1999) to identify permissive rocks. Geologic information in attribute tables associated with these maps allowed us to identify polygons representing lithologic assemblages containing rocks of the appropriate age and composition to be included in this permissive tract. We excluded polygons representing lithologic assemblages not considered permissive by reason of age or composition, and we recorded a reason for their exclusion in the attribute table for the tract.

Digital geologic map units that include polygons assigned to this permissive tract are listed in table A2 for intrusive and volcanic rocks. From each map unit listed, we selected only those sets of polygons that represent lithologic assemblages containing permissive rock types. Sets of polygons for which descriptions include rocks of ages or compositions that are permissive for more than one tract are included in each of the permissive tracts for which they are permissive.

To identify the area to be included in this permissive tract, we applied the following procedures. From descriptive information in the attribute tables that accompany the digital geologic maps of British Columbia and the Yukon Territory, we classified map units as permissive or nonpermissive, according to the geologic criteria described above (and summarized in table A2). The map units classified as permissive for this tract represent the bedrock-surface expressions of intermediate to felsic igneous rocks of calc-alkaline affinity and of Middle Triassic to Late Jurassic age in the Quesnel and Stikine accreted island-arc terranes.

To polygons or groups of polygons that represent the bedrock-surface expression of permissive map units, we added a 10-km buffer to the mapped margins of permissive intrusions. This buffer expanded the area of the permissive tract to include all significant porphyry copper prospects, and to include possible unexposed permissive rocks and porphyry copper deposits. Examples of permissive rock types below the mapped surface would include permissive plutons that expand downward, subsurface satellite cupolas of intrusions, and unmapped parts of plutons or porphyry copper occurrences that are covered by younger materials (such as basalt flows, glacial till, colluvium, alluvium, or basin-fill sediments less than 1 km thick) or are structurally covered. We also applied a 2-km buffer around the outer margins of polygons or groups of polygons representing permissive volcanic rocks, the thin edges of which might be discontinuous, covered, or otherwise not mapped at the scale of our source maps. For additional information on buffering, see the "Permissive Tracts for Porphyry Copper" section in the Introduction of this report.

After buffering, we examined aeromagnetic, gravimetric, and geochemical anomaly maps for evidence of unmapped permissive igneous rocks or hydrothermal systems (Natural Resources Canada, 2008a, b, c). Positive aeromagnetic and gravity anomalies were interpreted as possible evidence for granitoid intrusions, or magnetite-bearing hydrothermal systems (see Clark, 1999, for discussion). Stream-sediment geochemical anomalies for copper associated with molybdenum or zinc were interpreted as possible evidence for hydrothermal systems, some of which might be related to calc-alkaline porphyry Cu±Mo±Au deposits. Where such anomalies extended beyond the margins of the buffered permissive map units, the tract was expanded to include them.

A smoothing routine was then applied to the buffered tract. A description of the smoothing routine is included in the metadata in appendix H. After smoothing, tract-buffer zones were trimmed along terrane-bounding faults. Finally, areas of postaccretionary intrusions (surrounded by a 250-meter buffer) were excluded from the tract-buffer zones. Such intrusions and their buffer zones are included in a permissive tract for a later time interval.

Geologic Interpretation

Mihalynuk and others (1994, p. 575) proposed that Early Mesozoic Quesnellia and Stikinia "were joined through their northern ends as two adjacent arc festoons that faced south toward the Cache Creek ocean." Oceanic plateau remnants from the Tethyan realm collided with these island arcs during subduction of the Cache Creek oceanic lithosphere, which may have underlain a part of the Panthalassic Ocean (the expansive global ocean that surrounded Pangaea from Late Precambrian to the Jurassic time). Counterclockwise oroclinal rotation of the Stikine and Nisling terranes in the Late Triassic to Early Jurassic caused enclosure of the Cache Creek terrane. "Rotation continued until these terranes collided with Quesnellia in the Middle Jurassic."

This oroclinal hypothesis explains why volcanic and intrusive rocks of the Quesnel and Stikine terranes are so similar that volcanic successions in both arcs are assigned to the Takla Group. Another point of similarity is that these two island-arc terranes contain both calc-alkaline porphyry Cu±Mo±Au deposits and alkaline porphyry Cu-Au deposits.

In southern Quesnellia, calc-alkaline volcanic and plutonic rocks of the Nicola magmatic arc occur in the west, and calc-alkaline to alkaline rocks occur in the east. Inasmuch as alkalinity tends to increase with increasing depth of subduction, this indicates that the Nicola was a west-facing magmatic arc (Monger and others, 1991).

In Stikinia, the Schaft Creek calc-alkaline porphyry Cu±Mo±Au deposit is east of the Galore Creek alkaline porphyry Cu-Au deposit, which indicates that the Stikine magmatic arc now faces east. This is consistent with the hypothesis

Table A2. Map units that define tract 003pCu2001 (CA01), Intermontane Island-Arc—British Columbia and Yukon Territory, Canada.

[Province, map unit, age range, and principal rock types from 1:250,000 scale digital geologic maps of British Columbia (Massey and others, 2005) and Yukon Territory (Gordey and Makepeace, 1999)]

Province	Map unit	Age range	Rock types
			a. Intrusive rocks
BC	EJCM	Late Early Jurassic	granodioritic intrusive rocks
BC	EJdg	Early Jurassic	monzodioritic to gabbroic intrusive rocks
BC	EJEK	Early Jurassic	feldspar porphyritic intrusive rocks
BC	EJfp	Early Jurassic	feldspar porphyritic intrusive rocks
BC	EJg	Early Jurassic	intrusive rocks, undivided
BC	EJgd	Early Jurassic	granodioritic intrusive rocks
BC	EJGdr	Early Jurassic	dioritic intrusive rocks
BC	EJGMG	Early Jurassic	quartz dioritic intrusive rocks
BC	EJGMM	Early Jurassic	quartz dioritic intrusive rocks
BC	EJGMS	Early Jurassic	dioritic intrusive rocks
BC	EJgr	Early Jurassic	granite, alkali feldspar granite intrusive rocks
BC	EJHgb	Early Jurassic	gabbroic to dioritic intrusive rocks
BC	EJHgd	Early Jurassic	granodioritic intrusive rocks
BC	EJHhy	Middle Jurassic	intrusive rocks, undivided
BC	EJHqd	Early Jurassic	quartz dioritic intrusive rocks
BC	EJHqm	Early Jurassic	quartz monzonitic to monzogranitic intrusive rocks
BC	EJMy	Early Jurassic	quartz monzonitic intrusive rocks
BC	EJqd	Early Jurassic	quartz dioritic intrusive rocks
BC	EJqm	Early Jurassic	quartz monzonitic intrusive rocks
BC	EJTCdg	Early Jurassic	monzodioritic to gabbroic intrusive rocks
BC	EJTCqd	Early Jurassic	quartz dioritic intrusive rocks
BC	EJTCS	Early Jurassic	granodioritic intrusive rocks
BC	EJTpgd	Late Triassic to Early Jurassic	granodioritic intrusive rocks
BC	EMJSPd	Early to Middle Jurassic	dioritic intrusive rocks
BC	EMJSPgd	Early to Middle Jurassic	granodioritic intrusive rocks
BC	Jdr	Jurassic	dioritic intrusive rocks
BC	Jgd	Jurassic	granodioritic intrusive rocks
BC	JKCL	Early Jurassic to Late Cretaceous	quartz monzonitic to monzogranitic intrusive rocks
BC	JKdr	Jurassic to Cretaceous	dioritic intrusive rocks
BC	JKg	Jurassic to Cretaceous	intrusive rocks, undivided
BC	JKgd	Jurassic to Cretaceous	granodioritic intrusive rocks
BC	JKPP	Jurassic to Cretaceous	tonalite intrusive rocks
BC	JKqp	Jurassic to Cretaceous	high level quartz phyric, felsitic intrusive rocks
BC	JKto	Jurassic to Cretaceous	tonalite intrusive rocks
BC	JTfp	Jurassic to Tertiary	feldspar porphyritic intrusive rocks
BC	JTgr	Jurassic to Tertiary	granite, alkali feldspar granite intrusive rocks
BC	JTH	Jurassic to Tertiary	quartz monzonitic intrusive rocks
BC	JTqp	Jurassic to Tertiary	high level quartz phyric, felsitic intrusive rocks
BC	lJToAdqp	Lower Jurassic	high level quartz phyric, felsitic intrusive rocks
BC	lJToMqp	Lower Jurassic	high level quartz phyric, felsitic intrusive rocks
BC	LTrBG	Late Triassic	quartz dioritic intrusive rocks
BC	LTrgd	Late Triassic	granodioritic intrusive rocks
BC	LTrJCqm	Late Triassic to Early Jurassic	quartz monzonitic intrusive rocks
BC	LTrJdr	Late Triassic to Early Jurassic	dioritic intrusive rocks
BC	LTrJGB	Late Triassic to Early Jurassic	quartz monzonitic intrusive rocks
BC	LTrJGBe	Late Triassic to Early Jurassic	granodioritic intrusive rocks
BC	LTrJGBo	Late Triassic to Early Jurassic	quartz dioritic intrusive rocks
BC	LTrJgd	Late Triassic to Early Jurassic	granodioritic intrusive rocks
BC	LTrJGG	Late Triassic to Early Jurassic	granodioritic intrusive rocks
BC	LTrJGH	Late Triassic to Early Jurassic	granodioritic intrusive rocks
BC	LTrJGqm	Late Triassic to Early Jurassic	quartz monzonitic intrusive rocks
BC	LTrJGqp	Late Triassic to Early Jurassic	high level quartz phyric, felsitic intrusive rocks
BC	LTrJto	Late Triassic to Early Jurassic	tonalite intrusive rocks

Table A2. Map units that define tract 003pCu2001 (CA01), Intermontane Island-Arc—British Columbia and Yukon Territory, Canada.—Continued

[Province, map unit, age range, and principal rock types from 1:250,000 scale digital geologic maps of British Columbia (Massey and others, 2005) and Yukon Territory (Gordey and Makepeace, 1999)]

Province	Map unit	Age range	Rock types
(**a.** Intrusive rocks)			
BC	LTrJTpg	Late Triassic to Early Jurassic	intrusive rocks, undivided
BC	LTrJTpgd	Late Triassic to Early Jurassic	granodioritic intrusive rocks
BC	LTrqd	Late Triassic	quartz dioritic intrusive rocks
BC	LTrqm	Late Triassic	quartz monzonitic intrusive rocks
BC	LTrSC	Late Triassic	dioritic intrusive rocks
BC	LTrSe	Late Triassic	quartz monzonitic intrusive rocks
BC	LTrStdg	Late Triassic	monzodioritic to gabbroic intrusive rocks
BC	MJBo	Middle Jurassic	granodioritic intrusive rocks
BC	MJFO	Middle Jurassic	granodioritic intrusive rocks
BC	MJNgd	Middle Jurassic	granodioritic intrusive rocks
BC	MJOgd	Middle Jurassic	granodioritic intrusive rocks
BC	MJPg	Middle Jurassic	intrusive rocks, undivided
BC	MJqd	Middle Jurassic	quartz dioritic intrusive rocks
BC	MJqm	Middle Jurassic	quartz monzonitic intrusive rocks
BC	MJqp	Middle Jurassic	high level quartz phyric, felsitic intrusive rocks
BC	MJSLB	Early Jurassic	quartz dioritic intrusive rocks
BC	MJSLC	Middle Jurassic	quartz monzonitic to monzogranitic intrusive rocks
BC	MJSLL	Middle to Late Jurassic	quartz dioritic intrusive rocks
BC	MJSLM	Middle Jurassic	quartz dioritic intrusive rocks
BC	MJSLqd	Middle Jurassic	quartz dioritic intrusive rocks
BC	MJSLSh	Middle Jurassic	quartz monzonitic to monzogranitic intrusive rocks
BC	MJSLSqd	Middle Jurassic	quartz dioritic intrusive rocks
BC	MJSLTi	Middle Jurassic	granite, alkali feldspar granite intrusive rocks
BC	MJSm	Middle Jurassic	granodioritic intrusive rocks
BC	MJSMqm	Middle Jurassic	quartz monzonitic intrusive rocks
BC	MJSPgd	Middle Jurassic	granodioritic intrusive rocks
BC	MJSPT	Middle Jurassic	granodioritic intrusive rocks
BC	MJTgd	Middle Jurassic	granodioritic intrusive rocks
BC	MJTqd	Middle Jurassic	quartz dioritic intrusive rocks
BC	MJTSdg	Middle Jurassic	monzodioritic to gabbroic intrusive rocks
BC	MJTSqm	Middle Jurassic	quartz monzonitic intrusive rocks
BC	MJWdg	Middle Jurassic	monzodioritic to gabbroic intrusive rocks
BC	MLJdr	Middle Jurassic to Late Jurassic	dioritic intrusive rocks
BC	MLTrqd	Middle Triassic to Late Triassic	quartz dioritic intrusive rocks
BC	MLTrStgb	Middle Triassic to Late Triassic	gabbroic to dioritic intrusive rocks
BC	Mzfp	Mesozoic	feldspar porphyritic intrusive rocks
BC	Mzgr	Mesozoic	granite, alkali feldspar granite intrusive rocks
BC	PTrMgd	Permian to Triassic	granodioritic intrusive rocks
BC	TrJg	Triassic to Jurassic	intrusive rocks, undivided
BC	TrJqm	Triassic to Jurassic	quartz monzonitic intrusive rocks
BC	TrTdr	Triassic to Tertiary	dioritic intrusive rocks
BC	TrTg	Triassic to Tertiary	intrusive rocks, undivided
YT	LTrgS	Late Triassic	granite/granodiorite/orthogneiss/quartz diorite/diorite
YT	MJgB	mid-Jurassic	monzodiorite/quartz monzodiorite/hornblendite/granite/ granodiorite
YT	MJqB	mid-Jurassic	monzonite/syenite/granite/dykes
b. Volcanic rocks			
BC	JKca	Jurassic to Cretaceous	calc-alkaline volcanic rocks
BC	lJG	Lower Jurassic	calc-alkaline volcanic rocks
BC	lJH	Early Jurassic	andesitic volcanic rocks
BC	lJHAm	Lower Jurassic	basaltic volcanic rocks
BC	lJHB	Lower Jurassic	volcaniclastic rocks
BC	lJHCa	Lower Jurassic	basaltic volcanic rocks
BC	lJHCbm	Lower Jurassic	bimodal volcanic rocks
BC	lJHCvc	Lower Jurassic	basaltic volcanic rocks
BC	lJHCvf	Lower Jurassic	rhyolite, felsic volcanic rocks
BC	lJHE	Lower Jurassic	volcaniclastic rocks
BC	lJHK	Lower Jurassic	rhyolite, felsic volcanic rocks

Table A2. Map units that define tract 003pCu2001 (CA01), Intermontane Island-Arc—British Columbia and Yukon Territory, Canada.—Continued

[Province, map unit, age range, and principal rock types from 1:250,000 scale digital geologic maps of British Columbia (Massey and others, 2005) and Yukon Territory (Gordey and Makepeace, 1999)]

Province	Map unit	Age range	Rock types
		(**b.** Volcanic rocks)	
BC	lJHL	Lower Jurassic	andesitic volcanic rocks
BC	lJHMB	Lower Jurassic	undivided volcanic rocks
BC	lJHMBvb	Lower Jurassic	basaltic volcanic rocks
BC	lJHMBvf	Lower Jurassic	rhyolite, felsic volcanic rocks
BC	lJHNvc	Early Jurassic	volcaniclastic rocks
BC	lJHNvf	Lower Jurassic	rhyolitic, felsic volcanic rocks
BC	lJHT	Lower Jurassic	calc-alkaline and andesitic volcanic rocks
BC	lJHU	Lower Jurassic	andesitic volcanic rocks
BC	lJHva	Early to Middle Jurassic	andesitic volcanic rocks
BC	lJHvc	Lower Jurassic	volcaniclastic rocks
BC	lJToA	Lower Jurassic	dacitic volcanic rocks
BC	lJToAd	Lower Jurassic	dacitic volcanic rocks
BC	lJToAva	Lower Jurassic	andesitic volcanic rocks
BC	lJToAvc	Lower Jurassic	volcaniclastic rocks
BC	lJToMc	Lower Jurassic	andesitic volcanic rocks
BC	lJToMvl	Lower Jurassic	coarse volcaniclastic and pyroclastic volcanic rocks
BC	lJToS	Lower Jurassic	dacitic volcanic rocks
BC	lmJH	Lower Jurassic to Middle Jurassic	calc-alkaline volcanic rocks
BC	lmJHD	Lower Jurassic to Middle Jurassic	rhyolite, felsic volcanic rocks
BC	lmJHEvf	Early to Middle Jurassic	rhyolite, felsic volcanic rocks
BC	lmJHSH	Early to Middle Jurassic	undivided volcanic rocks
BC	lmJHSHva	Early to Middle Jurassic	andesitic volcanic rocks
BC	lmJHSHvb	Early to Middle Jurassic	basaltic volcanic rocks
BC	lmJHSHvc	Early to Middle Jurassic	volcaniclastic rocks
BC	lmJHSHvf	Early to Middle Jurassic	rhyolite, felsic volcanic rocks
BC	lmJHSvb	Lower Jurassic to Middle Jurassic	basaltic volcanic rocks
BC	lmJHvc	Lower Jurassic to Middle Jurassic	volcaniclastic rocks
BC	lmJHvf	Lower Jurassic to Middle Jurassic	dacite, rhyolite, felsic volcanic rocks
BC	lmJHvl	Early to Middle Jurassic	coarse volcaniclastic and pyroclastic volcanic rocks
BC	lmJva	Lower Jurassic to Middle Jurassic	andesitic volcanic rocks
BC	mJHEvf	Middle Jurassic	rhyolite, felsic volcanic rocks
BC	mJHN	Middle Jurassic	undivided volcanic rocks
BC	mJHNvc	Middle Jurassic	volcaniclastic rocks
BC	mJHNvd	Middle Jurassic	dacitic volcanic rocks
BC	mJHSmvc	Middle Jurassic	volcaniclastic rocks
BC	mJHvb	Middle Jurassic	basaltic volcanic rocks
BC	mJHvc	Middle Jurassic	volcaniclastic rocks
BC	muJHca	Middle Jurassic to Upper Jurassic	calc-alkaline volcanic rocks
BC	muJHM	Middle Jurassic to Upper Jurassic	calc-alkaline volcanic rocks
BC	muJHNa	Middle Jurassic to Upper Jurassic	rhyolite, felsic volcanic rocks
BC	muJHo	Middle Jurassic to Upper Jurassic	calc-alkaline volcanic rocks
BC	muJHSvb	Middle Jurassic to Upper Jurassic	basaltic volcanic rocks
BC	TrJN	Triassic to Jurassic	calc-alkaline volcanic rocks
BC	TrJNO	Triassic to Jurassic	calc-alkaline volcanic rocks
BC	uTrJN	Upper Triassic to Lower Jurassic	undivided volcanic rocks
BC	uTrJT	Upper Triassic to Lower Jurassic	undivided volcanic rocks
BC	uTrJv	Upper Triassic to Lower Jurassic	undivided volcanic rocks
BC	uTrMM	Upper Triassic	undivided volcanic rocks
BC	uTrN	Upper Triassic	undivided volcanic rocks
BC	uTrNva	Upper Triassic	andesitic volcanic rocks
BC	uTrNvb	Upper Triassic	basaltic volcanic rocks
BC	uTrNW	Upper Triassic	undivided volcanic rocks
BC	uTrSca	Upper Triassic	calc-alkaline volcanic rocks
BC	uTrSv	Upper Triassic	undivided volcanic rocks
BC	uTrSva	Upper Triassic	andesitic volcanic rocks
BC	uTrSvb	Upper Triassic	basaltic volcanic rocks
BC	uTrSvc	Upper Triassic	volcaniclastic rocks
BC	uTrTca	Upper Triassic	calc-alkaline volcanic rocks
BC	uTrTSm	Late Triassic	basaltic volcanic rocks
BC	uTrTv	Upper Triassic	undivided volcanic rocks
BC	uTrTva	Late Triassic	andesitic volcanic rocks
BC	uTrTvb	Late Triassic	basaltic volcanic rocks
YT	lJN	Lower Jurassic	sandstone/conglo/dacite/tuff

Table A3. Known calc-alkaline porphyry Cu±Mo±Au deposits in tract 003pCu2001 (CA01), Intermontane Island-Arc—British Columbia and Yukon Territory, Canada.

[Ma, million years; NA, not applicable; –, no data; Mt, million metric tons; t, metric ton; %, percent; g/t, gram per metric ton; Cu-Mo subtype, deposits that have Au/Mo ratios <3 or average Mo grades >0.03%; Cu-Au subtype, deposits that have Au/Mo ratios >30 or average Au grades >0.2 g/t. Contained Cu in metric tons is computed as (tonnage Mt x 1,000,000) x (percent Cu / 100); gs, coordinates of this site are used for the group location; *, estimated tonnage and grade from an unsubstantiated press release (not used in grade and tonnage model); **, partial tonnage and grade for a deposit that is known to be open to extension (not used in grade and tonnage model). For group aggregates: the latitude and longitude, subtype, and age is that of the deposit with the largest Cu resources; the Cu and Mo grades are tonnage-weighted averages calculated using the computed contained Cu and Mo as (t contained Cu or Mo / (Mt x 1,000,000)) x 100 (note that the computed contained Mo is not shown in this table); and the Au and Ag grades are a tonnage-weighted average calculated as g/t x Mt. For sources of age, tonnage, and grade information, see appendix F. Resource estimates are through 2009, but include updates for 2010 when available.]

Name	Latitude	Longitude	Subtype	Age (Ma)	Tonnage (Mt)	Cu (%)	Mo (%)	Au (g/t)	Ag (g/t)	Contained Cu (t)
HIGHLAND VALLEY GROUP										
Ann (included in Highmont)	50.42	-120.99	NA	207.00	43.40	0.27	–	–	–	117,000
Bethlehem	50.50	-120.99	Cu-Mo	201.00	677.00	0.45	0.02	0.01	0.40	3,050,000
Getty South (Trojan)	50.54	-120.99	NA	207.00	36.00	0.47	–	–	–	169,000
Highland Valley Copper ^{gs} (Valley Cu)	50.49	-121.05	Cu-Mo	208.00	1355.60	0.37	0.01	0.01	0.98	5,020,000
Highmont	50.43	-121.00	Cu-Mo	206.00	265.00	0.27	0.04	0.00	0.90	705,000
IDE-AM (included in Highmont)	50.43	-121.00	NA	207.00	11.50	0.27	0.01	–	–	31,000
JA	50.48	-120.98	NA	203.00	260.00	0.43	0.02	–	–	1,120,000
Krain (Getty North)	50.57	-121.00	NA	207.00	72.10	0.31	0.01	–	–	224,000
Lornex	50.45	-121.04	Cu-Mo	207.00	514.00	0.43	0.02	0.01	1.20	2,190,000
GROUP AGGREGATE	50.49	-121.05	Cu-Mo	207.00	3179.70	0.39	0.01	–	–	12,500,000
GIBRALTAR GROUP										
Gibraltar ^{gs}	52.52	-122.29	NA	210.00	1296.50	0.29	0.01	–	0.08	3,800,000
Sawmill	52.47	-122.27	NA	210.00	68.50	0.24	–	–	–	167,000
GROUP AGGREGATE	52.52	-122.29	NA	210.00	1365.00	0.29	–	–	–	3,970,000
KEMESS GROUP										
Kemess North ^{gs}	57.06	-126.76	NA	202.00	719.20	0.15	–	0.15	–	1,080,000
Kemess South	57.01	-126.75	Cu-Au	201.00	228.80	0.16	–	0.45	–	375,000
GROUP AGGREGATE	57.06	-126.76	NA	202.00	948.00	0.15	–	0.22	–	1,460,000
KINASKAN GROUP										
Goat	57.66	-130.26	Cu-Au	205.00	71.20	0.40	–	0.40	2.20	283,000
Kinaskan ^{gs}	57.65	-130.24	Cu-Au	205.00	176.00	0.31	–	0.36	–	528,000
GROUP AGGREGATE	57.65	-130.24	Cu-Au	205.00	247.20	0.34	–	0.37	–	811,000
KWANIKA GROUP										
Kwanika (Central) ^{gs}	55.53	-125.53	Cu-Au	199.00	182.60	0.29	–	0.28	–	530,000
Kwanika (South)	55.51	-125.33	NA	199.00	129.10	0.30	0.01	0.09	1.76	387,000
GROUP AGGREGATE	55.53	-125.53	Cu-Au	199.00	311.70	0.29	–	0.20	–	917,000
SCHAFT CREEK GROUP										
NABS	57.38	-131.01	Cu-Mo	222.00	90.70	0.34	0.05	–	–	306,000
Schaft Creek ^{gs}	57.36	-130.99	NA	222.00	1393.30	0.25	0.02	0.18	1.55	3,480,000
GROUP AGGREGATE	57.36	-130.99	NA	222.00	1484.00	0.26	0.02	–	–	3,790,000
INDIVIDUAL DEPOSITS										
Brenda	49.88	-120.01	Cu-Mo	195.00	227.00	0.16	0.04	0.01	0.63	363,000
Bronson Slope - Red Bluff	56.67	-131.09	Cu-Au	195.00	129.80	0.16	0.01	0.44	2.44	208,000
Eaglehead**	58.48	-129.11	NA	190.00	79.50	0.40	0.01	0.04	0.54	321,000
Gnat Lake (Gnat Pass)	58.25	-129.83	NA	200.00	30.40	0.39	–	–	–	119,000
HED*	49.52	-120.01	Cu-Mo	193.00	23.00	0.16	0.04	–	–	37,000
Pine	57.23	-126.73	Cu-Au	200.00	70.00	0.15	–	0.57	–	105,000
INDIVIDUAL DEPOSITS TOTAL					559.70					1,153,000
TRACT TOTAL					8095.30					24,601,000
TRACT ROUNDED TOTAL					8100.00					24,600,000

Table A4. Significant calc-alkaline porphyry Cu±Mo±Au prospects in tract 003pCu2001 (CA01), Intermontane Island-Arc—British Columbia and Yukon Territory, Canada.

[Ma, million years; –, not applicable; Mt, million metric tons; t, metric ton; %, percent; g/t, gram per metric ton; gs, group site-coordinates of this site are used for the group location. For sources and additonal information about age, tonnage, grade and comments, see appendix F. For mineral name abbreviations under “Comments”, see appendix F.]

Group	Name	Rank	Latitude	Longitude	Age (Ma)	Comments
Significant porphyry Cu prospects in groups of known porphyry Cu deposits and prospects						
Gibraltar	Gunn	2	52.503	-122.234	207	Resource: 0.862 Mt ore @ 0.28% Cu (2,410 t Cu)
Highland Valley	Highmont West	2	50.437	-121.008	207	Resource: 0.8 Mt ore @ 0.15% Cu (1,200 t Cu)
Highland Valley	Jericho	2	50.445	-120.914	207	Resource: 0.27 Mt ore @ 1% Cu (2,700 t Cu)
Highland Valley	MER	2	50.503	-121.137	207	Resource: 0.58 Mt ore @ 0.327% Cu (1,900 t Cu)
Highland Valley	Victor	2	50.462	-121.02	207	Resource: 0.1 Mt ore @ 1.5% Cu (1,500 t Cu)
Highland Valley	Wiz	2	50.335	-120.861	188	Resource: 0.294 Mt ore @ 1.26% Cu (3,700 t Cu)
Highland Valley	Yubet	2	50.38	-120.958	207	Resource: 0.04 Mt ore @ 2.1% Cu (874 t Cu); mineralized and altered rocks straddle contact of aplite dike
Highland Valley	Getty West	3	50.561	-121.016	207	Intercept: 42 m, 0.26% Cu, 0.02% Mo
Highland Valley	Rateria (Sky)	3	50.366	-120.958	207	Intercept: 177 m, 0.366% Cu, 0.019% Mo, 0.24 g/t Au, 5 g/t Ag; less than 5% outcrop
Highland Valley	BX	4	50.511	-120.935	207	Intercept: 3.3 m, 0.8% Cu
Kinaskan	Wolf	4	57.682	-130.172	205	Intercept: 10.85 m, 0.3% Cu, 0.1 g/t Au
Significant porphyry Cu prospects in a group with no known deposit						
Copper Creek	Go ^{gs}	4	58.214	-131.794	218	Intercept: 13.7 m, 0.58% Cu, 1.35 g/t Au
Copper Creek	Kid ^{gs}	4	58.241	-131.884	218	Intercept: interval unavailable; 3.6% Cu, 1.5 g/t Au; soil geochemical and IP anomalies, 4 pack-sack drill holes, total 47 m
Significant individual porphyry Cu prospects						
–	Dot	2	50.322	-120.849	207	Resource: 2.93 Mt ore @ 0.5% Cu (14,700 t Cu), (preliminary estimate)
–	Turlight	2	50.193	-120.609	188	Resource: 0.001 Mt ore @ 2.38% Cu (26 t Cu)
–	Bear	3	56.103	-126.874	200	Intercept: 179 m, 0.3% Cu, 0.083% Mo, 6.1 g/t Au, 8.4 g/t Ag
–	Prince	3	49.172	-120.002	168	Intercept: 46 m, 0.48% Cu, 0.05% Mo, 0.69 g/t Au, 13.7 g/t Ag
–	QC	3	57.761	-130.294	205	Intercept: 36 m, 0.249% Cu, 0.076% Mo
–	AL	4	57.744	-130.335	205	Intercept: 4 m, 0.72% Cu
–	Bud - North zone	4	49.445	-120.435	193	Intercept: 2 m, 0.22% Cu
–	Bud - South zone	4	49.425	-120.457	193	Intercept: 10.7 m, 0.184% Cu, 0.33 g/t Au, 8.7 g/t Ag
–	Clapper	4	50.292	-120.637	200	Intercept: interval unavailable; 0.37% Cu, 3.68 g/t Au
–	Copper Ace South (Bysouth)	4	52.617	-122.303	188	Intercept: interval unavailable; 7.2% Cu
–	King Edward	4	49.107	-119.812	168	Intercept: 6 m, 0.365% Cu, 0.169% Mo
–	MEX	4	57.204	-126.669	200	Intercept: interval unavailable; 0.146% Cu, 0.001% Mo, 0.007 g/t Au, 2.6 g/t Ag; patchy stockwork and disseminated cc, cpy
–	Mineral Hill	4	58.399	-131.787	200	Intercept: interval unavailable; 5.03% Cu, 0.54 g/t Au, 20.7 g/t Ag
–	Pil (Spartan)	4	57.366	-127.016	197	Intercept: 58 m, 0.128% Cu
–	Red	4	56.735	-126.301	200	Intercept: 3 m, 0.28% Cu
–	Sofia	4	57.333	-126.802	166	Intercept: interval unavailable; 0.05% Cu, 0.22 g/t Au
–	TUV	4	61.29	-134.823	214	Intercept: 1.5 m, 0.28% Cu, 0.479 g/t Au, 196 g/t Ag; 9 geochemical anomalies, broad IP anomaly, drill holes in weakly mineralized rocks
–	Woodjam	4	52.257	-121.381	197	Intercept: 361 m, 0.12% Cu, 0.84 g/t Au,

that the Stikine and Quesnel magmatic arcs originally faced westward, but oroclinal bending rotated Stikinia nearly 180 degrees counterclockwise, so that it now faces east.

Within the Lower Jurassic Hazelton Group, which overlies much of Stikinia, volcanic rocks occur in a pair of western and eastern volcanic chains, separated by a coeval sedimentary basin (the Hazelton trough). Marsden and Thorkelson (1992, p. 1266) suggested that the two volcanic chains indicate two magmatic arcs generated by subduction zones on opposite sides of Stikinia. They also suggested that rollback of these opposing subduction zones caused extensional subsidence in their shared back-arc region, forming the Hazelton trough, which filled with volcanic-derived sediments.

The Hazelton Group contains a diverse assemblage of subaqueous and subaerial volcanic and volcaniclastic rocks that range in composition from mafic to felsic and have medium to high potassium content. Compositional trends vary along both tholeiitic and calc-alkaline trends. The Kemess porphyry Cu-Au deposit is related to calc-alkaline, intermediate to felsic, subvolcanic intrusions in volcanic and sedimentary rocks of the Upper Triassic Takla and Lower Jurassic Hazelton groups (Rebagliati and others, 1995).

Accretion of Quesnellia and Stikinia to the continental margin occurred during Early to Middle Jurassic time (about 185±10 Ma). Murphy and others (1995), reported U-Pb age determinations for four intrusive bodies in the Kootenay arc that constrain the age of shortening of the sedimentary basin between Quesnellia and North America to late Early Jurassic (about 187 to 185 Ma) in southern British Columbia. Accretion probably progressed northward from southeastern Quesnellia, and then southward from northeastern Stikinia, as the orocline tightened. At the oroclinal crest, the Yukon-Tanana terrane became extremely deformed, sheared, and metamorphosed. Between the subparallel limbs of the fold, the oceanic Cache Creek terrane was reduced to a narrow belt of accretionary wedges. The resulting assemblage of the Quesnel, Yukon-Tanana, Stikine, and Cache Creek terranes comprises the Intermontane superterrane.

Known Deposits

There are 12 known calc-alkaline porphyry Cu±Mo±Au deposits in this tract, 6 of which include multiple ore bodies that are grouped according to the 2-km rule. For those that occur in groups, we list (in table A3) the name of the group, followed by the names of the ore bodies in the group. The tonnage, grade, and copper content of each ore body in the group are followed by the total tonnage, grade, and copper content of the group. The deposits and prospects are shown on figure A1.

These deposits fit descriptive models for porphyry copper deposits by Cox (1986a) and for calc-alkaline porphyry Cu±Mo±Au deposits of British Columbia by Panteleyev (1995). According to the criteria of Singer and others (2008), some of these ore bodies and deposits are of the porphyry Cu-Mo subtype of Cox (1986b), and some are of the Cu-Au subtype of Cox (1986c), as noted in table A3. (It is unknown how many deposits may be misclassified due to missing information.) In those ore bodies and deposits which contain Mo and Au, the copper zone commonly lies between an inner Mo zone and an outer Au zone, but such zones may overlap.

Porphyry copper deposits commonly consist of stockworks of intersecting veins and veinlets containing various proportions of quartz and chalcopyrite±bornite±molybdenite±pyrite±gold. Disseminated ore minerals also may occur in hydrothermally altered rocks around and between veins and veinlets, as well as in breccias.

Panteleyev (1995, p. 2) described three subtypes of the Canadian calc-alkaline porphyry Cu±Mo±Au deposit type: (1) plutonic Cu-Mo, (2) classic Cu±Mo±Au, and (3) volcanic Cu±Au±Mo. Deposits of the plutonic subtype occur in large plutons and batholiths. Deposits of the classic subtype are related to porphyritic stocks, within and around which mineralization occurred at relatively shallow depths. Deposits of the volcanic subtype are associated with multiple intrusions in subvolcanic settings of small stocks, sills, dikes, and breccias.

In this tract, the Highland Valley porphyry Cu-Mo and Gibraltar porphyry Cu-Mo deposits are examples of the plutonic subtype. The Brenda Cu-Mo deposit is transitional between the plutonic and classic subtypes. The Schaft Creek porphyry copper and Cu-Mo deposits are examples of the classic subtype (Scott and others, 2008). The Kemess South porphyry Cu-Au deposit is an example of the volcanic subtype.

In calc-alkaline porphyry Cu±Mo±Au deposits, the Mo zone commonly is in the lower, inner part of the copper zone or below it, and the Au zone commonly is in the upper-outer part of the copper zone, or above and around it. Potassic alteration assemblages, generally consisting of secondary K-feldspar and biotite, are common in the Cu-Mo zone. Phyllic alteration assemblages, generally consisting of quartz, pyrite, and sericite, are common in the copper zone. Argillic alteration assemblages, generally consisting of clay minerals, may be peripheral to, or superimposed upon, the phyllic zone, especially along late faults and fractures. Propylitic alteration, generally consisting of chlorite, epidote, and carbonate minerals, commonly surrounds the phyllic zone, and may overlap the Cu-Au zone. However, if the magmatic-hydrothermal system expands or collapses, or undergoes multiple pulses of intrusion and mineralization, different assemblages of ore and alteration minerals can be superimposed.

According to Panteleyev (1995, p. 3), “Oxidized and leached zones are marked by ferruginous cappings with supergene clay minerals, limonite (goethite, hematite and jarosite) and residual quartz.” Supergene minerals include chalcocite, covellite, digenite, chrysocolla, native copper and copper oxide, and carbonate and sulfate minerals. However, zones of supergene enrichment generally are not well developed or economically important in most Canadian Cordilleran deposits. Nevertheless, at the Gibraltar deposit, the Gibraltar East and Pollyanna ore bodies have supergene blankets that are about 30 m thick with copper-enrichment factors of about 1.35, under leached zones 10 to 25 m thick.

At the Krain deposit, a supergene zone with malachite, chrysocolla, neotocite(?), and traces of cuprite and native copper is up to 100 m thick with an enrichment factor of 1.1 over hypogene ore (Ney and others, 1976).

Many of the known ore bodies and prospects of this tract occur in groups, such that the zone of altered rocks around each is less than 2 km from that of another known ore body or prospect in the group. Table A3 lists the location and characteristics (including estimated tonnage and grade) for each ore body included in such a group. For the group locations, the largest ore body in the group represents the location on the tract maps in figures A1*A* and A1*B*. Furthermore, the total tonnage and average grade of the known ore bodies in the group is represented as a single known deposit in the grade-tonnage model.

We estimate that known deposits of this tract contain about 24,600,000 metric tons of copper (table A1). Some deposits and estimated resources listed in the table are aggregated differently than done by Singer and others (2008), and some include resources added as a result of recent drilling in extensions to previously known ore zones.

Large open-pit mines have operated on four calc-alkaline porphyry Cu±Mo±Au deposits in this permissive tract: the Highland Valley Copper Cu-Mo deposit, the Gibraltar Cu-Mo deposit, the Brenda Cu-Mo deposit (now depleted), and the Kemess South Cu-Au deposit.

The Highland Valley Copper mine, operated by Teck Cominco, Inc., is the fifth largest open-pit mine in the world. The nearby Highmont East pit is mined for ore with higher Mo grades (Schroeter and others, 2007). In 2007, the projected mine life for the Highland Valley Copper mine was extended from 2013 to 2019 by expansion and deepening of the Valley pit, based on the recent discovery of extensions to the known deposit (DeGrace and others, 2008).

At the Gibraltar open-pit mine, operated by Taseko Mines, Ltd., recent drilling around the Pollyana and Granite Lake pits resulted in a 40-percent increase in reserves, which may extend mine life to more than 21 years (Schroeter and others, 2007).

The Kemess South open pit mine, operated by Northgate Minerals Corp. has been a major producer of copper and gold since 2000, and mining is expected to continue until late 2010 (DeGrace and others, 2008). The Kemess North deposit underwent a feasibility study in 2008, which indicated it would support a 12-yr mine life. However, environmental concerns may block its development for lack of a good place to put tailings.

Estimated copper resources of the Kwanika (central and south) deposit have increased by more than an order of magnitude on the basis of recent drilling. Singer and others (2008) listed an estimated 72,000 t of contained copper. According to tonnage-and-grade estimates reported on the Web site of Serengeti Resources, Inc., this increased to an estimated 587,000 t of contained copper in 2008-2009, and now stands at an estimated 917,000 t of contained copper in 2010, with associated molybdenum, gold, and silver as listed in table A3.

As reported by Schroeter and others (2006, 2007) and DeGrace and others (2008), major drilling projects recently have increased the known resources of the Schaft Creek, Kinaskan GJ, and Eaglehead deposits. At the Schaft Creek deposit, a new round of drilling by Copper Fox Metals increased the known resource and led to a new feasibility study and an Environmental Analysis. At the Kinaskan GJ deposit, Canadian Gold Hunter Corp. drilled 80 holes to better delineate the Donnelly Cu-Au zone, which is mostly covered. At the Eaglehead deposit, Carmax Explorations, Ltd., drilled to test IP anomalies along the trend of the Cu-Mo zone. In one hole, Carmax reported a 334-m interval grading 0.257 percent copper, 0.009 percent molybdenum, and 0.059 grams per metric ton gold. Conversely, at the Bronson Slope deposit, Skyline Gold Corp. drilled 4,000 m in 2007, but the estimate of contained copper decreased somewhat, relative to that reported in Singer and others (2008).

Prospects, Mineral Occurrences, and Related Deposit Types

Table A4 lists significant prospects in this tract. These are copper-bearing mineral occurrences with characteristics that we regard as being largely consistent with the descriptive models for porphyry copper deposits. According to the 2-km rule, 10 of these prospects are within the Highland Valley group, and 1 is within the Kinaskan group of ore bodies. Any resources discovered at these prospects will, therefore, be added to the known deposit, so these prospects were not counted as possible undiscovered deposits. The Go and Kid prospects are in the Copper Creek group of prospects. There is no known deposit in the Copper Creek group, so these two prospects potentially may represent one undiscovered deposit.

This tract contains 18 significant individual porphyry copper prospects, each of which potentially may represent an undiscovered deposit. The Dot and Turlight prospects are of rank 2, meaning that, although they have been estimated to contain less than 16,000 t copper, they are not known completely and may represent parts of larger porphyry copper systems. The Bear, Prince, and QC prospects are of rank 3, meaning that they have intercepts of at least 20 m of at least 0.2 percent copper. The AL, Bud North, Bud South, Clapper, Copper Ace, King Edward, MEX, Mineral Hill, Pil, Red, Sofia, TUV, and Woodjam prospects are of rank 4. They have significant intercepts of at least 0.1 percent copper, but without more than 20 m of at least 0.2 percent copper (to the best of our knowledge).

Another eight prospects in this tract have no assay data, or very low copper assays, and are, therefore, not considered significant. There are also eight prospects of deposit types that may be associated with porphyry copper systems. These include six subvolcanic Cu-Ag-Au (As-Sb) vein-type deposits, one occurrence of podiform Cu-Fe and Fe sulfides in quartz monzonite, and one molybdenite-bearing skarn.

Table A5. Readily available recent exploration activities for deposits and prospects in tract 003pCu2001 (CA01), Intermontane Island-Arc—British Columbia and Yukon Territory, Canada.

[This information was compiled from Schroeter and others (2006, 2007) and DeGrace and others (2008, 2009). Website addresses of "Operators" are listed in the table in appendix F; AGP, airborne geophysics; AMG, airborne magnetic; ARAD, airborne radiometrics; CD, core drilling; EN, environmental baseline studies, monitoring, or remediation work; FS, feasibility studies; G, geologic mapping; GC, geochemical sampling (rock, soil, silt, etc.); IP, Induced Polarization; MG, magnetic surveys; MS, metallurgical studies; PD, percussion drilling; PFS, prefeasibility studies; TR, trenching; m, meters;–, no data.]

Name	Rank	Operator	Activities	CD (m)
Bronson Slope	1	Skyline Gold Corp.	CD	4,700
Eaglehead	1	Carmax Explorations, Inc.	CD	7,176
Gibraltar	1	Taseko Mines, Ltd.	CD	59,259
GJ	1	Canadian Gold Hunter Corp.	G, CD	34,527
Highland Valley	1	Highland Valley Copper	CD	6,482
Highmont East	1	Highland Valley Copper	G, MS, FS, EN, CD	4,000
Kemess North	1	Northgate Minerals Corp.	TR, G, GC, IP, FS, EN, CD	19,004
Kemess South	1	Northgate Minerals Corp.	CD	2,936
Krain (Getty North)	1	Getty Copper, Inc.	G, MS	–
Kwanika (Central, South)	1	Serengeti Resources, Inc.	G, GC, IP, MS, CD	78,889
Pine	1	Cascadero Copper Corp.	G, CD	3,980
Schaft Creek	1	Copper Fox Minerals, Inc.	MS, EN, CD	3,161
Dot	2	Dot Resources, Ltd.	CD	–
Bear	3	Northgate Minerals Corp.	G, CD	5,786
Rateria	3	Happy Creek Minerals, Ltd.	CD	3,341
Copper Ace	4	Copper Ridge Explorations, Inc.	G, CD	4,110
Pil	4	Finlay Minerals, Ltd.	TR, G, GC, CD	7,443
Woodjam, (Megabuck)	4	Fjordland Exploration Inc/Cariboo Rose Resources, Ltd.	CD	25,722

Exploration History

Table A5 lists porphyry copper exploration projects in the tract that have been active in British Columbia at any time since 2004. The information in this table is from annual British Columbia Mining and Mineral Exploration Overviews by Schroeter and others (2006, 2007), and DeGrace and others (2008, 2009). During the time interval, total expenditures for mineral exploration in British Columbia rose from about $150 M in 2004 to a record $216 M in 2007.

From 2004 to 2007, about 27 km of core drilling was done in this permissive tract (003pCu2001). About 83 percent of this drilling was done in and around known deposits, while about 3 percent was done on prospects of ranks 2 and 3, and 14 percent was done on prospects of rank 4.

Two major projects were under consideration for development: Kemess North and Schaft Creek. A surge in recent drilling in the Kwanika group of deposits and prospects has led to a recent announcement of 129 Mt of ore, grading 0.3 percent copper in the South zone.

Major projects also were undertaken to increase and improve resource estimates for the following known deposits: Bronson Slope, Eaglehead, Gibraltar, Highland Valley Copper, Highmont East, Krain (Getty North), Kemess South, Kinaskan (GJ), and Kemess Pine.

Prospects near known groups of ore zones were explored at the Rateria prospect near the Highland Valley group, the Bysouth (Copper Ace South) prospect near Gibraltar, and at the MEX prospect in the Kemess group.

At the Woodjam prospect, nearly 26,000 m of core drilling was done to explore a porphyry copper system beneath a system of subvolcanic copper veins. Recent exploration projects also occurred at the Bear and Pil prospects, which are not near known porphyry copper deposits. The Bear prospect is in northwestern British Columbia, about 170 km north of Smithers. Previous exploration in the area was for subvolcanic

Cu-Ag-Au (As-Sb) veins. Now the Bear prospect is being explored for porphyry Cu-Mo by Imperial Metals. They reported a drill hole that returned a 179 m interval grading 0.3 percent copper and 0.083 percent molybdenum within a 379 m interval grading 0.25 percent copper and 0.054 percent molybdenum. Another drill hole returned 296 m of 0.27 percent copper and 0.059 percent molybdenum.

The Pil prospect is in the Toodoggone region of northern British Columbia. Previous exploration was mostly for polymetallic epithermal veins, but Cominco has explored large zones of pervasively altered rock for porphyry copper. Finlay Minerals, Ltd., now holds the Pil claims, where they have done geologic mapping, geochemical, IP, and magnetic surveys. They report widespread quartz veins and veinlets, containing various combinations of copper, gold, zinc, lead, and silver values, and disseminated sulfides, mostly pyrite and traces of copper minerals. Although the disseminated ore minerals do not approach ore-grade concentrations, they are regarded as an indication that a porphyry-copper system may exist beneath Pil South.

