# 17. VEIN COPPER

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**R.V. Kirkham and W.D. Sinclair**

## INTRODUCTION

Vein copper deposits include various vein-type deposits in which copper is the dominant metal. The deposits are structurally controlled and occur in faults, fault systems, and vein-breccia zones; replacement zones in associated country rocks are also present. They are typically small, but are highly varied in both size and grade. Although vein copper deposits occur in association with many different host rocks and in diverse geological settings, two main subtypes are recognized, which are based on the associated intrusive rocks; the deposits do not necessarily occur in these rocks in all cases, but they are likely genetically related to them. The first subtype consists of vein copper deposits associated with mafic intrusive rocks; these have been referred to as 'Churchill type' after the Churchill Copper (Magnum) deposit in British Columbia (Kirkham, 1973). Other examples of this subtype include the Davis-Keays and Bull River deposits in British Columbia; Bruce Mines, Crownbridge, Ethel Copper, and some veins in the Cobalt district, Ontario; Icon-Sullivan, Quebec; and deposits in the East Arm of Great Slave Lake (e.g., Susu Lake) and Coppermine River (e.g., Copper Lamb) areas, Northwest Territories (Fig. 17-1).

The second subtype consists of vein copper deposits associated with intermediate to felsic intrusions, including some intrusions related to porphyry copper deposits. Canadian examples of this subtype include the Alwin copper deposit and copper-gold deposits of the Rossland camp, British Columbia; and the copper-gold deposits of the Chibougamau and Opemiska mining camps, Quebec (Fig. 17-1). Foreign examples include vein copper deposits of Magma, Arizona; Maria, Mexico; 'plutonic' copper veins in Chile such as Tamaya (Sillitoe, 1992); and polymetallic veins such as those of the Morococha and Quiruvilca districts, Peru, and the Ashio, Akenobe, and Osarizawa districts in Japan. The copper veins at Butte, Montana, many of which were mined individually, are also included although collectively they have many of the characteristics of porphyry copper deposits and, in some cases, were mined by bulk mining methods.

**Kirkham, R.V. and Sinclair, W.D.**
1996: Vein copper; in Geology of Canadian Mineral Deposit Types, (ed.) O.R. Eckstrand, W.D. Sinclair, and R.I. Thorpe; Geological Survey of Canada, Geology of Canada, no. 8, p. 399-408 (also Geological Society of America, The Geology of North America, v. P-1).

## IMPORTANCE

Although not of major importance in Canada at present, vein copper deposits were historically important as the source of the first copper produced in Canada, in 1847 at Bruce Mines, Ontario. They have been an important source of copper production in the Chibougamau and Opemiska mining camps, Quebec, which together have produced more than 60 Mt of ore grading about 2% Cu and 1-2 g/t Au (Table 17-1). Significant amounts of copper were also produced from the gold-rich veins of the Rossland area, British Columbia. Overall, vein copper deposits account for approximately 3% of Canada's copper production and less than 2% of copper reserves.

Historically, vein copper deposits have been important locally in various parts of the world, such as Cornwall and Devon, England where copper production in first half of the nineteenth century amounted to 40% of world output (Dines, 1956). In the latter part of the nineteenth century, 'plutonic' veins in Chile were a major source of world copper production (Sillitoe, 1992). Current production of copper from vein deposits, however, is small compared to production from other types of deposits.

## SIZE AND GRADE OF DEPOSITS

Vein copper deposits are relatively small, typically ranging from tens of thousands to a few million tonnes of ore, except for a few mining camps with more than 10 Mt, and the Butte deposits which have produced several hundred million tonnes of ore (Table 17-1). Copper grades are typically 1 to 3%, although some deposits contain greater than 10% (e.g., Maria, Mexico). Grade-tonnage relationships for the various selected vein copper deposits and districts are shown in Figure 17-2.

## GEOLOGICAL FEATURES

### Geological setting

Vein copper deposits occur in diverse tectonic environments. Churchill-type deposits apparently occur in extensional tectonic settings, particularly in Proterozoic sedimentary basins intruded by diabase and gabbro (e.g., Churchill Copper, British Columbia and Bruce Mines, Ontario; Kirkham, 1973) (Fig. 17-3). No mafic rocks have been documented in the immediate vicinity of the Icon-Sullivan deposit, but the deposit is truncated on its