The Bear and Pil prospects are difficult to classify because they have both epithermal-vein and porphyry-Cu-style stockworks. Both alkaline and calc-alkaline igneous rocks are present at the Pil and Sofia prospects, and we found no description of igneous rocks at the Bear prospect. We tentatively classify these prospects as possible calc-alkaline porphyry Cu±Mo±Au systems. Their owners compare them to deposits of the Kemess cluster, which we classify as the Au-rich part of a calc-alkaline porphyry Cu±Mo±Au system of the subvolcanic subtype.

In addition to porphyry copper prospects listed in table A4, the Atty, Bud 522, Porphyry Pearl, STU, and Willa prospects, which we classify as subvolcanic Cu-Au (As-Sb) vein systems, have been classified alternatively as porphyry Cu±Mo±Au systems. The Kenallan prospect, which is classified as a Mo-Cu-Au skarn prospect, may indicate potential for an associated porphyry copper system.

Sources of Information

Principal sources of information used by the assessment team for delineation of 003pCu2001 are listed in table A6.

Grade and Tonnage Model Selection

As discussed in the Introduction and as shown in appendix G, a new grade and tonnage model for Canadian Cu±Mo±Au deposits was constructed due to the lower copper grades present in Canadian examples compared to all Singer and others (2008) grade and tonnage models.

Porphyry Cu±Mo±Au

The deposits and prospects of permissive tract 003pCu2001 (CA01), as well as those of tracts 003pCu2003 (CA03), 003pCu2004 (CA04), and 003pCu2005 (CA05), fit the descriptive model for porphyry Cu±Mo±Au deposits of British Columbia (Panteleyev, 1995) and the Yukon Territory (Panteleyev, 2005). After spatial grouping according to the 2-km rule, 38 known deposits of this subtype are present in the Canadian Cordillera (12 of which occur in this tract). In aggregate, when compared to the Singer and others (2008) grade and tonnage models, the Canadian Cu±Mo±Au deposits appear on average lowest in tonnage, lowest in copper grade, higher in molybdenum grade (except for model 21a), higher in gold grade (except for model 20c), and highest in Ag grade.

Statistical tests at a 1-percent screening level on these deposits (as a group) indicate that their molybdenum grade and gold grade distribution means are not statistically different from the general (models 17, 20c, and 21a combined) or Cu subtype (model 17) porphyry copper grade and tonnage models of Singer and others (2008) (see tables G2a and b). Neither is their tonnage distribution mean statistically different from the general, Cu subtype, or Cu-Au subtype (model 20c) porphyry copper grade and tonnage models of Singer and others (2008) (see tables G2a, b, and c). However, the copper grade distribution mean is statistically different from the general model and all the individual subtype models (see tables G2a, b, c, and d). For this reason, a grade and tonnage model for the porphyry Cu±Mo±Au deposits in tracts 003pCu2001 (CA01), 003pCu2003 (CA03), 003pCu2004 (CA04) and 003pCu2005 (CA05) was constructed.

The complete model, which contains data current through December 2009, is described in appendix G. For deposits in tract 003pCu2001 (CA01), the formal group according to the 2-km rule, and the name of the independent or groups used, along with the tonnages and grades used in the development of the grade and tonnage model, are listed in table A7.

Estimate of the Number of Undiscovered Deposits

Rationale for the Estimate

Given the availability of MINFILE records for known porphyry copper prospects in British Columbia and Yukon, and knowing that the MINFILE data sets are quite complete and up-to-date, our rationale for estimation of numbers of undiscovered deposits was to estimate numbers of undiscovered deposits based largely on the distributions and qualities of those prospects within each permissive tract. We estimated numbers of undiscovered porphyry Cu±Mo±Au deposits in tract 003pCu2001(CA01) at 90-, 50-, and 10-percent levels of subjective probability. We did this after a review of the geology of the tract, the distribution of known deposits of this type, and the number, distribution, and relative qualities of documented prospects. We considered the area of the tract, and

Table A6. Principal sources of information used for tract 003pCu2001 (CA01), Intermontane Island-Arc—British Columbia and Yukon Territory, Canada.

[NA, not applicable]

Theme	Name or Title	Scale	Citation
Geology	GeoFile 2005-1: Digital Geology Map of British Columbia - Whole Province	1:250,000	Massey and others (2005)
	Yukon Digital Geology	1:250,000	Gordey and Makepeace (1999)
	Geoscience Map 2005-3: Geology of British Columbia	1:1,000,000	Massey and others (2005)
	Terrane Map of the Canadian Cordillera	1:2,000,000	Wheeler and others (1991)
	Tectonic Assemblage Map of the Canadian Cordillera	1:2,000,000	Wheeler and McFeely (1991); Journeay and Williams (1995); GIS vector representation of Wheeler and McFeely (1991)
	Metamorphic Map of the Canadian Cordillera	1:2,000,000	Read and others (1991)
	YukonAge 2004: A database of isotopic-age determinations for rock units from Yukon Territory	NA	Breitsprecher and Mortensen (2004a)
	BC Age 2004A-1: A database of isotopic-age Determinations for Rock Units from British Columbia	NA	Breitsprecher and Mortensen (2004b)
	Radiometric Age Data Bank (RADB); National Geochronological Data Base (NGDB)	NA	Zartman and others (1976); Marshall (1993)
Mineral occurrences	Porphyry Deposits	NA	Sinclair (2007)
	Porphyry Copper Deposits of the World	NA	Singer and others (2008)
	Lode mineral deposits	NA	Nokleberg and others (1998)
	MINFILE (British Columbia) Mineral Occurrences Database	NA	MINFILE BC (2009)
	MINFILE (Yukon) Mineral Occurrences Database	NA	MINFILE YT (2009)
	Porphyry Deposits of the Canadian Cordillera	NA	CIM SV 15 (Sutherland Brown, 1976)
	Porphyry Deposits of the Northwestern Cordillera of North America	NA	CIM SV 46 (Schroeter, 1995)
Geochemistry	National Geochemical Reconnaissance (NGR) Stream Sediment, Lake Sediment and Water Geochemical Data Base	NA	Natural Resources Canada (2008c)
	Yukon Regional Geochemical Database 2003 - Stream sediment analyses	NA	Heon (2003)
Geophysics	Canadian Geodetic Information System – Gravity (2km grid) – Bouguer anomaly, free-air anomaly, isostatic residual anomaly, observed gravity, vertical gradient, and horizontal gradient	~1:2,000,000	Natural Resources Canada (2008b)
	Canadian Aeromagnetic Data Base – 1 km and 200 m grid – Residual total field	~1:1,000,000 and ~1:200,000	Natural Resources Canada (2008a)
	Canadian Aeromagnetic Data Base – 500 m grid – Residual total field, reduced to pole	~1:500,000	B.J. Drenth (unpub. data, 2009)
Exploration	BC Mines and Mineral Exploration Overviews, Yukon Mineral Deposits, Natural Resources Canada, Top 100 Exploration and Deposit Appraisal Projects, 2008, websites of Mineral Exploration companies	NA	Schroeter and others (2006, 2007), DeGrace and others (2008, 2009)

Table A7. Tonnages and grades of deposits of this tract used in tonnage and grade models for Canadian Cordilleran calc-alkaline porphyry Cu±Mo±Au for tract 003pCu2001 (CA01), Intermontane Island-Arc—British Columbia and Yukon Territory, Canada.

[Groups include all deposits and prospects with well-defined grades and tonnages that meet the 2-km rule. Independent indicates that a deposit is not in a group. Mt, million metric tons; %, percent; g/t, grams per metric ton; –, no data. Resource estimates available in 2008-2009 have not been updated to include information added to appendix F after 2009.]

GROUP	NAME	Ore (Mt)	Cu (%)	Mo (%)	Au (g/t)	Ag (g/t)
Independent	Brenda	227	0.16	0.039	0.013	0.63
Independent	Bronson Slope - Red Bluff	129.8	0.16	0.008	0.44	2.44
Gibraltar	Gibraltar (Total)	1,365	0.291	0.006	–	0.077
Independent	Gnat Lake (Gnat Pass)	30.4	0.39	–	–	–
Highland Valley	Highland Valley (Total)	3,180	0.392	0.013	0.005	0.77
Kemess	Kemess (Total)	948	0.153	–	0.221	–
Kinaskan	Kinaskan (Total)	247.2	0.337	–	0.372	0.634
Kwanika	Kwanika (Total)	211.2	0.278	–	0.269	–
Independent	Pine	70	0.15	–	0.57	–
Schaft Creek	Schaft Creek (Total)	1,484	0.255	0.021	0.169	–

Table A8. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract 003pCu2001 (CA01), Intermontane Island-Arc—British Columbia and Yukon Territory, Canada.

[Nxx, estimated number of deposits associated with the xxth percentile; N_{und}, expected number of undiscovered deposits; s, standard deviation; Cv%, coefficient of variance; N_{known}, number of known deposits in the tract that are included in the grade and tonnage model; N_{total}, total of expected number of deposits plus known deposits; area, area of permissive tract in square kilometers; density, deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer and Menzie, 2005). In cases where individual estimates were tallied in addition to the consensus estimate, individual estimates are listed.]

Consensus undiscovered deposit estimates					Summary statistics					Tract area (km^2)	Deposit density (N_{total}/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
3	5	14	14	14	6.9	4.3	62	12	18.9	175,250	0.00011

Estimated number of undiscovered deposits					
Estimator	N90	N50	N10	N05	N01
Individual 1	3	6	12	12	12
Individual 2	3	6	13	13	13
Individual 3	3	5	10	10	10
Individual 4	3	5	10	10	10
Individual 5	5	8	10	10	10
Individual 6	3	7	12	12	12
Individual 7	3	7	20	20	20
Consensus	3	5	14	14	14

we qualitatively observed spatial density-distribution patterns of known deposits. We also considered history, patterns of exploration, and patterns of exposure versus cover, as experienced by our Canadian coworkers. We were influenced to various degrees by geochemical anomalies for copper, indicated by data from regional stream-sediment surveys and geophysical data (Natural Resources Canada, 2008a, b, c).

Porphyry-Cu style stockworks of chalcopyrite-bearing veinlets have been discovered recently in areas that are mostly covered. This indicates that a limited number of undiscovered deposits probably remain. Future discoveries probably will be made in association with known prospects or in areas that are largely covered, either by younger sedimentary or volcanic deposits, or by surficial deposits, such as glacial till, colluvium or alluvium.

Based on these considerations, each member of the assessment team independently estimated the number of undiscovered porphyry copper deposits that might exist in this tract at three levels of subjective probability. Estimates by every team member were then compiled and revealed to the team. Reasons for high and low estimates were elicited and discussed. On the basis of these discussions, team members were allowed to adjust their estimates until consensus (agreement on an estimate acceptable to the group) was reached. Individual and consensus estimates are shown in table A8.

We calculated the spatial density of deposits by dividing the total number of known plus estimated undiscovered deposits (12+6.9=18.9 deposits) by the tract area of 175,250 km^2, yielding a density of 0.00011 deposits/ km^2. We compared this spatial density to spatial densities of porphyry copper deposits in an area-based deposit density model by Singer and others (2005, 2008). This showed that our estimated deposit density of about 0.00011 deposits per km^2 is just slightly below the slope of the central tendency for spatial densities of porphyry copper deposits from thoroughly documented control areas used in their model. Based on this comparison, and the mean estimate of about 7 undiscovered deposits in a tract with 12 known deposits, the assessment team believed exploration in the this tract to be fairly mature, with most of the undiscovered deposits probably being concealed or in remote areas.

Probabilistic Assessment Simulation Results

Undiscovered resources for the tract were modeled using the consensus estimates for numbers of undiscovered porphyry Cu±Mo±Au deposits and the grade and tonnage models presented in appendix G of this report for Canadian Cu±Mo±Au porphyry copper deposits as input for the EMINERS Monte Carlo simulator program (Root and others, 1992; Bawiec and Spanski, in press). Selected simulation results are reported in table A9. Results of the Monte Carlo simulation are presented as cumulative frequency plots (fig. A2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

Table A9. Results of Monte Carlo simulations of undiscovered resources for tract 003pCu2001 (CA01), Intermontane Island-Arc—British Columbia and Yukon Territory, Canada.

[Cu, copper; Mo, molybdenum; Au, gold; and Ag, silver; in metric tons; Rock, in million metric tons]

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
Cu	690,000	1,500,000	6,900,000	20,000,000	24,000,000	8,900,000	0.4	0.03
Mo	7,300	36,000	270,000	850,000	1,100,000	370,000	0.39	0.04
Au	13	54	350	1,000	1,300	460	0.4	0.04
Ag	0	46	1,800	7,800	11,000	3,100	0.36	0.09
Rock	230	520	2,700	7,100	8,600	3,300	0.42	0.03

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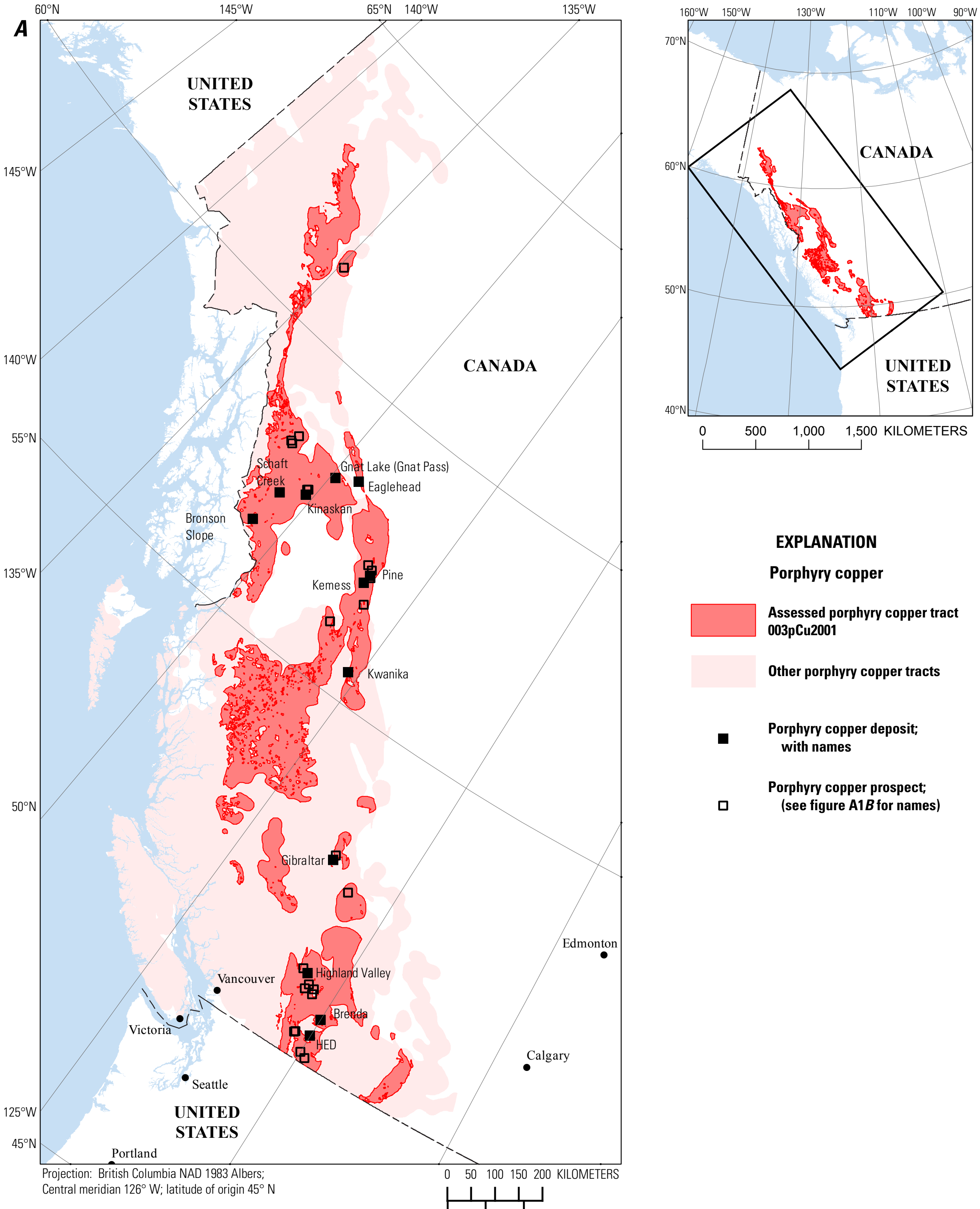
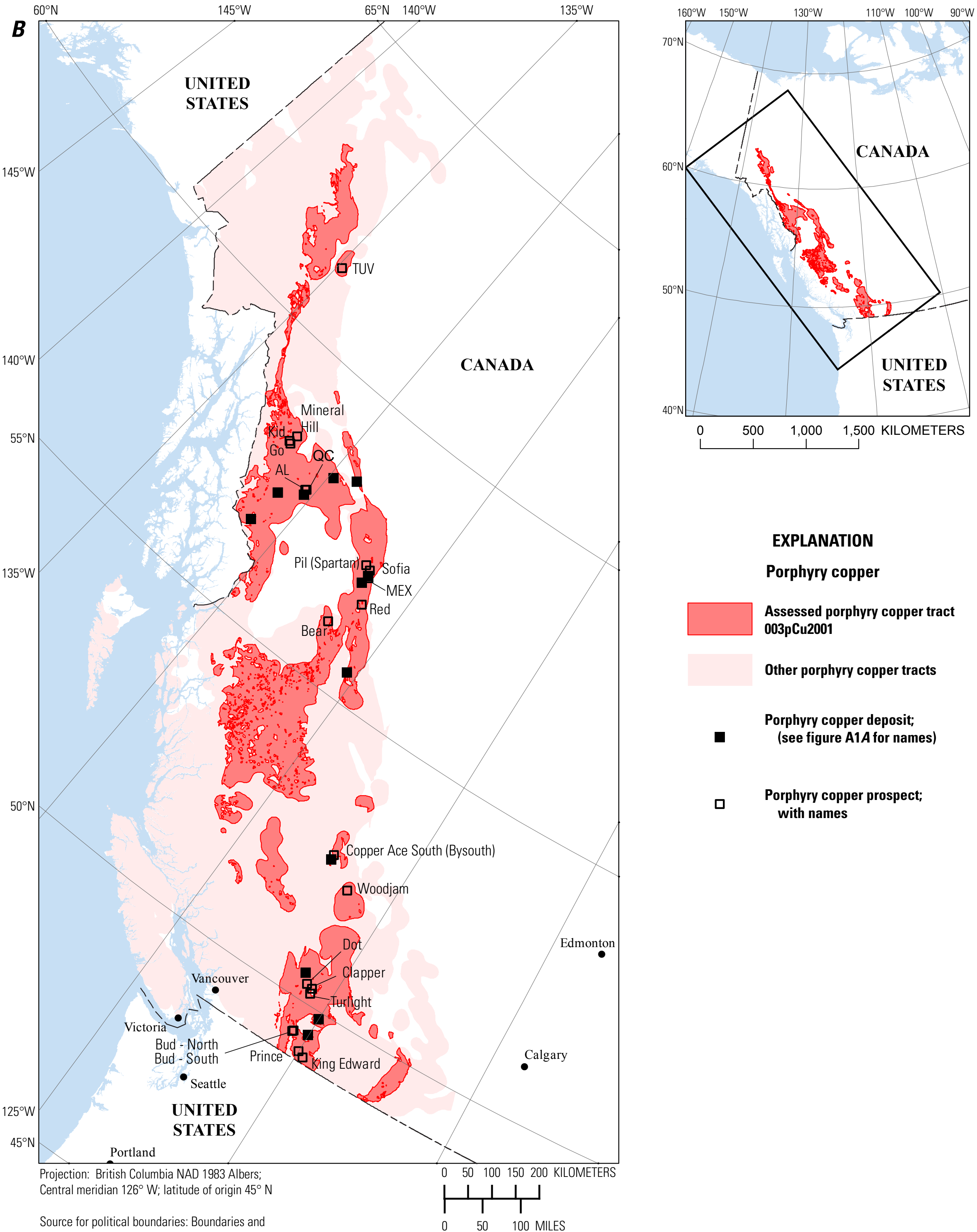


Projection: British Columbia NAD 1983 Albers;
Central meridian 126° W; latitude of origin 45° N

Source for political boundaries: Boundaries and
Sovereignty Encyclopedia,
U.S. Department of State, Office of the Geographer and Global Issues

Figure A1. Maps showing tract 003pCu2001 (CA01), Intermontane Island Arc—British Columbia and Yukon Territory, Canada. (*A*) Locations of known preaccretionary calc-alkaline porphyry Cu±Mo±Au deposits (named) and prospects (not named) in the Quesnel and Stikine accreted terranes, Canada. (*B*) Locations of significant calc-alkaline porphyry Cu±Mo±Au prospects (named) and deposits (not named) in the Quesnel and Stikine accreted terranes, Canada.



Projection: British Columbia NAD 1983 Albers;
Central meridian 126° W; latitude of origin 45° N

Source for political boundaries: Boundaries and Sovereignty Encyclopedia,
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Figure A1.—Continued

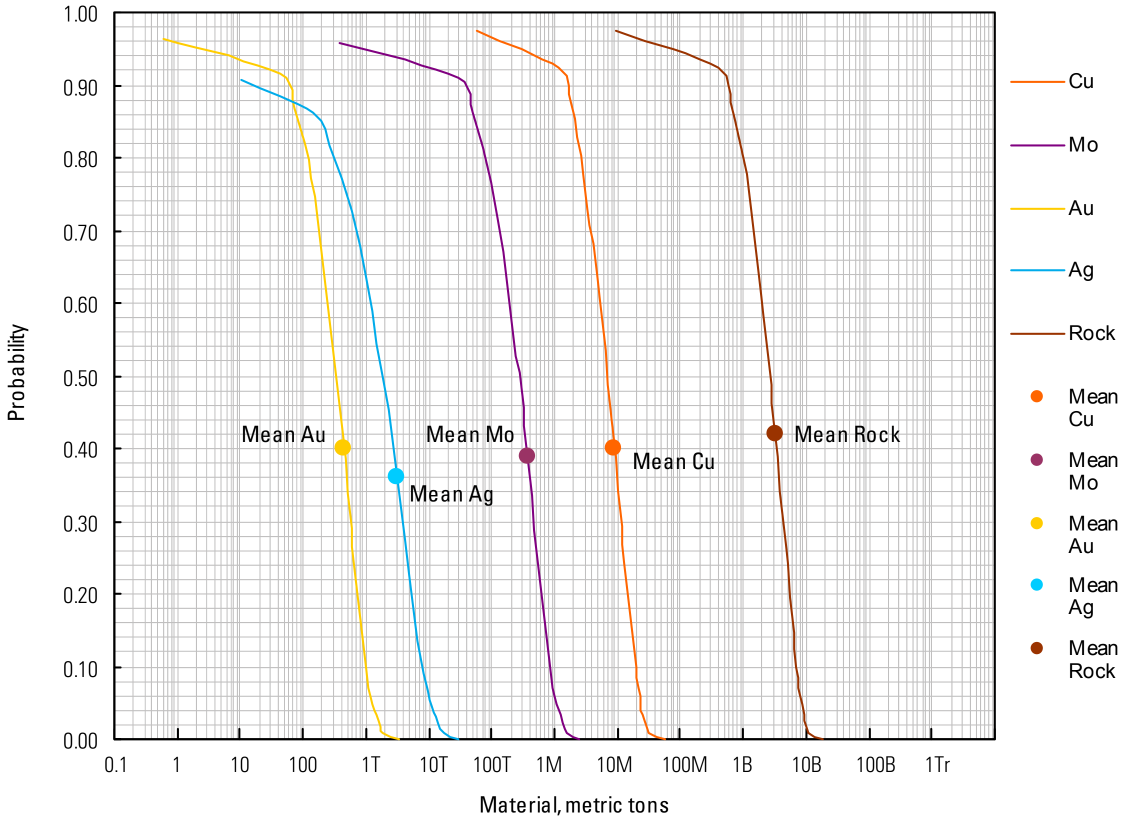

Figure A2. Cumulative frequency plot showing the results of a Monte Carlo computer simulation of undiscovered resources in Tract 003pCu2001 (CA01), Intermontane Island Arc—British Columbia and Yukon Territory, Canada. (T=thousands, M=millions, B=billions, Tr=trillions.)

Appendix B. Porphyry Copper Assessment for Tract 003pCu2002 (CA02), Intermontane Island-Arc Porphyry Cu-Au—British Columbia and Yukon Territory, Canada

By Mark J. Mihalasky[1] , Arthur A. Bookstrom[2] , Thomas P. Frost[3] , and Steve Ludington[4] , with contributions from James M. Logan[5] , Andre Panteleyev[6] , and Grant Abbott[7]

Deposit Type Assessed: Porphyry Copper, Copper-Gold (Cu-Au) Subtype

Descriptive model: Porphyry Cu-Au (Cox, 1986b), alkalic porphyry Cu-Au (Panteleyev, 1995)
Grade and tonnage model: Porphyry Cu-Au (Singer and others, 2008)
(Table B1 summarizes selected assessment results)

Table B1. Summary of selected resource-assessment results for tract 003pCu2002 (CA02), Intermontane Island-Arc Porphyry Cu-Au—British Columbia and Yukon Territory, Canada.

[km, kilometers; km^2, square kilometers; t, metric tons]

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known copper resources (t)	Mean estimate of undiscovered copper resources (t)	Median estimate of undiscovered copper resources (t)
2009	1	109,290	20,900,000	22,000,000	13,000,000

Location

This tract is in the Cordilleran region of western Canada. It includes the plateaus, hills, and valleys of the Intermontane belt, which is between the Coast Mountains and the inland Rocky Mountains in British Columbia and Yukon (figs. 1, B1).

Geologic Feature Assessed

Calc-alkaline igneous rocks of Middle Triassic to Late Jurassic age in preaccretionary island-arc terranes of the Intermontane belt.

Delineation of the Permissive Tract

Geologic Criteria

The fundamental units for delineation of this permissive tract are subduction-related magmatic arcs of Middle Triassic to Late Jurassic age that gave rise to the Quesnel and Stikine oceanic island-arc terranes before they were accreted to North America.

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Geologic units that define this permissive tract are preaccretionary alkaline igneous rocks of the Triassic-Jurassic Quesnel and Stikine terranes. Alkaline porphyry Cu-Au deposits and prospects that are preaccretionary with respect to Quesnellia and Stikinia range in age from Late Triassic to Early Jurassic (212 to 183 Ma). Map units that include rocks of this age-span also may include older or younger rocks, in this case rocks as old as earliest Middle Triassic (245 Ma) or as young as latest Late Jurassic (146 Ma).

Criteria for consideration of rock types as permissive for the occurrence of alkaline porphyry Cu-Au deposits are from descriptive models for porphyry copper and Cu-Au deposits by Cox (1986a, b) and for alkalic porphyry Cu-Au deposits of British Columbia by Panteleyev (1995). Phaneritic to porphyritic rock types associated with such deposits, and therefore considered permissive, are gabbro, diorite, monzodiorite, monzonite, syenite, and foidal syenite. Microcrystalline equivalents are microdiorite, micromonzonite, and microsyenite. Porphyro-aphanitic equivalents are porphyritic basalt, andesite, trachyandesite, latite, trachyte, and foidal trachyte porphyries. Pyroxene phenocrysts and a lack of primary quartz are particularly characteristic of alkaline volcanic rocks in Quesnellia and Stikinia, which are generally moderately potassic, according to Barrie (1993).

Although porphyry copper deposits commonly are associated with epizonal porphyritic intrusions, some are associated with predominantly phaneritic plutons, and some are associated with predominantly aphanitic subvolcanic intrusions and breccias. We therefore classify alkaline igneous rocks as permissive for alkaline porphyry Cu-Au deposits, whether they are plutonic, subvolcanic, volcanic, or volcaniclastic.

According to Monger and others (1991), much of Quesnellia is characterized by island-arc volcanic rocks of the Late Triassic to Early Jurassic Nicola Group in southern British Columbia and the coeval Takla Group in central to northern British Columbia. Alkaline volcanic strata of the Nicola and Takla groups are intruded by comagmatic alkaline plutons, some of which produced alkaline porphyry Cu-Au deposits, such as the Copper Mountain, Afton, Ajax, Mt. Polley, and Milligan deposits. Therefore, we classified alkaline volcanic rocks of the Nicola and Takla groups and associated alkaline intrusions as permissive for the occurrence of alkaline porphyry Cu-Au deposits in Quesnellia.

Similarly, much of Stikinia is characterized by island-arc volcanic rocks of the Late Triassic to Early Jurassic Takla and Stuhini groups (Monger and others, 1991). Such rocks in the Stikine terrane are separated from similar rocks of Quesnellia by the oceanic Cache Creek terrane (Nelson and Colpron, 2007). In the Takla and Stuhini groups of Stikinia, alkaline volcanic strata are intruded by comagmatic alkaline plutons, some of which produced alkaline porphyry Cu-Au deposits, such as the Galore Creek and Copper Canyon deposits. We therefore classified volcanic rocks of the Takla and Stuhini groups and their related intrusions as permissive for the occurrence of alkaline porphyry Cu-Au deposits in Stikinia.

Tract Delineation Process

We used digital tectonic-assemblage maps by Wheeler and McFeely (1991) and Journeay and Williams (1995) to identify the areas of the Quesnel and Stikine terranes. We identified permissive rocks of appropriate age and composition from descriptions of map units on digital geologic maps of British Columbia (Massey and others, 2005) and Yukon Territory (Gordey and Makepeace, 1999), and we recorded a reason for their inclusion or exclusion in the attribute table for the tract.

Digital geologic-map units that include polygons assigned to this permissive tract are listed in table B2 for intrusive and volcanic rocks. From each map unit listed, we selected only those sets of polygons that represent lithologic assemblages containing permissive rock types. Polygons representing rocks of ages or compositions that are permissive for more than one permissive tract are included in each of the permissive tracts for which they are considered permissive.

To define the area included in this permissive tract, we applied the following procedures. From descriptive information in the attribute tables that accompany the digital geologic maps of British Columbia and the Yukon Territory, we classified map units as permissive or nonpermissive (table B2). The map units classified as permissive for this tract represent the bedrock-surface expressions of mafic to felsic igneous rocks of alkaline affinity and of Middle Triassic to Late Jurassic age in the Quesnel and Stikine accreted island-arc terranes.

To polygons or groups of polygons that represent the bedrock-surface expression of permissive map units, we added a 10-km buffer to the mapped margins of permissive intrusions. This buffer expanded the area of the permissive tract to include all significant porphyry copper prospects and to include possible unexposed permissive rocks and porphyry copper deposits. Examples of permissive rock types below the mapped surface would include permissive plutons that expand downward, subsurface satellite cupolas of intrusions, and unmapped parts of plutons or porphyry copper occurrences that are covered by younger materials (such as basalt flows, glacial till, colluvium, alluvium, or basin-fill sediments less than 1 km thick) or are structurally covered. We also applied a 2-km buffer around the outer margins of polygons or groups of polygons representing permissive volcanic rocks, the thin edges of which might be discontinuous, covered, or otherwise not mapped at the scale of our source maps. For additional information on buffering, see the "Permissive Tracts for Porphyry Copper" section in the Introduction of this report.

After buffering, we examined aeromagnetic, gravimetric, and geochemical anomaly maps for evidence of unmapped permissive igneous rocks or hydrothermal systems (Natural Resources Canada, 2008a, b, c). Positive aeromagnetic and

Table B2. Map units that define tract 003pCu2002 (CA02), Intermontane Island-Arc Porphyry Cu-Au—British Columbia and Yukon Territory, Canada.

[Province, map unit, age range, and principal rock types from 1:250,000 scale digital geologic maps of British Columbia (Massey and others, 2005) and Yukon Territory (Gordey and Makepeace, 1999)]

Province	Map unit	Age range	Rock types
		a. Intrusive rocks	
BC	EJAC	Middle Jurassic	gabbroic to dioritic intrusive rocks
BC	EJdr	Early Jurassic	dioritic intrusive rocks
BC	EJE	Early Jurassic	dioritic intrusive rocks
BC	EJgb	Early Jurassic	gabbroic to dioritic intrusive rocks
BC	EJHCsy	Early Jurassic	syenitic to monzonitic intrusive rocks
BC	EJHD	Early Jurassic	syenitic to monzonitic intrusive rocks
BC	EJHdg	Early Jurassic	monzodioritic to gabbroic intrusive rocks
BC	EJHhy	Middle Jurassic	intrusive rocks, undivided
BC	EJHqm	Early Jurassic	quartz monzonitic to monzogranitic intrusive rocks
BC	EJMLM	Early Jurassic	monzodioritic to gabbroic intrusive rocks
BC	EJMy	Early Jurassic	quartz monzonitic intrusive rocks
BC	EJqd	Early Jurassic	quartz dioritic intrusive rocks
BC	EJqm	Early Jurassic	quartz monzonitic intrusive rocks
BC	EJRo	Early Jurassic	quartz monzonitic intrusive rocks
BC	EJSK	Early Jurassic	feldspar porphyritic intrusive rocks
BC	EJsy	Early Jurassic	syenitic to monzonitic intrusive rocks
BC	EJTCdg	Early Jurassic	monzodioritic to gabbroic intrusive rocks
BC	EJTpfp	Late Triassic to Early Jurassic	feldspar porphyritic intrusive rocks
BC	EJZ	Early Jurassic	dioritic intrusive rocks
BC	EMJdr	Early to Middle Jurassic	dioritic intrusive rocks
BC	Jdr	Jurassic	dioritic intrusive rocks
BC	Jsy	Jurassic	syenitic to monzonitic intrusive rocks
BC	LTrBgb	Late Triassic	gabbroic to dioritic intrusive rocks
BC	LTrdr	Late Triassic	dioritic intrusive rocks
BC	LTrgb	Late Triassic	gabbroic to dioritic intrusive rocks
BC	LTrJAgb	Late Triassic to Early Jurassic	gabbroic to dioritic intrusive rocks
BC	LTrJCsy	Late Triassic to Early Jurassic	syenitic to monzonitic intrusive rocks
BC	LTrJdr	Late Triassic to Early Jurassic	dioritic intrusive rocks
BC	LTrJgb	Late Triassic to Early Jurassic	gabbroic to dioritic intrusive rocks
BC	LTrJgd	Late Triassic to Early Jurassic	granodioritic intrusive rocks
BC	LTrJHgb	Late Triassic to Early Jurassic	gabbroic to dioritic intrusive rocks
BC	LTrJIC	Late Triassic to Early Jurassic	dioritic intrusive rocks
BC	LTrJIH	Late Triassic to Early Jurassic	dioritic intrusive rocks
BC	LTrJIP	Late Triassic to Early Jurassic	dioritic intrusive rocks
BC	LTrJIS	Late Triassic to Early Jurassic	dioritic intrusive rocks
BC	LTrJqm	Late Triassic to Early Jurassic	quartz monzonitic intrusive rocks
BC	LTrJsy	Late Triassic to Early Jurassic	syenitic to monzonitic intrusive rocks
BC	LTrJTe	Late Triassic to Early Jurassic	dioritic intrusive rocks
BC	LTrJTpgd	Late Triassic to Early Jurassic	granodioritic intrusive rocks
BC	LTrJTpT	Late Triassic to Early Jurassic	dioritic intrusive rocks
BC	LTrSMK	Late Triassic	dioritic intrusive rocks
BC	LTrStdg	Late Triassic	monzodioritic to gabbroic intrusive rocks
BC	MJD	Middle Jurassic	dioritic intrusive rocks
BC	MJfp	Middle Jurassic	feldspar porphyritic intrusive rocks
BC	MJKrsy	Middle Jurassic	syenitic to monzonitic intrusive rocks
BC	MJKx	Middle Jurassic	quartz monzonitic intrusive rocks
BC	MJNCgb	Middle Jurassic	gabbroic to dioritic intrusive rocks
BC	MJOlsy	Middle Jurassic	syenitic to monzonitic intrusive rocks
BC	MJPdr	Middle Jurassic	dioritic intrusive rocks
BC	MJPg	Middle Jurassic	intrusive rocks, undivided
BC	MJqm	Middle Jurassic	quartz monzonitic intrusive rocks
BC	MJSPsy	Middle Jurassic	syenitic to monzonitic intrusive rocks
BC	MJTSdg	Middle Jurassic	monzodioritic to gabbroic intrusive rocks
BC	MJTSdr	Middle Jurassic	dioritic intrusive rocks
BC	MJTSqm	Middle Jurassic	quartz monzonitic intrusive rocks
BC	MLTrdr	Middle Triassic to Late Triassic	dioritic intrusive rocks

Table B2. Map units that define tract 003pCu2002 (CA02), Intermontane Island-Arc Porphyry Cu-Au—British Columbia and Yukon Territory, Canada.—Continued

[Province, map unit, age range, and principal rock types from 1:250,000 scale digital geologic maps of British Columbia (Massey and others, 2005) and Yukon Territory (Gordey and Makepeace, 1999)]

Province	Map unit	Age range	Rock types
(**a.** Intrusive rocks)			
BC	MLTrqd	Middle Triassic to Late Triassic	quartz dioritic intrusive rocks
BC	MLTrStgb	Middle Triassic to Late Triassic	gabbroic to dioritic intrusive rocks
BC	Mzfp	Mesozoic	feldspar porphyritic intrusive rocks
BC	PJdr	Permian to Early Jurassic	dioritic intrusive rocks
BC	PTrMdr	Permian to Triassic	dioritic intrusive rocks
BC	Trdg	Triassic	monzodioritic to gabbroic intrusive rocks
BC	TrJB	Early Triassic to Late Jurassic	dioritic intrusive rocks
BC	TrJdr	Late Triassic to Early Jurassic	dioritic intrusive rocks
BC	TrJIk	Triassic to Jurassic	monzodioritic to gabbroic intrusive rocks
BC	TrJJ	Triassic to Jurassic	dioritic intrusive rocks
BC	TrJqm	Triassic to Jurassic	quartz monzonitic intrusive rocks
BC	TrJsy	Late Triassic to Early Jurassic	syenitic to monzonitic intrusive rocks
YT	EJgA (Minto pluton only)	Early Jurassic	granodiorite/diorite/monzodiorite
YT	EJyL	Early Jurassic	syenite
YT	MJgB	mid-Jurassic	monzodiorite/quartz monzodiorite/hornblendite/granite/granodiorite
YT	MJqB	mid-Jurassic	monzonite/syenite/granite/dykes
b. Volcanic rocks			
BC	EJTpN	Early Jurassic	coarse volcaniclastic and pyroclastic volcanic rocks
BC	EMJSPdb	Early to Middle Jurassic	diabase, basaltic subvolcanic rocks
BC	lJC	Early Jurassic	undivided volcanic rocks
BC	lJGvb	Lower Jurassic	basaltic volcanic rocks
BC	lJHCvc	Lower Jurassic	basaltic volcanic rocks
BC	lJHT	Early Jurassic	basaltic volcanic rocks
BC	lJNvc	Lower Jurassic	volcaniclastic rocks
BC	lJR	Lower Jurassic	basaltic volcanic rocks
BC	lJRE	Lower Jurassic	basaltic volcanic rocks
BC	lJTo	Lower Jurassic	basaltic volcanic rocks
BC	lJToMva	Lower Jurassic	andesitic volcanic rocks
BC	lmJHvb	Lower Jurassic to Middle Jurassic	basaltic volcanic rocks
BC	mJHvb	Middle Jurassic	basaltic volcanic rocks
BC	muTrTvb	Middle Triassic to Late Jurassic	basaltic volcanic rocks
BC	PTrva	Permian to Triassic	andesitic volcanic rocks
BC	TrJTvb	Triassic to Jurassic	basaltic volcanic rocks
BC	uTrJN	Upper Triassic to Lower Jurassic	undivided volcanic rocks
BC	uTrJNvc	Upper Triassic to Lower Jurassic	volcaniclastic rocks
BC	uTrJvk	Upper Triassic to Lower Jurassic	alkaline volcanic rocks
BC	uTrNE	Upper Triassic	basaltic volcanic rocks
BC	uTrNvb	Upper Triassic	basaltic volcanic rocks
BC	uTrS	Upper Triassic	undivided volcanic rocks
BC	uTrSva	Upper Triassic	andesitic volcanic rocks
BC	uTrSvb	Upper Triassic	basaltic volcanic rocks
BC	uTrTSa	Upper Triassic	basaltic volcanic rocks
BC	uTrTSh	Upper Triassic	undivided volcanic rocks
BC	uTrTSm	Late Triassic	basaltic volcanic rocks
BC	uTrTv	Upper Triassic	undivided volcanic rocks
BC	uTrTva	Late Triassic	andesitic volcanic rocks
BC	uTrTvb	Late Triassic	basaltic volcanic rocks
BC	uTrTW	Late Triassic	volcaniclastic rocks
YT	mTrJ	Middle Triassic	basalt/andesite/microdiorite/flows/ diamictite/gabbro/diorite
YT	uTrP	Upper Triassic	argillite/sandstone/basalt/flows/breccia/ tuff/schist/amphibolite/gneiss
YT	uTrP?	Upper Triassic	argillite/sandstone/basalt/flows/breccia/ tuff/schist/amphibolite/gneiss

gravity anomalies were interpreted as possible evidence for granitoid intrusions, or magnetite-bearing hydrothermal systems (see Clark, 1999, for discussion). Stream-sediment geochemical anomalies for copper associated with nickel were interpreted as evidence for mafic igneous rocks. Anomalies for copper not associated with nickel were interpreted as possible evidence of hydrothermal systems, some of which might be related to alkaline porphyry Cu-Au deposits. Where such anomalies extended beyond the margins of the buffered permissive map units, the tract was expanded to include them.

A smoothing routine was then applied to the buffered tract. A description of the smoothing routine is included in the metadata in appendix H. After smoothing, tract-buffer zones were trimmed along terrane-bounding faults. Finally, areas of post-accretionary intrusions (surrounded by a 250-meter buffer) were excluded from the tract-buffer zones. Such intrusions and their buffer zones are included in a permissive tract for a later time interval.

Geologic Interpretation

Mihalynuk and others (1994, p. 575) proposed that early Mesozoic Quesnellia and Stikinia "were joined through their northern ends as two adjacent arc festoons that faced south toward the Cache Creek ocean." Oceanic plateau remnants from the Tethyan realm collided with these island arcs during subduction of Cache Creek oceanic lithosphere, which may have underlain a part of the Panthalassic Ocean (the expansive global ocean that surrounded Pangaea from Late Precambrian to Jurassic time). Counterclockwise oroclinal rotation of the Stikine and Nisling terranes in the Late Triassic to Early Jurassic caused enclosure of the Cache Creek terrane. Rotation continued until these terranes collided with Quesnellia in the Middle Jurassic (Mihalynuk and others, 1994).

This oroclinal hypothesis explains why volcanic and intrusive rocks of the Quesnel and Stikine terranes are so similar that volcanic successions in both arcs are assigned to the Takla Group. In Yukon, similar porphyries occur in both terranes, and the line of Triassic-Jurassic intrusions clearly bends in an acute angle around the hinge of the orocline. Furthermore, the Quesnel and Stikine island-arc terranes contain both calc-alkaline porphyry Cu±Mo±Au deposits, as well as alkaline porphyry Cu-Au deposits.

In southern Quesnellia, calc-alkaline volcanic and plutonic rocks of the Nicola magmatic arc occur in the west, and calc-alkaline to alkaline rocks occur in the east. Inasmuch as alkalinity tends to increase with increasing depth of subduction, this indicates that the Nicola was a west-facing magmatic arc (Monger and others, 1991).

In Stikinia, the Schaft Creek calc-alkaline porphyry Cu±Mo±Au deposit is east of the Galore Creek alkaline porphyry Cu-Au deposit, which indicates that the Stikine magmatic arc now faces east. This is consistent with the hypothesis that the Stikine and Quesnel magmatic arcs originally faced westward, but oroclinal bending rotated Stikinia nearly 180 degrees counterclockwise, so that it now faces east.

Alkaline porphyry Cu-Au deposits of Quesnellia and Stikinia formed during a relatively short time interval that lasted from about 212 to 183 Ma and peaked at about 205±5 Ma (Mortensen and others, 1995). This suggests that these deposits formed in response to a plate-tectonic reorganization, such as oroclinal bending of the Quesnel, Yukon-Tanana, and Stikine terranes around the Cache Creek oceanic plate.

Accretion of Quesnellia and Stikinia to the continental margin occurred during Early to Middle Jurassic time (about 185±10 Ma). Murphy and others (1995) reported U-Pb age determinations for four intrusive bodies in the Kootenay arc that constrain the age of shortening of the sedimentary basin between Quesnellia and North America to late Early Jurassic (about 187 to 185 Ma) in southern British Columbia. Accretion probably progressed northward from southeastern Quesnellia, and then southward from northeastern Stikinia, as the orocline tightened. At the oroclinal crest, the Yukon-Tanana terrane became extremely deformed, sheared, and metamorphosed. Between the subparallel limbs of the fold, the oceanic Cache Creek terrane was reduced to a narrow belt of accretionary wedges. The resulting assemblage of the Quesnel, Yukon-Tanana, Stikine, and Cache Creek terranes forms the Intermontane superterrane.

Known Deposits

There are 12 known alkaline porphyry Cu-Au deposits in this tract, 7 of which include multiple ore bodies that are grouped according to the 2-km rule (table B3). These deposits fit descriptive models for porphyry Cu-Au deposits by Cox (1986b) and for alkalic porphyry Cu-Au deposits of British Columbia by Panteleyev (1995). However, most of the 33 individual ore bodies or deposits that make up these 12 grouped deposits cannot be classified according to Cox's gold-to-molybdenum ratio criterion (ppm Au / percent Mo > 30 in the ore zone) because they lack data for molybdenum and (or) contain less than 0.2 g/t gold.

Ore bodies generally are within or near alkaline igneous intrusions. Common types of ore-related intrusions are upward-branching tops of stocks, dike swarms, igneous intrusive breccias, volcanic-vent breccias, and hydrothermal-explosion breccias. Ore commonly occurs along or near igneous contacts—either internal contacts between intrusive phases, or external contacts between intrusions and host rocks. Ore also may occur along fracture zones in host rocks, which are commonly volcanic rocks that are generally comagmatic with ore-related intrusions. At the Williams Creek and Minto deposits, ore occurs in raft-like pendants, screens, and inclusions of mafic-alkaline metavolcanic and metasedimentary rocks in granodioritic post-ore plutons.

Most alkaline porphyry Cu-Au deposits are of the volcanic subtype, as described by McMillan (1991) and Panteleyev (1995). These are commonly associated with multiple high-level intrusions, such as small stocks, sills, dikes, and breccias. Alkaline porphyry Cu-Au deposits of the Galore Creek cluster apparently formed in the throat of a Late Triassic volcano (McMillan, 1991; Logan and Panteleyev, 1991). The Mount Polley deposit is transitional between the volcanic and classic stock-centered subtypes. It is above and around the upward-branching cupola of an alkaline composite stock (Fraser and others, 1995). The Afton deposits are within the composite Iron Mask batholith and may be of the plutonic subtype. However, the main deposit at Afton is hosted in brecciated, late-stage Cherry Creek micromonzonite and microsyenite (McMillan, 1991). It probably formed in association with late intrusions into the uppermost part of the batholith.

Table B3. Known alkaline porphyry Cu-Au deposits in tract 003pCu2002 (CA02), Intermontane Island-Arc Porphyry Cu-Au—British Columbia and Yukon Territory, Canada.

[Ma, million years; NA, not applicable; –, no data; Mt, million metric tons; t, metric ton; %, percent; g/t, gram per metric ton; Cu-Mo subtype, deposits that have Au/Mo ratios <3 or average Mo grades >0.03%; Cu-Au subtype, deposits that have Au/Mo ratios >30 or average Au grades >0.2 g/t. Contained Cu in metric tons is computed as (tonnage Mt x 1,000,000) x (percent Cu / 100); gs, coordinates of this site are used for the group location; *, estimated tonnage and grade from an unsubstantiated press release (not used in grade and tonnage model); **, partial tonnage and grade for a deposit that is known to be open to extension (not used in grade and tonnage model). For group aggregates: the latitude and longitude, subtype, and age is that of the deposit with the largest Cu resources; the Cu and Mo grades are tonnage-weighted averages calculated using the computed contained Cu and Mo as (t contained Cu or Mo / (Mt x 1,000,000)) x 100 (note that the computed contained Mo is not shown in this table); and the Au and Ag grades are a tonnage-weighted average calculated as g/t x Mt. For sources of age, tonnage, and grade information, see appendix F. Resource estimates are through 2009, but include updates for 2010 when available.]

Name	Latitude	Longitude	Subtype	Age (Ma)	Tonnage (Mt)	Cu (%)	Mo (%)	Au (g/t)	Ag (g/t)	Contained Cu (t)
AFTON-AJAX GROUP										
Afton (old pit + new block-cave)	50.661	-120.515	Cu-Au	202	96.8	1.014	–	0.709	3.099	981,958
Ajax area (JV) ^{gs}	50.608	-120.404	Cu-Au	205	523	0.288	0.001	0.185	–	1,510,000
Big Onion (Afton)	50.663	-120.437	Cu-Au	205	3.3	0.71	–	0.44	–	23,200
DM-Audra-Crescent	50.665	-120.486	NA	204	108.8	0.203	–	0.1	–	221,000
Galaxy	50.643	-120.423	Cu-Au	205	5.4	0.59	–	0.21	–	31,900
Iron Mask	50.655	-120.438	Cu-Au	205	2.4	0.84	–	0.4	–	20,200
Rainbow	50.636	-120.465	NA	205	30.7	0.528	–	0.119	–	162,000
GROUP AGGREGATE	50.608	-120.404	Cu-Au	205	770.4	0.382	–	0.238	–	2,950,000
AXE-PRIMER GROUP										
Axe ^{gs}	49.648	-120.526	NA	205	116.7	0.43	0.012	–	–	501,810
Axe - South zone (included in Axe)	49.641	-120.526	NA	205	37.2	0.48	–	–	–	179,000
Axe - West zone (included in Axe)	49.655	-120.542	NA	205	5.8	0.47	–	–	–	27,000
Primer - North zone	49.768	-120.475	NA	197	23	0.7	–	–	–	161,000
GROUP AGGREGATE	49.648	-120.526	NA	205	139.7	0.474	–	–	–	663,000
COPPER MTN GROUP										
Alabama	49.343	-120.519	NA	195	29	0.35	–	0.16	–	102,000
Copper Mountain ^{gs} (Similco-Ingerbelle)	49.339	-120.556	Cu-Au	204	455.7	0.38	0.001	0.26	3.056	1,730,000
GROUP AGGREGATE	49.339	-120.556	Cu-Au	204	484.7	0.378	–	0.254	–	1,830,000
POLLEY GROUP										
Lloyd-Nordik	52.571	-121.645	Cu-Au	205	7.2	0.31	–	0.243	–	22,300
Mount Polley ^{gs} (Cariboo-Bell)	52.554	-121.642	Cu-Au	205	204.8	0.324	–	0.31	–	664,000
GROUP AGGREGATE	52.554	-121.642	Cu-Au	205	212.5	0.323	–	0.307	–	686,000
LORRAINE GROUP										
Jajay ^{gs} (Lorraine)	55.928	-125.441	NA	178	31.9	0.66	–	0.17	4.7	210,000
Misty	55.916	-125.514	NA	178	3	0.6	–	–	–	18,000
TAM	55.972	-125.504	NA	178	7.2	0.55	–	–	4.11	39,600
GROUP AGGREGATE	55.928	-125.441	NA	178	42.2	0.635	–	–	–	268,000
GALORE CREEK GROUP										
Galore - C, J, NJ, SW, WFG	57.136	-131.456	Cu-Au	211	1,382.6	0.41	–	0.22	4.009	5,670,000
Galore – Central ^{gs} (included in Galore)	57.136	-131.456	Cu-Au	211	233.9	0.67	–	0.35	7	1,570,000
Galore - Copper Canyon	57.116	-131.347	Cu-Au	205	164.8	0.35	–	0.54	7.15	575,000
Galore - Junction (included in Galore)	57.141	-131.485	Cu-Au	211	101.6	0.548	–	0.325	3.758	567,000
Galore - North Junction (included in Galore)	57.144	-131.486	NA	211	7.7	1.5	–	–	–	116,000
Galore - Southwest (included in Galore)	57.123	-131.476	Cu-Au	211	170.6	0.349	–	0.633	2.485	595,000
Galore - West Fork Glacier (included in Galore)	57.114	-131.465	Cu-Au	211	60.8	0.495	–	0.348	4.916	301,000
GROUP AGGREGATE	57.136	-131.456	Cu-Au	211	1,547	0.404	–	0.254	4.344	6,250,000
SULPHURETS GROUP										
Kerr	56.468	-130.269	Cu-Au	196	225.3	0.41	–	0.23	–	924,000
Mitchell ^{gs}	56.531	-130.25	Cu-Au	196	1,509.9	0.18	–	0.64	–	2,720,000
Sulphurets Gold	56.504	-130.268	Cu-Au	196	87.3	0.27	–	0.72	–	236,000
GROUP AGGREGATE	56.531	-130.25	Cu-Au	196	1,822.5	0.213	–	0.593	–	3,880,000
INDIVIDUAL DEPOSITS										
Chuchi	55.263	-124.545	Cu-Au	183	50	0.21	–	0.21	–	105,000
Minto	62.609	-137.238	Cu-Au	200	34.4	1.187	–	0.323	4.165	408,000
Mount Milligan	55.124	-124.028	Cu-Au	183	602.7	0.192	–	0.349	–	1,160,000
Red Chris	57.7	-129.805	Cu-Au	204	714.8	0.356	–	0.281	1.5	2,540,000
Williams Creek (Carmacks)	62.349	-136.694	Cu-Au	200	15.5	1.01	–	0.483	4.62	157,000
INDIVIDUAL DEPOSITS TOTAL					1417.4					4,370,000
TRACT TOTAL					6,436.8					20,897,000
TRACT ROUNDED TOTAL					6,440					20,900,000

According to Panteleyev (1995), sodic, potassic and propylitic alteration-mineral assemblages are typical of alkaline porphyry Cu-Au deposits. Ore is commonly cospatial with central, early, high-temperature hydrothermal K-feldspar and biotite±anhydrite. Deep in the central zone, a sodic assemblage of albite±minerals such as epidote, pyrite, diopside, garnet, actinolite, scapolite, or prehnite may occur. Chalcopyrite and bornite grade outward to pyrite, and biotite grades outward to chlorite in an extensive propylitic zone. Phyllic assemblages of sericite and pyrite±siderite and clay minerals generally are lacking, but may be superimposed locally along fracture zones.

Most alkaline porphyry Cu-Au deposits do not have well-developed zones of supergene leaching or enrichment. Production of acidic groundwater required for supergene solution and transport of copper probably is hampered by a dominance of propylitic relative to phyllic alteration products. At Afton, however, there is a supergene-enriched zone that extends to an average depth of 500 m. According to Ney and others (1976) this supergene zone contains native copper, subordinate chalcocite, minor cuprite, tenorite, malachite, azurite and minor relict chalcopyrite. Supergene enrichment probably occurred at Afton during Early Eocene time, when the climate was warm and wet. The Afton supergene zone was then down-faulted and buried by Upper Eocene sediments, which protected it from later erosion.

Alkaline porphyry Cu-Au ore bodies generally are smaller than calc-alkaline porphyry Cu±Mo±Au ore bodies but have higher concentrations of both copper and gold. Furthermore, they commonly occur in groups of ore bodies that are less than 2 km from one another. Thus, the total tonnages of grouped Cu-Au ore bodies are similar to those of porphyry Cu±Mo±Au deposits. In table B3, we list the group name, followed by the ore-body name. The Afton-Ajax group contains 7 ore bodies, the Axe-Primer group 4, the Copper Mountain group 2, the Polley group 2, the Lorraine group 3, the Galore group 7, and the Sulphurets group 3. The Red Chris and Minto deposits are not known to be composite.

We estimate that known deposits of this tract contain about 20,900,000 metric tons of copper (table B1). Some of the tonnages and grades listed in tables B2 and B3 do not match those of Singer and others (2008). Some estimates listed here include recently published additions to known resources, and some may have been calculated using different cutoff grades. In some cases our grouping of ore bodies may differ from that done by Singer and others (2008).

In the Yukon Territory, the Minto deposit was put into production in 2007 by Sherwood Copper Corp. Meanwhile, drilling continued to expand the known resource of Area 2, which is between 100 and 500 m southeast of the planned limit of the Minto open-pit mine. About 168,000 t copper and 4,790 kg gold will be recovered during the projected 8-year life of the Minto mine. The Minto deposit is in the Yukon cataclastic belt of the Stikine terrane. The ore zones are in flat, tabular, raft-like inclusions of gneiss in a weakly foliated granodiorite batholith. The gneissic inclusions appear to have been partially assimilated by granodiorite, and locally the granodiorite contains ore minerals near the inclusions. Its ore-mineral assemblage (chalcopyrite, bornite, pyrite, and magnetite) is similar to those of alkaline porphyry Cu-Au deposits. However, it also has potassic and propylitic alteration assemblages, resembling those of alkaline Cu-Au deposits, and phyllic alteration that resembles that of calc-alkaline porphyry-Cu systems.

In southeastern British Columbia, the Mount Polley open-pit copper-gold mine was reopened in 2005 by Imperial Metals Corp. From 2005 through 2007 the mine produced 25,000 to 34,000 ton/yr of copper, 1,060 to 1,560 kg/yr gold, and 6,600 to 12,600 kg/yr silver (Schroeter and others, 2007; DeGrace and others, 2008). A test heap was operated in 2007 to test feasibility of leaching metal from the copper oxide cap above the sulfide zone in the Springer pit (DeGrace and others, 2009). According to Fraser and others (1995, p. 609), “The Mount Polley deposit is characterized by multiple intrusions that vary from diorite to crowded plagioclase porphyry to monzonite.” Abundant hydrothermal breccias, which occur on the margins and above plagioclase porphyry intrusions, contain the highest concentrations of copper and gold. In the core of the deposit, actinolite, biotite, and K-feldspar alteration assemblages contain a chalcopyrite-magnetite-bornite ore-mineral assemblage. This passes outward to a magnetite-pyrite-chalcopyrite assemblage. The core alteration assemblage is overprinted by discontinuous zones of calc-silicate minerals, which grade outward to a propylitic zone.

Prospects, Mineral Occurrences, and Related Deposit Types

Table B4 lists 87 significant prospects with characteristics of alkaline porphyry Cu-Au deposits in this permissive tract. Of these, 30 are within 6 groups of alkaline porphyry Cu-Au deposits and prospects. These 30 prospects are regarded as possible additions to the known resources of the respective 6 groups in which they occur. They are not counted as potential undiscovered deposits. Six of these prospects are in the Afton-Ajax group, 5 in the Axe-Primer group, 14 in the Copper Mountain group, 2 in the Galore Creek group, 2 in the Lorraine group, and 1 in the Sulphurets group. Additionally, 3 significant prospects (Peach-Melba, Peach 3, and Ann North) are within a single group (Lac La Heche) that does not include a known deposit.

There are 54 other significant alkaline porphyry Cu-Au prospects in this permissive tract. There are 3 rank-2 prospects, which are prospects on small but incompletely known ore bodies, which may belong to larger porphyry copper systems. There are 12 rank-3 prospects, each of which has at least one intercept of 20 m or more of at least 0.2 percent copper. Two of these are in the Lac La Heche group of prospects and can be counted only as one possible deposit. There are 39 rank-4 prospects, with samples containing more

Table B4. Significant alkalic porphyry Cu-Au prospects in tract 003pCu2002 (CA02), Intermontane Island-Arc Porphyry Cu-Au—British Columbia and Yukon Territory, Canada.

[Ma, million years; –, not applicable; Mt, million metric tons; t, metric ton; %, percent; g/t, gram per metric ton; gs, group site-coordinates of this site are used for the group location. For sources and additonal information about age, tonnage, grade and comments, see appendix F. For mineral name abbreviations under "Comments", see appendix F.]

Group	Name	Rank	Latitude	Longitude	Age (Ma)	Comments
Significant porphyry Cu prospects in groups of known porphyry Cu deposits and prospects						
Afton-Ajax	Crescent	2	50.6647	-120.4683	205	Past producer (Sinclair, 2007); 1.448 Mt ore @ 0.44% Cu (6,371t Cu)
Afton-Ajax	Kimberly	2	50.628	-120.354	205	Resource: 0.363 Mt ore @ 0.35% Cu (1,270t Cu)
Afton-Ajax	Python	2	50.644	-120.398	205	Resource: 0.848 Mt ore @ 0.875% Cu (7,420t Cu)
Afton-Ajax	Ace	3	50.585	-120.318	205	Intercept: 52 m, 0.38% Cu
Afton-Ajax	Admiral Dewy	4	50.589	-120.327	205	Intercept: 18 m, 0.19% Cu
Afton-Ajax	Fargo	4	50.584	-120.352	205	Intercept: 15 m, 0.223% Cu
Axe-Primer	Coke (Ketchan Creek)	3	49.746	-120.533	197	Intercept: 83 m, 0.23% Cu
Axe-Primer	Log	3	49.78	-120.554	197	Intercept: 86 m, 0.3786% Cu
Axe-Primer	Man	3	49.751	-120.483	197	Intercept: 120 m, 0.21% Cu, 0.92 g/t Au
Axe-Primer	Primer - South zone	3	49.756	-120.46	197	Intercept: 207 m, 0.25% Cu; 12 km NE of Axe
Axe-Primer	Rum (Ketchan)	4	49.734	-120.533	197	Intercept: 183 m, 0.16% Cu
Copper Mountain	Oriole	2	49.319	-120.514	199	Resource: 2.65 Mt ore @ 0.437% Cu (11,600t Cu)
Copper Mountain	Virginia (in Similco)	2	49.341	-120.512	200	Resource: 1.305 Mt ore @ 0.42% Cu (5,480t Cu)
Copper Mountain	Voigt	2	49.34	-120.501	193	Resource: 0.2204 Mt ore @ 1.21% Cu (2,670t Cu)
Copper Mountain	Duke of York	3	49.347	-120.544	204	Intercept: 90 m, 0.37% Cu
Copper Mountain	Friday Creek	3	49.3	-120.561	199	Intercept: 42.6 m, 0.28% Cu
Copper Mountain	Jennie Silkman	3	49.313	-120.508	204	Intercept: 66 m, 0.58% Cu
Copper Mountain	Deep Gulch	4	49.314	-120.557	199	Intercept: 15 m, 0.79% Cu, 1.37 g/t Au; in trenches and core holes
Copper Mountain	Fraser	4	49.332	-120.549	204	Intercept: interval unavailable; 2.8% Cu, 0.69 g/t Au, 34 g/t Ag
Copper Mountain	ILK	4	49.294	-120.556	204	Intercept: 6.1 m, 2.16% Cu
Copper Mountain	June Bug	4	49.345	-120.516	204	Intercept: interval unavailable; 1.5% Cu (grab sample; two shafts and old trenches
Copper Mountain	Marquis of Lorne	4	49.292	-120.514	199	Intercept: 5 m, 0.563% Cu, 3.6 g/t Ag
Copper Mountain	Oronoco	4	49.346	-120.536	200	Intercept: 12 m, 0.32% Cu
Copper Mountain	Ray	4	49.35	-120.549	200	Intercept: 261 m, 0.18% Cu
Copper Mountain	Reco	4	49.285	-120.545	204	Intercept: 1 m, 0.4% Cu, 0.88 g/t Au, 2.9 g/t Ag
Galore Ck	Galore - North Rim	4	57.151	-131.472	211	Intercept: 7 m, 2.37% Cu, 9.26 g/t Au
Galore Ck	Galore - Saddle	4	57.11	-131.432	211	Intercept: 12 m, 2.49% Cu, 3.98 g/t Au
Lorraine	All Alone Dome	4	55.939	-125.465	178	Intercept: 12 m, 0.13% Cu; net veins and migmatite (deep emplacement?)
Lorraine	Jeno	4	55.907	-125.421	175	Intercept: interval unavailable; 10% Cu, 14 g/t Au, 276 g/t Ag; 1.86 - 3.46 g/t Pd in podiform massive sulfides
Sulphurets	Bornite	4	56.486	-130.277	196	Intercept: interval unavailable; 1.86% Cu, 2.74 g/t Au; in epithermal veins and disseminations
Significant porphyry Cu prospects in a group with no known deposit						
Lac La Heche	Ann North	3	51.974	-121.313	200	Intercept: 107.3 m, 0.29% Cu, 0.33 g/t Au
Lac La Heche	Peach-Melba	3	51.981	-121.337	214	Intercept: 77.4 m, 0.23% Cu, 0.23 g/t Au
Lac La Heche	Peach 3	4	51.961	-121.295	214	Intercept: 1 m, 1% Cu, 0.07 g/t Au
Significant individual porphyry Cu prospects						
–	COL	2	55.249	-124.759	183	Resource: 1.8 Mt ore @ 0.6% Cu (10,800t Cu)
–	G.E.	2	49.486	-120.458	197	Resource: 0.54 Mt ore @ 0.27% Cu (1,460t Cu)
–	Joker	2	50.575	-120.3	205	Resource: 0.068 Mt ore @ 0.6% Cu (408t Cu)
–	ATO (Rhondah)	3	55.913	-125.292	183	Intercept: 55 m, 0.51% Cu
–	Dick Creek	3	58.234	-131.733	214	Intercept: 52 m, 0.8% Cu, 0.73 g/t Au
–	Eagle	3	55.184	-124.863	183	Intercept: 27.3 m, 0.87% Cu, 0.32 g/t Au, 3.85 g/t Ag
–	Grizzly	3	57.129	-130.639	211	Intercept: 38 m, 0.74% Cu, 1.1 g/t Au in altered rocks (drilling failed to extend)
–	Lucky	3	49.544	-120.433	214	Intercept: 24.4 m, 0.42% Cu

Table B4. Significant alkalic porphyry Cu-Au prospects in tract 003pCu2002 (CA02), Intermontane Island-Arc Porphyry Cu-Au—British Columbia and Yukon Territory, Canada.—Continued

[Ma, million years; –, not applicable; Mt, million metric tons; t, metric ton; %, percent; g/t, gram per metric ton; gs, group site-coordinates of this site are used for the group location. For sources and additonal information about age, tonnage, grade and comments, see appendix F. For mineral name abbreviations under "Comments", see appendix F.]

Group	Name	Rank	Latitude	Longitude	Age (Ma)	Comments
			(Significant individual porphyry Cu prospects)			
–	Mouse Mountain	3	53.05	-122.321	205	Intercept: 24.3 m, 0.333% Cu, 0.03 g/t Au
–	Murphy Lake	3	52.029	-121.264	187	Intercept: 41.7 m, 0.41% Cu
–	Pine (Axe-Primer)	3	49.698	-120.598	200	Intercept: 48.8 m, 0.2% Cu
–	Redgold (Shiko)	3	52.464	-121.484	196	Intercept: 28.5 m, 0.39% Cu, 1 g/t Au; IP survey and 2295 m in 11 core holes
–	Siwash	3	49.822	-120.394	197	Intercept: 21.3 m, 0.42% Cu
–	Tim #1	3	51.937	-121.249	214	Intercept: 42.7 m, 2.76% Cu, 0.6 g/t Au
–	Wood GP	3	50.614	-120.531	214	Intercept: 275 m, 0.3% Cu in one drill hole, but several others with little Cu
–	Aplite Creek	4	55.324	-124.879	183	Intercept: 6 m, 0.098% Cu, 6.4 g/t Au
–	Auddie	4	55.74	-125.43	200	Intercept: interval unavailable; 0.213% Cu; encouraging results at early stage of exploration
–	Aurizon Gold zone	4	51.958	-121.286	214	Intercept: 4 m, 0.22% Cu, 11.4 g/t Au
–	Big Bulk	4	55.663	-129.349	188	Intercept: 16 m, 1.22% Cu
–	Big Kidd	4	49.943	-120.596	214	Intercept: 14 m, 0.9% Cu, 0.141 g/t Au, 13.66 g/t Ag
–	Blue Jay	4	49.981	-120.599	200	Intercept: 97.6 m, 0.19% Cu, 0.204 g/t Au
–	Camp	4	55.083	-124.585	183	Intercept: 127 m, 0.18% Cu
–	Clay	4	51.88	-120.922	200	Intercept: interval unavailable; 25% Cu, 102.9 g/t Au
–	Copper Creek	4	58.219	-131.706	199	Intercept: interval unavailable; 1.04% Cu, 3.4 g/t Au, 30.8 g/t Ag
–	Discovery	4	55.828	-125.303	183	Intercept: interval unavailable; 12.54% Cu
–	Dorothy	4	55.885	-125.338	183	Intercept: 15 m, 0.75% Cu
–	Falcon	4	55.204	-125.095	183	Intercept: interval unavailable; 0.44% Cu, 0.013% Mo
–	Grey Mask	4	50.581	-120.298	205	Intercept: 2.35 m, 1.1% Cu, 3.28 g/t Au
–	Hat	4	56.74	-126.327	200	Intercept: 3 m, 0.93% Cu, 0.4 g/t Au
–	Heath #1	4	55.271	-125.163	183	Intercept: interval unavailable; 0.76% Cu, 4.97 g/t Au, 1419.4 g/t Ag
–	Hilltop	4	50.748	-120.632	205	Intercept: 45 m, 0.16% Cu
–	Hoey	4	58.19	-131.577	218	Intercept: interval unavailable; 0.17% Cu, 6.1 g/t Au, 5.1 g/t Ag; three areas of geochemical and VLF anomalies
–	HU	4	58.345	-130.191	200	Intercept: interval unavailable; 1.14% Cu, 1.3 g/t Au; geologic map, soil geochem, IP, mag
–	Katie	4	49.148	-117.337	188	Intercept: 6 m, 0.24% Cu, 0.2 g/t Au
–	MacKenzie	4	55.831	-125.333	183	Intercept: 1.6 m, 2.68% Cu, 0.4 g/t Au, 16.1 g/t Ag
–	Maxine	4	50.758	-120.658	205	Intercept: interval unavailable; 4.1% Cu, 74.4 g/t Ag
–	MFJ	4	57.796	-129.873	198	Intercept: 15 m, 1.07% Cu, 0.04 g/t Au
–	Miner	4	49.476	-120.474	214	Intercept: interval unavailable; 0.295% Cu
–	Miracle	4	51.947	-121.311	214	Intercept: 6 m, 1.38% Cu, 5.1 g/t Au
–	Moss	4	55.137	-124.531	183	Intercept: 56 m, 0.12% Cu, 1.6 g/t Au
–	Osilinka (Cat)	4	56.063	-125.36	200	Intercept: 5.15 m, 5.7% Cu, 3.1 g/t Au, 4.6 g/t Ag; in 97 m, 0.12% Cu.
–	Phil	4	50.554	-120.299	205	Intercept: 8 m, 0.17% Cu, 0.5 g/t Au
–	Pip	4	49.645	-120.513	197	Intercept: 3.05 m, 0.185% Cu
–	Rats	4	49.561	-120.466	214	Intercept: 51.8 m, 0.17% Cu, 3.4 g/t Ag
–	Rayfield Copper	4	51.313	-121.089	173	Intercept: 33.9 m, 0.18% Cu
–	Skook	4	55.2	-124.528	183	Intercept: 1 m, 0.49% Cu, 0.022 g/t Au, 11.7 g/t Ag
–	SRM	4	55.234	-124.523	183	Intercept: 5 m, 0.7% Cu, 0.97 g/t Au
–	Star	4	49.449	-117.364	176	Intercept: interval unavailable; 0.0944% Cu, 0.66 g/t Au
–	TAK	4	55.704	-125.246	183	Intercept: interval unavailable; 1.53% Cu, 1.8 g/t Au, 40.5 g/t Ag
–	Thalia	4	49.837	-120.567	197	Intercept: 32 m, 0.14% Cu
–	Timber	4	55.831	-125.323	183	Intercept: interval unavailable; 0.44% Cu, 2.385 g/t Au, 64.5 g/t Ag
–	Vector	4	55.202	-124.889	183	Intercept: 17.9 m, 0.82% Cu, 0.47 g/t Au, 4.11 g/t Ag
–	Wolverine	4	58.12	-131.678	199	Intercept: 8 m, 1.8% Cu, 94 g/t Au
–	Worldstock	4	51.531	-120.287	214	Intercept: interval unavailable; 0.78% Cu; EM and mag amomalies

than 0.1 percent of Cu but less than 20 m of 0.2 percent copper.

In addition to the 87 significant alkaline porphyry Cu-Au prospects in this tract, there are also at least 14 prospects and showings that are not primarily porphyry copper prospects but could be associated with alkaline porphyry Cu-Au systems (see appendix F). There are 3 prospects on Au veins, 1 on Au-Ag veins, 1 on Au-Cu veins, and 1 on Cu-Fe-Au-Ag veins. There also are prospects on Fe-Au-, Au-, and Au-Ag-bearing skarns and 1 on an Au-Ag-Cu-bearing roof pendant.

Exploration History

During the 1980s, porphyry Cu-Au deposits became very profitable because of high gold prices. In British Columbia, the discovery of the Mount Milligan porphyry Cu-Au deposit also spurred exploration for more porphyry Cu-Au deposits (McMillan and others, 1995).

Table B5 summarizes recent exploration activities on alkaline porphyry Cu-Au prospects in British Columbia from 2004 to 2007. The information in this table is from annual British Columbia Mining and Mineral Exploration Overviews by Schroeter and others (2006, 2007), and DeGrace and others (2008, 2009). During this time interval total expenditures for mineral exploration in British Columbia rose from about $150 M in 2004 to a record $216 M in 2007.

In this permissive tract, about 430 km of core drilling was done from 2004 to 2007. About 96 percent of this drilling was done in and around previously known deposits or groups of known ore zones, while 3 percent was done on rank 3 prospects, and 1 percent was done on rank 4 prospects.

The New Afton, Copper Mountain, and Lorraine-Jajay projects are under consideration to be reopened, and the Red Chris deposit, Galore Creek, and Sulphurets groups of ore bodies are under consideration for development.

At the New Afton project, New Gold, Inc., completed about 30,000 m of drilling in support of a feasibility study for an underground block-caving mine that may be developed soon. The Afton deposit is at the northwestern edge of the northwest-elongate Iron Mask batholith, which is a composite alkaline intrusion of Early Jurassic age, hosted by mafic volcanic rocks of the Nicola Group (Lang and Stanley, 1995). According to Stakiw (2004) and the mine operators (New Gold Inc., 2011), the top of the New Afton deposit is directly beneath the Afton open pit, which was mined from 1977 to 1987. The underground deposit is much larger than the upper part of the deposit, which was mined from the open pit. At a cutoff grade of 0.5 percent copper, the New Afton deposit is about 1 km long and extends from the bottom of the pit, at an elevation of about 400 m above sea level, to about 350 m below sea level. Other past-producers in the Iron Mask batholith include the Crescent, Pothook, and DM ore bodies, which were mined from open pits. These ore bodies, and the grounds between and around them, are currently being explored as a joint venture between the Abacus Mining and Exploration Corp. and New Gold, Inc.

At Copper Mountain (Similco-Ingerbelle), which has been on standby since 1996, Copper Mountain Mining Corp. did a major drilling campaign in 2007. The purpose of this drilling was to confirm and expand known resources by exploring the saddle zones between pits 1, 2, and 3 in preparation for a new feasibility study (DeGrace and others, 2008).

At Lorraine-Jajay, Teck Cominco, Ltd., drilled 17 holes in 2005. The purpose of this drilling was to explore for additional resources, which might support reopening the mine.

In the Galore Creek-Copper Canyon area, NovaGold Resources expanded the previously known resources and discovered additional zones of mineralized rocks (Schroeter and others, 2006). East of a proposed pit, they found the new Bountiful zone at depth (Schroeter and others, 2007). In 2007 they drilled on the Butte zone in the Copper Canyon area. They also announced a 50-50 joint venture with Teck Cominco to form the Galore Creek Mining Corporation (DeGrace and others, 2008). According to Enns and others (1995), the Galore Creek alkaline porphyry Cu-Au deposits are hosted by alkaline volcanic rocks, related syenitic intrusions, and breccias of Upper Triassic to Lower Jurassic age. The Central, Southwest, and Junction zones are the most important of 12 identified Cu-Au ore zones.

In the Sulphurets area, Seabridge Gold, Inc., drilled 15,000 m in 2007 at the Mitchell, Kerr, and Sulphurets Gold deposits. This drilling was done to upgrade and increase the resource estimates, to bring the Kerr and Sulphurets data into compliance with NI 43-101 requirements, and to support a preliminary economic assessment.

At Mount Milligan, Terrane Metals Corp. did a preliminary economic assessment based on a proposed annual production of 44,000 t/yr copper and 7,748 kg/yr gold for the first 6 years of a 14.5-year mine life. They also drilled 11,444 m in support of a feasibility study, scheduled for completion in 2008 (DeGrace and others, 2008). According to Sketchley and others (1995) the Main deposit is centered on the intersection of a monzonitic stock and a protruding dike. The Southern Star deposit is around another nearby monzonitic stock. The core of the deposit is in a biotite-rich subzone of the potassic zone, which is surrounded by a propylitic zone.

At the Red Chris deposit, bcMetals Corp. did a feasibility study in 2005, which indicated potential for a production rate of 47,000 t/yr copper and 2,200 kg/yr gold during a 25-year mine life (Schroeter and others, 2007). At the end of 2006, Imperial Metals Corp. acquired the deposit. Confirmation drilling was done on the Main and East zones, and exploration drilling was done on the nearby Gully zone. Six deep holes were drilled, one of which intersected 1,024 m grading 1.01 percent copper, 1.26 g/t gold, and 3.92 g/t silver. This indicates a high-grade zone that extends 700 m below the current pit design (DeGrace and others, 2008). McMillan (1991) classified the Red Chris deposit as an alkaline porphyry Cu-Au deposit, but it has mixed characteristics. Its associated igneous

Table B5. Readily available recent exploration activities for deposits and prospects in tract 003pCu2002. (CA02), Intermontane Island-Arc Porphyry Cu-Au—British Columbia and Yukon Territory, Canada.

[This information was compiled from Schroeter and others (2006, 2007) and DeGrace and others (2008, 2009). Web-site addresses of "Operators" are listed in the table in appendix F; AGP, airborne geophysics; AMG, airborne magnetic; ARAD, airborne radiometrics; CD, core drilling; EN, environmental baseline studies, monitoring, or remediation work; FS, feasibility studies; G, geologic mapping; GC, geochemical sampling (rock, soil, silt, or other); IP, Induced Polarization; MG, magnetic surveys; PD, percussion drilling; PFS, pre-feasibility studies; TR, trenching; m, meters.]

Name	Rank	Operator	Activities	CD (m)
Ajax JV	1	JV: Abacus Mining and Exploration Corp./New Gold, Inc.	CD	69,940
Axe, West	1	Westar Resources Corp., Bearclaw Capital Corp.	CD	1,700
Copper Canyon	1	NovaGold Resources, Inc.	CD	4,990
Galaxy	1	Discovery Corp. Enterprises, Inc.	G, GC, CD	286
Galore Creek	1	NovaGold Resources, Inc.	FS, EN	89,409
Jajay	1	Teck Cominco, Ltd.	G, GC, IP, CD	7,300
JTM, Misty, Slide	1	Teck Cominco, Ltd.	G, GC, CD	3,070
Kerr (KSM)	1	Seabridge Gold, Inc..	CD	9,129
Lloyd-Nordik	1	Valley High Ventures, Ltd.	CD	5,600
Man/Prime	1	Candorado Operating Co., Ltd.	CD, IP	2,209
Misty	1	Teck Cominco, Ltd.	IP, MG, CD	1,200
Mitchell (KSM)	1	Seabridge Gold, Inc.	CD	15,000
Mount Milligan	1	Terrane Metals Corp.	CD	8,500
Mount Polley	1	Imperial Metals, Corp.	TR, G, GC, PFS, FS, CD, PD, FS	78,693
New Afton	1	New Gold, Inc.	AGP, CD	50,000
Red Chris	1	Imperial Metals Corp.	CD	4,675
Similco-Ingerbelle	1	Copper Mountain Mining Corp.	CD	60,000
Ann North	3	GWR Resources, Inc.	TR, AGP	7,788
Friday Creek (Princeton)	3	Anglo Canadian uranium Corp.	CD	1,500
Mouse Mountain	3	Richfield Ventures Corp., Oak Point Capital Corp.	TR, G, GC, IP, FS, EN, CD	2,842
Murphy Lake	3	Candorado Operating Co., Ltd.	GC, IP, ARAD, AMG, CD	800
All Alone Dome	4	Teck Cominco, Ltd.	GC, IP, CD	1,000
Copper Creek	4	Firesteel Resources	CD	1,524
Osilinka	4	Lysander Minerals Corp.	TR	1,447
Redton (TAK)	4	Geoinformatics Exploration, Inc.	CD	2,060

rocks include mildly alkaline monzodiorite and monzonite, as well as calc-alkaline quartz diorite, quartz monzonite, and granodiorite. Its high gold values and lack of molybdenite are characteristic of alkaline Cu-Au deposits, but its phyllic alteration is more typical of calc-alkaline porphyry copper deposits (Newell and Peatfield, 1995).

At the Williams Creek (or Carmacks) deposit, Western Copper Corp. did engineering studies to plan development of an open-pit mine with associated heap-leach and solvent-extraction/electrowinning facilities. The Williams Creek deposit is about 50 km southeast of the Minto deposit and is in the Yukon cataclastic belt of the Stikine terrane. The ore bodies at Williams Creek are in raft-like tabular inclusions of mafic gneiss in post-ore granodiorite. The Williams Creek deposit is, therefore, interpreted to be a volcanic-style alkaline porphyry Cu-Au deposit that underwent dynamothermal metamorphism, and was then intruded by and incorporated into a post-ore granodiorite batholith. After uplift and exposure, the upper part of the deposit was oxidized, and the oxide zone is preserved, because most of the deposit was not glaciated.

Recent exploration activities also were recorded at four prospects that are not parts of known deposits or groups of ore bodies and prospects. The Friday Creek prospect, near

Princeton, British Columbia, was explored by Anglo Canadian Uranium Corp. The Mouse Mountain prospect was explored by Richfield Ventures Corp. and Oak Point Capital Corp. The Murphy Lake prospect was explored by Candorado Operating Co., and the Osilinka prospect was explored by Lysander Minerals Corp.

Sources of Information

Principal sources of information used by the assessment team for delineation of 003pCu2002 are listed in table B6.

Grade and Tonnage Model Selection

Alkaline Porphyry Cu-Au

The deposits of permissive tract 003pCu2002 (CA02) fit the descriptive model for alkalic porphyry Cu-Au of Panteleyev (1995). For the statistical testing against world-wide Cu-Au porphyries, the grade and tonnage reported by Singer and others (2008) for porphyry Cu-Au (20c) were used as that is the most complete dataset we are aware of for similar deposits. Following the spatial grouping exercise discussed in the Introduction, 12 deposits are present in tract 003pCu2002 (CA02) (table B7).

Students t-test at a 1-percent screening level on deposits from the tract indicate that they are not distinguishable in tonnage or grade from the Cu-Au model (20c) of Singer and others (2008). For this reason, we used the model 20c tonnage and grade distributions to estimate the endowment of undiscovered porphyry Cu-Au deposits for tract CA02.

Estimate of the Number of Undiscovered Deposits

Rationale for the Estimate

Our rationale for estimation of undiscovered alkaline porphyry Cu-Au deposits in this tract was based on the

Table B6. Principal sources of information used for tract 003pCu2002 (CA02), Intermontane Island-Arc Porphyry Cu-Au—British Columbia and Yukon Territory, Canada.

[NA, not applicable]

Theme	Name or title	Scale	Citation
Geology	GeoFile 2005-1: Digital Geology Map of British Columbia-Whole Province	1:250,000	Massey and others (2005)
	Yukon Digital Geology	1:250,000	Gordey and Makepeace (1999)
	Geoscience Map 2005-3: Geology of British Columbia	1:1,000,000	Massey and others (2005)
	Terrane Map of the Canadian Cordillera	1:2,000,000	Wheeler and others (1991)
	Tectonic Assemblage Map of the Canadian Cordillera	1:2,000,000	Wheeler and McFeely (1991); Journeay and Williams (1995; GIS vector representation of Wheeler and McFeely, 1991)
	Metamorphic Map of the Canadian Cordillera	1:2,000,000	Read and others (1991)
	YukonAge 2004: A database of isotopic age determinations for rock units from Yukon Territory	NA	Breitsprecher and Mortensen (2004a)
	BC Age 2004A-1: A database of Isotopic Age Determinations for Rock Units from British Columbia	NA	Breitsprecher and Mortensen (2004b)
	Radiometric Age Data Bank (RADB); National Geochronological Data Base (NGDB)	NA	Zartman and others (1976); Marshall (1993)
Mineral occurrences	Porphyry Deposits	NA	Sinclair (2007)
	Porphyry Copper Deposits of the World	NA	Singer and others (2008)
	Lode mineral deposits	NA	Nokleberg and others (1998)
	MINFILE (British Columbia) Mineral Occurrences Database	NA	MINFILE BC (2009)
	MINFILE (Yukon) Mineral Occurrences Database	NA	MINFILE YT (2009)
	Porphyry Deposits of the Canadian Cordillera	NA	CIM SV 15 (Sutherland Brown, 1976)
	Porphyry Deposits of the Northwestern Cordillera of North America	NA	CIM SV 46 (Schroeter, 1995)
Geochemistry	National Geochemical Reconnaissance (NGR) Stream Sediment, Lake Sediment and Water Geochemical Data Base	NA	Natural Resources Canada (2008c)
	Yukon Regional Geochemical Database 2003 - Stream sediment analyses	NA	Heon (2003)
Geophysics	Canadian Geodetic Information System – Gravity (2km grid) – Bouguer anomaly, free-air anomaly, isostatic residual anomaly, observed gravity, vertical gradient, and horizontal gradient	~1:2,000,000	Natural Resources Canada (2008a)
	Canadian Aeromagnetic Data Base – 1 km and 200 m grid – Residual total field	~1:1,000,000 and ~1:200,000	Natural Resources Canada (2008b)
	Canadian Aeromagnetic Data Base – 500 m grid – Residual total field, reduced to pole	~1:500,000	B.J. Drenth (unpub. data, 2009)
Exploration	BC Mines and Mineral Exploration Overviews, Yukon Mineral Deposits, Natural Resources Canada, Top 100 Exploration and Deposit Appraisal Projects, 2008, Web sites of Mineral Exploration companies	NA	Schroeter and others (2006, 2007), DeGrace and others (2008, 2009)

Table B7. Tonnages and grades of deposits of this tract used in comparing Canadian Cordilleran alkaline porphyry Cu-Au deposits to the world model of Singer and others (2008) for porphyry Cu-Au deposits (model 20c) for tract 003pCu2002 (CA02), Intermontane Island-Arc Porphyry Cu-Au—British Columbia and Yukon Territory, Canada.

[Groups include all deposits and prospects with well-defined grades and tonnages that meet the 2-km rule. Independent indicates that a deposit is not in a group. Mt, million metric tons; %, percent; g/t, grams per metric ton; –, no data. Resource estimates available in 2008-2009 have not been updated to include information added to appendix F after 2009.]

Group	Name	Ore (Mt)	Cu (%)	Mo (%)	Au (g/t)	Ag (g/t)
Afton-Ajax	Afton-Ajax (Total)	770.4	0.382	–	0.238	0.39
Axe-Primer	Axe-Primer (Total)	139.7	0.474	0.01	–	–
Independent	Chuchi	50	0.21	–	0.21	–
Copper Mtn	Copper Mtn (Total)	484.7	0.378	0.001	0.254	2.873
Galore	Galore (Total)	1,547.40	0.404	–	0.254	4.344
Lorraine	Lorraine (Total)	42.2	0.635	–	0.129	4.254
Independent	Minto	34.4	1.187	–	0.323	4.165
Independent	Mount Milligan	602.7	0.192	–	0.349	–
Polley	Polley (Total)	212.5	0.323	–	0.307	–
Independent	Red Chris	714.8	0.356	–	0.281	1.5
Sulphurets	Sulphurets (Total)	1,822.50	0.213	0.004	0.593	2.1
Independent	Williams Creek	19.3	0.95	–	0.376	3.592

Table B8. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract 003pCu2002 (CA02), Intermontane Island-Arc Porphyry Cu-Au—British Columbia and Yukon Territory, Canada.

[Nxx, estimated number of deposits associated with the xxth percentile; N_{und}, expected number of undiscovered deposits; s, standard deviation; Cv%, coefficient of variance; N_{known}, number of known deposits in the tract that are included in the grade and tonnage model; N_{total}, total of expected number of deposits plus known deposits; area, area of permissive tract in square kilometers; density, deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer and Menzie, 2005). In cases where individual estimates were tallied in addition to the consensus estimate, individual estimates are listed.]

Consensus undiscovered deposit estimates					Summary statistics					Tract area (km^2)	Deposit density (N_{total}/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
3	6	13	13	13	7	3.8	54	12	19	109,290	0.00017

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Individual 1	2	5	7	7	7
Individual 2	3	5	12	12	12
Individual 3	4	8	15	15	15
Individual 4	2	5	12	12	12
Individual 5	3	6	10	10	10
Individual 6	3	7	15	15	15
Individual 7	2	6	14	14	14
Consensus	3	6	13	13	13

Table B9. Results of Monte Carlo simulations of undiscovered resources for tract 003pCu2002 (CA02), Intermontane Island-Arc Porphyry Cu-Au—British Columbia and Yukon Territory, Canada.

[Cu, copper; Mo, molybdenum; Au, gold; and Ag, silver; in metric tons; Rock, in million metric tons]

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
Cu	860,000	2,200,000	13,000,000	55,000,000	74,000,000	22,000,000	0.34	0.03
Mo	0	0	44,000	380,000	590,000	130,000	0.26	0.14
Au	88	210	1,100	3,600	4,700	1,600	0.37	0.03
Ag	0	130	2,700	20,000	36,000	7,400	0.24	0.08
Rock	200	510	2,900	11,000	13,000	4,400	0.36	0.03

distribution and relative qualities of known deposits and prospects in the Quesnel and Stikine accreted island-arc terranes. Our knowledge of this was based mostly on information in the British Columbia and Yukon MINFILE databases (MINFILE BC, 2009; MINFILE YT, 2009). In MINFILE records, deposits and prospects generally are classified in terms of mineral deposit models, such as the model for alkalic porphyry Cu-Au deposits by Panteleyev (1995), which is appropriate to this tract. Table B6 lists the sources of information used to define the tract and estimates.

Our estimates for undiscovered deposits in this tract are supported by an inventory of porphyry copper prospects and show a large inventory of 54 significant prospects that are not in any group with a known deposit, and they are, therefore, eligible to be counted as possible undiscovered deposits. Of these 40 significant prospects, 3 are of rank 2 (with small estimated resources), 12 are of rank 3 (with intercepts of at least 20 m of 0.2 percent copper), and 39 are of rank 4 (with intercepts of at least 0.1 percent copper).

Our estimates are constrained by the spatial density of known deposits in Quesnellia and Stikinia and by the perception that these terranes are well explored for porphyry copper. That is why Singer and others (2005) used these terranes as examples of well-explored areas in their model of deposit densities to be expected in relatively unexplored areas. Nevertheless, there are large areas in this permissive tract where bedrock exposures mostly are covered by glacial till. Although glacial till is not shown on maps of bedrock geology, it is widely distributed and can mostly to completely hide features the size of a porphyry copper deposit.

There are enough promising independent prospects in this tract that we were able to estimate numbers of undiscovered deposits at subjective probability levels of 90 percent and 50 percent. However, there is enough uncertainty about the qualities of the many other prospects with little or no assay data to indicate the possibility of many more undiscovered deposits at the 10-percent level of subjective probability.

The first round of balloting was private, so we cannot know exactly how each panel member weighed the available information. Our Canadian panel members could draw on the most knowledge and experience, which they generously shared during the presentations and discussions that preceded estimation.

Estimates by each team member were compiled and revealed to the team. Reasons for high and low estimates were elicited and discussed. On the basis of these discussions, team members were allowed to adjust their estimates until consensus (agreement on an estimate acceptable to the group) was reached. Individual and consensus estimates are shown in table B8.

We calculated the spatial density of deposits indicated by the 12 known deposits plus our mean estimate of 7 undiscovered deposits for a total expected number of 19 deposits, divided by the tract area of 109,290 km^2, yielding a density of 0.00017 deposits/km^2. We compared this spatial density to spatial densities of porphyry copper deposits in well-studied permissive tracts of the world according to Singer and others (2005, 2008). This showed that our estimated deposit density of about 0.00017 deposits per km^2 is just slightly above the slope of the central tendency for spatial densities of porphyry copper deposits in well-explored areas used to define the deposit density model. Based on this comparison, and the mean estimate of 7 undiscovered deposits in a tract with 12 known deposits, the assessment team believed exploration in the this tract to be fairly mature, with most of the undiscovered deposits being concealed or in remote areas.

Probabilistic Assessment Simulation Results

Undiscovered resources for the tract were modeled using the consensus estimates for numbers of undiscovered alkaline porphyry Cu-Au deposits with the porphyry Cu-Au model (model 20c; Singer and others, 2008) as input for the EMINERS Monte Carlo simulator program (Root and others, 1992; Bawiec and Spanski, in press). Selected simulation results are reported in table B9, and results of the Monte Carlo simulation are presented as cumulative frequency plots (fig. B2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

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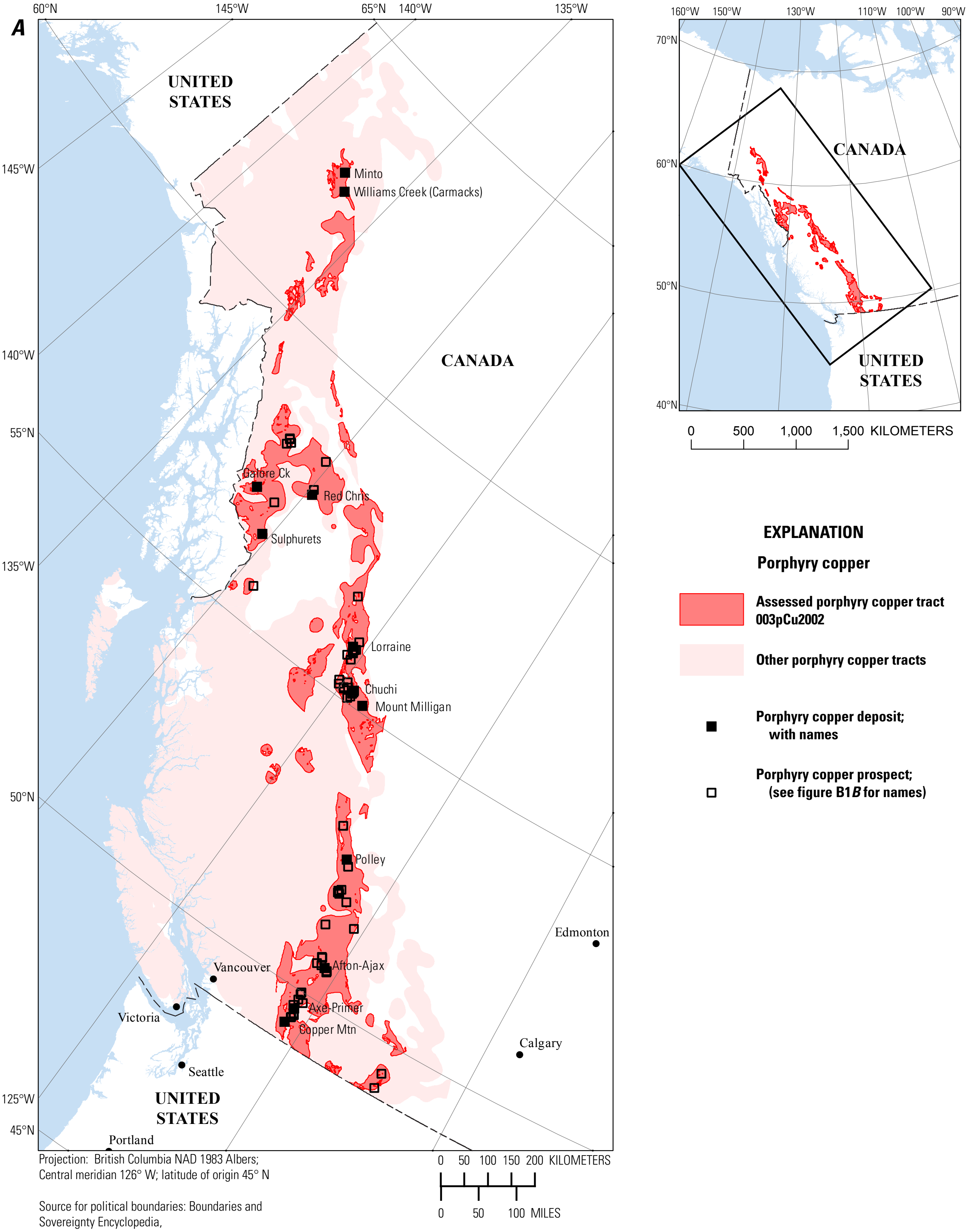
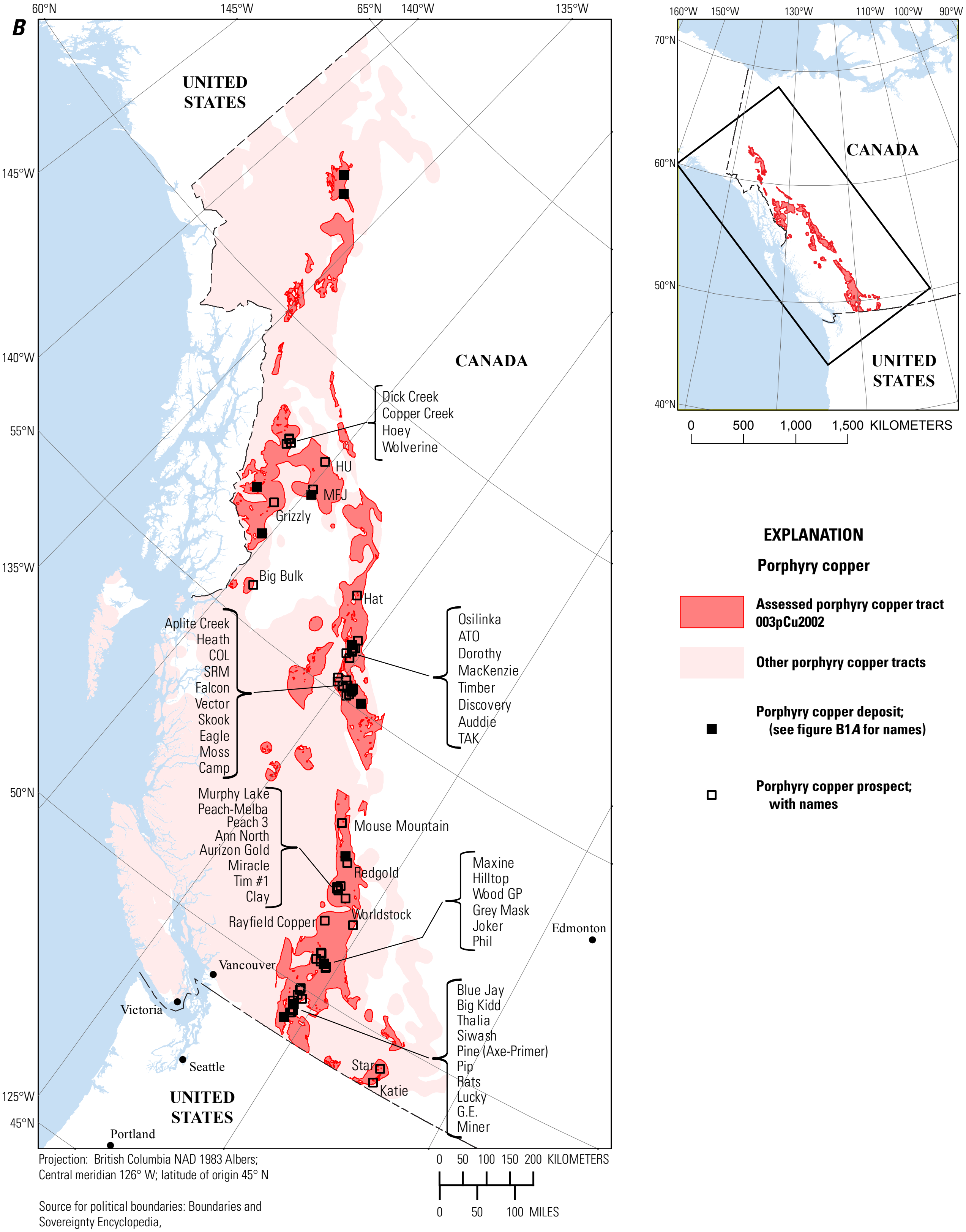


Projection: British Columbia NAD 1983 Albers;
Central meridian 126° W; latitude of origin 45° N

Source for political boundaries: Boundaries and
Sovereignty Encyclopedia,
U.S. Department of State, Office of the Geographer and Global Issues

Figure B1. Maps showing permissive tract 003pCu2002 (CA02), Intermontane Island-Arc Porphyry Cu-Au—British Columbia and Yukon Territory, Canada. *A,* Locations of known preaccretionary alkalic porphyry Cu-Au deposits (named) and significant prospects (not named). *B,* Locations of preaccretionary alkalic porphyry Cu-Au deposits (not named) and significant prospects (named).



Projection: British Columbia NAD 1983 Albers;
Central meridian 126° W; latitude of origin 45° N

Source for political boundaries: Boundaries and
Sovereignty Encyclopedia,
U.S. Department of State, Office of the Geographer and Global Issues

Figure B1.—Continued

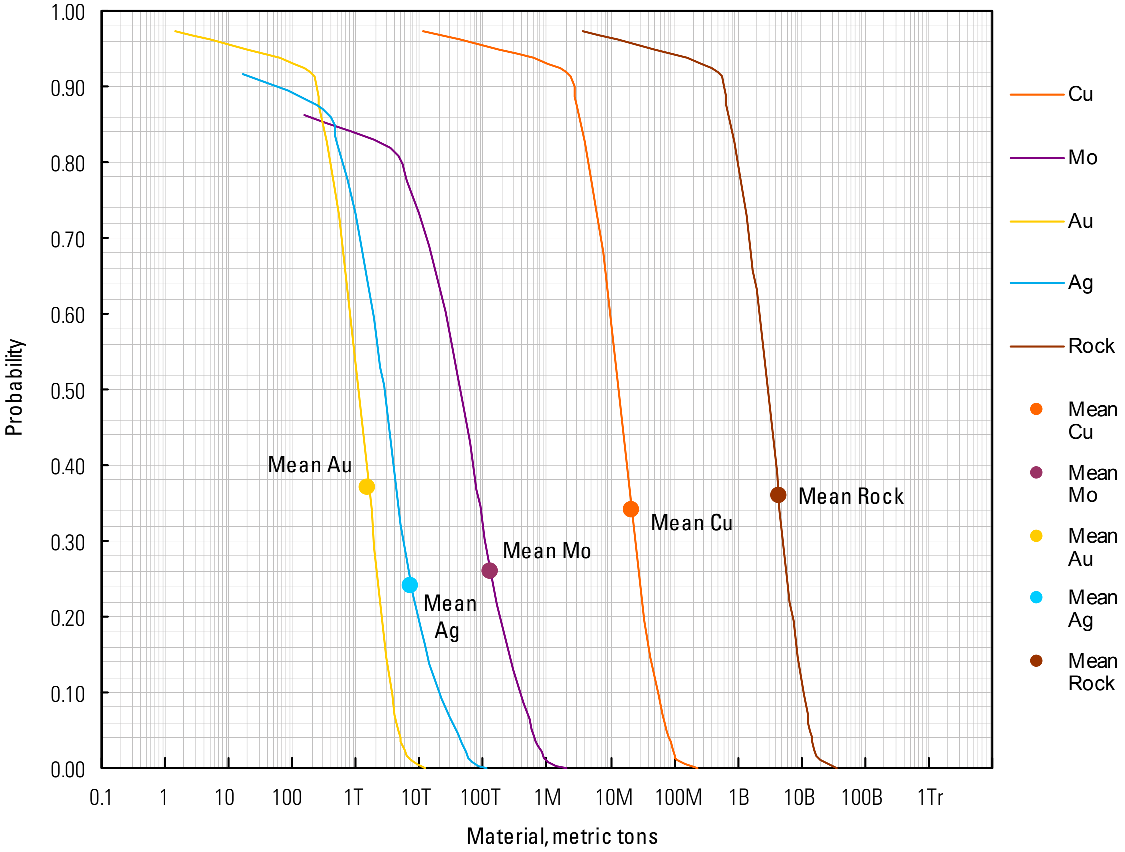


Figure B2. Cumulative frequency plot showing the results of a Monte Carlo computer simulation of undiscovered resources in tract 003pCu2002 (CA02), Intermontane Island-Arc Porphyry Cu-Au—British Columbia and Yukon Territory, Canada. (T=thousands, M=millions, B=billions, Tr=trillions).

Appendix C. Porphyry Copper Assessment for Tract 003pCu2003 (CA03), Insular Mixed Island-and Continental Arc—British Columbia and Yukon Territory, Canada

By Mark J. Mihalasky[1] , Arthur A. Bookstrom[2] , Thomas P. Frost[3] , and Steve Ludington[4] , with contributions from James M. Logan[5] , Andre Panteleyev[6] , and Grant Abbott[7]

Deposit Type Assessed: Porphyry Copper

Descriptive model: Porphyry copper (Cox, 1986a, Berger and others, 2008), porphyry Cu-Mo (Cox, 1986b), porphyry Cu-Au (Cox, 1986c), porphyry Cu±Mo±Au (Panteleyev, 1995)
Grade and tonnage model: Canadian Cordillera Porphyry Cu±Mo±Au (appendix G)
(Table C1 summarizes selected assessment results)

Table C1. Summary of selected resource assessment results for tract 003pCu2003 (CA03), Insular Mixed Island- and Continental Arc—British Columbia and Yukon Territory, Canada.

[km, kilometers; km^2, square kilometers; t, metric tons]

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known copper resources (t)	Mean estimate of undiscovered copper resources (t)	Median estimate of undiscovered copper resources (t)
2009	1	58,360	3,170,000	3,000,000	1,900,000

Location

This tract is in the Cordilleran region of western Canada. It is in the Insular belt, which includes the westernmost margin and offshore islands of western British Columbia and southwestern Yukon (figs. 1, C1).

Geologic Feature Assessed

Calc-alkaline igneous rocks of mainly Jurassic (Late Triassic to Early Cretaceous) age in accreted and synaccretionary terranes of mixed island-arc and continental arc affinities.

Delineation of the Permissive Tract

Geologic Criteria

The fundamental units for delineation of this permissive tract are Mesozoic calc-alkaline igneous rocks of the Insular belt, which is outboard from (west of) the Coast belt of batholithic and metamorphic rocks (fig. 1). The Insular belt consists of the

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Table C2. Map units that define tract 003pCu2003 (CA03), Insular Mixed Island- and Continental Arc—British Columbia and Yukon Territory, Canada.

[Province, map unit, age range, and principal rock types from 1:250,000 scale digital geologic maps of British Columbia (Massey and others, 2005) and Yukon Territory (Gordey and Makepeace, 1999)]

Province	Map unit	Age range	Rock types
		a. Intrusive rocks	
BC	JKdr	Jurassic to Cretaceous	dioritic intrusive rocks
BC	JKg	Jurassic to Cretaceous	intrusive rocks, undivided
BC	JKgd	Jurassic to Cretaceous	granodioritic intrusive rocks
BC	TrKgr	Triassic to Cretaceous	granite, alkali feldspar granite intrusive rocks
BC	EMJIfp	Early Jurassic to Middle Jurassic	feldspar porphyritic intrusive rocks
BC	EMJIgd	Early Jurassic to Middle Jurassic	granodioritic intrusive rocks
BC	MJSC	Middle Jurassic to Late Jurassic	quartz dioritic intrusive rocks
BC	MLJBI	Middle Jurassic to Late Jurassic	monzodioritic to gabbroic intrusive rocks
YT	JKS	Late Jurassic to earliest Cretaceous	granodiorite/tonalite
		b. Volcanic rocks	
BC	lJvf	Lower Jurassic	rhyolite, felsic volcanic rocks
BC	lJBca	Lower Jurassic	calc-alkaline volcanic rocks

Wrangellia terrane in its southern part and the Alexander terrane in its northern part (fig. 2). Wrangellia was connected to the Alexander terrane by Pennsylvanian time and accreted to the Intermontane terranes of the North American margin by the mid-Jurassic (see Nelson and Colpron, 2007). Both of these terranes consist of volcanic island arcs, oceanic plateaus, and associated rock assemblages that are superimposed on older fragments of continental crust. Thus, arc magmatism in these terranes had mixed continental and oceanic influences. Furthermore, the known porphyry copper deposits and prospects in this tract formed as Wrangellia collided with Stikinia, during the accretion of Quesnellia, Stikinia, and Wrangellia to the western margin of North America. Thus, the formation of porphyry copper deposits in Wrangellia involved magmatism related to a subduction zone that extended beneath both the island arcs and the continental margin to which they were accreting.

Criteria for consideration of rock types as permissive for the occurrence of porphyry Cu±Mo±Au deposits are from descriptive models for porphyry copper and Cu-Mo deposits by Cox (1986a, b) and for calc-alkaline porphyry Cu±Mo±Au deposits of British Columbia by Panteleyev (1995). Permissive rock types include phaneritic to porphyritic quartz diorite, tonalite, granodiorite, quartz monzonite, monzogranite, and granite of calc-alkaline affinity. Equivalent porphyro-aphanitic rock types are quartz-andesite, dacite, rhyodacite, quartz-latite, and rhyolite porphyries of calc-alkaline affinity.

According to Gehrels and others (2009), a western magmatic belt of the Coast Mountains batholith was active in the Alexander and Wrangellia terranes from 177 to 162 Ma, and from 157 Ma (Early Jurassic) to 142 Ma (Early Cretaceous). Calc-alkaline igneous rocks of the Insular terranes that range in age from the beginning of Early Jurassic to the end of Early Cretaceous time (200 to 100 Ma) are, therefore, considered permissive and included in this Insular permissive tract.

As represented on digital geologic maps of British Columbia by Massey and others (2005), and of the Yukon by Gordey and Makepeace (1999), igneous rocks of permissive compositions are included in map units that contain rocks ranging in age from Triassic to Cretaceous (251 to 65 Ma). In order to capture all permissive rocks of Jurassic to Early Cretaceous age, it was necessary to include some rocks of older and younger ages. Thus, the Insular permissive tract is artificially large, and therefore its predicted spatial density of deposits is lower than would be expected. Nevertheless, we decided that a larger-than-intended permissive tract was necessary to include all permissive areas. Given more complete dating of igneous rock units, the tract could be made smaller and internally consistent.

Tract Delineation Process

We used digital tectonic-assemblage maps by Wheeler and McFeely (1991) and by Journeay and Williams (1995) to identify the areas of the Insular Superterrane and its constituent Wrangel and Alexander terranes. We used digital geologic maps of British Columbia by Massey and others (2005) and the Yukon Territory by Gordey and Makepeace (1999) to identify areas of permissive rocks. Geologic information in attribute tables associated with those maps allowed us to identify polygons representing lithologic assemblages containing rocks of the appropriate age and composition to be included in this permissive tract. We excluded polygons representing lithologic assemblages not considered permissive by reason of age or composition, and we recorded a reason for their exclusion in the attribute table for the tract.

Digital geologic-map units that include polygons assigned to this permissive tract are listed in table C2 for intrusive rocks and volcanic rocks. From each map unit listed, we selected only those sets of polygons that represent lithologic assemblages containing permissive rock types. Sets of polygons for which descriptions include rocks of ages or compositions that are permissive for more than one tract are included in each of the tracts for which they are permissive.

To define the area included in this permissive tract, we applied the following procedures. From descriptive information in the attribute tables that accompany the digital geologic maps of British Columbia and the Yukon Territory, we classified map units as permissive or nonpermissive, according to the geologic criteria described above and summarized in table C2. The map units classified as permissive for this tract represent the bedrock-surface expressions of intermediate to felsic igneous rocks of calc-alkaline affinity and of Late Triassic to Early Cretaceous age in the Wrangel and Alexander accreted island-arc terranes.

To polygons or groups of polygons that represent the bedrock-surface expression of permissive map units, we added a 10-km buffer to the mapped margins of permissive intrusions. This buffer expanded the area of the permissive tract to include all significant porphyry copper prospects, and to include possible unexposed permissive rocks and porphyry copper deposits. Examples of permissive rock types below the mapped surface would include permissive plutons that expand downward, subsurface satellite cupolas of intrusions, and unmapped parts of plutons or porphyry copper occurrences that are covered by younger materials (such as basalt flows, glacial till, colluvium, alluvium, or basin-fill sediments less than 1 km thick) or are structurally covered. We also applied a 2-km buffer around the outer margins of polygons or groups of polygons representing permissive volcanic rocks, the thin edges of which might be discontinuous, covered, or otherwise not mapped at the scale of our source maps. For additional information on buffering, see the “Permissive Tracts for Porphyry Copper” section in the Introduction of this report.

After buffering, we examined aeromagnetic, gravimetric, and geochemical anomaly maps for evidence of unmapped permissive igneous rocks or hydrothermal systems (Natural Resources Canada, 2008a, b, c). Positive aeromagnetic and gravity anomalies were interpreted as possible evidence for granitoid intrusions, or magnetite-bearing hydrothermal systems (see Clark, 1999, for discussion). Particular caution was exercised in the Yukon Territory, because magnetic highs also correlated with nonpermissive flood basalts of the Nikolai greenstone belt. We trimmed the northeastern part of the northern segment of this permissive tract in order to exclude probable Nikolai greenstones in the subsurface. West of that, we interpreted a large gravity low (Natural Resources Canada, 2008b) to represent a large, low-density, probably granitoid subsurface intrusion. Although this anomaly is based on widely spaced data points, we extended the permissive tract to include it.

A smoothing routine was then applied to the buffered tract. A description of the smoothing routine is included in the metadata in appendix H. After smoothing, tract-buffer zones were trimmed along terrane-bounding faults. Finally, areas of post-accretionary intrusions (surrounded by a 250-meter buffer) were excluded from the tract-buffer zones. Such intrusions and their buffer zones are included in a permissive tract for a later time interval.

Geologic Interpretation

According to Nelson and Colpron (2007), the Insular terranes originated in the Arctic regime in latest Proterozoic to early Paleozoic time. By Late Triassic time, they had migrated around the northwest end of Pangea, and in Late Triassic time, they passed over a hot spot. This caused widespread Nikolai-Karmutsen basaltic volcanism in Wrangellia and rifting with basaltic volcanism and formation of volcanic massive sulfide deposits in the Alexander terrane. In Middle Jurassic time, the Insular terranes collided with Stikinia during the accretion of the Intermontane terranes to the western margin of North America.

As the Insular terranes approached the Stikinia in Early Jurassic time, eastward subduction beneath the western edge of Wrangellia produced andesitic volcanic strata of the Bonanza Group, which hosts most of the porphyry copper deposits of Vancouver Island. As Wrangellia collided with Stikinia, syncollisional plutonism produced calc-alkaline porphyry Cu±Mo±Au systems in southern Wrangellia. Although all of the known porphyry copper deposits and significant prospects are on or near Vancouver Island, the Insular terranes contain relatively widespread occurrences of permissive calc-alkaline igneous rocks on the Queen Charlotte Islands and further north.

Known Deposits

The Hushamu and Island Copper deposits (table C3) are the only porphyry copper deposits in this tract (after grouping using the 2-km rule).

The Island Copper mine is in the northern part of Vancouver Island. It was mined from 1971 to 1994, from an open pit that began near sea level, and bottomed at 380 m below sea level. According to Perello and others (1995) it was a porphyry Cu±Mo±Au deposit in and around a Middle Jurassic dike-like composite intrusion of rhyodacite porphyries with marginal and interior hydrothermal breccias. This intrusion was emplaced into andesitic volcanic rocks of the Lower Jurassic Bonanza Group. The intrusion strikes west-northwest and dips steeply northeast. It is about 1.2 km long and 100 to 300 m thick. Ore, consisting of several generations of chalcopyrite- and molybdenite-bearing veins, occurs as an annulus around a low-grade to barren core of relatively unaltered rock. This core is surrounded by a quartz-amphibole-magnetite zone, which grades progressively outward to

Table C3. Known calc-alkaline porphyry Cu±Mo±Au deposits in tract 003pCu2003 (CA03), Insular Mixed Island- and Continental Arc—British Columbia and Yukon Territory, Canada.

[Ma, million years; NA, not applicable; –, no data; Mt, million metric tons; t, metric ton; %, percent; g/t, gram per metric ton; Cu-Mo subtype, deposits that have Au/Mo ratios <3 or average Mo grades >0.03%; Cu-Au subtype, deposits that have Au/Mo ratios >30 or average Au grades >0.2 g/t. Contained Cu in metric tons is computed as (tonnage Mt x 1,000,000) x (percent Cu / 100); gs, coordinates of this site are used for the group location; *, estimated tonnage and grade from an unsubstantiated press release (not used in grade and tonnage model); **, partial tonnage and grade for a deposit that is known to be open to extension (not used in grade and tonnage model). For group aggregates: the latitude and longitude, subtype, and age is that of the deposit with the largest Cu resources; the Cu and Mo grades are tonnage-weighted averages calculated using the computed contained Cu and Mo as (t contained Cu or Mo / (Mt x 1,000,000)) x 100 (note that the computed contained Mo is not shown in this table); and the Au and Ag grades are a tonnage-weighted average calculated as g/t x Mt. For sources of age, tonnage, and grade information, see appendix F. Resource estimates are through 2009, but include updates for 2010 when available.]

Name	Latitude	Longitude	Subtype	Age (Ma)	Tonnage (Mt)	Cu (%)	Mo (%)	Au (g/t)	Ag (g/t)	Contained Cu (t)
HUSHAMU GROUP										
Hushamu [gs]	50.675	-127.858	NA	170	735.4	0.198	0.011	0.247	–	1,460,000
Red Dog	50.711	-127.972	Cu-Au	172	45	0.35	0.006	0.44	–	158,000
GROUP AGGREGATE	50.675	-127.858	NA		780.4	0.207	0.011	0.258	–	1,620,000
INDIVIDUAL DEPOSIT										
Island Copper	50.6	-127.475	NA	167	377	0.41	0.017	0.19	1.4	1,550,000
INDIVIDUAL DEPOSIT TOTAL					377					1,550,000
TRACT TOTAL					1,157.40					3,170,000
TRACT ROUNDED TOTAL					1,160					3,170,000

biotite-magnetite, chlorite-magnetite, and epidote zones. Most of the ore is in the biotitic zones. Chalcopyrite is the main copper-bearing mineral. Bornite occurs in marginal breccias.

The Hushamu deposit is about 26 km west-northwest of the Island Copper mine, in the northern part of Vancouver Island. Like the Island Copper deposit, the Hushamu deposit is elongate west-northwest. It is exposed along the northeastern slope of McIntosh Mountain. According to Dasler and others (1995), ore is characterized by multistage quartz-magnetite-chalcopyrite-pyrite stockworks and disseminations. Early potassic alteration assemblages are overprinted by chlorite and minor albite. A deep Cu-Au zone coincides with Middle Jurassic quartz diorite and feldspar porphyry intrusions into andesitic volcanic host rocks of the Lower Jurassic Bonanza Group. Intermediate exposures are dominated by a large multi-stage hydrothermal breccia complex containing mineralized fragments cut by moderately mineralized feldspar porphyry intrusions, pebble breccias and late rhyolite dikes. Uppermost exposures consist of silicified hydrothermal breccias and vuggy silica rock with an epithermal alteration assemblage of clay minerals.

Prospects, Mineral Occurrences, and Related Deposit Types

The Island Copper deposit is the central deposit in a west-northwest-trending group of at least 5 porphyry copper occurrences that is about 14 km long. From the southeast to northwest, these include the Rupert prospect at Rupert Inlet, the Yankee Girl prospect at Red Island, the Island Copper deposit, the Bay prospects near Bay Lake, and the Northwest zone of copper and molybdenum anomalies. These occurrences are listed in table C4, and shown in figure 4 of Perello and others (1995, p. 218). They are considered part of the Island Copper group. Therefore, they are not shown individually in figures C1*A* and C1*B*. Similarly, the HEP prospect is considered part of the Hushamu group.

The Rupert, Road, and Yankee Grid prospects are east-southeast of the Island Copper pit, and the Bay prospects are to the west-northwest. Perello and others (1995) also mentioned a copper skarn zone, called the NW zone, which is about 1 km northwest of the Bay prospects. Their zones of altered rocks are less than about 2 km apart, thus ore found in them will be considered part of the Island Copper deposit. Four have characteristics of both epithermal and porphyry copper deposits, and the NW zone has characteristics of both skarn and porphyry copper deposits. Each is associated with intrusions that are elongate west-northwest, and they are arranged in an en-echelon pattern. Perello and others (1995) suggested that they formed in dilational jogs along a right-lateral fault zone.

The HEP prospect is within the Hushamu group, and the Lois prospect also is in the northern part of Vancouver Island. The Camp and Tex (Dude) prospects are in the east-central part of the island.

The Camp, Lois, and Dude prospects are classified as significant independent, rank 4 prospects. Grab-sample assays from these prospects indicate more than 0.1 percent copper, but significantly long intercepts of higher-grade copper concentrations have not been reported.

No other prospects in the Insular terrane are known to be significant porphyry copper prospects.

Table C4. Significant porphyry Cu±Mo±Au prospects in tract 003pCu2003 (CA03), Insular Mixed Island- and Continental Arc—British Columbia and Yukon Territory, Canada.

[Ma, million years; –, not applicable; Mt, million metric tons; t, metric ton; g/t, gram per metric ton; gs, group site-coordinates of this site are used for the group location. For sources and additonal information about age, tonnage, grade and comments, see appendix F. For mineral name abbreviations under "Comments", see appendix F.]

Group	Name	Rank	Latitude	Longitude	Age (Ma)	Comments
Significant porphyry Cu prospects in groups of known porphyry Cu deposits and prospects						
Hushamu	HEP	3	50.694	-127.893	172	Resource: 0.046 Mt ore @ 0.8% Cu (362t Cu); with porphyry-Cu and epithermal features
Island	Bay 21	4	50.611	-127.512	165	Intercept: 1.4 m, 4.17% Cu, 0.34 g/t Au, 34.3 g/t Ag; with porphyry-Cu and epithermal features
Island	Bay 29	5	50.596	-127.456	165	Intercept: interval unavailable; with porphyry-Cu and epithermal features
Island	Bay 56	5	50.631	-127.522	165	Intercept: interval unavailable; with porphyry-Cu and epithermal features
Island	Road	5	50.597	-127.463	167	Intercept: interval unavailable; with porphyry-Cu and epithermal features
Island	Rupert	5	50.588	-127.39	165	Intercept: interval unavailable; with porphyry-Cu and epithermal features
Island	Yankee Girl	5	50.593	-127.456	165	Intercept: interval unavailable; with porphyry-Cu and epithermal features
Significant individual porphyry Cu prospects						
–	Camp Lake	4	49.907	-125.616	168	Intercept: interval unavailable; 0.439% Cu, 0.0019% Mo, 0.163 g/t Au, 2.5 g/t Ag; hand trenching, geochem, ground mag, 576 m drilled, 7 holes
–	Lois	4	50.259	-127.616	154	Intercept: interval unavailable; 0.15% Cu; several styles and locations of weak mineralization; erratic cpy and mo in biotite-altered zone
–	Tex (Dude)	4	49.63	-124.312	168	Intercept: interval unavailable; 0.147% Cu, 0.006%Mo

Exploration History

Aeromagnetic surveys by the British Columbia Department of Mines sparked interest in the Island Copper and Hushamu areas. Exploration in the area of the Island Copper group began in 1965, and the discovery hole was drilled at Island Copper in 1967. By 1969, the Island Copper deposit had been defined on the basis of 35,600 m of drilling in 185 core holes. The Expo claim block, which contains the Hushamu deposit, was staked in 1966. By 1975, the Hushamu deposit had been identified as the best prospect in the Expo claim block, and a preliminary estimate of the Hushamu resource had been made.

Table C5 summarizes recent porphyry-copper exploration activities in this tract. These exploration activities have all occurred on Vancouver Island in the Wrangel terrane of the Insular Superterrane. From 2004 to 2007 there was about 8.9 km of drilling in and around known ore zones of the Hushamu group and about 1.27 km of drilling on the rank-4 Tex (or Dude) prospect. Thus, about 87 percent of this drilling has been done in or around a known group of ore zones, and about 13 percent has been done on a single rank-4 prospect. This information is from annual British Columbia Mines and Mineral Exploration overviews by Schroeter and others (2006, 2007) and DeGrace and others (2008, 2009).

Sources of Information

Principal sources of information used by the assessment team for delineation of tract 003PCu2003 are listed in table C6.

Grade and Tonnage Model Selection

As discussed in the Introduction, and as shown in appendix G, a new grade and tonnage model for Canadian Cu±Mo±Au deposits was constructed due to the lower copper grades present in Canadian examples compared to global models (Singer and others 2008).

Porphyry Cu±Mo±Au

The deposits and prospects of permissive tract 003pCu2003 (CA03), as well as those of tracts 003pCu2001 (CA01), 003pCu2004 (CA04), and 003pCu2005 (CA05), fit the descriptive model for Porphyry Cu±Mo±Au deposits of British Columbia (Panteleyev, 1995) and the Yukon Territory (Panteleyev, 2005). After spatial grouping according to the 2-km rule, 34 known deposits of this subtype are present in the Canadian Cordillera (2 of which occur in this tract). In aggregate, when compared to the Singer and others (2008) grade and tonnage models, the Canadian Cu±Mo±Au deposits are on average lowest in tonnage, lowest in copper grade, higher in molybdenum grade (except for model 21a), higher in gold grade (except for model 20c), and highest in Ag grade.

Statistical tests at a 1-percent screening level on these deposits (as a group) indicate that their molybdenum grade and gold grade distribution means are not statistically different from the general (models 17, 20c, and 21a combined) or Cu subtype (model 17) porphyry copper grade and tonnage models of Singer and others (2008) (see tables G2a and b). Neither is their tonnage distribution mean statistically different from the general, Cu subtype, or Cu-Au subtype

Table C5. Readily available recent exploration activities for deposits and prospects in tract 003pCu2003 (CA03), Insular Mixed Island- and Continental Arc—British Columbia and Yukon Territory, Canada.

[This information was compiled from Schroeter and others (2006, 2007) and DeGrace and others (2008, 2009). Web-site addresses of "Operators" are listed in the table in appendix F; AMG, airborne magnetic; CD, core drilling; EM, electromagnetic surveys; G, geologic mapping; GC, geochemical sampling (rock, soil, silt, etc.); PR, prospecting; RCD, reverse-circulation drilling; m, meters.]

Name	Rank	Operator	Activities	CD (m)
Hushamu	1	Lumina Resource Corp, Western Copper Corp.	PR, G, GC, AMG, EM, CD	8,900
Tex (Dude)	4	Pathfinder Resources, Ltd.	RCD, GC, CD	1,270

Table C6. Principal sources of information used for tract 003pCu2003 (CA03), Insular Mixed Island- and Continental Arc—British Columbia and Yukon Territory, Canada.

[NA, not applicable]

Theme	Name or title	Scale	Citation
Geology	GeoFile 2005-1: Digital Geology Map of British Columbia-Whole Province	1:250,000	Massey and others (2005)
	Yukon Digital Geology	1:250,000	Gordey and Makepeace (1999)
	Geoscience Map 2005-3: Geology of British Columbia	1:1,000,000	Massey and others (2005)
	Terrane Map of the Canadian Cordillera	1:2,000,000	Wheeler and others (1991)
	Tectonic Assemblage Map of the Canadian Cordillera	1:2,000,000	Wheeler and McFeely (1991); Journeay and Williams (1995); GIS vector representation of Wheeler and McFeely, 1991)
	Metamorphic Map of the Canadian Cordillera	1:2,000,000	Read and others (1991)
	YukonAge 2004: A database of isotopic age determinations for rock units from Yukon Territory	NA	Breitsprecher and Mortensen (2004a)
	BC Age 2004A-1: A database of Isotopic Age Determinations for Rock Units from British Columbia	NA	Breitsprecher and Mortensen (2004b)
	Radiometric Age Data Bank (RADB); National Geochronological Data Base (NGDB)	NA	Zartman and others (1976); Marshall (1993)
Mineral occurrences	Porphyry Deposits	NA	Sinclair (2007)
	Porphyry Copper Deposits of the World	NA	Singer and others (2008)
	Lode mineral deposits	NA	Nokleberg and others (1998)
	MINFILE (British Columbia) Mineral Occurrences Database	NA	MINFILE BC (2009)
	MINFILE (Yukon) Mineral Occurrences Database	NA	MINFILE YT (2009)
	Porphyry Deposits of the Canadian Cordillera	NA	CIM SV 15 (Sutherland Brown, 1976)
	Porphyry Deposits of the Northwestern Cordillera of North America	NA	CIM SV 46 (Schroeter, 1995)
Geochemistry	National Geochemical Reconnaissance (NGR) Stream Sediment, Lake Sediment and Water Geochemical Data Base	NA	Natural Resources Canada (2008c)
	Yukon Regional Geochemical Database 2003 - Stream sediment analyses	NA	Heon (2003)
Geophysics	Canadian Geodetic Information System – Gravity (2 km grid) – Bouguer anomaly, free-air anomaly, isostatic residual anomaly, observed gravity, vertical gradient, and horizontal gradient	~1:2,000,000	Natural Resources Canada (2008b)
	Canadian Aeromagnetic Data Base–1 km and 200 m grid–Residual total field	~1:1,000,000 and ~1:200,000	Natural Resources Canada (2008a)
	Canadian Aeromagnetic Data Base–500 m grid–Residual total field, reduced to pole	~1:500,000	B.J. Drenth (unpub. data, 2009)
Exploration	BC Mines and Mineral Exploration Overviews, Yukon Mineral Deposits, Natural Resources Canada, Top 100 Exploration and Deposit Appraisal Projects, 2008, Web sites of Mineral Exploration companies	NA	Schroeter and others (2006, 2007), DeGrace and others (2007, 2008)

(model 20c) porphyry copper grade and tonnage models of Singer and others (2008) (see tables G2a, b, and c). However, the copper grade distribution mean is statistically different from the general model and all the individual subtype models (see tables G2a, b, c, and d). For this reason, a grade and tonnage model for the porphyry Cu±Mo±Au deposits in tracts 003pCu2001 (CA01), 003pCu2003 (CA03), 003pCu2004 (CA04) and 003pCu2005 (CA05) was constructed.

The complete model, which contains data current through December 2009, is described in appendix G. For deposits in tract 003pCu2003 (CA03), the formal group according to the 2-km rule, and the name of the independent or groups used, along with the tonnages and grades used in the development of the grade and tonnage model, are listed in table C7.

Estimate of the Number of Undiscovered Deposits

Rationale for the Estimate

Our rationale for estimation of undiscovered porphyry Cu±Mo±Au deposits in the Insular terranes was based mostly on the distribution and relative qualities of known deposits and prospects in the Wrangel terrane. Excellent records in the British Columbia and Yukon MINFILE databases informed our estimates. These estimates were influenced by the relatively small inventory of known porphyry copper deposits and significant prospects in this tract. Nevertheless, the geology is permissive, and there are large areas of heavily forested land where bedrock exposures are poor, especially where largely covered by unmapped glacial till. Although western Canada generally is well explored, it is still possible that undiscovered deposits may be hidden by relatively thin cover in this tract.

The first round of balloting was private, so we cannot know exactly how each panel member weighed the available information. Our Canadian panel members could draw on the most knowledge and experience, which they generously shared during the presentations and discussions that preceded estimation. Estimates by each team member were compiled and revealed to the team. Reasons for high and low estimates were elicited and discussed. On the basis of these discussions, team members were allowed to adjust their estimates until consensus (agreement on an estimate acceptable to the group) was reached. Individual and consensus estimates are shown in table C8. Although two participants estimated zero undiscovered deposits at the 90-percent level of probability, the consensus estimate was for 1 undiscovered deposit at the 90-percent level.

We calculated the spatial density of deposits indicated by the 2 known deposits plus our mean estimate of 2.3 undiscovered deposits, for a total of 4.3 deposits, which, when divided by the tract area of 58,360 km^2, yields a density of 0.00007 deposits/km^2. We compared this spatial density to spatial densities of porphyry copper deposits in well-studied areas of the world according to Singer and others (2005, 2008). This showed that, although this estimated spatial density is well below the trend of the central tendency of the deposit density model, it is within the 10- to 90-percent confidence envelope for spatial densities of porphyry copper deposits used to define the deposit density model of Singer and others (2005, 2008).

This result can indicate that the estimated number of deposits is unusually low for the size of the tract, or that the permissive tract is unusually large for the number of deposits it is estimated to contain. Alternatively, it may indicate that the tract is not particularly prospective compared to the other tracts. This tract contains geologic units representing much longer time spans than those indicated by the ages of the known deposits. The tract is, therefore, larger than it would be if the geologic map allowed designation of permissive map units according to smaller time intervals, similar to that of the known deposits (see the “Geologic Criteria” section above for additional information). It is interesting to note, however, that a small pulse of magmatism, centered at about 170 Ma (see fig. 3*B*), occurs over an otherwise fairly level interval of dated igneous rocks during the time-extent of this tract. This pulse, if not an artifact of sampling, is consistent with the ages of the known deposits (see fig. 3*A*; Hushamu, 170 Ma; Island Copper, 167 Ma; and Red Dog, 171.5 Ma).

Table C7. Tonnages and grades of deposits of this tract used in tonnage and grade models for Canadian Cordilleran calc-alkaline porphyry Cu±Mo±Au for tract 003pCu2003 (CA03), Insular Mixed Island- and Continental Arc—British Columbia and Yukon Territory, Canada.

[Groups include all deposits and prospects with well-defined grades and tonnages that meet the 2-km rule. Mt, million metric tons; %, percent; g/t, grams per metric ton; –, no data. Resource estimates available in 2008–2009 have not been updated to include information added to appendix F after 2009.]

GROUP	NAME	Ore (Mt)	Cu (%)	Mo (%)	Au (g/t)	Ag (g/t)
Hushamu	Hushamu (Total)	780.4	0.207	0.011	0.258	–
Island	Island (Total)	377	0.41	0.017	0.19	1.4

Table C8. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract 003pCu2003 (CA03), Insular Mixed Island- and Continental Arc—British Columbia and Yukon Territory, Canada.

[Nxx, estimated number of deposits associated with the xxth percentile; N_{und}, expected number of undiscovered deposits; s,standard deviation; Cv%, coefficient of variance; N_{known}, number of known deposits in the tract that are included in the grade and tonnage model; N_{total}, total of expected number of deposits plus known deposits; area, area of permissive tract in square kilometers; density, deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer and Menzie, 2005). In cases where individual estimates were tallied in addition to the consensus estimate, individual estimates are listed.]

Consensus undiscovered deposit estimates					Summary statistics					Tract Area (km^2)	Deposit density (N_{total}/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
1	2	4	5	6	2.3	1.5	66	2	4.3	58,360	0.00007

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Individual 1	0	1	3	6	6
Individual 2	1	3	5	5	5
Individual 3	0	1	3	5	5
Individual 4	1	2	4	6	6
Individual 5	1	2	4	4	4
Individual 6	1	2	4	4	4
Individual 7	1	2	3	3	3
Consensus	1	2	4	5	6

Table C9. Results of Monte Carlo simulations of undiscovered resources for tract 003pCu2003 (CA03), Insular Mixed Island- and Continental Arc—British Columbia and Yukon Territory, Canada.

[Cu, copper; Mo, molybdenum; Au, gold; and Ag, silver; in metric tons; Rock, in million metric tons]

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
Cu	0	200,000	1,900,000	7,200,000	9,800,000	3,000,000	0.35	0.07
Mo	0	0	63,000	340,000	520,000	130,000	0.33	0.17
Au	0	0	88	390	550	160	0.32	0.13
Ag	0	0	270	3,100	4,900	1,100	0.27	0.32
Rock	0	51	740	2,900	3,700	1,100	0.37	0.07

Probabilistic Assessment Simulation Results

Undiscovered resources for the tract were modeled using the consensus estimates for numbers of undiscovered porphyry Cu±Mo±Au deposits and the grade and tonnage models presented in appendix G of this report for Canadian Cu±Mo±Au porphyry copper deposits as input for the EMINERS Monte Carlo simulator program (Root and others, 1992; Bawiec and Spanski, in press). Selected simulation results are reported in table C9, and results of the Monte Carlo simulation are presented as cumulative frequency plots (fig. C2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean for each commodity and for total mineralized rock.

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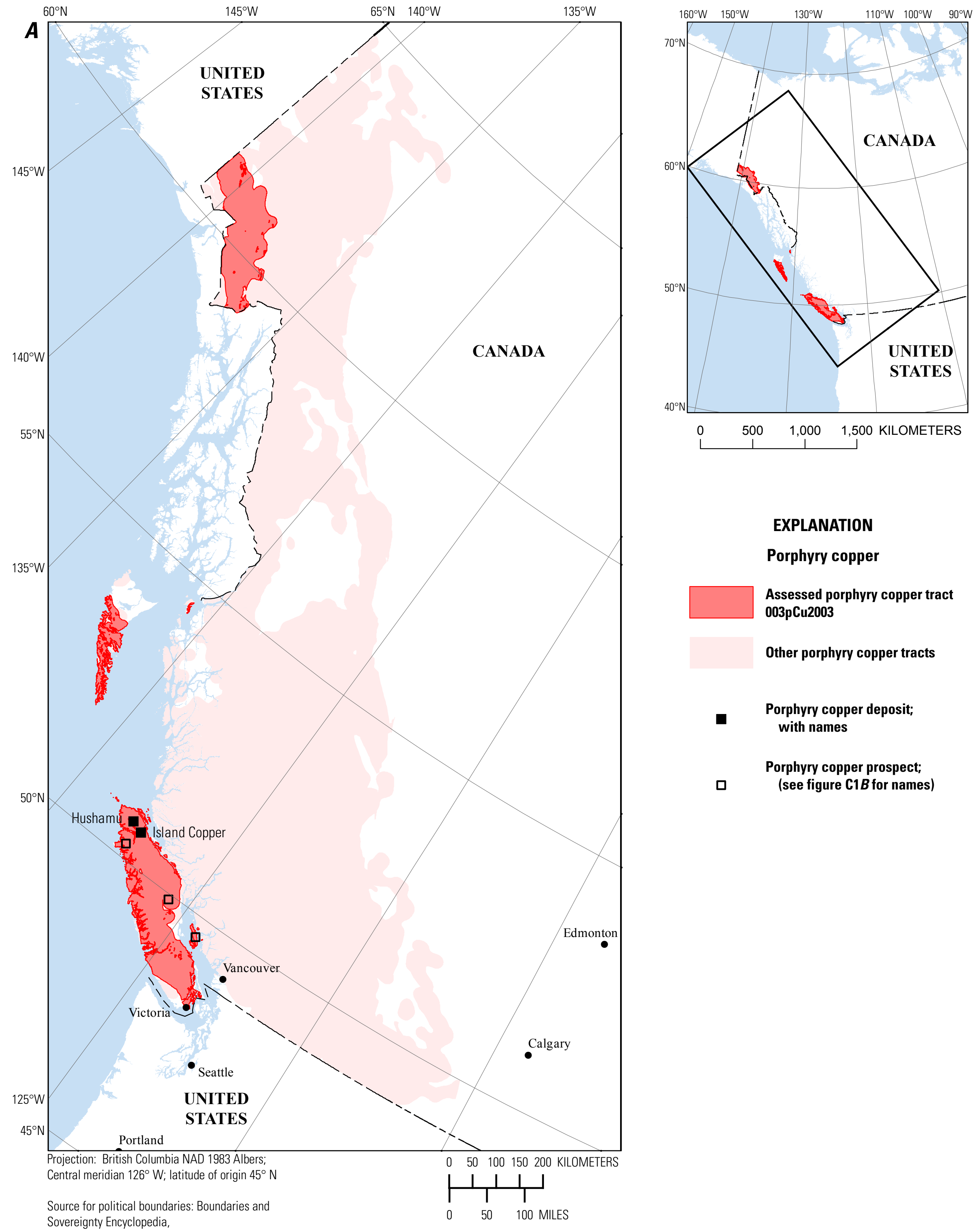
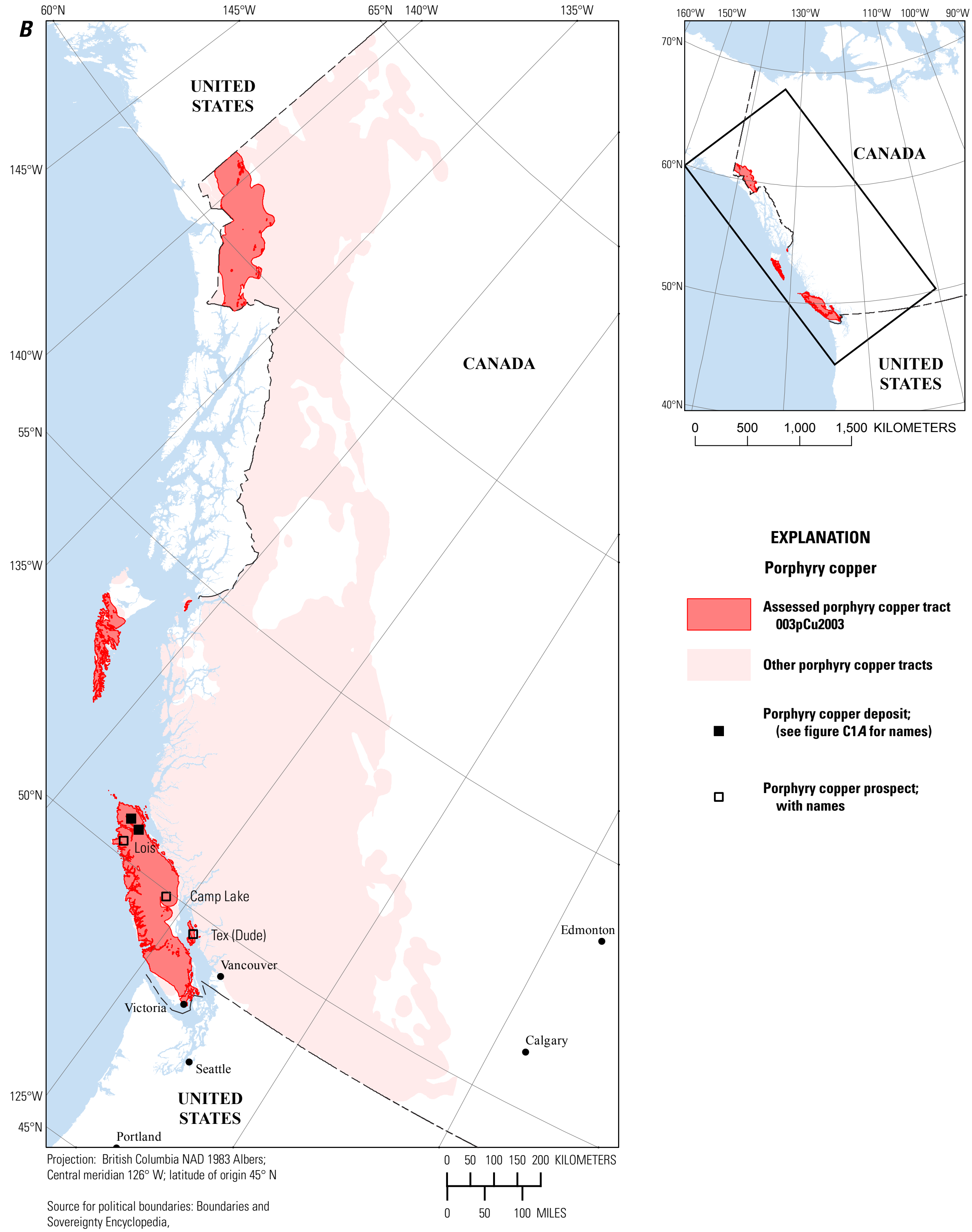


Projection: British Columbia NAD 1983 Albers;
Central meridian 126° W; latitude of origin 45° N

Source for political boundaries: Boundaries and
Sovereignty Encyclopedia,
U.S. Department of State, Office of the Geographer and Global Issues

Figure C1. Maps showing tract 003pCu2003 (CA03), Insular Mixed Island-and Continental Arc Porphyry Cu—British Columbia and Yukon Territory, Canada. *A*, Locations of known preaccretionary calc-alkaline porphyry Cu±Mo±Au deposits (named) and prospects (not named). *B*, Locations of significant prospects for preaccretionary calc-alkaline porphyry Cu±Mo±Au (named) and deposits (not named).



Projection: British Columbia NAD 1983 Albers;
Central meridian 126° W; latitude of origin 45° N

Source for political boundaries: Boundaries and
Sovereignty Encyclopedia,
U.S. Department of State, Office of the Geographer and Global Issues

Figure C1.—Continued

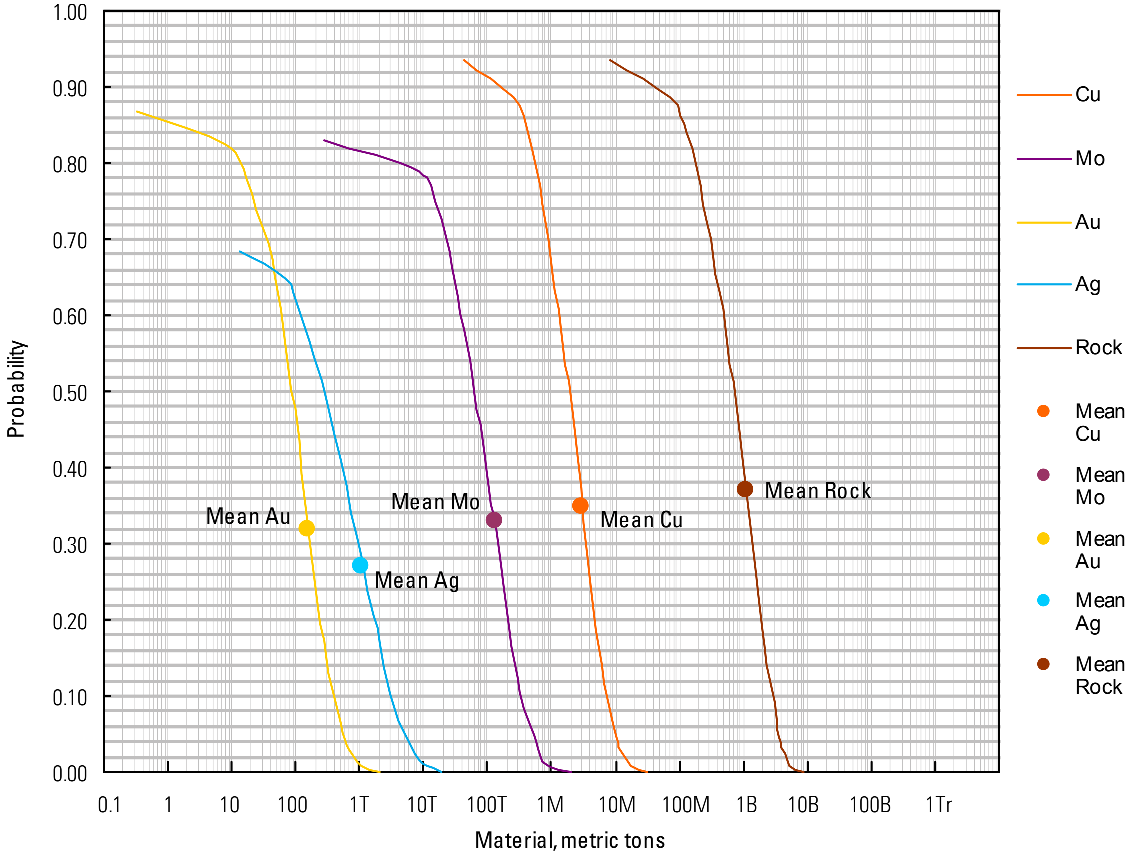


Figure C2. Cumulative frequency plot showing the results of a Monte Carlo computer simulation of undiscovered resources in tract 003pCu2003 (CA03), Insular Mixed Island-and Continental Arc Porphyry Cu—British Columbia and Yukon Territory, Canada. (T=thousands, M=millions, B=billions, Tr=trillions).

Appendix D. Porphyry Copper Assessment for Tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada

By Mark J. Mihalasky[1] , Arthur A. Bookstrom[2] , Thomas P. Frost[3] , and Steve Ludington[4] , with contributions from James M. Logan[5] , Andre Panteleyev[6] , and Grant Abbott[7]

Deposit Type Assessed: Porphyry Copper

Descriptive model: Porphyry copper (Cox, 1986a, Berger and others, 2008), porphyry Cu-Mo (Cox, 1986b), porphyry Cu-Au (Cox, 1986c), porphyry Cu±Mo±Au (Panteleyev, 1995)
Grade and tonnage model: Canadian Cordillera Porphyry Cu±Mo±Au (appendix G)
(Table D1 summarizes selected assessment results)

Table D1. Summary of selected resource assessment results for tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada.

[km, kilometers; km^2, square kilometers; t, metric tons]

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known copper resources (t)	Mean estimate of undiscovered copper resources (t)	Median estimate of undiscovered copper resources (t)
2009	1	639,500	17,900,000	13,000,000	11,000,000

Location

This tract is in the Cordilleran region of western Canada. It extends the length of the Canadian Cordillera and from the outermost coastal islands to about 600 km inland from them. It includes most of the Insular, Coast, and Intermontane belts and part of the Omineca belt in British Columbia and Yukon (figs. 1, D1).

Geologic Feature Assessed

Calc-alkaline igneous rocks of mainly Jurassic (Late Triassic to Early Cretaceous) age in accreted and synaccretionary terranes of mixed island-arc and continental arc affinities.

Delineation of the Permissive Tract

Geologic Criteria

We delineated the tract based on the distribution of predominantly calc-alkaline igneous rocks that formed during subduction-related continental-arc magmatism that occurred after Middle Jurassic accretion of the Intermontane and Insular

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terranes but before Oligocene magmatism in the northern part of the Cascadian magmatic arc of the Pacific Northwest region of the conterminous United States.

Lithologic criteria for consideration of rock types as permissive for the occurrence of calc-alkaline porphyry Cu±Mo±Au deposits are from descriptive models for porphyry copper, Cu-Mo, and Cu-Au deposits by Cox (1986a, b, c) and for calc-alkaline porphyry Cu±Mo±Au deposits of British Columbia by Panteleyev (1995). Phaneritic to porphyritic rock types associated with such deposits, and therefore considered permissive, are quartz diorite, tonalite, granodiorite, quartz monzonite, monzogranite, and granite of calc-alkaline affinity (table D2a). Porphyro-aphanitic equivalents are quartz-andesite, dacite, rhyodacite, quartz-latite, and rhyolite porphyries of calc-alkaline affinity and volcaniclastic rocks of appropriate age and composition (table D2b).

Most intrusions in this tract are calc-alkaline, but a relatively few mildly alkaline (monzonitic to syenitic) intrusions of this age-range also are included (these primarily occur in central British Columbia, in small spatial clusters in the Eocene Endako Group volcanics and the Cretaceous Wolverine Range plutonic suite). Calc-alkaline porphyry Cu±Mo±Au systems generally have concentric zones of mineralized and altered rocks. Copper tends to be concentrated in a central zone with phyllic alteration. Molybdenum tends to be concentrated in an inner zone with potassic alteration assemblages. Gold tends to be concentrated in an outer zone with propylitic and argillic alteration minerals.

Permissive rocks of this tract are products of post-accretionary, subduction-related, continental-arc magmatism that preceded Cascadian magmatism. This imposes age limits of Middle Jurassic (172 Ma) to latest Eocene (34 Ma). Ages of known porphyry copper deposits and significant prospects in this time span range from that of the Middle Jurassic Empress prospect (166 Ma) to that of the latest Eocene Mt. Washington Copper prospect (35 Ma). However, as represented on digital geologic source maps of British Columbia by Massey and others (2005) and the Yukon Territory by Gordey and Makepeace (1999), some map units represent lithologic assemblages containing igneous rocks as old as earliest Early Jurassic (200 Ma), and therefore, this tract does include some older rocks.

Most of the northern part of the inland boundary of this tract is limited by the northwest-striking Tintina Fault (see fig. 2), which probably has 430 to 490 km of right-lateral displacement (Gabrielse and others, 2006). Most of the southern part of the inland boundary of this tract is limited by a zone of north-striking normal faults along the eastern margin of the Rocky Mountain trench. Price (2009) interpreted the Rocky Mountain trench as a broad pull-apart zone, developed during Late Cretaceous to Paleocene right-lateral transpression south of a northwest-southeast to north-south dilational bend in the Tintina fault system.

In the northern part of the assessment region, east of the Tintina Fault, peraluminous to metaluminous intrusions are present, which generally fit the geologic criteria described earlier, but we do not consider all of these rocks permissive for porphyry copper, and exclude some of them from this permissive tract. These rocks include the Tombstone, Mayo, and Tungsten plutonic suites of granitic intrusions, described by Hart and others (2004), and collectively form the mid-Cretaceous Tombstone-Tungsten Belt. Intrusions of the Tungsten Suite, located northeast of the Tintina Fault along the southeastern border of Yukon (see Hart and others, 2004, fig. 1), are peraluminous and of the reduced, ilmenite series type. Some of these have associated world-class tungsten skarn deposits and geochemical anomalies for copper, zinc, tin and molybdenum, but no known porphyry copper deposits or prospects. These rocks are considered nonpermissive. Extending to the northwest, intrusions of the Mayo Suite are sub-alkalic, metaluminous to weakly peraluminous. Some of these have associated geochemical anomalies for gold, bismuth, tellurium, tungsten, arsenic, silver and lead, but no known porphyry copper deposits or prospects. Further to the northwest are the alkalic intrusions of the Tombstone Suite. Some of these have associated geochemical anomalies for gold-copper-bismuth, or uranium-thorium-fluorine. Despite their alkaline affinity, some intrusions of this suite have been prospected for porphyry copper deposits. The intrusions of the northern Mayo Suite and the Tombstone Suite are therefore considered permissive for porphyry copper deposits and are included in this tract.

Tract Delineation Process

We used digital geologic maps of British Columbia by Massey and others (2005) and of the Yukon Territory by Gordey and Makepeace (1999) to identify areas of permissive rocks. Geologic information in attribute tables associated with those maps allowed us to identify polygons representing lithologic assemblages containing rocks of the appropriate age and composition to be included in this permissive tract. We excluded polygons representing lithologic assemblages not considered permissive by reason of age or composition or depth of emplacement, and we recorded a reason for their exclusion in the attribute table for the tract.

Digital geologic-map units that include polygons assigned to this permissive tract are listed in table D2a for intrusive rocks and table D2b for volcanic rocks. From each map unit listed, we selected only those sets of polygons that represent lithologic assemblages containing permissive rock types. Sets of polygons for which descriptions include rocks of ages or compositions that are permissive for more than one tract are included in each of the tracts for which they are permissive.

To identify the area to be included in this permissive tract, we applied the following procedures. From descriptive information in the attribute tables that accompany the digital geologic maps of British Columbia and the Yukon Territory, we classified map units as permissive or nonpermissive, according to the geologic criteria described above (and summarized in tables D2a and D2b). The map units classified

Table D2. Map units that define tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada.

[Province, map unit, age range, and principal rock types from 1:250,000 scale digital geologic maps of British Columbia (Massey and others, 2005) and Yukon Territory (Gordey and Makepeace, 1999)]

Province	Map unit	Age range	Rock types
a. Intrusive rocks			
BC	Czfp	Cenozoic	feldspar porphyritic intrusive rocks
BC	Czgr	Cenozoic	granite, alkali feldspar granite intrusive rocks
BC	EA	Eocene	quartz monzonitic intrusive rocks
BC	EBdr	Eocene	dioritic intrusive rocks
BC	EBfp	Eocene	feldspar porphyritic intrusive rocks
BC	EBgd	Eocene	granodioritic intrusive rocks
BC	EBo	Eocene	granodioritic intrusive rocks
BC	EBqd	Eocene	quartz dioritic intrusive rocks
BC	EBqp	Eocene	high level quartz phyric, felsitic intrusive rocks
BC	ECgd	Early Eocene	granodioritic intrusive rocks
BC	ECH	Eocene	granodioritic intrusive rocks
BC	ECsy	Eocene	syenitic to monzonitic intrusive rocks
BC	Edr	Eocene	dioritic intrusive rocks
BC	EFL	Eocene	granodioritic intrusive rocks
BC	EFLgd	Eocene	granodioritic intrusive rocks
BC	Efp	Eocene	feldspar porphyritic intrusive rocks
BC	Efp	Eocene	feldspar porphyritic intrusive rocks
BC	Eg	Eocene / Middle Eocene	intrusive rocks, undivided
BC	Egd	Eocene	granodioritic intrusive rocks
BC	EGo	Eocene	granite, alkali feldspar granite, granodiorite, monzodioritic to gabbroic intrusive rocks
BC	Egr	Eocene	granite, alkali feldspar granite intrusive rocks
BC	EKaqp	Eocene	high level quartz phyric, felsitic intrusive rocks
BC	EKdr	Early Cretaceous	dioritic intrusive rocks
BC	EKEnH	Early Cretaceous	granodioritic intrusive rocks
BC	EKfp	Early Cretaceous to Pliocene	feldspar porphyritic intrusive rocks
BC	EKg	Early Cretaceous	intrusive rocks, undivided
BC	EKgd	Early Cretaceous	granodioritic intrusive rocks
BC	EKGm	Early Cretaceous	granite, alkali feldspar granite intrusive rocks
BC	EKgr	Early Cretaceous	granite, alkali feldspar granite intrusive rocks
BC	EKH	Early Cretaceous	granite, alkali feldspar granite intrusive rocks
BC	EKHM	Early Cretaceous	monzodioritic to gabbroic intrusive rocks
BC	EKK	Early Cretaceous	granite, alkali feldspar granite intrusive rocks
BC	EKMAgd	Early Cretaceous	granodioritic intrusive rocks
BC	EKMAqd	Early Cretaceous	quartz dioritic intrusive rocks
BC	EKMAto	Early Cretaceous	tonalite intrusive rocks
BC	EKMdr	Early Cretaceous	dioritic intrusive rocks
BC	EKMgd	Early Cretaceous	granodioritic to quartz dioritic intrusive rocks
BC	EKMqm	Early Cretaceous	quartz monzonitic intrusive rocks
BC	EKP	Early Cretaceous	dioritic intrusive rocks
BC	EKqd	Early Cretaceous	quartz dioritic intrusive rocks
BC	EKqm	Early Cretaceous	quartz monzonitic to monzogranitic intrusive rocks
BC	EKto	Early Cretaceous	tonalite intrusive rocks
BC	EMH	Eocene	granite, alkali feldspar granite intrusive rocks
BC	EMJSPd	Early to Middle Jurassic	dioritic intrusive rocks
BC	ENg	Eocene	intrusive rocks, undivided
BC	ENqm	Eocene	quartz monzonitic intrusive rocks
BC	EOlK	Eocene to Oligocene	intrusive rocks, undivided
BC	EOlM	Eocene to Oligocene	quartz dioritic intrusive rocks
BC	EOlT	Oligocene	intrusive rocks, undivided
BC	EQ	Eocene	granite, alkali feldspar granite, porphyritic intrusive rocks
BC	Eqm	Eocene	quartz monzonitic intrusive rocks
BC	Eqp	Eocene	high level quartz phyric, felsitic intrusive rocks
BC	ESR	Eocene	granite, alkali feldspar granite intrusive rocks
BC	ETE	Eocene	tonalite intrusive rocks
BC	ETg	Paleogene	intrusive rocks, undivided
BC	ETgd	Paleogene	granodioritic intrusive rocks
BC	ETgr	Paleogene	granite, alkali feldspar granite intrusive rocks
BC	Eto	Eocene / Early Eocene	tonalite intrusive rocks
BC	ETqd	Paleogene	quartz dioritic intrusive rocks
BC	ETqm	Paleogene	quartz monzonitic intrusive rocks
BC	ETS	Paleogene	quartz monzonitic intrusive rocks
BC	ETSBE	Paleogene	granite, alkali feldspar granite intrusive rocks
BC	ETTs	Paleogene	granodioritic intrusive rocks
BC	Evf	Eocene	intrusive rocks, undivided
BC	Jdr	Jurassic	dioritic intrusive rocks
BC	JFgr	Middle to Late Jurassic	granite, alkali feldspar granite intrusive rocks
BC	Jgd	Jurassic	granodioritic intrusive rocks
BC	JKCL	Early Jurassic to Late Cretaceous	quartz monzonitic to monzogranitic intrusive rocks
BC	JKdr	Jurassic to Cretaceous	dioritic intrusive rocks
BC	JKg	Jurassic to Cretaceous	intrusive rocks, undivided
BC	JKgd	Jurassic to Cretaceous	granodioritic intrusive rocks
BC	JKM	Jurassic to Cretaceous	gabbroic to dioritic intrusive rocks

Table D2. Map units that define tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada.—Continued

[Province, map unit, age range, and principal rock types from 1:250,000 scale digital geologic maps of British Columbia (Massey and others, 2005) and Yukon Territory (Gordey and Makepeace, 1999)]

Province	Map unit	Age range	Rock types
			a. Intrusive rocks
BC	JKP	Jurassic to Cretaceous	quartz dioritic intrusive rocks
BC	JKPP	Jurassic to Cretaceous	tonalite intrusive rocks
BC	JKqp	Jurassic to Cretaceous	high level quartz phyric, felsitic intrusive rocks
BC	JKto	Jurassic to Cretaceous	tonalite intrusive rocks
BC	Jqm	Jurassic	quartz monzonitic intrusive rocks
BC	JTfp	Jurassic to Tertiary	feldspar porphyritic intrusive rocks
BC	JTgr	Jurassic to Tertiary	granite, alkali feldspar granite intrusive rocks
BC	JTH	Jurassic to Tertiary	quartz monzonitic intrusive rocks
BC	JTqp	Jurassic to Tertiary	high level quartz phyric, felsitic intrusive rocks
BC	KAP	Cretaceous	granodioritic intrusive rocks
BC	KAS	Cretaceous	granodioritic intrusive rocks
BC	KB	Cretaceous	granodioritic intrusive rocks
BC	Kdr	Cretaceous	dioritic intrusive rocks
BC	Kg	Cretaceous	intrusive rocks, undivided
BC	Kgd	Cretaceous	granodioritic intrusive rocks
BC	Kgr	Cretaceous	granite, alkali feldspar granite intrusive rocks
BC	KGWgd	Cretaceous	granodioritic intrusive rocks
BC	KNa	Cretaceous	granite, alkali feldspar granite intrusive rocks
BC	KOL	Cretaceous	intrusive rocks, undivided
BC	Kqd	Cretaceous	quartz dioritic intrusive rocks
BC	Kqm	Cretaceous	quartz monzonitic intrusive rocks
BC	Ksy	Cretaceous	syenitic to monzonitic intrusive rocks
BC	KTgd	Cretaceous to Tertiary	granodioritic intrusive rocks
BC	KTgr	Early Cretaceous to Pliocene	granite, alkali feldspar granite intrusive rocks
BC	KTqm	Cretaceous to Tertiary	quartz monzonitic intrusive rocks
BC	KTqp	Cretaceous to Tertiary	high level quartz phyric, felsitic intrusive rocks
BC	KTsy	Early Cretaceous to Pliocene	syenitic to monzonitic intrusive rocks
BC	KTW	Cretaceous to Tertiary	granodioritic intrusive rocks
BC	KW	Cretaceous	granite, alkali feldspar granite intrusive rocks
BC	KWh	Cretaceous	granodioritic intrusive rocks
BC	KWpe	Cretaceous	pegmatitic intrusive rocks
BC	LJdr	Late Jurassic	dioritic intrusive rocks
BC	LJEnS	Middle to Late Jurassic	dioritic intrusive rocks
BC	LJFC	Late Jurassic	granite, alkali feldspar granite intrusive rocks
BC	LJFCL	Late Jurassic	quartz monzonitic to monzogranitic intrusive rocks
BC	LJFE	Middle to Late Jurassic	granodioritic intrusive rocks
BC	LJFF	Late Jurassic	granodioritic intrusive rocks
BC	LJFG	Middle to Late Jurassic	granite, alkali feldspar granite intrusive rocks
BC	LJFN	Late Jurassic	quartz monzonitic to monzogranitic intrusive rocks
BC	LJFT	Middle to Late Jurassic	granite, alkali feldspar granite intrusive rocks
BC	LJgd	Late Jurassic	granodioritic intrusive rocks
BC	LJHP	Late Jurassic	tonalite intrusive rocks
BC	LJKdr	Late Jurassic to Early Cretaceous	dioritic intrusive rocks
BC	LJKgd	Late Jurassic to Early Cretaceous	granodioritic intrusive rocks
BC	LJKgr	Late Jurassic to Early Cretaceous	granite, alkali feldspar granite intrusive rocks
BC	LJKP	Late Jurassic to Early Cretaceous	dioritic intrusive rocks
BC	LJKqd	Late Jurassic to Early Cretaceous	quartz dioritic intrusive rocks
BC	LJKqm	Late Jurassic to Early Cretaceous	quartz monzonitic intrusive rocks
BC	LJKto	Late Jurassic to Early Cretaceous	tonalite intrusive rocks
BC	LJLagr	Late Jurassic	granite, alkali feldspar granite intrusive rocks
BC	LJLaqd	Late Jurassic	quartz dioritic intrusive rocks
BC	LJLaqm	Late Jurassic	quartz monzonitic to monzogranitic intrusive rocks
BC	LJMT	Late Jurassic	granodioritic intrusive rocks
BC	LJqd	Late Jurassic	quartz dioritic intrusive rocks
BC	LJto	Late Jurassic	tonalite intrusive rocks
BC	LKBdr	Late Cretaceous	dioritic intrusive rocks
BC	LKBfp	Late Cretaceous	feldspar porphyritic intrusive rocks
BC	LKBg	Late Cretaceous	intrusive rocks, undivided
BC	LKBgd	Late Cretaceous	granodioritic to quartz dioritic intrusive rocks
BC	LKBqm	Late Cretaceous	quartz monzonitic to monzogranitic intrusive rocks
BC	LKBqp	Late Cretaceous	high level quartz phyric, felsitic intrusive rocks
BC	LKCa	Late Cretaceous	granodioritic intrusive rocks
BC	LKCL	Late Cretaceous	quartz monzonitic to monzogranitic intrusive rocks
BC	LKCT	Late Cretaceous	dioritic intrusive rocks
BC	LKdr	Late Cretaceous to Eocene	dioritic intrusive rocks
BC	LKEnFLgd	Late Cretaceous	granodioritic intrusive rocks
BC	LKEnFLqm	Early Cretaceous	quartz monzonitic to monzogranitic intrusive rocks
BC	LKEngr	Late Cretaceous	granite, alkali feldspar granite intrusive rocks
BC	LKEnP	Late Cretaceous	tonalite intrusive rocks
BC	LKEnqp	Late Cretaceous	high level quartz phyric, felsitic intrusive rocks
BC	LKgb	Late Cretaceous	gabbroic to dioritic intrusive rocks
BC	LKgd	Late Cretaceous	granodioritic intrusive rocks
BC	LKGlgr	Late Cretaceous	granite, alkali feldspar granite intrusive rocks
BC	LKH	Late Cretaceous	feldspar porphyritic intrusive rocks

Table D2. Map units that define tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada.—Continued

[Province, map unit, age range, and principal rock types from 1:250,000 scale digital geologic maps of British Columbia (Massey and others, 2005) and Yukon Territory (Gordey and Makepeace, 1999)]

Province	Map unit	Age range	Rock types
a. Intrusive rocks			
BC	LKi	Late Cretaceous to Pliocene	intrusive rocks, undivided
BC	LKJ	Late Cretaceous	granodioritic intrusive rocks
BC	LKKP	Late Cretaceous	granodioritic intrusive rocks
BC	LKPedr	Late Cretaceous to Paleocene	dioritic intrusive rocks
BC	LKPegb	Late Cretaceous to Paleocene	gabbroic to dioritic intrusive rocks
BC	LKPegd	Late Cretaceous to Paleocene	granodioritic intrusive rocks
BC	LKPeqd	Late Cretaceous to Paleocene	quartz dioritic intrusive rocks
BC	LKqd	Late Cretaceous	quartz dioritic intrusive rocks
BC	LKqm	Late Cretaceous	quartz monzonitic intrusive rocks
BC	LKTDfp	Late Cretaceous to Pliocene	feldspar porphyritic intrusive rocks
BC	LKTdr	Late Cretaceous to Paleogene	dioritic intrusive rocks
BC	LKTfp	Late Cretaceous to Paleogene	feldspar porphyritic intrusive rocks
BC	LKTg	Late Cretaceous to Paleogene	intrusive rocks, undivided
BC	LKTgd	Late Cretaceous to Paleogene	granodioritic intrusive rocks
BC	LKto	Late Cretaceous	tonalite intrusive rocks
BC	LKTpg	Late Cretaceous to Paleogene	pegmatitic intrusive rocks
BC	LKTqd	Late Cretaceous to Paleogene	quartz dioritic intrusive rocks
BC	LKTqm	Late Cretaceous to Paleogene	quartz monzonitic intrusive rocks
BC	LKTqp	Late Cretaceous to Paleogene	high level quartz phyric, felsitic intrusive rocks
BC	LKTSfp	Late Cretaceous to Pliocene	feldspar porphyritic intrusive rocks
BC	LKTto	Late Cretaceous to Paleogene	tonalite intrusive rocks
BC	LKWfp	Late Cretaceous	feldspar porphyritic intrusive rocks
BC	LKWqd	Late Cretaceous	quartz dioritic intrusive rocks
BC	LTrKB	Late Triassic to Early Cretaceous	gabbroic to dioritic intrusive rocks
BC	MJA	Middle Jurassic	granodioritic intrusive rocks
BC	MJdr	Middle Jurassic	dioritic intrusive rocks
BC	MJgd	Middle Jurassic	granodioritic intrusive rocks
BC	MJgr	Middle Jurassic	granite, alkali feldspar granite intrusive rocks
BC	MJKFgr	Middle Jurassic to Early Cretaceou	granite, alkali feldspar granite intrusive rocks
BC	MJKFqp	Middle Jurassic to Early Cretaceou	high level quartz phyric, felsitic intrusive rocks
BC	MJMc	Middle Jurassic	dioritic intrusive rocks
BC	MJqd	Middle Jurassic	quartz dioritic intrusive rocks
BC	MJSe	Middle Jurassic	granodioritic intrusive rocks
BC	MJSLB	Early Jurassic	quartz dioritic intrusive rocks
BC	MJSLC	Middle Jurassic	quartz monzonitic to monzogranitic intrusive rocks
BC	MJSLL	Middle to Late Jurassic	quartz dioritic intrusive rocks
BC	MJSLM	Middle to Late Jurassic	quartz dioritic intrusive rocks
BC	MJSLqd	Middle Jurassic	quartz dioritic intrusive rocks
BC	MJSLSqd	Middle Jurassic	quartz dioritic intrusive rocks
BC	MJSLSt	Middle to Late Jurassic	gabbroic to dioritic intrusive rocks
BC	MJSLSu	Middle to Late Jurassic	granodioritic intrusive rocks
BC	MJSLTw	Middle to Late Jurassic	dioritic intrusive rocks
BC	MJTqd	Middle Jurassic	quartz dioritic intrusive rocks
BC	MJTSto	Middle Jurassic	tonalite intrusive rocks
BC	MKAdg	Mid-Cretaceous	monzodioritic to gabbroic intrusive rocks
BC	MKBagr	Mid-Cretaceous	granite, alkali feldspar granite intrusive rocks
BC	MKEdr	Mid-Cretaceous	dioritic intrusive rocks
BC	MKEgd	Mid-Cretaceous	granodioritic intrusive rocks
BC	MKEqd	Mid-Cretaceous	quartz dioritic intrusive rocks
BC	MKEqm	Mid-Cretaceous	quartz monzonitic intrusive rocks
BC	MKgb	Mid-Cretaceous	gabbroic to dioritic intrusive rocks
BC	MKgd	Mid-Cretaceous	granodioritic intrusive rocks
BC	MKGlgd	Mid-Cretaceous	granodioritic intrusive rocks
BC	MKGlqd	Mid-Cretaceous	quartz dioritic intrusive rocks
BC	MKgr	Mid-Cretaceous	granite, alkali feldspar granite intrusive rocks
BC	MKqd	Mid-Cretaceous	quartz dioritic intrusive rocks
BC	MKqm	Mid-Cretaceous	quartz monzonitic intrusive rocks
BC	MLJBdr	Middle Jurassic to Late Jurassic	dioritic intrusive rocks
BC	MLJBgd	Middle Jurassic to Late Jurassic	granodioritic intrusive rocks
BC	MLJBqd	Middle Jurassic to Late Jurassic	quartz dioritic intrusive rocks
BC	MLJBqm	Middle Jurassic to Late Jurassic	quartz monzonitic intrusive rocks
BC	MLJdr	Middle Jurassic to Late Jurassic	dioritic intrusive rocks
BC	MLJG	Middle Jurassic to Late Jurassic	quartz dioritic intrusive rocks
BC	MLJgd	Middle Jurassic to Late Jurassic	granodioritic intrusive rocks
BC	MLJqd	Middle Jurassic to Late Jurassic	quartz dioritic intrusive rocks
BC	Mzfp	Mesozoic	feldspar porphyritic intrusive rocks
BC	PeEC	Paleocene to Eocene	intrusive rocks, undivided
BC	PeEfp	Paleocene to Eocene	feldspar porphyritic intrusive rocks
BC	PeEgd	Paleocene to Eocene	granodioritic intrusive rocks
BC	PeEgr	Paleocene to Eocene	granite, alkali feldspar granite intrusive rocks
BC	PeEqm	Paleocene to Eocene	quartz monzonitic intrusive rocks
BC	PeEShgr	Paleocene to Eocene	granite, alkali feldspar granite intrusive rocks
BC	PeEShqd	Paleocene to Eocene	quartz dioritic intrusive rocks
BC	PeEShqp	Paleocene to Eocene	high level quartz phyric, felsitic intrusive rocks

Table D2. Map units that define tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada.—Continued

[Province, map unit, age range, and principal rock types from 1:250,000 scale digital geologic maps of British Columbia (Massey and others, 2005) and Yukon Territory (Gordey and Makepeace, 1999)]

Province	Map unit	Age range	Rock types
			a. Intrusive rocks
BC	Pegd	Paleocene	granodioritic intrusive rocks
BC	Tfp	Tertiary	feldspar porphyritic intrusive rocks
BC	Tg	Tertiary	intrusive rocks, undivided
BC	Tgd	Tertiary	granodioritic intrusive rocks
BC	Tgr	Tertiary	granite, alkali feldspar granite intrusive rocks
BC	Tqm	Tertiary	quartz monzonitic intrusive rocks
BC	Tqp	Tertiary	high level quartz phyric, felsitic intrusive rocks
BC	TrJg	Triassic to Jurassic	intrusive rocks, undivided
BC	TrJqm	Triassic to Jurassic	quartz monzonitic intrusive rocks
BC	TrKgr	Triassic to Cretaceous	granite, alkali feldspar granite intrusive rocks
BC	TrTdr	Triassic to Tertiary	dioritic intrusive rocks
BC	TrTg	Triassic to Tertiary	intrusive rocks, undivided
BC	TTgd	Tertiary	granodioritic intrusive rocks
BC	?gr	Age Unknown	granite, alkali feldspar granite intrusive rocks
YT	EJgA	Early Jurassic	granodiorite/diorite/monzodiorite
YT	EJL	Early Jurassic	quartz monzonite/granite/aplite/pegmatite/ syenite
YT	EJqL	Early Jurassic	quartz monzonite/granite/aplite/pegmatite
YT	EKgT	Early Cretaceous	granite/granodiorite/quartz monzonite/quartz monzodiorite
YT	EKK	Late Early Cretaceous	granodiorite/quartz diorite/quartz monzonite/diorite
YT	ES	Eocene	tonalite/granodiorite
YT	ETgN	Early Tertiary	granodiorite/quartz monzonite/quartz diorite/diorite/porphyry
YT	ETqN	Early Tertiary	granite/alaskite/quartz monzonite/granodiorite
YT	JKS	Late Jurassic to earliest Cretaceous	granodiorite/tonalite
YT	LKfP	Late Cretaceous to Tertiary	porphyry
YT	LKgP	Late Cretaceous to Tertiary	granodiorite/diorite/quartz diorite
YT	LKP?	Late Cretaceous to Tertiary	quartz monzonite/granite/alaskite/granodiorite/ diorite/quartz diorite
YT	LKqM	Late Cretaceous	granite/quartz monzonite
YT	LKqP	Late Cretaceous to Tertiary	quartz monzonite/granite/alaskite/granodiorite
YT	LKyP	Late Cretaceous to Tertiary	syenite
YT	LTrgS	Late Triassic	granite/granodiorite/orthogneiss/quartz diorite/diorite
YT	MJgB	mid-Jurassic	monzodiorite/quartz monzodiorite/hornblendite/granite/ granodiorite
YT	mKdW	mid-Cretaceous	quartz diorite/diorite
YT	mKgS	mid-Cretaceous	quartz monzonite/granodiorite/quartz diorite/syenite
YT	mKgW	mid-Cretaceous	granodiorite/quartz diorite
YT	mKqC	mid-Cretaceous	granite/quartz monzonite/granodiorite
YT	mKqC?	mid-Cretaceous	granite/quartz monzonite/granodiorite
YT	mKqS	mid-Cretaceous	granite/quartz monzonite/granodiorite
YT	mKqT	mid-Cretaceous	granite/quartz monzonite/granodiorite
YT	mKqW	mid-Cretaceous	quartz monzonite/granite/monzonite/syenite
YT	mKT	mid-Cretaceous	syenite/quartz syenite/granite/monzogranite/clinopyrrox/ tinguiate/granite/quartz m
YT	mKW	mid-Cretaceous	quartz monzonite/granite/monzonite/syenite/ granodiorite/quartz diorite
YT	mKyS	mid-Cretaceous	syenite
YT	mKyT	mid-Cretaceous	syenite/quartz syenite/granite/monzogranite/ clinopyroxenite/tinguiate
YT	mKyW	mid-Cretaceous	syenite/granite/granodiorite
			b. Volcanic rocks
BC	EEBvb	Eocene	basaltic volcanic rocks
BC	EEG	Eocene	andesitic and alkaline volcanic rocks
BC	EEv	Eocene to Oligocene	undivided volcanic rocks
BC	EEva	Eocene to Oligocene	andesitic volcanic rocks
BC	EEvf	Eocene to Oligocene	rhyolite, felsic volcanic rocks
BC	EKaca	Eocene	calc-alkaline volcanic rocks
BC	EKav	Eocene	undivided volcanic rocks
BC	EMiE	Eocene to Lower Miocene	basaltic volcanic rocks
BC	EO	Eocene to Oligocene	rhyolite, felsic volcanic rocks
BC	EOH	Eocene to Oligocene	dacitic volcanic rocks
BC	EOlCMv	Eocene to Oligocene	undivided volcanic rocks
BC	EOlCMva	Eocene to Oligocene	andesitic volcanic rocks
BC	EOlCMvd	Eocene to Oligocene	dacitic volcanic rocks
BC	EOldb	Eocene to Oligocene	diabase, basaltic subvolcanic rocks
BC	EOlEv	Eocene to Oligocene	undivided volcanic rocks
BC	EON	Eocene	andesitic volcanic rocks
BC	EONva	Eocene	andesitic volcanic rocks
BC	EOva	Eocene to Oligocene	andesitic volcanic rocks
BC	EOvd	Eocene	dacitic volcanic rocks
BC	EOvf	Eocene to Oligocene	rhyolite, felsic volcanic rocks
BC	EPeM	Eocene	trachytic volcanic rocks
BC	EPeMK	Eocene	undivided volcanic rocks
BC	EPev	Eocene	undivided volcanic rocks
BC	EPrb	Eocene	andesitic volcanic rocks
BC	ESv	Early Eocene	undivided volcanic rocks
BC	ESva	Early Eocene	andesitic volcanic rocks
BC	ESvb	Early Eocene	basaltic volcanic rocks
BC	ESvc	Early Eocene	volcaniclastic rocks

Table D2. Map units that define tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada.—Continued

[Province, map unit, age range, and principal rock types from 1:250,000 scale digital geologic maps of British Columbia (Massey and others, 2005) and Yukon Territory (Gordey and Makepeace, 1999)]

Province	Map unit	Age range	Rock types
			a. Intrusive rocks
BC	ESvf	Early Eocene	rhyolite, felsic volcanic rocks
BC	ESvl	Early Eocene	coarse volcaniclastic and pyroclastic volcanic rocks
BC	Evc	Eocene	volcaniclastic rocks
BC	Evd	Eocene	dacitic volcanic rocks
BC	JKca	Jurassic to Cretaceous	calc-alkaline volcanic rocks
BC	Kca	Cretaceous	calc-alkaline volcanic rocks
BC	Ktva	Early Cretaceous to Pliocene	andesitic volcanic rocks
BC	KTvc	Early Cretaceous to Pliocene	volcaniclastic rocks
BC	Kva	Cretaceous	andesitic volcanic rocks
BC	lJHva	Early to Middle Jurassic	andesitic volcanic rocks
BC	lKca	Lower Cretaceous	calc-alkaline volcanic rocks
BC	lKGca	Lower Cretaceous	calc-alkaline volcanic rocks
BC	lKGM	Lower Cretaceous	calc-alkaline volcanic rocks
BC	lKGva	Lower Cretaceous	andesitic volcanic rocks
BC	lKSB	Lower Cretaceous	calc-alkaline volcanic rocks
BC	lKSBP	Lower Cretaceous	undivided volcanic rocks
BC	lKSBPva	Lower Cretaceous	andesitic volcanic rocks
BC	lKSBSva	Lower Cretaceous	andesitic volcanic rocks
BC	lKSN	Lower Cretaceous	undivided volcanic rocks
BC	lKSRvf	Early Cretaceous	rhyolite, felsic volcanic rocks
BC	lKSvf	Early Cretaceous	rhyolite, felsic volcanic rocks
BC	lKTca	Lower Cretaceous	calc-alkaline volcanic rocks
BC	lmJBv	Lower Jurassic to Middle Jurassic	undivided volcanic rocks
BC	luKvc	Lower Cretaceous to Upper Cretaceo	volcaniclastic rocks
BC	luKWv	Mid-Cretaceous to Upper Cretaceous	undivided volcanic rocks
BC	luKWvf	Mid-Cretaceous to Upper Cretaceous	rhyolite, felsic volcanic rocks
BC	mJv	Middle Jurassic	undivided volcanic rocks
BC	muJHNa	Middle Jurassic to Upper Jurassic	rhyolite, felsic volcanic rocks
BC	muJHo	Middle Jurassic to Upper Jurassic	calc-alkaline volcanic rocks
BC	muJHSvb	Middle Jurassic to Upper Jurassic	basaltic volcanic rocks
BC	PeEca	Paleocene to Eocene	calc-alkaline volcanic rocks
BC	PeEF	Paleocene to Eocene	calc-alkaline volcanic rocks
BC	PeEvf	Paleocene to Eocene	rhyolite, felsic volcanic rocks
BC	TrJN	Triassic to Jurassic	calc-alkaline volcanic rocks
BC	TrJNO	Triassic to Jurassic	calc-alkaline volcanic rocks
BC	uJBvd	Middle to Late Jurassic	dacitic volcanic rocks
BC	uKEvf	Upper Cretaceous to Eocene	rhyolite, felsic volcanic rocks
BC	uKK	Cretaceous / Late Cretaceous	andesitic volcanic rocks
BC	uKPo	Upper Cretaceous	undivided volcanic rocks
BC	uKPovc	Upper Cretaceous	volcaniclastic rocks
BC	uKQG	Upper Cretaceous	andesitic volcanic rocks
BC	uKva	Late Cretaceous	andesitic volcanic rocks
BC	uKvf	Late Cretaceous	dacitic volcanic rocks
BC	uTrTca	Upper Triassic	calc-alkaline volcanic rocks
YT	ETfN	Early Tertiary	porphyry/dykes/flows
YT	lES1	Lower Eocene	rhyolite/andesite/flows/breccia/tuffs/ conglomerate/domes/plugs/laccoliths
YT	lES2	Lower Eocene	mudstone/sandstone/conglomerate/tuff/ breccia/dacite/rhyolite/flows/dykes/sill
YT	lES2?	Lower Eocene	mudstone/sandstone/conglomerate/tuff/ breccia/dacite/rhyolite/flows/dykes/sill
YT	lTR2	Lower Tertiary, mostly(?) Eocene	rhyolite/flows/tuff/breccia
YT	lTR4	Lower Tertiary, mostly(?) Eocene	porphyry/rhyolite
YT	mKN	mid-Cretaceous	andesite/dacite/breccia/tuffs/rhyolite/ porphyry/plugs/dykes/sills
YT	mKN?	mid-Cretaceous	andesite/dacite/breccia/tuffs/rhyolite/ porphyry/plugs/dykes/sills
YT	uKC1	Upper Cretaceous	basalt/breccia/andesite/porphyry/dacite/ trachyte
YT	uKC2	Upper Cretaceous	tuff/plugs/necks/flows/porphyry
YT	uKW	Upper Cretaceous	dacite/flows/tuffs/basalt/dykes/sandstone

as permissive for this tract represent the bedrock-surface expressions of intermediate to felsic igneous rocks of calc-alkaline affinity and of Jurassic to Eocene age in subduction-related magmatic arcs along the continental margin.

To polygons or groups of polygons that represent the bedrock-surface expression of permissive map units, we added a 10-km buffer to the mapped margins of permissive intrusions. This buffer expanded the area of the permissive tract to include all significant porphyry copper prospects, and to include possible unexposed permissive rocks and porphyry copper deposits. Examples of permissive rock types below the mapped surface would include permissive plutons that expand downward, subsurface satellite cupolas of intrusions, and unmapped parts of plutons or porphyry copper occurrences that are covered by younger materials (such as basalt flows, glacial till, colluvium, alluvium, or basin-fill sediments less than 1 km thick) or are structurally covered. We also applied a 2-km buffer around the outer margins of polygons or groups of polygons representing permissive volcanic rocks, the thin edges of which might be discontinuous, covered, or otherwise not mapped at the scale of our source maps. For additional information on buffering, see the "Permissive Tracts for Porphyry Copper" section in the Introduction of this report.

After buffering, we examined aeromagnetic, gravimetric, and geochemical anomaly maps for evidence of unmapped permissive igneous rocks or hydrothermal systems (Natural Resources Canada, 2008a, b, c). Positive aeromagnetic and gravity anomalies were interpreted as possible evidence for granitoid intrusions or magnetite-bearing hydrothermal systems (see Clark, 1999, for discussion). Stream-sediment geochemical anomalies for copper associated with molybdenum or zinc were interpreted tentatively as possible evidence for hydrothermal systems. Where such anomalies appeared to indicate that permissive intrusions or geochemical anomalies associated with this tract might extend beyond the margins of the preliminary tract buffers, the tract was expanded to include them. However, we excluded geochemical anomalies associated with tungsten.

A smoothing routine (described in appendix H, metadata) was then applied to the buffered tract. Finally, buffer zones were trimmed so as not to extend east of the Tintina Fault, which bounds the northeastern margin of the tract.

Geologic Interpretation

The Endako porphyry Mo deposit, in central British Columbia, is the oldest porphyry-style deposit in this magmatic belt. The age of the Endako deposit is about 144 Ma, according to Re-Os dates on molybdenite from the Endako deposit and U-Pb dates on zircon from the Endako Quartz Monzonite (Selby and Creaser, 2001; Whalen and others, 2001; Bysouth and Wong, 1995). According to Nelson and Colpron (2007, p. 779), the Endako deposit formed near the inboard margin of early post-accretionary continental-arc magmatism (150 to 135 Ma). The Jean porphyry copper deposit, near the east-central margin of this tract, is associated with granodiorite, dated 134±6 Ma (average of K-Ar age determinations on biotite and hornblende, from 1996, reported in BC MINFILE record number 093N 079).

At least 12 porphyry copper occurrences probably formed within this tract during the interval between 105 and 95 Ma. These include the Ball Creek, Colossus, Copper Canyon, Dobbin, Trudy, Maloney, Suits, and Rita prospects. Most of these prospects are in the Intermontane terranes, near the long central axis of this permissive tract, but the Colossus prospect (~105 Ma) is in Wrangellia, just inland from the northern half of Vancouver Island.

At least 21 porphyry copper deposits formed in Late Cretaceous to middle Eocene time, during the interval between about 95 and 45 Ma. In southern British Columbia, most Late Cretaceous-Eocene porphyry copper deposits are inboard from the Coast Range batholith, but a few are outboard from it. In central British Columbia most porphyry copper deposits of this age are inboard from the Coast Range batholith. Many are concentrated along the northeast-trending Skeena arch, which is marginal to the south end of the Bowser Basin (see fig. 1). In northern British Columbia and the Yukon Territory, most porphyry copper deposits and prospects of this age are inboard from the Coast Range batholith.

Braided networks of northwest-trending dextral faults of Cretaceous and Cenozoic ages parallel the Canadian Cordillera (fig. D2). According to Gabrielse and others (2006, p. 255), "Geological constraints suggest a total cumulative dextral displacement of about 860 km of outermost parts of the Cordillera with respect to rocks tied directly to the North American craton at their current latitudes." About half of this displacement occurred on mid-Cretaceous faults, such as the Teslin, Cassiar, Pinchi, and Northern Rocky Mountain Trench Faults. The rest of this displacement occurred during Eocene time, primarily on the Tintina and Northern Rocky Mountain Trench Faults and splays.

Plate-movement reconstructions by Engebretson and others (1985) for time intervals from 85 to 61 Ma indicate that the Cordilleran margin of North America moved west-northwestward over the Kula Plate. During this time interval, the Kula Plate was moving northward at about four times the westward rate of the North American Plate. This would have resulted in oblique subduction of the Kula Plate, which would have imposed dextral transpressional stress on the overriding continental margin.

Histograms of age determinations on igneous rocks indicate that rates of magmatism increased sharply at about 58 Ma, spiked at about 51 Ma, and then decreased sharply after about 48 Ma (see fig. 3*B*). This flare-up in rates of magmatism probably was related to changes in rates and directions of plate movements. According to a plate-movement model by Haeussler and others (2003, p. 867), "synchronous near-trench magmatism from southeastern Alaska to Puget Sound at about 50 Ma documents the Eocene subduction of a spreading center, the crest of which was subparallel to the continental margin." There is no record of this in the pattern of magnetic anomalies on the sea floor, because the hypothetical Resurrection plate and the spreading ridges that bounded it were subducted.

According to Haeussler and others (2003), onshore clues to the previous existence of the Resurrection plate are provided by evidence for two trench-ridge-trench (TRT) triple junctions. One of these is in southern Alaska, and another is centered on the Cascadian margin near Puget Sound. The Alaskan TRT is characterized by near-trench anatectic granites, intruded into subduction-related accretionary-wedge complexes. Ages of such granites decrease eastward along the length of the south Alaskan margin. This indicates that between 61 Ma and 48 Ma, the Alaskan TRT migrated 2,100 km eastward. The Cascadian TRT was relatively stationary and is characterized by a thick section of oceanic basalts of the Siletz River Volcanics, dated between about 64 and 48 Ma. Haeussler and others (2003) suggested that for these two TRT junctions to have been active simultaneously requires a northeast-moving Resurrection plate between the Farallon and Kula plates. If the spreading ridge between the Resurrection and Kula plates were oriented northwest and moved northeast, that would move the Alaskan TRT eastward along the southern edge of Alaska. If the spreading ridge between Resurrection and Farallon plates were oriented northeast and moving northeast, the position of the Cascadian TRT would remain relatively stationary.

As the Resurrection plate was progressively consumed by subduction, the northwest-trending ridge between the Resurrection and Kula plates would have approached the continental margin to be drawn into the subduction zone. Being subparallel to the western Canadian continental margin, that spreading ridge would have been subducted nearly simultaneously along the length of the Canadian Cordillera. As suggested by Haeussler and others (2003), subduction of progressively younger and warmer parts of the Resurrection plate would have caused voluminous magmatism and rapid uplift in the Canadian continental margin prior to 50 Ma.

Subsequent subduction of a nearly trench-parallel spreading ridge between the Resurrection and Kula plates would have caused a surge in rates of generation of Eocene igneous rocks and associated porphyry copper deposits. Such a surge occurred between about 52 Ma and 48 Ma, as shown by the histograms in figure 3. Post-compressional extension, possibly related to subduction of this spreading ridge, also would have promoted the rise and exhumation of metamorphic core complexes and the extensional collapse of the Cordilleran fold-and-thrust belt (Haeussler and others, 2003).

Then subduction of the nearly trench-perpendicular spreading ridge between the Kula and Farallon plates would have opened a downward-widening window between these plates as they continued to separate while being subducted (Breitsprecher and others, 2003; Haeussler and others, 2003). Magmatism of the Challis magmatic belt, which extends from the Absaroka and Challis volcanic fields in Wyoming, Montana, and Idaho to British Columbia south of Kamloops, may have formed as the North American Plate obliquely overrode such a slab window (Breitsprecher and others, 2003, see fig. 1). The Lexington-Lone Star deposit, which is in the northwestern part of the Challis-Kamloops magmatic belt, is the only known porphyry copper deposit that formed in this part of the tract between about 58 Ma and 48 Ma.

Before the magmatism related to the development and subduction of the Resurrection and Kula plates, recent work by James K. Mortensen and Craig J.R. Hart, at the University of British Columbia, Mineral Deposit Research Unit, suggests that latest Cretaceous magmatism in the northern Cordillera of southernmost Yukon and east-central Alaska (which involved only the Farallon Plate) may be related to post-accretionary, non-arc-related processes (see Richards, 2009) in a waning- or post-subduction setting (written commun., J.K. Mortensen, 2011; oral communs., J.K. Mortensen and C.J.R. Hart, 2010; Mortensen and Hart, 2010; Hart, 2010).

New U-Pb zircon crystallization age dates for igneous rocks and new aeromagnetic-based mapping of Early and mid-Cretaceous oxidized and reduced igneous rocks (magnetite- and ilmenite-series, respectively), indicate an early arc magmatic phase (115-99 Ma), then a latter inboard-migrating magmatic phase consisting of either (1) extension in the back-arc and melting of enriched mantle (95-90 Ma) (Mair and others, 2006; oral commun., C.J.R. Hart, 2010), or (2) flat-slab subduction with crustal thickening and anatexis (99-94 Ma), with terminal slab break-off (94-90 Ma) (written commun., J.K. Mortensen, 2011).

After this latter phase, an early Late Cretaceous (78-72 Ma) magmatic pulse occurred in a narrow northwest-trending band (in which occur the 74-Ma Casino and 76-Ma Cash deposits), followed by a widespread, late Late Cretaceous (72-67 Ma) magmatic pulse that occurred simultaneously across the region between the Denali and Tintina Faults, showing no age progression relative to earlier magmatic arc orientations. Mortensen (written commun., 2011; oral commun., 2010) suggests that the widespread extent and lack of age progression, as well as the broadly adakitic compositions characterizing some of the igneous units, precludes a normal arc origin for this magmatic pulse. He further maintains that these observations are most consistent with post-subduction lithospheric detachment in late Late Cretaceous time. Given this scenario, Mortensen suggests that, “widespread lithospheric delamination [occurred] under a large area of western Yukon (and eastern Alaska?) at about 72 Ma, which triggered both partial melting of the foundering block (producing arc-like, adakitic melts) and simultaneous partial melting of enriched mantle that flowed upwards to displace the sinking block” (written commun., 2011).

Mortensen acknowledges that there are some problems with the proposed lithospheric delamination model: “Most importantly, in such a scenario one commonly observes widespread crustal uplift when the block detaches, and also eruption of abundant ignimbrites related to partial melting of the base of the crust by heat from a mafic magmatic underplate” (written commun., 2011). However, while there is evidence for Late Cretaceous ignimbrites and block faulting before and during Late Cretaceous magmatism, there is little evidence for significant uplift at this time (written commun., 2011). Research is currently underway by the University of

British Columbia, Mineral Deposit Research Unit, to further resolve and investigate these magmatic events.

Known Deposits

There are 23 known calc-alkaline porphyry copper deposits in tract 003pCu4002 (CA04), 3 of which include multiple ore bodies that are grouped according to the 2-km rule. These deposits fit descriptive models for porphyry copper deposits by Singer and others (2008), and for calc-alkaline porphyry Cu±Mo±Au deposits of British Columbia by Panteleyev (1995). According to the criteria of Singer and others (2008), some of these ore bodies and deposits are of the porphyry Cu-Mo subtype, and some are of the Cu-Au subtype, as noted in table D3.

These are bulk-mineable ore bodies and deposits, which generally are associated with igneous intrusions of calc-alkaline composition and porphyritic texture. For those that occur in groups, we list (in table D3) the name of the group, followed by the names of the ore bodies in the group. The tonnage, grade, and copper content of each ore body in the group is followed by the total tonnage, grade, and copper content of the group.

Porphyry copper deposits commonly consist of stockworks of intersecting veins and veinlets, containing various proportions of quartz and chalcopyrite±bornite±molybdenite±pyrite±gold. Disseminated ore minerals also may occur in hydrothermally altered rocks around and between veins and veinlets, and in breccias. Associated igneous rocks include porphyritic, aplitic, and aphanitic to phaneritic varieties of diorite, quartz monzodiorite, and quartz monzonite to tonalite, granodiorite, and monzogranite.

Panteleyev (1995, p. 2) described three subtypes of the Canadian calc-alkaline porphyry Cu±Mo±Au deposit type: (1) plutonic Cu-Mo, (2) classic Cu±Mo±Au, and (3) volcanic Cu±Au±Mo. Deposits of the classic and volcanic subtypes occur in this tract. Deposits of the classic subtype are related to porphyritic stocks, within and around which mineralization occurred at relatively shallow depths. Deposits of the volcanic subtype are associated with multiple intrusions in subvolcanic settings of small stocks, sills, dikes, and breccias.

In calc-alkaline porphyry Cu±Mo±Au deposits, the Mo zone commonly is in the lower, inner part of the copper zone or below it, and the Au zone is commonly in the upper-outer part of the copper zone, or above and around it. Potassic alteration assemblages, generally consisting of secondary K-feldspar and biotite, are common in the Cu-Mo zone. Phyllic alteration assemblages, generally consisting of quartz, pyrite, and sericite, are common in the copper zone. Argillic alteration assemblages, generally consisting of clay minerals, may be peripheral to, or superimposed upon the phyllic zone, especially along late faults and fractures. Propylitic alteration, generally consisting of chlorite, epidote, and carbonate minerals, commonly surrounds the phyllic zone and may overlap the Cu-Au zone. However, if the magmatic-hydrothermal system expands or collapses, or undergoes multiple pulses of intrusion and mineralization, different assemblages of ore and alteration minerals can be superimposed.

According to Panteleyev (1995, p. 3), “Oxidized and leached zones are marked by ferruginous cappings with supergene clay minerals, limonite (goethite, hematite, and jarosite) and residual quartz.” Supergene minerals include chalcocite, covellite, digenite, chrysocolla, native copper and copper oxide, carbonate and sulfate minerals. However, zones of supergene enrichment generally are not well developed or economically important in deposits of this tract. The Bell and Berg deposits are exceptions. They have fairly continuous zones of moderately supergene enriched ore, which probably are post-glacial in age.

Three of the known deposits in this tract include nearby deposits and prospects that are grouped with the main deposit according to the 2-km rule of Singer and others (2005). That rule states that porphyry copper deposits or prospects that have mineralized or altered rocks that are separated by less than 2 km are grouped for purposes of modeling tonnage, grade, and deposit density (for additional information, see the “Grade and Tonnage Models,” “Groups of Porphyry-Cu Deposits and Prospects (Aggregated According to the 2-km Rule)” section in the Introduction of this report). Nevertheless, we are interested in the character and distribution of individual ore bodies and prospects, so we list both the groups and their constituent ore bodies in table D3. However, only the location of the largest ore body in the group is shown on the maps in figures D1*A* and D1*B*.

We estimate that known deposits of this tract contain about 17,900,000 metric tons of copper (table D1). Some estimates listed here include recent additions to known resources, and some of our groups are aggregated differently from those of Singer and others (2008). Named deposits followed by one asterisk are not included in our tonnage and grade models because estimated tonnages and grades are based on unsubstantiated press releases. Named deposits followed by two asterisks are not included in our tonnage and grade models because they are open in one or more directions, are being actively explored, and their resource estimates are being changed. Additional descriptive information about known porphyry copper deposits and additional references are included in the table in appendix F.

Prospects, Mineral Occurrences, and Related Deposit Types

Appendix F lists 82 porphyry copper prospects in this tract. Of those, we consider 61 to be significant porphyry copper prospects. Three of those are rank 2 prospects, estimated to contain less than 16 kt copper, but are incompletely known and possibly related to larger porphyry copper systems. Seventeen are rank 3 prospects with intercepts of at least 20 m of at least 0.2-percent copper. Forty-one are rank 4 prospects with samples or sampled intervals containing

Table D3. Known calc-alkaline porphyry Cu±Mo±Au deposits in tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada.

[Ma, million years; NA, not applicable; –, no data; Mt, million metric tons; t, metric ton; %, percent; g/t, gram per metric ton; Cu-Mo subtype, deposits that have Au/Mo ratios <3or average Mo grades >0.03%; Cu-Au subtype, deposits that have Au/Mo ratios >30 or average Au grades >0.2 g/t. Contained Cu in metric tons is computed as (tonnage Mt x 1,000,000) x (percent Cu / 100); gs, coordinates of this site are used for the group location; *, estimated tonnage and grade from an unsubstantiated press release (not used in grade and tonnage model); **, partial tonnage and grade for a deposit that is known to be open to extension (not used in grade and tonnage model). For group aggregates: the latitude and longitude, subtype, and age is that of the deposit with the largest Cu resources; the Cu and Mo grades are tonnage-weighted averages calculated using the computed contained Cu and Mo as (t contained Cu or Mo / (Mt x 1,000,000)) x 100 (note that the computed contained Mo is not shown in this table); and the Au and Ag grades are a tonnage-weighted average calculated as g/t x Mt. For sources of age, tonnage, and grade information, see appendix F. Resource estimates are through 2009, but include updates for 2010 when available.]

Name	Latitude	Longitude	Subtype	Age (Ma)	Tonnage (Mt)	Cu (%)	Mo (%)	Au (g/t)	Ag (g/t)	Contained Cu (t)
DOROTHY-NAK GROUP										
Dorothy	55.248	-126.168	NA	50	45	0.26	0.01	–	–	117,000
NAK [gs]	55.286	-126.238	NA	52	271	0.184	–	0.133	–	499,000
GROUP AGGREGATE	55.286	-126.238	NA	51	316	0.195	–	–	–	616,000
HUCKLEBERRY GROUP										
Huckleberry [gs]	53.681	-127.178	Cu-Mo	82.5	177.5	0.468	0.014	0.023	0.844	831,000
Ox Lake	53.674	-127.057	NA	83.5	21.4	0.34	0.008	–	–	72,800
GROUP AGGREGATE	53.681	-127.178	Cu-Mo	83	198.9	0.454	0.013	–	–	904,000
OK GROUP										
OK [gs]	50.042	-124.651	NA	36	143	0.24	0.009	–	–	343,000
Okeover	50	-124.667	NA	36	86.8	0.31	0.014	–	–	269,000
GROUP AGGREGATE	50.042	-124.651	NA	36	230	0.266	0.011	–	–	612,000
INDIVIDUAL DEPOSITS										
Bell Copper	55.003	-126.232	Cu-Au	52	495	0.36	0.005	0.16	1	1,780,000
Berg	53.804	-127.435	Cu-Mo	48.5	650.6	0.284	0.036	0.018	3.6	1,850,000
Big Onion (Cimbria)	54.81	-126.896	NA	48.5	94.4	0.42	0.02	0.064	1	396,000
Cash	62.429	-137.62	NA	76	36	0.28	0.021	0.17	–	101,000
Casino	62.738	-138.828	NA	74	964	0.22	0.02	0.24	1.8	2,120,000
Catface	49.256	-125.981	NA	48.5	308	0.37	0.007	0.05	–	1,140,000
Fish Lake (Prosperity)	51.464	-123.626	Cu-Au	80	1,150.00	0.22	0.002	0.41	2.3	2,530,000
Gambier Island	49.515	-123.369	Cu-Mo	88	114	0.29	0.018	0.03	1.3	331,000
Granisle	54.945	-126.157	NA	51.5	171.2	0.41	–	0.144	0.4	488,000
Hi-Mars*	49.941	-124.359	NA	81	82	0.3	–	–	–	246,000
Jean**	55.105	-124.956	NA	134	27	0.3	0.015	–	–	81,000
Lexington-Lone Star	49.012	-118.615	Cu-Au	57	19.5	0.56	–	0.55	–	109,000
Louise Lake	54.852	-127.69	NA	89	151	0.238	0.008	0.228	–	359,000
Maggie	50.924	-121.421	NA	63	181.4	0.28	0.029	–	–	508,000
Morrison (Hearne Hill)	55.183	-126.286	Cu-Au	54	206.9	0.337	0.004	0.177	–	697,000
New Nanik (Nanika)	53.751	-127.687	NA	48.5	16.5	0.437	–	–	–	71,900
Poison Mountain	51.133	-122.614	NA	57.5	808	0.24	0.008	0.12	3	1,940,000
Poplar	54.017	-126.99	NA	73	236	0.37	–	–	–	873,000
Rey Lake	50.338	-120.711	NA	69	46.9	0.17	0.018	–	–	80,000
Taseko	51.104	-123.4	Cu-Au	86	15	0.53	0.012	0.53	–	79,500
INDIVIDUAL DEPOSITS TOTAL					5,773.4					15,780,400
TRACT TOTAL					6,518.3					17,912,400
TRACT ROUNDED TOTAL					6,520					17,900,000

at least 0.1-percent copper, but less than 20 m of 0.2-percent copper. In addition, 4 are rank 4.5 prospects with Mo/Cu greater than 1/3. Eighteen are rank 5 prospects with geological indications of porphyry-copper-style mineralized rocks but negligible assay results for copper or no assay data. Eighteen are not primarily porphyry copper prospects but are of types that could be related to nearby porphyry copper systems. These include porphyry gold-, porphyry molybdenum-, and various types of skarn- and vein-type deposits. Table D4 lists the significant porphyry copper prospects in this tract. Additional descriptive information and references are included in appendix F.

Exploration History

Recent exploration activities in this tract include about 220 km of core drilling from 2004 to 2007 in British Columbia (see Sinclair, 2007, for a discussion on earlier exploration and exploration methods). About 62 percent of this drilling was in or around known porphyry copper deposits or groups of known deposits and prospects. This probably includes infill drilling to provide data needed in preparation for development, and to meet the recently tightened reporting requirements of Canadian NI 43-101. This surge in recent drilling within and around known deposits in this tract has yielded significant

Table D4. Significant porphyry copper prospects in tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada.

[Ma, million years; NA, not applicable; Mt, million metric tons; t, metric ton; g/t, gram per metric ton; gs, group site-coordinates of this site are used for the group location. For sources and additonal information about age, tonnage, grade and comments, see appendix F. For mineral name abbreviations under “Comments”, see appendix F.]

Group	Name	Rank	Latitude	Longitude	Age (Ma)	Comments
Significant porphyry Cu prospects in groups of known porphyry Cu deposits and prospects						
Catface	Hecate Bay	3	49.248	-125.957	49	Intercept: 300 m, 0.25% Cu (extension of Catface deposit)
Catface	Irishman Creek	3	49.266	-125.987	49	Intercept: 155 m, 0.63% Cu, 6.7 g/t Ag (extension of Catface deposit)
Huckleberry	Seel	3	53.654	-127.094	82	Intercept: 127 m, 0.46% Cu, 0.012% Mo, 0.364 g/t Au, 4.538 g/t Ag; 7 holes with >100-m ore-grade core (extension of Huckleberry deposit)
Significant individual porphyry copper prospects						
NA	Colossus	2	50.531	-125.203	105	Resource: 0.118 Mt ore @ 2.5% Cu (2,950 t Cu)
NA	Mount Wash-ington Copper	2	49.763	-125.302	35	Resource: 0.306 Mt ore @ 1.07% Cu (3,270 t Cu); cpy-py-qtz stockwork and disseminated cpy and bn along along the subhorizontal upper contact of a Tertiary dioritic sill; 8 m x 750 m porphyry-Cu prospect with an epithermal gold-copper-arsenic overprint (Minfile BC, 2008).
NA	Uebell	2	50.032	-126.813	38	Resource: 0.146 Mt ore @ 1.996% Cu (2,900 t Cu)
NA	Ball Creek (Mary)	3	57.278	-130.417	105	Intercept: 231 m, 0.208% Cu, 0.005% Mo, 0.535 g/t Au
NA	Bear Lake	3	56.114	-126.883	53	Intercept: 159 m, 0.27% Cu, 0.061% Mo
NA	Copper Canyon (Duke)	3	50.173	-121.204	105	Intercept: 57.9 m, 0.63% Cu
NA	Copper zone	3	51.04	-123.371	83	Intercept: 288.6 m, 0.276% Cu, 0.023% Mo
NA	Croesus (CR)	3	54.288	-126.817	46	Intercept: 63.6 m, 0.51% Cu, 0.016% Mo, 0.08 g/t Au, 9 g/t Ag
NA	Dobbin	3	50.003	-119.778	105	Intercept: 122 m, 0.3% Cu
NA	IXL	3	49.545	-118.41	46	Intercept: 24 m, 0.78% Cu, 0.16 g/t Au; porphyry-Cu with Zn-Cu-Au skarn
NA	Kino	3	54.558	-128.327	65	Intercept: 30 m, 0.37% Cu
NA	Nucleus	3	62.334	-137.336	65	Intercept: 117 m, 0.24% Cu, 0.86 g/t Au
NA	Row-bottom	3	51.078	-123.417	83	Intercept: 45.7 m, 0.41% Cu, 0.034% Mo
NA	Sylvia	3	53.85	-127.181	49	Intercept: 63 m, 0.33% Cu, 0.02% Mo
NA	Trail Peak	3	55.412	-126.312	49	Intercept: 30 m, 0.36% Cu, 0.18 g/t Au; four holes with Cu and Mo in K-altered rocks
NA	Whipsaw	3	49.293	-120.759	65	Intercept: 26 m, 0.298% Cu, 0.0115% Mo
NA	Zymo	3	54.835	-127.944	89	Intercept: 97.7 m, 0.296% Cu, 0.342 g/t Au, 270 g/t Ag; porphyry-Cu and epithermal-style features
NA	Ann	4	57.059	-131.55	48	Intercept: interval unavailable; 0.15% Cu
NA	Babs	4	54.854	-126.002	51	Intercept: 77 m, 0.19% Cu
NA	Ben 37	4	51.304	-124.417	44	Intercept: interval unavailable; 0.1% Cu, 0.002% Mo
NA	Blue 33-36	4	51.223	-124.489	63	Intercept: 3 m, 0.75% Cu, 6.8 g/t Ag
NA	Buzzer (Taseko)	4	51.101	-123.353	87	Intercept: interval unavailable; 0.6% Cu
NA	Charlie	4	51.177	-123.671	65	Intercept: interval unavailable; 13.68% Cu, 10.6 g/t Au, 13.68 g/t Ag; sampled vein is above stockwork on valley floor
NA	Chita	4	51.25	-123.536	82	Intercept: interval unavailable; 0.29% Cu, 0.01% Mo
NA	Coles Creek	4	53.533	-127.233	85	Intercept: interval unavailable; 0.25% Cu, 0.03% Mo, 0.24 g/t Au, 33 g/t Ag
NA	Copper Mtn (Trigger Lk)	4	51.002	-123.14	82	Intercept: 10 m, 0.28% Cu, 0.25 g/t Ag
NA	Copper Star	4	54.229	-127.268	49	Intercept: 1.8 m, 0.49% Cu
NA	Cyprus (Mt Nansen)	4	62.09	-137.199	58	Intercept: interval unavailable; 0.35% Cu, 0.035% Mo
NA	Fawley	4	60.185	-135.391	46	Intercept: interval unavailable; 1.12% Cu, 4.45 g/t Au, 21.9 g/t Ag
NA	Fly	4	51.608	-124.492	65	Intercept: interval unavailable; 0.68% Cu
NA	Gem Lake	4	49.684	-125.411	49	Intercept: 18 m, 1% Cu
NA	Giant	4	62.644	-137.304	67	Intercept: 3 m, 0.1% Cu, 0.69 g/t Au, 1.4 g/t Ag
NA	Goulter	4	62.078	-137.194	67	Intercept: interval unavailable; maximum grades reported: 2% Cu, 0.05% Mo, 120 g/t Au, 3,428 g/t Ag
NA	Independence	4	49.638	-120.967	46	Intercept: 149 m, 0.119% Cu, 0.011% Mo
NA	Jake North	4	56.236	-127.323	46	Intercept: interval unavailable; 0.16% Cu, 2.25 g/t Au, 8.4 g/t Ag
NA	Jay	4	49.386	-119.068	46	Intercept: 1 m, 0.31% Cu, 2.05 g/t Ag
NA	Klazan	4	62.381	-137.493	50	Intercept: 44 m, 0.17% Cu; AuAg soil geochemical anomalies on gossan
NA	Lori	4	49.71	-122.924	154	Intercept: 3 m, 0.22% Cu, 0.008% Mo
NA	Lynx	4	49.388	-119.338	54	Intercept: 2.65 m, 0.61% Cu, 0.51 g/t Ag
NA	Maloney	4	62.009	-137.905	104	Intercept: interval unavailable; 0.2% Cu; AuAgPbZn soil geochem near Cu-Mo zone; IP anomaly 1300 x 200 m
NA	MIM	4	62.357	-138.571	92	Intercept: interval unavailable; 0.35% Cu, 1.2 g/t Au; CuMoAuAs soil geochem 1200 x 800 m; mag low, IP chargeability high
NA	Mohawk	4	51.095	-123.388	87	Intercept: 2.4 m, 4.56% Cu, 10.63 g/t Au, 22.29 g/t Ag
NA	Murex	4	49.761	-125.25	35	Intercept: 4 m, 4.08% Cu, 6.31 g/t Au, 32.91 g/t Ag
NA	Newmac	4	51.732	-124.636	65	Intercept: 18 m, 0.3% Cu, 0.54 g/t Au
NA	Newton Hill	4	51.803	-123.635	46	Intercept: 3 m, 0.49% Cu, 2.8 g/t Au, 13.1 g/t Ag
NA	PAL	4	62.61	-137.204	67	Intercept: 11 m, 0.6% Cu, 0.34 g/t Au, 6.5 g/t Ag
NA	Pam	4	53.859	-127.016	49	Intercept: 73 m, 0.11% Cu, 0.01% Mo
NA	Revenue	4	62.325	-137.269	65	Intercept: 40 m, 0.12% Cu, 0.03% Mo; Cu-Au and Cu-Mo soil anomalies; mag lows correlate with gold anomalies
NA	Rhyolite	4	61.848	-138.508	44	Intercept: interval unavailable; 0.17% Cu, 0.006% Mo
NA	Rita	4	49.631	-120.478	97	Intercept: interval unavailable; 0.209% Cu, 4.7 g/t Ag
NA	Rum 66	4	51.266	-124.291	65	Intercept: interval unavailable; 0.5% Cu
NA	Silver Queen	4	60.226	-135.049	46	Intercept: interval unavailable; 0.2% Cu, 0.34 g/t Au, 3620 g/t Ag; dissappointing drill results
NA	Suits	4	60.816	-135.481	104	Intercept: interval unavailable; 0.225% Cu, 0.001% Mo; dissappointing drill results
NA	Tarn Creek	4	51.267	-123.857	82	Intercept: interval unavailable; 0.48% Cu, 3 g/t Au
NA	Thezar 75 (Lennac Lk)	4	54.75	-126.338	77	Intercept: 6 m, 0.26% Cu, <0.004% Mo, <.14 g/t Ag
NA	Trudi (Trudy)	4	62.047	-140.983	105	Intercept: interval unavailable; 0.13% Cu, 0.005% Mo; geochem anomaly for Cu in soil; drilling found low-grade Cu, very low-grade Mo
NA	WEL	4	49.375	-120.897	145	Intercept: interval unavailable; 0.89% Cu, 0.89 g/t Au
NA	Wolf (Bee)	4	55.215	-126.367	46	Intercept: 1.2 m, 4.2% Cu; sample from porphyry with dissem cpy and cpy films +/- minor mo on fractures
Significant individual porphyry Mo-Cu prospects						
NA	Empress	4.5	49.671	-120.176	166	Porphyry Mo-Cu, intercept: 15.25 m, 0.0093% Cu, 0.0852% Mo
NA	Pattison	4.5	62.526	-138.614	65	Porphyry Mo-Cu, intercept: interval unavailable; 0.01% Cu, 0.015% Mo; Mo soil anomalies; weak IP response
NA	Porphyry Creek	4.5	56.452	-125.995	81	Includes Davie Creek Mo-Cu zone (intercept: 136 m, 0.1% Cu, 0.1% Mo, 0.03 g/t Au, 0.3 g/t Ag), and Croy-Bloom qtz-Cu-Au vein zone (intercept: 1 m, 1.02% Cu)
NA	Red Bird	4.5	53.299	-127.01	46	Porphyry Mo-Cu, resource: 88.2 Mt at 0.061% Mo, 0.068% Cu (60,000t Cu)

Table D5. Readily available recent exploration activities for deposits and prospects in tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada.

[This information was compiled from Schroeter and others (2006, 2007) and DeGrace and others (2008, 2009). Web-site addresses of "Operators" are listed in the table in appendix F; CD, core drilling; EN, environmental baseline studies, monitoring, or remediation work; FS, feasibility studies; G, geologic mapping; GC, geochemical sampling (rock, soil, silt, etc.); IP, Induced Polarization; MG, magnetic surveys; MS, metallurgical studies; PR, prospecting; TR, trenching; m, meters; –, no data.]

Name	Rank	Operator	Activities	CD (m)
Berg	1	Terrane Metals Corp	CD	11,300
Big Onion (Cimbria)	1	Eagle Peak Resources Ltd	CD	19,300
Catface	1	Selkirk Metals Corp	CD	2,400
Fish Lake (Prosperity)	1	Taseko Mines Ltd	FS, EN	–
Hi-Mars	1	Dentonia Resources Ltd	CD	–
Huckleberry	1	Huckleberry Mines Ltd	CD	6,388
Jean	1	Newstrike Resources Ltd	CD	2,105
Louise Lake	1	North American Gem Inc	CD	9,587
Morrison	1	Pacific Booker Minerals Inc	MS, EN, CD	1,700
OK	1	Goldrush Resources Ltd	CD	968
Okeover (OK)	1	Prophecy Resource Corp	CD	2,000
Ox Lake	1	Gold Reach Resources Ltd	IP, CD	–
Poplar	1	Aumega Discoveries Ltd	CD	3,000
Ball Creek (Mary)	3	Paget Resources Corp	CD	3,800
Seel	3	Gold Reach Resources Ltd	CD	18,419
Whipsaw	3	Canfleur Mining Inc	TR, CD	12,200
Zymo	3	Canadian Gold Hunter	PR	–
Coles Creek	4	Callinan Mines, Ltd	GC, IP, CD	4,495
Newmac	4	Newmac Resources Inc	IP, CD	1,800
Newton Hill	4	High Ridge Resources Inc	TR, CD	2,019
Kliyul Creek	0	Geoinformatics Exploration Inc	G, GC, CD, TR, G, GC, IP	751
Lustdust	0	Alpha Gold Corp	CD	10,310
McConnell Creek	0	GGL Diamond Corp	CD	1,000
Red Bird	0	Torch River Resources Ltd	CD	2,143
Snip North	0	Newcastle Minerals Ltd	CD	1,095

increases in the estimated copper resources of the Berg deposit, as documented in table D5.

About 16 percent of the 220 km of core drilling that was done in this tract between 2004 and 2007 was on rank 3 porphyry-copper prospects, while 4 percent was done on rank 4 porphyry copper prospects and 19 percent was done on prospects for other types of deposits that may (or may not) be related to porphyry copper systems. At the rank 3 Seel prospect (in the Huckleberry group) about 18 km of drilling was done. At the rank 3 Whipsaw prospect, about 12 km of additional drilling was done to follow up on a previous intercept of 26 m of mineralized rock containing 0.298-percent copper and 0.0115-percent molybdenum. At the rank 4 Coles Creek prospect, about 8.3 km of core drilling was done to test an area from which samples containing 0.25-percent copper, 0.03-percent molybdenum, 0.24 g/t gold, and 33 g/t silver previously had been reported.

About 15 km of core drilling in this tract was done at prospects for deposit types that may (or may not) be related to porphyry copper systems. At the Lustdust prospect, about 10 km of core drilling was done in search of porphyry copper deposits that may underlie a system of polymetallic veins. A similar target related to polymetallic veins was explored at the McConnel Creek prospect. A zone of intrusion-related gold-pyrrhotite veins was explored for associated porphyry copper mineralization at the Snip North prospect, which probably is part of the Bronson Slope porphyry copper system. Porphyry molybdenum systems were drilled for molybdenum and copper at the Red Bird and Kliyul Creek prospects.

The percentage of exploration drilling that was done outside of known deposits or groups of deposits and prospects was higher in this tract (nearly 30 percent) than in tracts 003pCu2001 (12 percent), 003pCu2002 (4 percent), or

Table D6. Principal sources of information used for tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada.

[NA, not applicable]

Theme	Name or Title	Scale	Citation
Geology	GeoFile 2005-1: Digital Geology Map of British Columbia - Whole Province	1:250,000	Massey and others (2005)
	Yukon Digital Geology	1:250,000	Gordey and Makepeace (1999)
	Geoscience Map 2005-3: Geology of British Columbia	1:1,000,000	Massey and others (2005)
	Terrane Map of the Canadian Cordillera	1:2,000,000	Wheeler and others (1991)
	Tectonic Assemblage Map of the Canadian Cordillera	1:2,000,000	Wheeler and McFeely (1991); Journeay and Williams (1995; GIS vector representation of Wheeler and McFeely, 1991)
	Metamorphic Map of the Canadian Cordillera	1:2,000,000	Read and others (1991)
	Paleocene to Oligocene forearc, arc, and backarc magmatism of the Pacific Northwest, USA	~1:2,000,000	Madsen and others (2006, figure 1)
	Main structural elements of the southeastern Omineca Belt showing the distribution of prominent normal faults	~1:1,000,000	Parrish and others (1992; figure 17.85)
	YukonAge 2004: A database of isotopic age determinations for rock units from Yukon Territory	NA	Breitsprecher and Mortensen (2004a)
	BC Age 2004A-1: A database of isotopic age determinations for rock units from British Columbia	NA	Breitsprecher and Mortensen (2004b)
	Radiometric Age Data Bank (RADB); National Geochronological Data Base (NGDB)	NA	Zartman and others (1976); Marshall (1993)
Mineral occurrences	Porphyry deposits	NA	Sinclair (2007)
	Porphyry copper deposits of the world	NA	Singer and others (2008)
	Lode mineral deposits	NA	Nokleberg and others (1998)
	MINFILE (British Columbia) Mineral occurrences database	NA	MINFILE BC (2009)
	MINFILE (Yukon) Mineral occurrences database	NA	MINFILE YT (2009)
	Porphyry deposits of the Canadian Cordillera	NA	CIM SV 15 (Sutherland Brown, 1976)
	Porphyry deposits of the Northwestern Cordillera of North America	NA	CIM SV 46 (Schroeter, 1995)
Geochemistry	National Geochemical Reconnaissance (NGR) Stream sediment, lake sediment and Water Geochemical Data Base	NA	Natural Resources Canada (2008c)
	Yukon regional geochemical database 2003 ! Stream sediment analyses	NA	Heon (2003)
Geophysics	Canadian Geodetic Information System–Gravity (2 km grid)–Bouguer anomaly, free-air anomaly, isostatic residual anomaly, observed gravity, vertical gradient, and horizontal gradient	~1:2,000,000	Natural Resources Canada (2008b)
	Canadian Aeromagnetic Data Base–1 km and 200 m grid–Residual total field	~1:1,000,000 & ~1:200,000	Natural Resources Canada (2008a)
	Canadian Aeromagnetic Data Base–500m grid–Residual total field, reduced to pole	~1:500,000	B.J. Drenth (unpub. data, 2009)
Exploration	BC mines and mineral exploration overviews, Yukon mineral deposits, Natural resources Canada, Top 100 exploration and deposit appraisal projects, 2008, web sites of mineral exploration companies	NA	Schroeter and others (2006, 2007), DeGrace and others (2008, 2009)

003pCu2003 (13 percent). This may indicate this tract is perceived to have greater potential for undiscovered deposits than the other tracts. About 70 percent of the drilling in tract 003pCu2004 (CA04) was done in and around known deposits (rank 1), 22 percent was done on prospects of ranks 3 and 4, and 8 percent was done on prospects that are not classified primarily as porphyry-copper-type, but commonly are associated with porphyry-copper systems.

Sources of Information

Principal sources of information used by the assessment team for delineation of 003pCu2004 (CA04) are listed in table D6.

Grade and Tonnage Model Selection

As discussed in the Introduction and as shown in appendix G, a new grade and tonnage model for Canadian Cu±Mo±Au deposits was constructed due to the lower copper grades present in Canadian examples compared to the global porphyry copper models (Singer and others 2008).

Porphyry Cu±Mo±Au

The deposits and prospects of permissive tract 003pCu2004 (CA04), as well as those of tracts 003pCu2001 (CA01), 003pCu2003 (CA03), and 003pCu2005 (CA05), fit the descriptive model for Porphyry Cu±Mo±Au deposits of British Columbia (Panteleyev, 1995) and the Yukon Territory (Panteleyev, 2005). After spatial grouping according to the 2-km rule, 34 known deposits of this subtype are present in the Canadian Cordillera (23 of which occur in this tract). In aggregate, when compared to the Singer and others (2008) grade and tonnage models, the Canadian Cu±Mo±Au deposits are on average lowest in tonnage, lowest in copper grade, higher in molybdenum grade (except for model 21a), higher in gold grade (except for model 20c), and highest in Ag grade.

Statistical tests at a 1-percent screening level on these deposits (as a group) indicate that their molybdenum grade and gold grade distribution means are not statistically different from the general (models 17, 20c, and 21a combined) or Cu subtype (model 17) porphyry copper grade and tonnage models of Singer and others (2008) (see tables G2a and b). Neither is their tonnage distribution mean statistically different from the general, Cu subtype, or Cu-Au subtype (model 20c) porphyry copper grade and tonnage models of Singer and others (2008) (see tables G2a, b, and c). However, the copper grade distribution mean is statistically different from the general model and all the individual subtype models (see tables G2a, b, c, and d). For this reason, a grade and tonnage model for the porphyry Cu±Mo±Au deposits in tracts 003pCu2001 (CA01), 003pCu2003 (CA03), 003pCu2004 (CA04) and 003pCu2005 (CA05) was constructed.

The complete model, which contains data current through December 2009, is described in appendix G. For deposits in tract 003pCu2004 (CA04), the formal group according to the 2-km rule and the name of the independent or groups used, along with the tonnages and grades used in the development of the grade and tonnage model, are listed in table D7.

Estimate of the Number of Undiscovered Deposits

Rationale for the Estimate

Our rationale for estimation of undiscovered porphyry Cu±Mo±Au deposits in this tract was based on the distribution and relative qualities of known deposits and prospects in the continental magmatic arcs included in this tract. Our knowledge of this was based mostly on information in the British Columbia and Yukon MINFILE databases. In MINFILE records, deposits and prospects generally are classified in terms of mineral deposit models, such as the model for calc-alkaline porphyry Cu±Mo±Au deposits by Panteleyev (1995), which is appropriate to this tract.

Our estimates for this tract are supported by an inventory of 58 significant prospects that are not in any group with a known deposit, and are therefore eligible to be counted as possible undiscovered deposits. Of these, 3 are of rank 2 (with small estimated resources), 14 are of rank 3 (with intercepts of at least 20 m of 0.2 percent copper), 41 are of rank 4 (with intercepts of at least 0.1 percent copper), and 4 are classified as porphyry Mo-Cu deposits of rank 4.5 with Cu/Mo less than 1/3.

Our estimates are constrained by the spatial density of known deposits in this tract, and by the perception that the Canadian Cordilleran region is well explored for porphyry copper. Nevertheless, there are large areas in this permissive tract where bedrock exposures are mostly covered by glacial till. Although glacial till is not shown on maps of bedrock geology, it is distributed widely and can mostly to completely hide features the size of a porphyry copper deposit.

There are enough promising independent prospects in this tract that we were able to confidently estimate numbers of undiscovered deposits at the 90- and 50- percent levels of subjective probability. But for the 10-percent level, there is sufficient uncertainty about the quality of many of the prospects (due to little or no assay data), and as such, there may be many more undiscovered deposits at this probability level than we estimated.

The first round of balloting was private, so we cannot know exactly how each panel member weighed the available information. Our Canadian panel members could draw on the most knowledge and experience, which they shared during the presentations and discussions that preceded estimation.

Estimates by each team member were compiled and revealed to the team. Reasons for high and low estimates were elicited and discussed. On the basis of these discussions, team members were allowed to adjust their estimates until consensus (agreement on an estimate acceptable to the group) was reached. Individual and consensus estimates are shown in table D8.

We compared the spatial density of deposits indicated by the 23 known deposits plus our estimated 9.6 undiscovered deposits, for a total of 32.6 deposits, divided by the tract area of 639,500 km^2, yielding a density of 0.00005 deposits/km^2. We compared this to the deposit density model of Singer and others (2005, 2008). This comparison showed that our estimated deposit density is similar to densities observed in comparable tracts throughout the world.

Probabilistic Assessment Simulation Results

Undiscovered resources for the tract were modeled using the consensus estimates for numbers of undiscovered porphyry Cu±Mo±Au deposits and the grade and tonnage models presented in appendix G of this report for Canadian Cu±Mo±Au porphyry copper deposits as input for the EMINERS Monte Carlo simulator program (Root and others, 1992; Bawiec and Spanski, in press). Selected simulation results are reported in table D9. Results of the Monte Carlo simulation are presented as cumulative frequency plots (fig. D2). The cumulative frequency plots show the estimated

Table D7. Tonnages and grades of deposits of this tract used in tonnage and grade models for Canadian Cordilleran calc-alkaline porphyry Cu±Mo±Au for tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada.

[Groups include all deposits and prospects with well-defined grades and tonnages that meet the 2-km rule. Independent indicates that a deposit is not in a group. Mt, million metric tons; %, percent; g/t, grams per metric ton; –, no data. Resource estimates available in 2008–2009 have not been updated to include information added to appendix F after 2009.]

Group	Name	Ore (Mt)	Cu (%)	Mo (%)	Au (g/t)	Ag (g/t)
Independent	Bell Copper	495	0.36	0.005	0.16	1
Independent	Berg	650.6	0.284	0.036	0.018	3.6
Independent	Big Onion (Cimbria)	94.4	0.42	0.02	0.064	1
Independent	Cash	36	0.28	0.021	0.17	–
Independent	Casino	964	0.22	0.02	0.24	1.8
Independent	Catface	308	0.37	0.007	0.05	–
Bell	Dorothy-Nak (Total)	316	0.195	–	0.114	–
Independent	Fish Lake (Prosperity)	1,150	0.22	0.002	0.41	2.3
Independent	Gambier Island	114	0.29	0.018	0.03	1.3
Independent	Granisle	171.2	0.41	–	0.144	0.4
Huckleberry	Huckleberry (Total)	198.9	0.454	0.013	0.021	0.753
Independent	Lexington-Lone Star	19.5	0.56	–	0.55	–
Independent	Louise Lake	151	0.238	0.008	0.228	–
Independent	Maggie	181.4	0.28	0.029		–
Independent	Morrison (Hearne Hill)	206.9	0.337	0.004	0.177	–
Independent	New Nanik (Nanika)	16.5	0.437	–	–	–
Ok	Ok (Total)	230	0.266	0.011	–	–
Independent	Poison Mountain	808	0.24	0.008	0.12	3
Independent	Poplar	236	0.37	–	–	–
Independent	Rey Lake	46.9	0.17	0.018	–	–
Independent	Taseko	15	0.53	0.012	0.53	–

Table D8. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada.

[Nxx, estimated number of deposits associated with the xxth percentile; N_{und}, expected number of undiscovered deposits; s, standard deviation; Cv%, coefficient of variance; N_{known}, number of known deposits in the tract that are included in the grade and tonnage model; N_{total}, total of expected number of deposits plus known deposits; area, area of permissive tract in square kilometers; density, deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer and Menzie, 2005). In cases where individual estimates were tallied in addition to the consensus estimate, individual estimates are listed.]

Consensus undiscovered deposit estimates					Summary statistics						
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}	Tract area (km^2)	Deposit density (N_{total}/km^2)
3	8	19	19	19	9.6	5.9	61	23	32.6	639,500	0.00005

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Individual 1	4	9	20	20	20
Individual 2	4	8	21	21	21
Individual 3	4	8	12	12	12
Individual 4	3	6	9	9	9
Individual 5	3	5	13	13	13
Individual 6	3	6	9	9	9
Individual 7	6	14	32	32	32
Consensus	3	8	19	19	19

Table D9. Results of Monte Carlo simulations of undiscovered resources for tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada.

[Cu, copper; Mo, molybdenum; Au, gold; and Ag, silver, in metric tons; Rock, in million metric tons]

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
Cu	650,000	1,700,000	11,000,000	26,000,000	31,000,000	13,000,000	0.43	0.03
Mo	4,900	45,000	420,000	1,200,000	1,400,000	530,000	0.41	0.05
Au	19	76	500	1,400	1,700	640	0.41	0.04
Ag	0	120	3,000	11,000	14,000	4,400	0.38	0.08
Rock	200	630	4,100	9,700	11,000	4,700	0.44	0.03

resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

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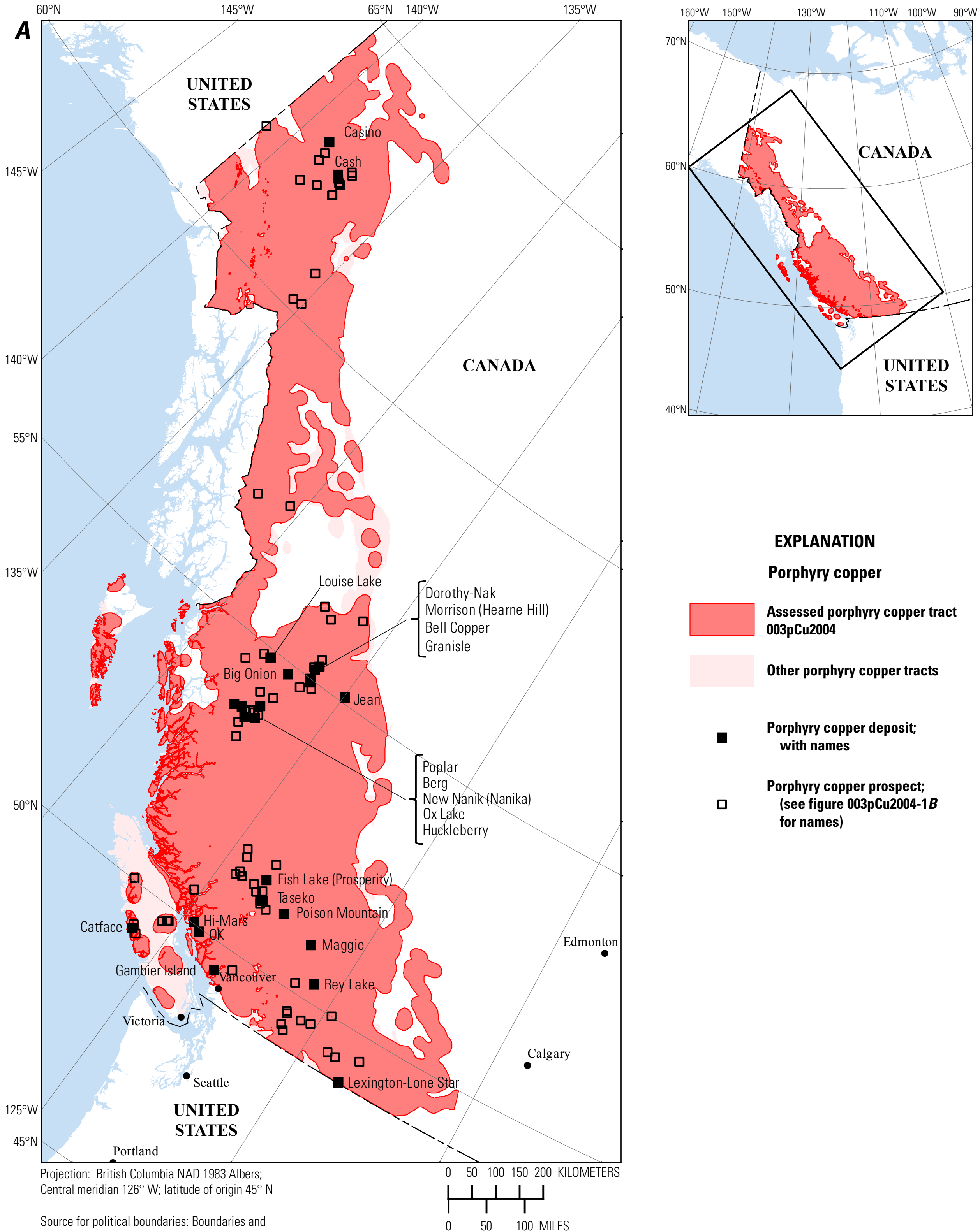

Projection: British Columbia NAD 1983 Albers;
Central meridian 126° W; latitude of origin 45° N

Source for political boundaries: Boundaries and
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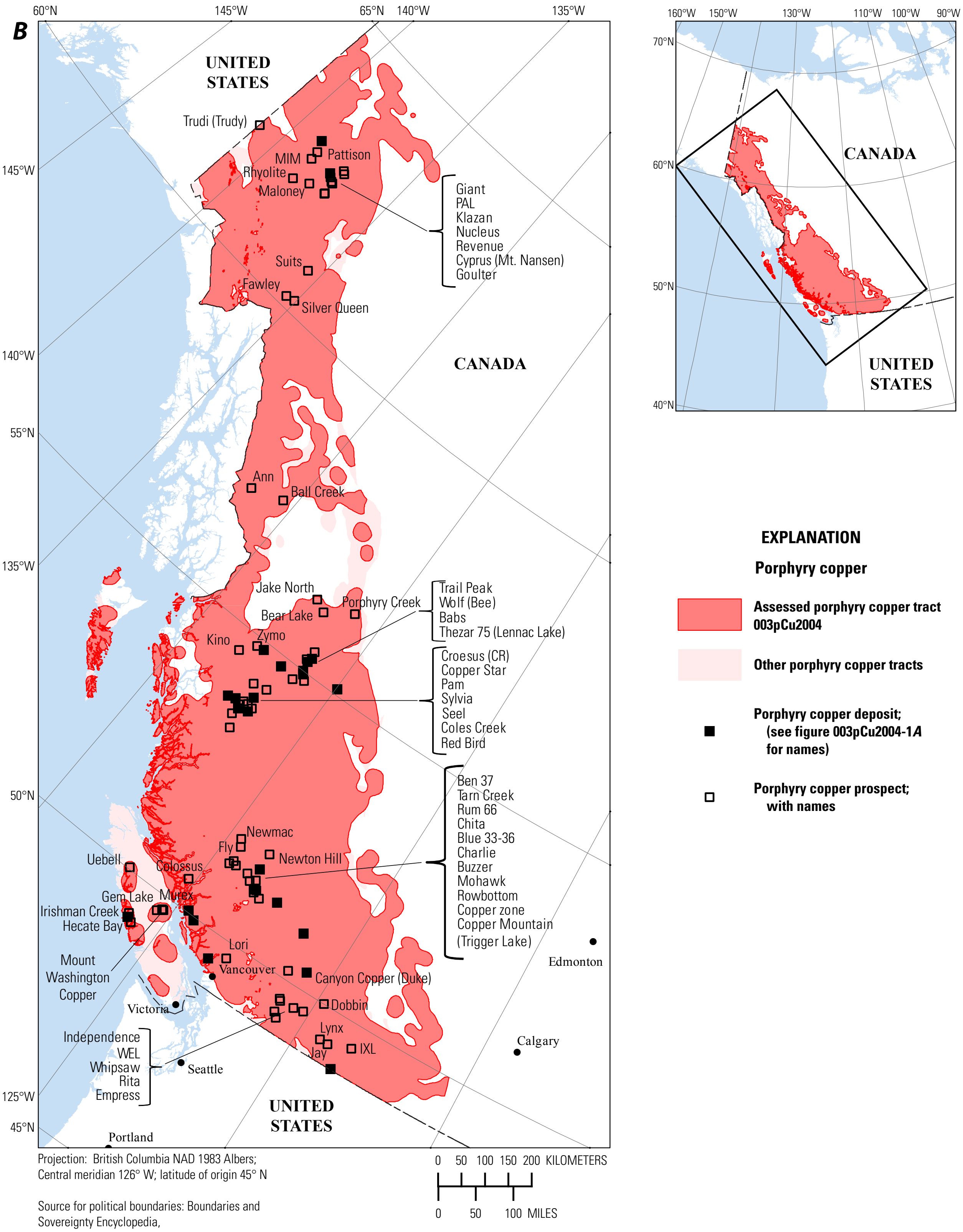
U.S. Department of State, Office of the Geographer and Global Issues

Figure D1. Maps showing permissive tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory. *A*, Locations of known porphyry copper deposits (named) and significant prospects (not named). *B*, Locations of significant prospects (named) and known porphyry copper deposits (not named).



Projection: British Columbia NAD 1983 Albers;
Central meridian 126° W; latitude of origin 45° N

Source for political boundaries: Boundaries and Sovereignty Encyclopedia,
U.S. Department of State, Office of the Geographer and Global Issues

Figure D1.—Continued

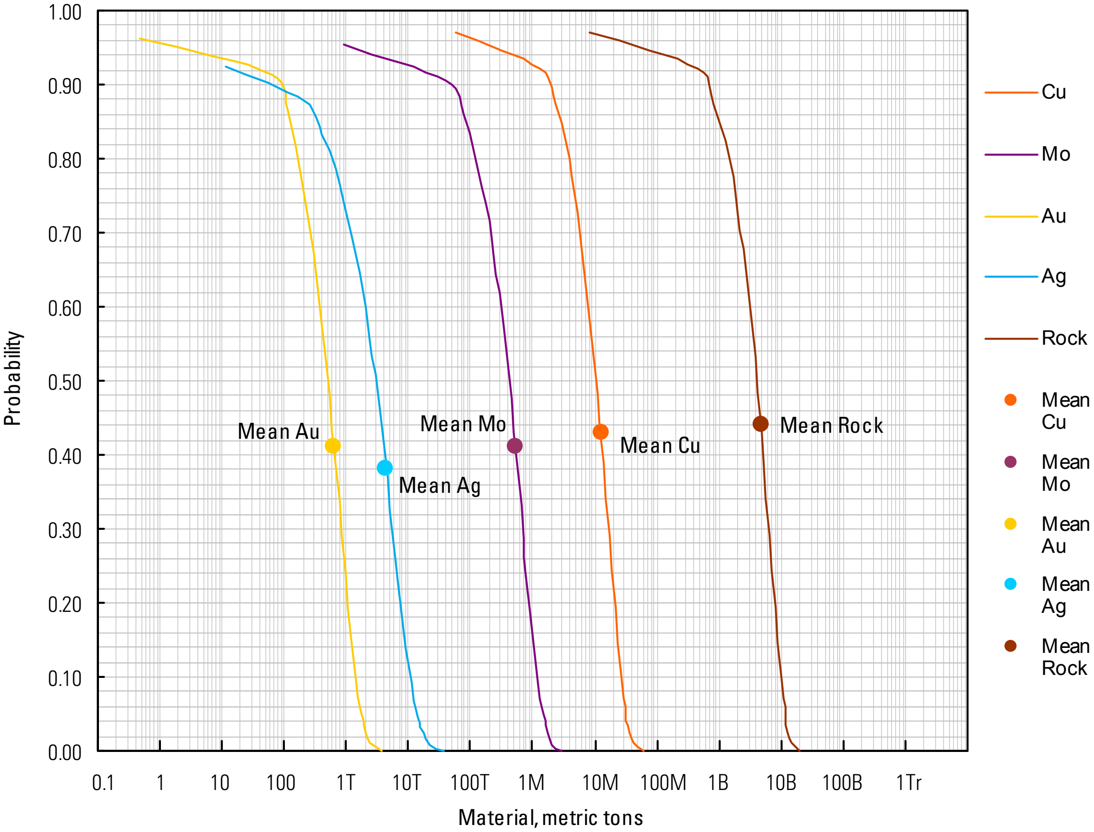


Figure D2. Cumulative frequency plot showing the results of a Monte Carlo computer simulation of undiscovered resources in tract 003pCu2004 (CA04), Cordilleran Continental Arc—British Columbia and Yukon Territory, Canada. (T=thousands, M=millions, B=billions, Tr=trillions).

Appendix E. Porphyry Copper Assessment for Tract 003pCu2005 (CA05), Late Continental Arc—British Columbia and Yukon Territory Canada

By Mark J. Mihalasky[1] , Arthur A. Bookstrom[2] , Thomas P. Frost[3] , and Steve Ludington[4] , with contributions from James M. Logan[5] , Andre Panteleyev[6] , and Grant Abbott[7]

Deposit Type Assessed: Porphyry Copper

Descriptive model: Porphyry copper (Cox, 1986a, Berger and others, 2008), porphyry Cu-Mo (Cox, 1986b), porphyry Cu-Au (Cox, 1986c), porphyry Cu±Mo±Au (Panteleyev, 1995)
Grade and tonnage model: Canadian Cordillera Porphyry Cu±Mo±Au (appendix G)
(Table E1 summarizes selected assessment results)

Table E1. Summary of selected resource assessment results for tract 003pCu2005 (CA05), Late Continental Arc—British Columbia and Yukon Territory, Canada.

[km, kilometers; km^2, square kilometers; t, metric tons]

Date of assessment	Assessment depth (km)	Tract area (km^2)	Known copper resources (t)	Mean estimate of undiscovered copper resources (t)	Median estimate of undiscovered copper resources (t)
2009	1	32,840	224,000	1,800,000	720,000

Location

This tract is in the Cordilleran region of western Canada in the Coast and Insular belts. Its southern segment is in the Coast Mountains east of Vancouver, British Columbia. Its northern segment is in the St. Elias Mountains of northern British Columbia and southwestern Yukon (figs. 1, E1).

Geologic Feature Assessed

Calc-alkaline igneous rocks in post-accretionary continental magmatic arcs of Oligocene to Pliocene age.

Delineation of the Permissive Tract

Geologic Criteria

The fundamental units defining this permissive tract are continental magmatic arcs that have been active along the continental margin of North America since Oligocene time (since about 34 Ma). Criteria for inclusion of rock types as

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permissive for the occurrence of calc-alkaline porphyry Cu±Mo±Au deposits are from descriptive models for porphyry copper, Cu-Mo, and Cu-Au deposits by Cox (1986a, b, c) and for calc-alkaline porphyry Cu±Mo±Au deposits of British Columbia by Panteleyev (1995). Phaneritic to porphyritic rock types associated with such deposits include quartz diorite, tonalite, granodiorite, quartz monzonite, monzogranite, and granite of calc-alkaline affinity (table E2a). Also included in the tract are porphyro-aphanitic equivalents including quartz-andesite, dacite, rhyodacite, quartz-latite, and rhyolite porphyries of calc-alkaline affinity and temporally equivalent volcanic and volcaniclastic rocks (table E2b).

Map units that represent calc-alkaline igneous rocks ranging in age from the beginning of Oligocene time (34 Ma) to the end of Pliocene time (1.8 Ma) are included in this permissive tract. This age span includes the dated porphyry copper deposits and prospects in this tract, which range in age from Oligocene (29 Ma) to late Miocene (7 Ma).

Calc-alkaline igneous rocks of Oligocene to Pliocene age in the Garibaldi-Pemberton magmatic arc of southern British Columbia form the southern segment of this permissive tract. At about 49°N the orientation of the trend of the Cascades magmatic arc curves from nearly north-south in the United States to northwest in southern British Columbia, and its name changes from the Cascades magmatic arc to the Garibaldi-Pemberton magmatic arc, although there is no change in the fundamental nature of the arc.

Calc-alkaline igneous rocks of Oligocene to Miocene age in the Wrangel-Stikine magmatic arc form the northern segment of this permissive tract. The Wrangel-Stikine magmatic arc extends from northwestern British Columbia, through southeastern Alaska, and along the southwestern margin of the Yukon Territory into southern Alaska. In northern British Columbia and southwestern Yukon, much of this arc is covered by alpine glaciers.

Tract Delineation Process

We used digital geologic maps of British Columbia by Massey and others (2005) and of Yukon by Gordey and Makepeace (1999) to identify permissive rocks. Geologic information in attribute tables associated with those maps allowed us to identify polygons representing lithologic assemblages of the appropriate age and composition to be included in this permissive tract. We excluded polygons representing lithologic assemblages not considered permissive by reason of age or composition, and we recorded a reason for their exclusion in the attribute table for the tract.

Digital geologic-map units that include polygons assigned to this permissive tract are listed in table E2a for intrusive rocks and table E2b for volcanic rocks. From each map unit listed, we selected only those sets of polygons that represent lithologic assemblages containing permissive rock types.

Table E2. Map units that define tract 003pCu2005 (CA05), Late Continental Arc—British Columbia and Yukon Territory, Canada.

[Province, map unit, age range, and principal rock types from 1:250,000 scale digital geologic maps of British Columbia (Massey and others, 2005) and Yukon Territory (Gordey and Makepeace, 1999)]

Province	Map unit	Age range	Rock types
		a. Intrusive rocks	
BC	LTgd	Neogene	granodioritic intrusive rocks
BC	Migd	Miocene	granodioritic intrusive rocks
BC	Miqd	Miocene	quartz dioritic intrusive rocks
BC	Miqm	Miocene	quartz monzonitic intrusive rocks
BC	OlMiCo	Late Oligocene to Early Miocene	calc-alkaline volcanic rocks
BC	OlMigd	Oligocene to Miocene	granodioritic intrusive rocks
BC	?dr	Oligocene?	dioritic rocks
BC	OlTg	Oligocene	intrusive rocks, undivided
BC	OlTgr	Oligocene	granite, alkali feldspar granite intrusive rocks
BC	OlTqp	Oligocene	high level quartz phyric, felsitic intrusive rocks
BC	Olfp	Oligocene	feldspar porphyritic intrusive rocks
YT	OT	Oligocene	granite/granodiorte/quartz diorite/diorite/gabbro
		b. Volcanic rocks	
BC	MiPiCO	Miocene to Pliocene	rhyolite, felsic volcanic rocks
BC	MiPivb	Miocene to Pliocene	basalt and andesite flows, breccia, tuff
BC	MiPivc	Upper Miocene to Pliocene	volcaniclastic rocks
BC	MiPivd	Upper Miocene to Pliocene	dacitic volcanic rocks
BC	Miv	Miocene	undivided volcanic rocks
BC	Miva	Miocene	andesitic volcanic breccia, lesser basalt
BC	Mivb	Miocene	basaltic volcanic rocks
BC	Mivf	Miocene	rhyolite, felsic volcanic rocks
YT	MW	Mid to Late Miocene	granodiorite/diorite/gabbro/rhyolite/ rhyodacite/dacite/trachyte

We excluded igneous rocks of the Miocene Anahim igneous assemblage, which occur along a nearly east-trending belt in west-central British Columbia and have been interpreted as a product of a mantle plume (see Ernst and Buchan, 2001). This assemblage includes basaltic, trachytic, and rhyolitic volcanic rocks and subvolcanic intrusions of granite and alkali-feldspar granite, and is probably not associated with a porphyry copper deposit-forming tectonic environment.

We excluded igneous rocks of Quaternary age, except where included in a geologic unit with rocks of Oligocene to Pliocene age. Thus, we excluded most of the Quaternary volcanic rocks associated with active and dormant volcanoes of the Cascades-Garibaldi-Pemberton magmatic arc. Although porphyry copper deposits may be forming beneath some of these volcanoes, they would probably be at depths of more than 1 km.

After selecting permissive units, we added a 10-km buffer zone around the mapped margins of permissive intrusions. We also put a 10-km buffer zone around the Owl Creek group of porphyry copper prospects, which are associated with dioritic intrusions that are not depicted on the map, probably because they are too small to be represented. The buffer ensures that we included possible unexposed permissive rocks and porphyry copper deposits. Examples of permissive rock types below the mapped surface could include permissive plutons that expand downward, subsurface satellite cupolas of intrusions, or parts of plutons or porphyry copper occurrences that are covered by unmapped surficial materials. We also added a 2-km buffer zone around the outer margins of polygons or groups of polygons representing permissive volcanic rocks that might hide subvolcanic intrusions. This 2-km buffer was added to include small or covered exposures of volcanic rocks near the margins of larger mapped exposures. For additional information on buffering, see the “Permissive Tracts for Porphyry Copper” section in the Introduction of this report.

After buffering, we examined aeromagnetic, gravimetric, and geochemical anomaly maps for evidence of unmapped permissive igneous rocks or hydrothermal systems (Natural Resources Canada, 2008a, b, c). Positive aeromagnetic and gravity anomalies were interpreted as possible evidence for granitoid intrusions, or magnetite-bearing hydrothermal systems (see Clark, 1999, for discussion). Where such anomalies extend beyond the margins of the buffered permissive map units, the tract was extended to include them. Stream-sediment geochemical anomalies for copper also were considered (Natural Resources Canada, 2008c). Areas with geochemical anomalies for copper, molybdenum, and zinc are interpreted to represent hydrothermal systems and were included in the tract if there was reason to believe they were as young as late Tertiary. Areas with anomalies for copper and nickel, without molybdenum or zinc, are interpreted to represent areas of mafic igneous rocks, and were not included in the tract.

Finally, a smoothing routine was applied to the buffered tract. A description of the smoothing routine is included in the metadata in appendix H.

Geologic Interpretation

The Cascades-Garibaldi-Pemberton magmatic arc is related to subduction of the northeast-moving Juan de Fuca Plate beneath the western margin of the southwest-moving North American Plate (Riddihough and Hyndman, 1991). Subduction of the Juan de Fuca Plate probably began at about 40 Ma and continues to the present. Dated porphyry copper deposits and prospects of the Cascades-Garibaldi-Pemberton magmatic arc mostly are younger than about 30 Ma.

Inasmuch as the Wrangel-Stikine magmatic arc contains Oligocene to Miocene intrusions of generally calc-alkaline affinity, we consider this magmatic arc to be permissive for porphyry copper deposits. Nevertheless, we are uncertain whether or how any of these igneous rocks are related to subduction beneath the continental margin, which probably ended during the transition from subduction to transform plate-margin tectonic environment, after about 39 Ma (see Madsen and others, 2006). Skulski and others (1991) indicated that the late Cenozoic Wrangel volcanic belt records a transition from a subduction to transform margin, and that the northwestern segment comprises calc-alkaline lavas emplaced above a Benioff zone, whereas the southeastern segment comprises transitional lavas, with minor alkaline and calc-alkaline lavas, emplaced over a leaky transform fault zone. However, only the northwesternmost part of our tract coincides with this northwestern segment of the Wrangel volcanic belt, which extends from westernmost Yukon well northwestward into Alaska (see Skulski and others, 1991, fig. 1).

Near the northernmost part of the southern segment of this tract, the Quartz Hill porphyry Mo deposit is related to granitic intrusions of Oligocene age (30-24 Ma). We know of no porphyry copper deposits or significant porphyry copper prospects within the northern segment of this tract in northern British Columbia, Yukon, or southeastern Alaska.

Known Deposits

The Giant Copper deposit (22 Ma) is the only known porphyry copper deposit in this tract. It includes a northwest-elongate cluster of at least five breccia pipes, as well as tourmaline-sulfide-magnetite replacement bodies, a Cu-Au vein, and polymetallic veins. These breccias, replacement bodies, and veins are related to the Oligocene Invermay quartz-diorite stock.

According to BC MINFILE record 092HSW001, the AM breccia pipe is the largest and highest grade ore body in the Giant Copper group. It contains chalcopyrite, pyrrhotite, and lesser pyrite. Chalcopyrite rims breccia fragments and is disseminated in the matrix of the breccias. Chalcopyrite also occurs in subordinate veinlets that cut both the breccia fragments and matrix. The Invermay zone is a relatively poorly mineralized breccia, cut by the higher grade Invermay Cu-Au vein, which has received more exploration attention than the breccia. Table E3 summarizes the estimated resources of the AM and Invermay ore bodies, and of the Giant Copper group.

Table E3 lists known deposits in this permissive tract. Additional information about these deposits is included in the table for deposits and prospects in appendix F.

Prospects, Mineral Occurrences, and Related Deposit Types

Significant prospects are listed in table E4. The No. 1 prospect is part of the Giant Copper group, and therefore was not treated as a possible undiscovered deposit.

The Hannah prospect is characterized by pyrite, chalcopyrite, and molybdenite in veins, stockworks, and shear zones in a quartz monzonite stock with phyllic and argillic alteration assemblages. Although undated, the Hannah prospect is assigned to this tract because it is believed to be late Tertiary (see BC MINFILE record number 092N 028) and is on the trend of the Garibaldi-Pemberton magmatic-arc, which is the fundamental feature that defines this tract.

The Owl Creek group of prospects is a northwest-trending string of three prospects, A-zone, B-zone, and C-zone, spaced at 1.5-km intervals. Because each prospect is less than 2 km from its nearest neighbor, these three prospects are grouped. They are interpreted as manifestations of the same hydrothermal system and are considered to represent one possible undiscovered porphyry copper deposit. These Owl Creek prospects are associated with predominantly dioritic intrusions that are described in BC MINFILE records but are not shown on our geologic source maps. These intrusions and their associated mineralized and altered rocks occur within a northwest-striking shear zone along the trend of the Cascade-Garibaldi volcanic chain. Isotopic age determinations are not available for these intrusions, but they are probably about mid-Oligocene in age (see Nokleberg and others, 2005).

The A-zone prospect is at the southeast end of the Owl Creek group of prospects where chalcopyrite, molybdenite, pyrite, and magnetite are disseminated in propylitized and argillized rocks. These occur along shear zones intruded by small bodies of diorite, quartz diorite, granodiorite, and feldspar porphyry. A 185-m intercept of 0.2-percent copper is

Table E3. Known calc-alkaline porphyry Cu±Mo±Au deposits in tract 003pCu2005 (CA05), I Late Continental Arc—British Columbia and Yukon Territory, Canada.

[Ma, million years; NA, not applicable; –, no data; Mt, million metric tons; t, metric ton; %, percent; g/t, gram per metric ton; Cu-Mo subtype, deposits that have Au/Mo ratios <3 or average Mo grades >0.03%; Cu-Au subtype, deposits that have Au/Mo ratios >30 or average Au grades >0.2 g/t. Contained Cu in metric tons is computed as (tonnage Mt x 1,000,000) x (percent Cu / 100); gs, coordinates of this site are used for the group location; *, estimated tonnage and grade from an unsubstantiated press release (not used in grade and tonnage model); **, partial tonnage and grade for a deposit that is known to be open to extension (not used in grade and tonnage model). For group aggregates: the latitude and longitude, subtype, and age is that of the deposit with the largest Cu resources; the Cu and Mo grades are tonnage-weighted averages calculated using the computed contained Cu and Mo as (t contained Cu or Mo / (Mt x 1,000,000)) x 100 (note that the computed contained Mo is not shown in this table); and the Au and Ag grades are a tonnage-weighted average calculated as g/t x Mt. For sources of age, tonnage, and grade information, see appendix F. Resource estimates are through 2009, but include updates for 2010 when available.]

Name	Latitude	Longitude	Subtype	Age (Ma)	Tonnage (Mt)	Cu (%)	Mo (%)	Au (g/t)	Ag (g/t)	Contained Cu (t)
GIANT COPPER GROUP										
Giant Copper ^{gs} (AM Breccia)	49.164	-121.025	NA	22	29.5	0.65	0.007	0.011	0.36	192,000
Invermay	49.178	-121.031	Cu-Au	22	15.3	0.21	–	0.38	7.92	32,200
GROUP AGGREGATE	49.164	-121.025	NA	22	44.8	0.5	–	0.137	2.945	224,200
TRACT TOTAL					44.8					224,200
TRACT ROUNDED TOTAL					44.8					224,000

Table E4. Significant calc-alkaline porphyry Cu±Mo±Au prospects in tract 003pCu2005 (CA05), Late Continental Arc—British Columbia and Yukon Territory, Canada.

[Ma, million years; NA, not applicable; Mt, million metric tons; t, metric ton; %, percent; g/t, gram per metric ton; gs, group site-coordinates of this site are used for the group location. For sources and additonal information about age, tonnage, grade and comments, see appendix F. For mineral name abbreviations under "Comments", see appendix F.]

Group	Name	Rank	Latitude	Longitude	Age (Ma)	Comments
Significant porphyry Cu prospects in groups of known porphyry Cu deposits and prospects						
Giant Copper	No. 1	3	49.171	-121.028	29	Intercept: 27 m, 0.67% Cu, 247 g/t Ag; sphal, gn, py, cpy; breccia, veins, disseminations in potassic hornfels with tourmaline
Owl Creek	A zone	3	50.38	-122.758	30	Intercept: 185 m, 0.20% Cu
Owl Creek	C zone	3	50.398	-122.795	30	Intercept: 91.4 m, 0.40 % Cu
Significant individual porphyry Cu prospects						
NA	Hannah 8, 10, 11	4	51.291	-125.404	7	Intercept: 2 m, 1% Cu, 85 g/t Au, 51 g/t Ag; py, cpy, mo; vein, stockwork, shear; phyllic and argillic alteration assemblages

reported from the A-zone, which is, therefore, classified as a significant rank 3 prospect.

The B-zone prospect is between the A- and C-zones where chalcopyrite, molybdenite, pyrite, and magnetite occur in stockworks or veinlets. No assay data are available for the B zone, which is, therefore, classified as a rank 5 prospect.

The C-zone prospect is at the northwest end of the Owl Creek group of prospects where chalcopyrite, molybdenite, pyrite, and magnetite occur in veins and stockworks of veinlets in shear zones intruded by hornblende diorite. Propylitic, phyllic, and silicic alteration assemblages accompany the intrusions, veins, and stockworks. A 91-m intercept of 0.4-percent copper is reported from the C-zone, which is, therefore, classified as a significant rank 3 prospect.

Exploration History

The only exploration reported to have been done in this tract from 2005 to 2008 was done in the Giant Copper group of deposits and prospects, where Imperial Metals Corp. did about 1,870 m of core drilling. The property was first staked in the 1930s, and the Invermay zone discovered in 1933 (Robertson, 2006).

The Owl Creek group of prospects were first recognized when showings of the Copper Queen (the A-zone Owl Creek prospect) were reported in1913, but with workings likely before that date (Butler, 2008). Exploration was carried out by an underground adit developed in the early 1900’s, followed by three drill holes in 1928 that intersected as much as 300 feet of low grade copper found in several zones of probable porphyry type deposits (Butler, 2008). Assessment reports from 1973 and 1986 (see BC MINFILE number 092JSE004) indicated significant intercepts of hydrothermally altered rocks containing 0.2 to 0.4 percent copper.

Sources of Information

Principal sources of information used by the assessment team for delineation of tract 003pCu2005 are listed in table E5.

Grade and Tonnage Model Selection

As discussed in the Introduction and as shown in appendix G, a new grade and tonnage model for Canadian Cu±Mo±Au deposits was constructed due to the lower copper grades present in Canadian examples compared to the global models (Singer and others, 2008).

Porphyry Cu±Mo±Au

The deposits and prospects of permissive tract 003pCu2005 (CA05), as well as those of tracts 003pCu2001 (CA01), 003pCu2003 (CA03), and 003pCu2004 (CA04), fit the descriptive model for Porphyry Cu±Mo±Au deposits of British Columbia (Panteleyev, 1995) and the Yukon Territory (Panteleyev, 2005). After spatial grouping according to the 2-km rule, 34 known deposits of this subtype are present in the Canadian Cordillera (1 of which occurs in this tract). In aggregate, when compared to the Singer and others (2008) grade and tonnage models, the Canadian Cu±Mo±Au deposits are on average lowest in tonnage, lowest in copper grade, higher in molybdenum grade (except for model 21a), higher in gold grade (except for model 20c), and highest in Ag grade.

Statistical tests at a 1-percent screening level on these deposits (as a group) indicate that their molybdenum grade and gold grade distribution means are not statistically different from the general (models 17, 20c, and 21a combined) or Cu subtype (model 17) porphyry copper grade and tonnage models of Singer and others (2008) (see tables G2a and b). Neither is their tonnage distribution mean statistically different from the general, Cu subtype, or Cu-Au subtype (model 20c) porphyry copper grade and tonnage models of Singer and others (2008) (see tables G2a, b, and c). However, the copper grade distribution mean is statistically different from the general model and all the individual subtype models (see tables G2a, b, c, and d). For this reason, a grade and tonnage model for the porphyry Cu±Mo±Au deposits in tracts 003pCu2001 (CA01), 003pCu2003 (CA03), 003pCu2004 (CA04) and 003pCu2005 (CA05) was constructed.

The complete model, which contains data current through December 2009, is described in appendix G. For deposits in tract 003pCu2005 (CA05), the formal group according to the 2-km rule, and the name of the independent or groups used, along with the tonnages and grades used in the development of the grade and tonnage model, are listed in table E6.

Estimate of the Number of Undiscovered Deposits

Rationale for the Estimate

Given the availability of MINFILE records for known porphyry copper prospects in British Columbia and Yukon, and knowing that the MINFILE data sets are quite complete and up-to-date, our rationale for estimation of numbers of undiscovered deposits was to estimate numbers of undiscovered deposits based largely on the distributions and qualities of those prospects within each permissive tract. At the 90-percent level of subjective probability we could not identify prospects that we were confident would become deposits. At the 50-percent level of probability we tried to identify prospects with a good chance of becoming deposits, but we also considered overall exploration maturity and the spatial density of known deposits as possible limiting factors. At the 10-percent level of probability we considered the preceding factors plus the potential for undiscovered prospects and deposits in areas that are largely covered by mapped and unmapped surficial deposits, and in areas of unexplained geophysical and geochemical anomalies that might be indicative of undiscovered porphyry copper deposits. At the 5-percent level of probability, our consensus estimate (agreement on an estimate acceptable to the group) was the same as our estimate at the 10-percent level of probability. The estimates and consensus results are presented in table E8.

The southern segment of this tract contains one known porphyry copper deposit and four significant prospects (tables E3 and E4). The No. 1 prospect is grouped with the known deposit and is, therefore, regarded as a possible extension to the known deposit and not as a possible undiscovered deposit. The two significant prospects of the Owl Creek group are regarded as manifestations of one possible undiscovered porphyry copper system. Otherwise, this permissive tract

Table E5. Principal sources of information used for tract 003pCu2005 (CA05), Late Continental Arc—British Columbia and Yukon Territory, Canada.

[NA, not applicable]

Theme	Name or title	Scale	Citation
Geology	GeoFile 2005-1: Digital Geology Map of British Columbia! Whole Province	1:250,000	Massey and others (2005)
	Yukon Digital Geology	1:250,000	Gordey and Makepeace (1999)
	Geoscience Map 2005-3: Geology of British Columbia	1:1,000,000	Massey and others (2005)
	Terrane Map of the Canadian Cordillera	1:2,000,000	Wheeler and others (1991)
	Tectonic Assemblage Map of the Canadian Cordillera	1:2,000,000	Wheeler and McFeely (1991); Journeay and Williams (1995; GIS vector representation of Wheeler and McFeely, 1991)
	Metamorphic Map of the Canadian Cordillera	1:2,000,000	Read and others (1991)
	YukonAge 2004: A database of isotopic age determinations for rock units from Yukon Territory	NA	Breitsprecher and Mortensen (2004a)
	BC Age 2004A-1: A database of Isotopic Age Determinations for Rock Units from British Columbia	NA	Breitsprecher and Mortensen (2004b)
	Radiometric Age Data Bank (RADB); National Geochronological Data Base (NGDB)	NA	Zartman and others (1976); Marshall (1993)
Mineral occurrences	Porphyry Deposits	NA	Sinclair (2007)
	Porphyry Copper Deposits of the World	NA	Singer and others (2008)
	Lode mineral deposits	NA	Nokleberg and others (1998)
	MINFILE (British Columbia) Mineral Occurrences Database	NA	MINFILE BC (2009)
	MINFILE (Yukon) Mineral Occurrences Database	NA	MINFILE YT (2009)
	Porphyry Deposits of the Canadian Cordillera	NA	CIM SV 15 (Sutherland Brown, 1976, ed.)
	Porphyry Deposits of the Northwestern Cordillera of North America	NA	CIM SV 46 (Schroeter, 1995, ed.)
Geochemistry	National Geochemical Reconnaissance (NGR) Stream Sediment, Lake Sediment and Water Geochemical Data Base	NA	Natural Resources Canada (2008c)
	Yukon Regional Geochemical Database 2003 ! Stream Sediment Analyses	NA	Heon (2003)
Geophysics	Canadian Geodetic Information System—Gravity (2-km grid)—Bouguer anomaly, free-air anomaly, isostatic horizontal gradient	~1:2,000,000	Natural Resources Canada (2008b)
	Canadian Aeromagnetic Data Base – 1km and 200m grid – Residual total field	~1:1,000,000 and ~1:200,000	Natural Resources Canada (2008a)
	Canadian Aeromagnetic Data Base – 500m grid – Residual total field, reduced to pole	~1:500,000	B.J. Drenth (unpub. data, 2009)
Exploration	BC Mines and Mineral Exploration Overviews, Yukon Mineral Deposits, Natural Resources Canada, Top 100 Exploration and Deposit Appraisal Projects, 2008, websites of Mineral Exploration companies	NA	Schroeter and others (2006, 2007), DeGrace and others (2008, 2009)

Table E6. Tonnages and grades of deposits of this tract used in tonnage and grade models for Canadian Cordilleran calc-alkaline porphyry Cu±Mo±Au for tract 003pCu2005 (CA05), Late Continental Arc—British Columbia and Yukon Territory, Canada.

[Groups include all deposits and prospects with well-defined grades and tonnages that meet the 2-km rule. Mt, million metric tons; %, percent; g/t, grams per metric ton. Resource estimates available in 2008–2009 have not been updated to include information added to appendix F after 2009.]

GROUP	NAME	Ore (Mt)	Cu (%)	Mo (%)	Au (g/t)	Ag (g/t)
Giant Copper	Giant Copper (Total)	44.8	0.5	0.005	0.137	2.945

Table E7. Undiscovered deposit estimates, deposit numbers, tract area, and deposit density for tract 003pCu2005 (CA05), Late Continental Arc—British Columbia and Yukon Territory, Canada.

[Nxx, estimated number of deposits associated with the xxth percentile; N_{und}, expected number of undiscovered deposits; s, standard deviation; Cv%, coefficient of variance; N_{known}, number of known deposits in the tract that are included in the grade and tonnage model; N_{total}, total of expected number of deposits plus known deposits; area, area of permissive tract in square kilometers; density, deposit density reported as the total number of deposits per km^2. N_{und}, s, and Cv% are calculated using a regression equation (Singer and Menzie, 2005). In cases where individual estimates were tallied in addition to the consensus estimate, individual estimates are listed.]

Consensus undiscovered deposit estimates					Summary statistics					Tract area (km^2)	Deposit density (N_{total}/km^2)
N90	N50	N10	N05	N01	N_{und}	s	Cv%	N_{known}	N_{total}		
0	1	3	4	4	1.4	1.4	99	1	2.4	32,840	0.00007

	Estimated number of undiscovered deposits				
Estimator	N90	N50	N10	N05	N01
Individual 1	0	1	2	2	2
Individual 2	0	1	2	4	4
Individual 3	0	0	1	3	5
Individual 4	0	1	3	5	5
Individual 5	0	1	1	3	3
Individual 6	0	2	3	4	4
Individual 7	0	2	4	6	6
Consensus	0	1	3	4	4

Table E8. Results of Monte Carlo simulations of undiscovered resources for tract 003pCu2005 (CA05), Late Continental Arc—British Columbia and Yukon Territory, Canada.

[Cu, copper; Mo, molybdenum; Au, gold; and Ag, silver, in metric tons; Rock, in million metric tons]

Material	Probability of at least the indicated amount						Probability of	
	0.95	0.9	0.5	0.1	0.05	Mean	Mean or greater	None
Cu	0	0	720,000	5,000,000	7,400,000	1,800,000	0.31	0.29
Mo	0	0	17,000	220,000	340,000	76,000	0.29	0.41
Au	0	0	27	260	390	92	0.3	0.36
Ag	0	0	0	2,100	3,400	660	0.23	0.54
Rock	0	0	260	1,900	2,800	680	0.33	0.29

appears to be less thoroughly explored than other permissive tracts of the Canadian Cordillera. These considerations influenced our estimates at the 50-, 10- and 5-percent levels of subjective probability.

We calculated the spatial density of deposits indicated by the one known deposit plus our mean estimate of 1.4 undiscovered deposits, for a total of 2.4 deposits, divided by the tract area of 32,840 km^2, yielding a density of 0.00007 deposits/km^2. We compared this spatial density to spatial densities of porphyry copper deposits in well-studied areas of the world according to Singer and others (2005, 2008). This showed that although this estimated spatial density is well below the trend of the central tendency, it is just within the 10- to 90-percent confidence envelope for the spatial density of known deposits used to construct the deposit density model (as calculated by Singer and others, 2005).

Probabilistic Assessment Simulation Results

Undiscovered resources for the tract were modeled using the consensus estimates for numbers of undiscovered porphyry Cu±Mo±Au deposits and the grade and tonnage models presented in appendix G of this report for Canadian Cu±Mo±Au porphyry copper deposits as input for the EMINERS Monte Carlo simulator program (Root and others, 1992; Bawiec and Spanski, in press). Selected simulation results are reported in table E9. Results of the Monte Carlo simulation are presented as cumulative frequency plots (fig. E2). The cumulative frequency plots show the estimated resource amounts associated with cumulative probabilities of occurrence, as well as the mean, for each commodity and for total mineralized rock.

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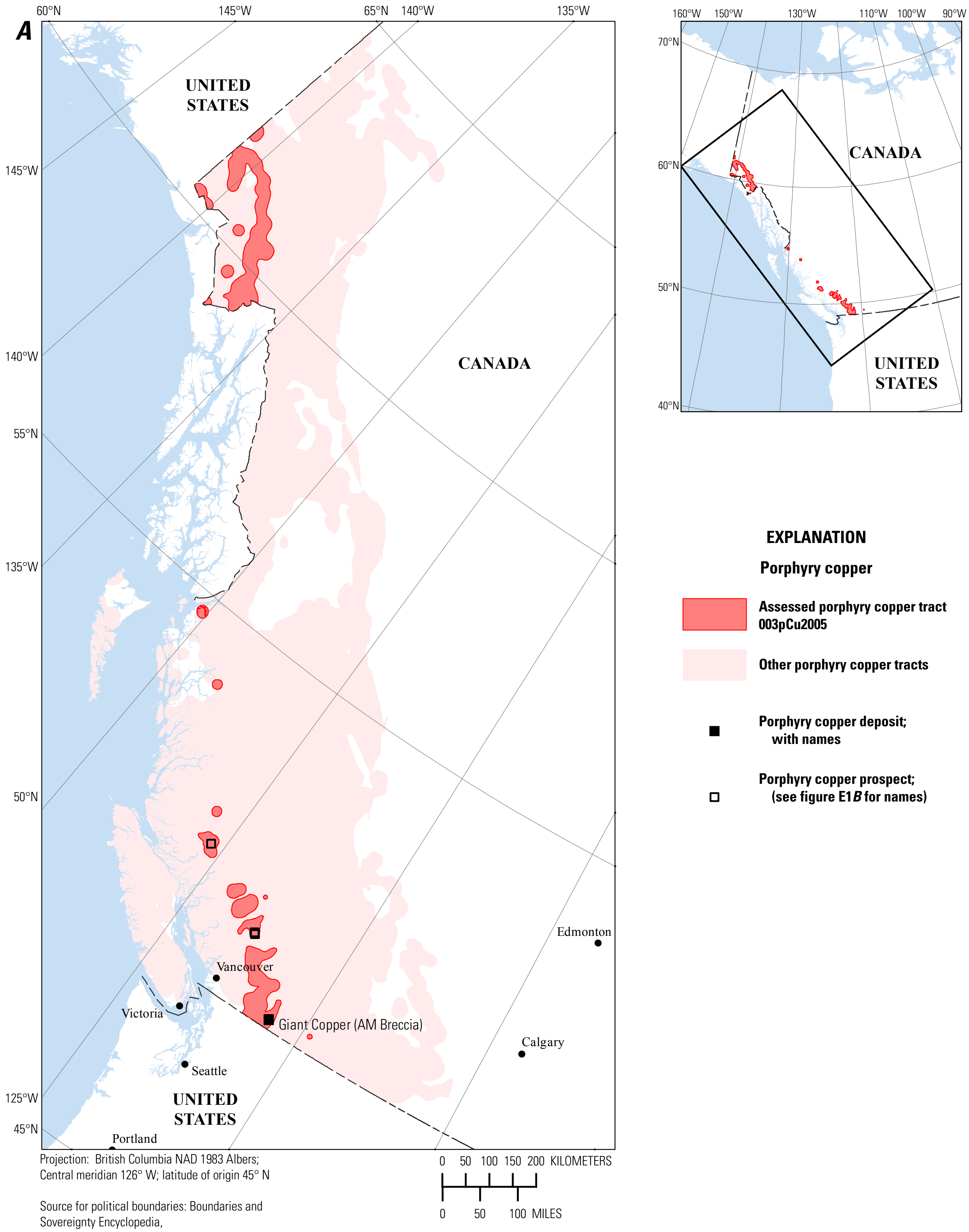
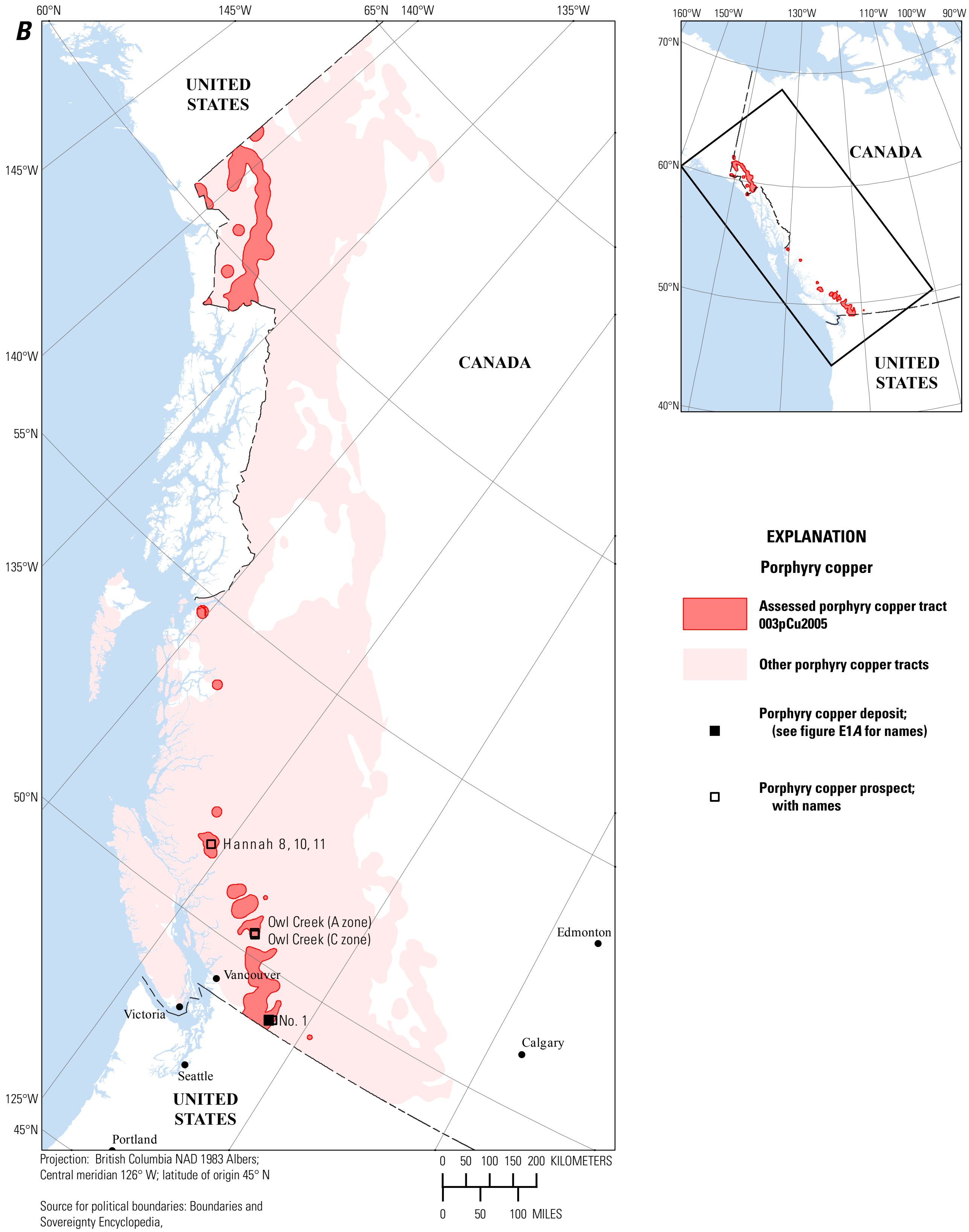


Projection: British Columbia NAD 1983 Albers;
Central meridian 126° W; latitude of origin 45° N

Source for political boundaries: Boundaries and
Sovereignty Encyclopedia,
U.S. Department of State, Office of the Geographer and Global Issues

Figure E1. Maps showing permissive tract 003pCu2005 (CA05), Late Continental Arc—British Columbia and Yukon Territory, Canada. *A*, Locations of known porphyry copper deposits (named) and significant prospects (not named). *B*, Locations of significant prospects (named) and known porphyry copper deposits (not named).



Projection: British Columbia NAD 1983 Albers;
Central meridian 126° W; latitude of origin 45° N

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Figure E1.—Continued

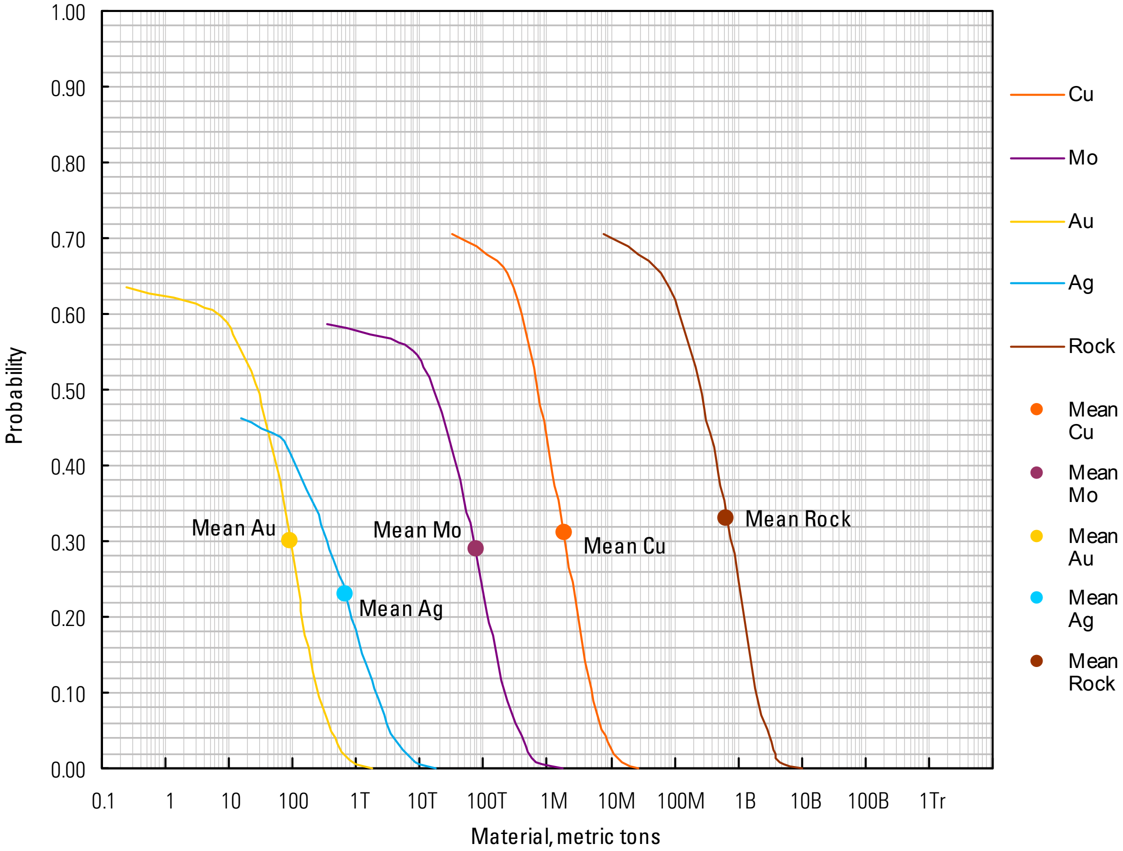

Figure E2. Cumulative frequency plot showing the results of a Monte Carlo computer simulation of undiscovered resources in tract 003pCu2005 (CA05), Late Continental Arc—British Columbia and Yukon Territory, Canada. (T=thousands, M=millions, B=billions, Tr-trillions).

Appendix F. Table of Attributes of Porphyry Copper Deposits and Prospects, British Columbia and Yukon Territory, Canada

(See attached file)

Appendix G. Grade and Tonnage Model for Calc-Alkaline Porphyry Cu±Mo±Au Deposits of the Canadian Cordillera

By Thomas P. Frost[1], Arthur A. Bookstrom[1], and Mark J. Mihalasky[1]

Description

Deposits included in this grade and tonnage model all fit the descriptive model for calc-alkaline porphyry Cu±Mo±Au in the Canadian Cordillera (Panteleyev, 1995 and 2005), but they occur in four different permissive tracts: 003pCu2001 (CA01), 003pCu2003(CA03), 003pCu2004 (CA04), and 003pCu2005(CA05). That they are in different tracts does not preclude them from being included in the same grade and tonnage model, despite differences in age and original tectonic setting.

Table G1 lists estimated tonnages and grades for deposits and groups of deposits that are included in our grade and tonnage model for calc-alkaline porphyry Cu±Mo±Au in the Canadian Cordillera. This model is based on resource estimates that were available through the end of 2009. It has not been updated with resource estimates made to the deposits or prospects listed in appendix F in 2010. Estimated resources of spatially grouped deposits are aggregated according to the 2-km rule (explained in the Introduction to this report). Sites with estimated resources of less than 16,000 metric tons of contained copper are not included because they are considered too small to represent a complete porphyry copper deposit.

Table G2 summarizes the results of t-tests of the distributions of tonnage, copper, molybdenum, gold, and silver for deposits from tracts 003pCu2001 (CA01), 003pCu2003(CA03), 003pCu2004 (CA04), and 003pCu2005(CA05) in Canada against Singer and others (2008) global models for general porphyry copper (porphyry Cu models 17, 20c, 21a, combined), porphyry Cu (model 17), porphyry Cu-Au (model 20c), and porphyry Cu-Mo (model 21a).

Before performing any tests, the Canadian Cordillera porphyry copper deposits listed in the Singer and others (2008) database were removed. For the test against the general model (table G2a), tonnage, molybdenum grade, and gold grade distributions are not rejected, but copper grade is too low and silver is too high to fit the general model. For the test against model 17 (table G2b), tonnage, molybdenum grade, and gold grade distributions are not rejected, but copper and silver are rejected. For the test against model 20c (table G2c), only tonnage is not rejected. For the test against model 21a, only the silver grade was not rejected.

Because of these inconsistencies in tonnage and grade between the Canadian porphyry Cu±Mo±Au deposits and any of Singer and others (2008) global porphyry copper models, we have developed a new regional grade and tonnage model specifically for the Canadian deposits. The cumulative frequency curves for tonnage, copper and molybdenum grade in percent, and gold and silver grade in grams per metric ton are shown in figures G1 through G5, respectively.

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[1] U.S. Geological Survey, Spokane, WA..

Table G1. Estimated resources of deposits used in the grade and tonnage model for Canadian Cu±Mo±Au deposits.

[Mt, million metric tons; g/t, grams per metric ton; –, no data; NA, not applicable. Independent indicates that a deposit is not in a group.]

TRACT ID	CLUSTER	GROUP	NAME	ORE (Mt)	Cu (%)	Mo (%)	Au (g/t)	Ag (g/t)
CA01	NA	Independent	Brenda	227	0.16	0.039	0.013	0.63
CA01	Bronson	Independent	Bronson Slope - Red Bluff	129.8	0.16	0.008	0.44	2.44
CA01	Gibraltar	Gibraltar	Gibraltar (Total)	1,365	0.291	0.006	–	0.077
CA01	NA	Independent	Gnat Lake (Gnat Pass)	30.4	0.39	–	–	–
CA01	Highland Valley	Highland Valley	Highland Valley (Total)	3,180	0.392	0.013	0.005	0.77
CA01	Kemess	Kemess	Kemess (Total)	948	0.153	–	0.221	–
CA01	Kinaskan	Kinaskan	Kinaskan (Total)	247.2	0.337	–	0.372	0.634
CA01	Kwanika	Independent	Kwanika (Swan)	211.2	0.278	–	0.269	–
CA01	Kemess	Independent	Pine	70	0.15	–	0.57	–
CA01	Schaft Creek	Schaft Creek	Schaft Creek (Total)	1,484	0.255	0.021	0.169	–
CA03	Hushamu	Hushamu	Hushamu (Total)	780.4	0.207	0.011	0.258	–
CA03	Island	Island	Island (Total)	377	0.41	0.017	0.19	1.4
CA04	Bell (Babine)	Independent	Bell Copper	495	0.36	0.005	0.16	1
CA04	Berg	Independent	Berg	650.6	0.284	0.036	0.018	3.6
CA04	Bell	Independent	Big Onion (Cimbria)	94.4	0.42	0.02	0.064	1
CA04	NA	Independent	Cash	36	0.28	0.021	0.17	–
CA04	Casino	Independent	Casino	964	0.22	0.02	0.24	1.8
CA04	Catface	Independent	Catface	308	0.37	0.007	0.05	–
CA04	Bell	Bell	Dorothy-Nak (Total)	316	0.195	–	0.114	–
CA04	Fish Lake	Independent	Fish Lake (Prosperity)	1,150	0.22	0.002	0.41	2.3
CA04	NA	Independent	Gambier Island	114	0.29	0.018	0.03	1.3
CA04	Bell (Babine)	Independent	Granisle	171.2	0.41	–	0.144	0.4
CA04	Huckleberry	Huckleberry	Huckleberry (Total)	198.9	0.454	0.013	0.021	0.753
CA04	NA	Independent	Lexington-Lone Star	19.5	0.56	–	0.55	–
CA04	Louise Lake	Independent	Louise Lake	151	0.238	0.008	0.228	–
CA04	NA	Independent	Maggie	181.4	0.28	0.029	–	–
CA04	Bell (Babine)	Independent	Morrison (Hearne Hill)	206.9	0.337	0.004	0.177	–
CA04	Berg	Independent	New Nanik (Nanika)	16.5	0.437	–	–	–
CA04	Ok	OK	Ok (Total)	230	0.266	0.011		–
CA04	NA	Independent	Poison Mountain	808	0.24	0.008	0.12	3
CA04	Berg	Independent	Poplar	236	0.37	–	–	–
CA04	NA	Independent	Rey Lake	46.9	0.17	0.018	–	–
CA04	Fish Lake	Independent	Taseko	15	0.53	0.012	0.53	–
CA05	Giant Copper	Giant Copper	Giant Copper (Total)	44.8	0.5	0.005	0.137	2.945

Table G2. Summary of t-test results for Canadian Cu±Mo±Au deposits against the four porphyry copper deposit model distributions of Singer and others (2008).

[Shown are the number of deposits in each distribution, percentiles, means and standard deviations, differences of means, and p-values for the t-test. Prob > |t|, p-value for the two-tailed t-test; Prob > t, p-value for a one-tailed t-test; *, Prob > |t| is <0.01, indicating significantly different sample means at the 99-percent confidence level (shaded). Log-Mt, logarithm (to base 10) of million metric tons; Log-%, logarithm (to base 10) of percent; Log-g/t, logarithm (to base 10) of grams per metric ton.]

a. Canadian deposits tested against the global Cu general model (models 17, 20c, and 21a)

	Tonnage (Log-Mt)		Copper (Log-%)		Molybdenum (Log-%)		Gold (Log-g/t)		Silver (Log-g/t)	
	Model	Canadian	Model	Canadian	Model	Canadian	Model	Canadian	Model	Canadian
No. of deposits	364	34	364	34	188	24	211	27	141	16
Min	0.643	1.176	-1.155	-0.824	-3.301	-2.699	-2.959	-2.308	-1.022	-1.114
10%	1.544	1.386	-0.561	-0.796	-2.457	-2.367	-1.582	-1.773	-0.208	-0.613
25%	1.915	1.943	-0.444	-0.657	-2.155	-2.147	-1.125	-1.194	0.089	-0.179
Median	2.423	2.340	-0.337	-0.542	-1.854	-1.898	-0.678	-0.770	0.301	0.057
75%	2.875	2.833	-0.222	-0.402	-1.620	-1.699	-0.426	-0.570	0.589	0.381
90%	3.223	3.098	-0.114	-0.322	-1.391	-1.491	-0.194	-0.273	0.775	0.501
Max	4.328	3.502	0.255	-0.252	-1.000	-1.409	0.114	-0.024	1.322	0.556
Mean	2.401	2.319	-0.341	-0.534	-1.900	-1.936	-0.802	-0.891	0.313	0.039
SD	0.665	0.594	-0.194	0.162	0.431	-0.320	0.562	-0.535	0.388	0.418
Diff. of means	0.083		0.162		0.036		0.088		0.274	
Prob > |t|	0.446		<0.0001*		0.620		0.428		0.022*	
Prob > t	0.223		<0.0001*		0.310		0.214		0.011*	

b. Canadian deposits tested against the global Cu subtype model (model 17 only)

	Tonnage (Log-Mt)		Copper (Log-%)		Molybdenum (Log-%)		Gold (Log-g/t)		Silver (Log-g/t)	
	Model	Canadian	Model	Canadian	Model	Canadian	Model	Canadian	Model	Canadian
No. of deposits	231	34	231	34	118	24	94	27	78	15
Min	0.643	1.176	-1.155	-0.824	-3.000	-2.699	-2.000	-2.308	-1.022	-1.114
10%	1.482	1.386	-0.553	-0.796	-2.305	-2.367	-1.523	-1.773	-0.230	-0.613
25%	1.903	1.942	-0.444	-0.658	-2.097	-2.147	-1.224	-1.194	0.138	-0.179
Median	2.455	2.340	-0.337	-0.542	-1.854	-1.898	-0.921	-0.770	0.301	0.057
75%	2.869	2.833	-0.237	-0.402	-1.667	-1.699	-0.699	-0.570	0.546	0.381
90%	3.191	3.098	-0.126	-0.322	-1.523	-1.491	-0.469	-0.273	0.800	0.501
Max	4.226	3.502	0.114	-0.252	-1.108	-1.409	0.000	-0.244	1.301	0.556
Mean	2.381	2.309	-0.349	-0.534	-1.805	-1.936	-0.947	-0.891	0.307	0.039
SD	0.655	0.594	-0.880	0.162	0.348	0.320	0.397	0.535	0.401	0.418
Diff. of means	0.062		0.185		0.031		-0.056		0.268	
Prob > |t|	0.577		<0.0001*		0.670		0.616		0.0285*	
Prob > t	0.288		<0.0001*		0.335		0.692		0.0143*	

c. Canadian deposits tested against the global Cu-Au subtype model (model 20c only)

	Tonnage (Log-Mt)		Copper (Log-%)		Molybdenum (Log-%)		Gold (Log-g/t)		Silver (Log-g/t)	
	Model	Canadian	Model	Canadian	Model	Canadian	Model	Canadian	Model	Canadian
No. of deposits	92	34	92	34	29	24	92	27	40	16
Min	1.078	1.176	-0.699	-0.824	-3.301	-2.699	-1.523	-2.308	-0.721	-1.114
10%	1.544	1.386	-0.569	-0.796	-3.000	-2.367	-0.620	-1.773	-0.143	-0.613
25%	1.892	1.943	-0.465	-0.658	-2.581	-2.147	-0.523	-1.194	-0.079	-0.179
Median	2.255	2.340	-0.357	-0.542	-2.301	-1.898	-0.423	-0.766	0.398	0.057
75%	2.772	2.283	-0.196	-0.402	-2.126	-1.699	-0.222	-0.570	0.586	0.381
90%	3.105	3.095	-0.086	-0.322	-1.959	-1.491	-0.110	-0.273	0.770	0.501
Max	4.048	3.502	0.255	-0.252	-1.699	-1.409	0.114	-0.244	1.322	0.556
Mean	2.334	2.319	-0.329	-0.534	-2.403	-1.936	-0.395	-0.891	0.350	0.039
SD	0.615	0.594	-0.199	0.162	0.364	0.320	0.248	0.535	0.385	0.418
Diff. of means	0.015		0.205		-0.467		0.496		0.311	
Prob > |t|	0.902		<0.0001*		<0.0001*		<0.0001*		0.0162*	
Prob > t	0.451		<0.0001*		<0.0001*		<0.0001*		0.0081*	

Table G2. Summary of t-test results for Canadian Cu±Mo±Au deposits against the four porphyry copper deposit model distributions of Singer and others (2008)—Continued.

[Shown are the number of deposits in each distribution, percentiles, means and standard deviations, differences of means, and p-values for the t-test. Prob > |t|, p-value for the two-tailed t-test; Prob > t, p-value for a one-tailed t-test; *, Prob > |t| is <0.01, indicating significantly different sample means at the 99-percent confidence level (shaded). Log-Mt, logarithm (to base 10) of million metric tons; Log-%, logarithm (to base 10) of percent; Log-g/t, logarithm (to base 10) of grams per metric ton.]

d. Canadian deposits tested against the global Cu-Mo subtype model (model 21a only)

	Tonnage (Log-Mt)		Copper (Log-%)		Molybdenum (Log-%)		Gold (Log-g/t)		Silver (Log-g/t)	
	Model	Canadian	Model	Canadian	Model	Canadian	Model	Canadian	Model	Canadian
	41	34	41	34	41	24	25	27	23	16
Min	1.255	1.176	-0.921	-0.824	-2.097	-2.699	-2.959	-2.308	-0.481	-1.114
0.100	1.681	1.386	-0.674	-0.796	-2.000	-2.367	-2.643	-1.773	-0.232	-0.613
0.250	2.109	1.943	-0.431	-0.658	-1.784	-2.147	-2.000	-1.194	0.079	-0.179
Median	2.505	2.340	-0.292	-0.542	-1.495	-1.898	-1.638	-0.770	0.204	0.057
0.750	3.203	2.833	-0.209	-0.402	-1.314	-1.699	-1.523	-0.570	0.602	0.381
0.900	3.792	3.098	-0.067	-0.322	-1.076	-1.491	-1.101	-0.273	0.738	0.501
Max	4.328	3.502	0.000	-0.252	-1.000	-1.409	-0.921	-0.244	0.934	0.556
Mean	2.671	2.319	-0.332	-0.534	-1.529	-1.936	-1.758	-0.891	0.271	0.039
SD	0.771	0.594	0.214	0.162	0.311	0.320	0.503	0.535	0.355	0.418
Diff. of means	0.352		0.202		0.407		-0.868		0.232	
Prob > |t|	0.029*		<0.0001*		<0.0001*		<0.0001*		0.0803	
Prob > t	0.014*		<0.0001*		<0.0001*		<0.0001*		0.0401	

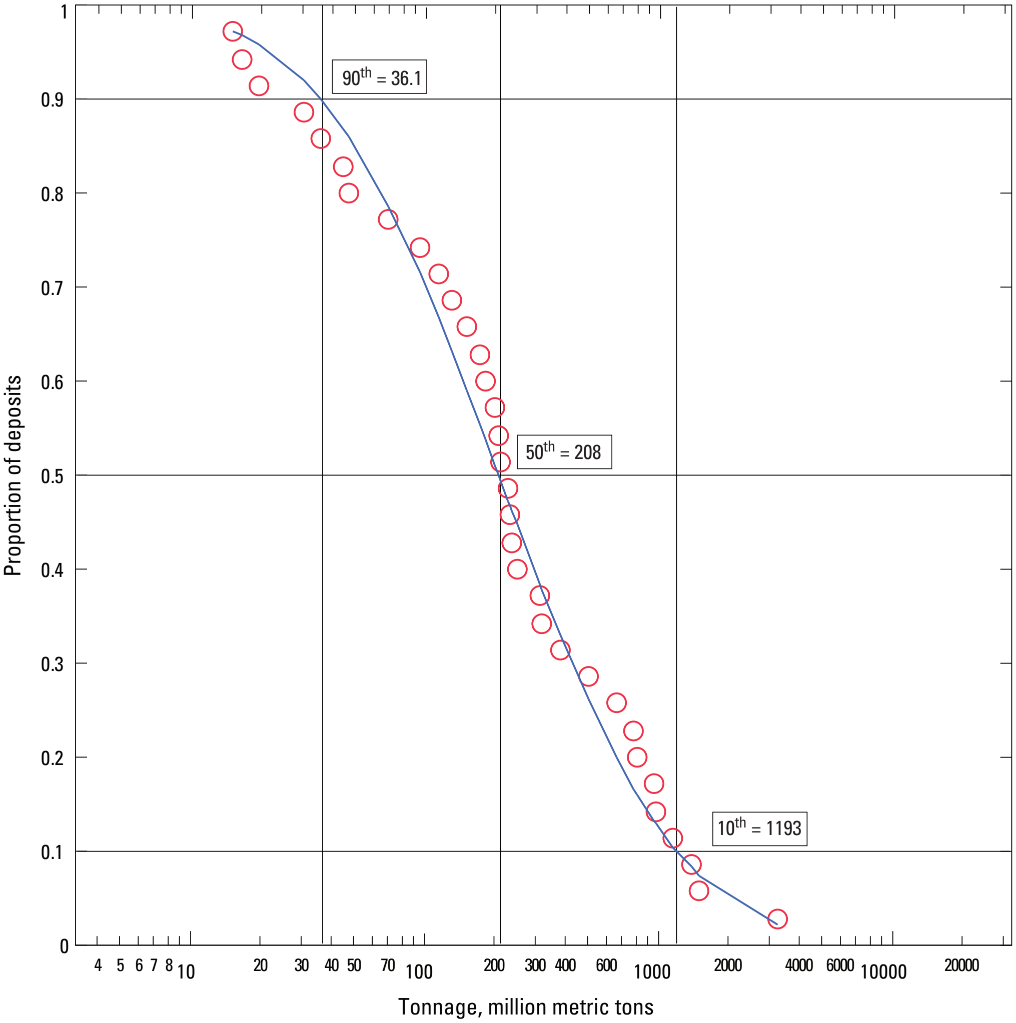

Figure G1. Tonnage model for Canadian Cu±Mo±Au deposits, in log (base 10) of millions of metric tons.

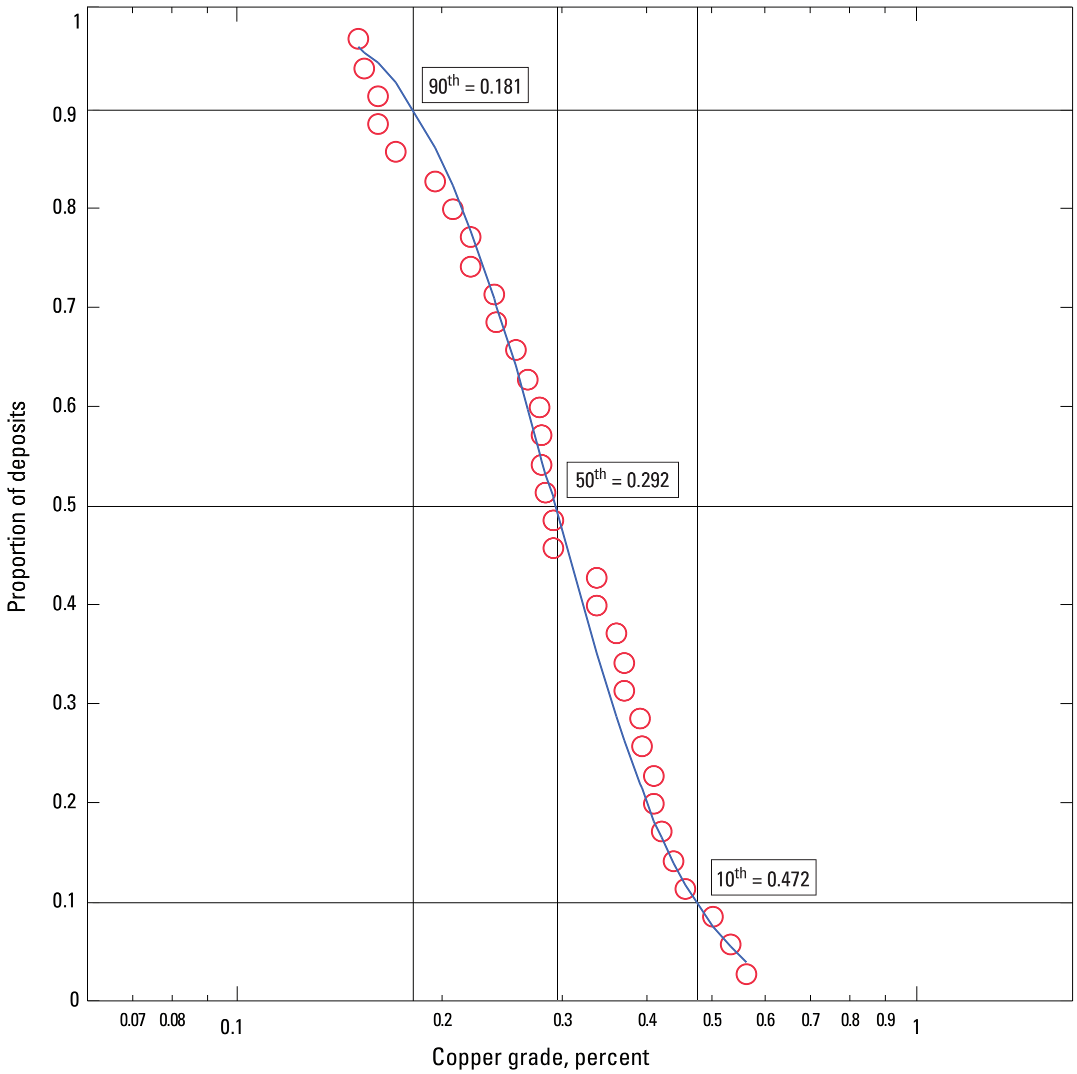

Figure G2. Copper grade model for Canadian Cu±Mo±Au deposits, in log (base 10) of percent.

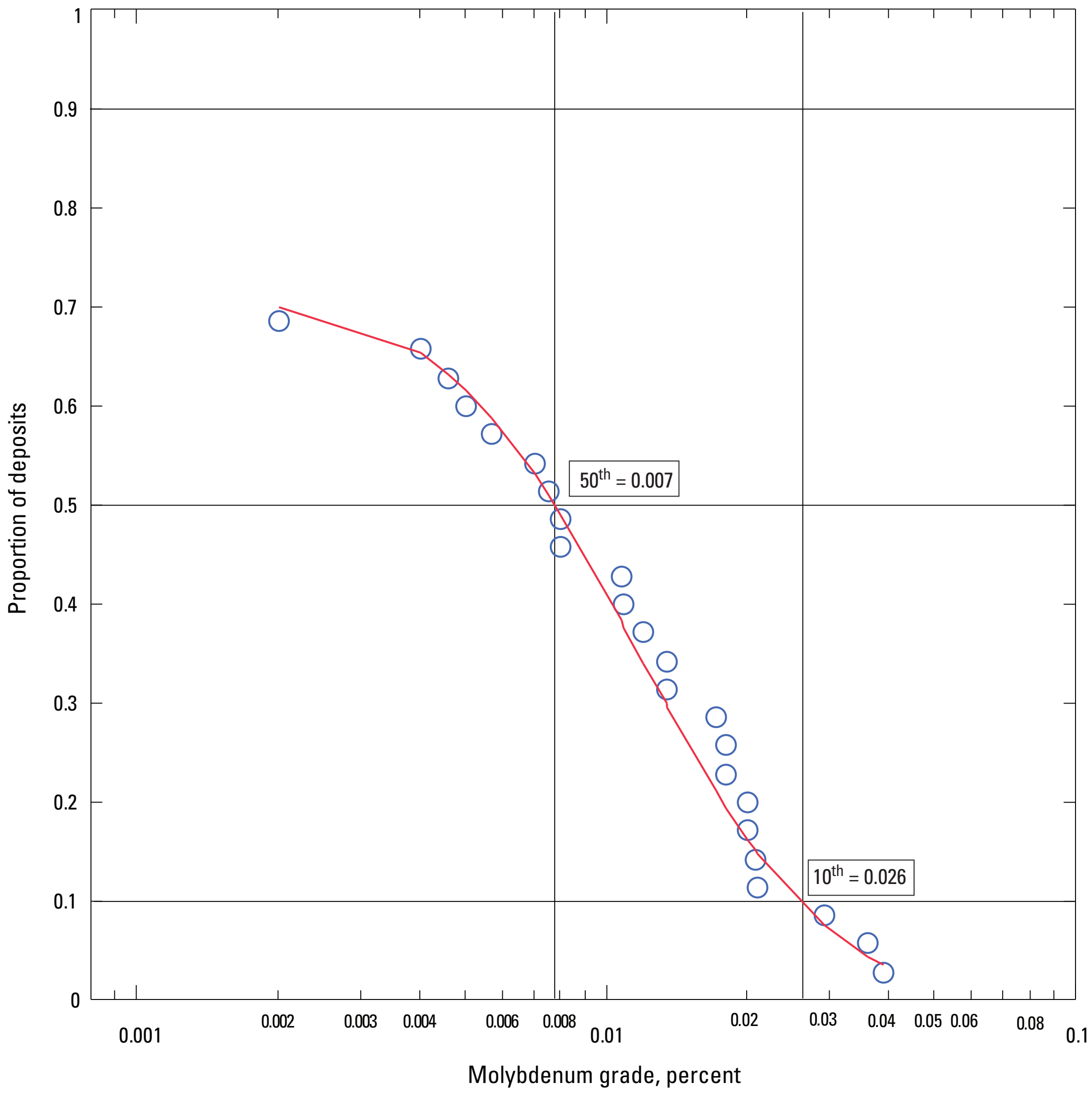

Figure G3. Molybdenum grade model for Canadian Cu±Mo±Au deposits, in log (base 10) of percent.

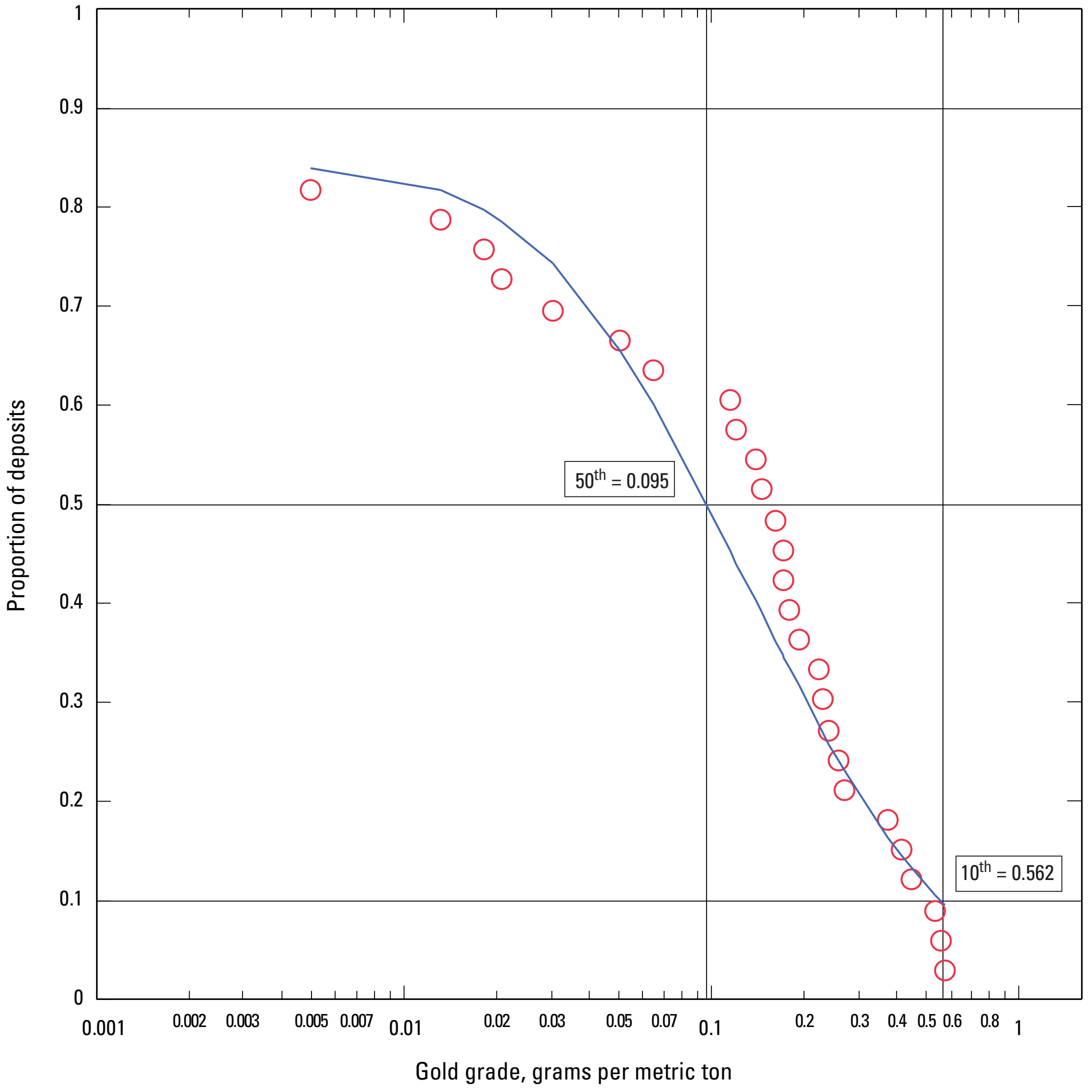

Figure G4. Gold grade model for Canadian Cu±Mo±Au deposits, in log (base 10) of grams per metric ton.

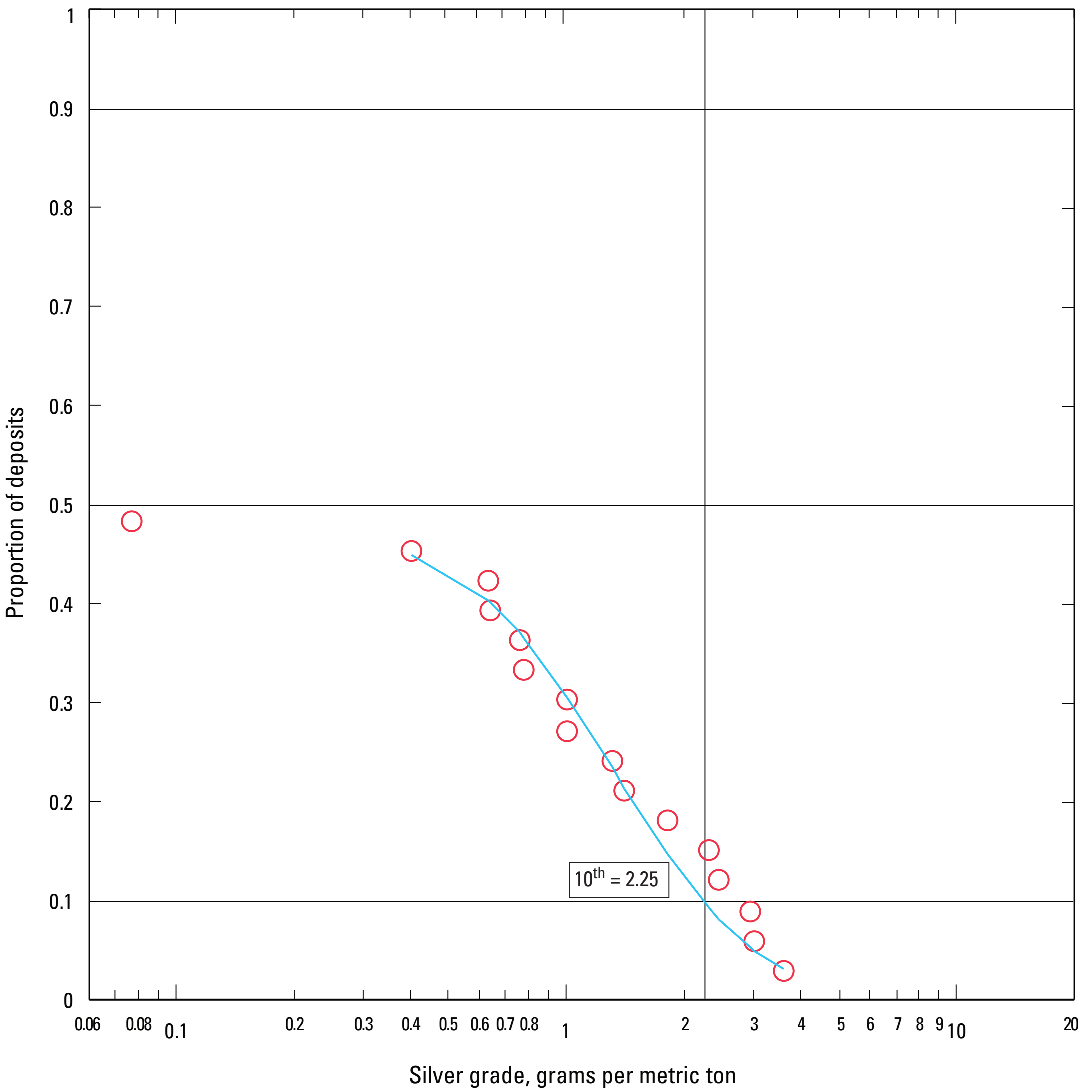

Figure G5. Silver grade model for Canadian Cu±Mo±Au deposits, in log (base 10) of grams per metric ton.

Appendix H. Geographic Information System (GIS) Files Representing the Porphyry Copper Mineral Resource Assessment Permissive Tracts, Deposits and Significant Prospects, and Accompanying Metadata, Porphyry Copper Assessment, British Columbia and Yukon Territory, Canada

By Mark J. Mihalasky[1], Arthur A. Bookstrom[2], Thomas P. Frost[3], and Steve Ludington[4]

Description of GIS Files

An ESRI file-geodatabase (003pCu.gdb), containing three feature classes, and an ESRI map document (.mxd) are included with this assessment report. These files may also be downloaded from the USGS publications Web site as a compressed file sir2010-5090c_appendix_h.zip. The file-geodatabase feature classes are as follows:

boundary_003pCu is a vector (polygon) feature class that represents an outline of Canada, including country political boundary and coastline. The dataset was extracted from U.S. Department of State (2009) SSIB spatial database.

mineral_sites_003pCu is a vector (point) feature class that represents porphyry copper mineral sites (deposits, significant prospects, and deposit-prospect groups) for the Canadian Cordillera. As defined for this mineral resource assessment, a “mineral site” includes deposits, significant prospects, and spatial groupings of proximal deposits and(or) significant prospects. This dataset includes an inventory of mineral resources in 89 known porphyry copper (and 2 related copper-bearing polymetallic vein) ore zones, representing 50 porphyry copper deposits, and lists key characteristics of 280 additional porphyry copper and related copper-bearing prospects. See metadata and report for additional details. See appendix F for cited references.

tracts_003pCu is a vector (polygon) feature class that represents porphyry copper mineral resource assessment permissive tracts for the Canadian Cordillera. A mineral resource assessment tract is defined as a geographic area (a tract of land) which is determined to possess certain characteristics and attributes that permit the occurrence of a particular type of mineral deposit. This feature class contains five permissive tracts for the occurrence of porphyry copper deposits: two island-arc tracts, one tract of transitional, mixed island-arc and continental arc affinities, and two continental arc tracts. These polygon features spatially overlap and may require setting a definition query (for example "Tract_ID"='CAOIPC') in order to separately display the entire tract. When displaying multiple tracts at the same time, portions of some tracts will be concealed. The attribute table associated with each tract contains cursory information about geologic setting, mineral deposits, and mineral resource assessment estimates. See report and metadata for additional details.

These datasets are contained in an ESRI map document (version 9.3): GIS_SIR5090-C.mxd. Also included are separate ASCII files of the metadata for the mineral sites and tracts, located in the folder “003pCu.met”.

Reference Cited

U.S. Department of State, 2009, Small-scale digital international land boundaries (SSIB)—Lines, edition 10 and Polygons, beta edition 1: U.S. Department of State, Office of the Geographer and Global Issues, Boundaries and Sovereignty Encyclopedia (B.A.S.E.).

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Appendix I. Assessment Team Member Information

Grant Abbott is former Director of the Yukon Geological Survey (retired 2008). He graduated from the University of British Columbia in 1971 with a B.A.Sc. in Geological Engineering and from Queens University in 1976 with a M.A.Sc. in Geological Engineering. He is an economic geologist and has largely spent his time in the Yukon—from 1970 to 1979 as a student and exploration geologist and since 1980 as a government geoscientist undertaking mineral deposit studies and regional bedrock mapping. He has a comprehensive knowledge of mineral deposits in the northern Cordillera and their regional setting and has participated in several regional mineral assessments in Alaska and Yukon.

Arthur A. Bookstrom is a Research Geologist with the USGS in Spokane, Washington. He received a B.A. in geology from Dartmouth College (1961), an M.S. in geology from the University of Colorado (1964), and a Ph.D. in geology from Stanford University (1975). He worked as a mine geologist at the Climax molybdenum mine in Colorado, El Romeral magnetite mine in Chile, and the Rochester silver mine in Nevada. He has done exploration-project work at sites in Colorado, Nevada, and Montana, as well as regional exploration for molybdenum in Colorado and regional exploration for gold in Nevada, Montana, and Saudi Arabia. His work with the USGS has included regional geologic studies, metallogenic studies, mineral-environmental studies, and mineral-resource assessments.

Thomas P. Frost is a Research Geologist with the USGS in Spokane, Washington. He completed his B.A. in Geology in 1975 at U.C. Santa Barbara and his Ph.D. at Stanford in 1987. He has experience as a marine geologist working on environmental hazards associated with oil leasing in the Gulf of Alaska and Cook Inlet, a petrologist working on rheologic modeling of mafic and felsic magma interaction in granitic plutons in the Sierra Nevada, and a geochemist doing geochemical surveys and geologic mapping. Recent work includes the Interior Columbia Basin Ecosystem Management Project, which was charged with assessing forest-landscape-aquatic-social-economic conditions in the Columbia Basin and developing adaptive management plans for Federal lands in the basin. He has participated in porphyry copper mineral resource assessments of Russia, Mongolia, northern China, and Kazakhstan.

James M. Logan is a Professional Geologist (P.Geo.) and mineral deposit specialist with the Geological Survey Branch of the British Columbia Ministry of Energy and Mines. He obtained a B.Sc. degree from Brock University, Ontario, in 1977 and completed a M.Sc. degree at the University of British Columbia in 1986. He has worked as an exploration geologist, mapping and evaluating a variety of precious and base metal mineral deposits across Canada and the western United States. His recent experience has included regional mapping and mineral deposit studies in northwest, central, and southeast British Columbia, including research on the geological setting, geochronology, and metallogenic characteristics of alkaline Cu-Au porphyry deposits of the Mesozoic arc sequences of the Intermontane Belt of British Columbia.

Steve Ludington is a Research Geologist with the USGS in Menlo Park, California. He received a BA in Geology from Stanford University (1967) and a Ph.D. in Geology from the University of Colorado (1974). He worked as an exploration geologist in Colorado, New Mexico, and Arizona before joining the USGS in 1974. His work with the USGS has included regional geologic studies, metallogenic and geochemical studies, wilderness studies, and mineral-resource assessments. He has done mineral-resource assessment work in the United States, Costa Rica, Bolivia, Mongolia, Afghanistan, and Mexico and was a coordinator for the 1998 USGS National Mineral Resource Assessment.

Mark J. Mihalasky is a Research Geologist with the USGS in Spokane, Washington. He received a B.S. in Geology in 1984 from Stockton State College, a M.S. in 1988 from Eastern Washington University in Geology, and a Ph.D. in Earth Sciences in 1999 from the University of Ottawa. He has worked as an exploration geologist and GIS consultant, Assistant Professor of Earth and Marine Geology and Coastal Research Center Director of Research at The Richard Stockton College of New Jersey, and, since joining the USGS in 2008, a geospatial analyst and resource assessment scientist. He has experience in economic geology, mineral and interdisciplinary natural resource assessment, and quantitative analysis and modeling of geospatial data. He has been involved with metallic mineral resource assessments (gold, silver, copper) in Nevada, China, Afghanistan, and western Asia (eastern Russia, Mongolia, northern China, Kazakhstan), diamond resources in Mali and Central African Republic, and interdisciplinary natural resource assessments in Madagascar, Gabon, and the United States.

Andre Panteleyev is an economic geologist, formerly with the British Columbia Department of Mines of the British Columbia Geological Survey. He received his B.Sc. (Honours, 1964), M.Sc. (1969), and Ph.D. (1976) from the University of British Columbia. He specialized in economic geology studies at Queen's University from 1967 to 1969, and is registered as a Professional Engineer (P.Eng.) with the Association of Professional Engineers and Geoscientists of British Columbia. He specializes in intrusion-related and subvolcanic mineralized environments, conceptual mineral deposit modeling, the genetic interrelationships of mineral deposits, regional metallogeny, methodologies and applications of regional mineral potential assessments, and multisector land use negotiations. His work experience includes nine field seasons in the Canadian Cordillera with Kennco Explorations (Western) Ltd (a Canadian subsidiary of Kennecott Copper Corporation) doing porphyry copper exploration. He has worked and lectured extensively in Canada, Mongolia, China, Argentina, Bolivia, Chile, and Perú, as well as the United States, El Salvador, Fiji, Mexico, and Sweden.

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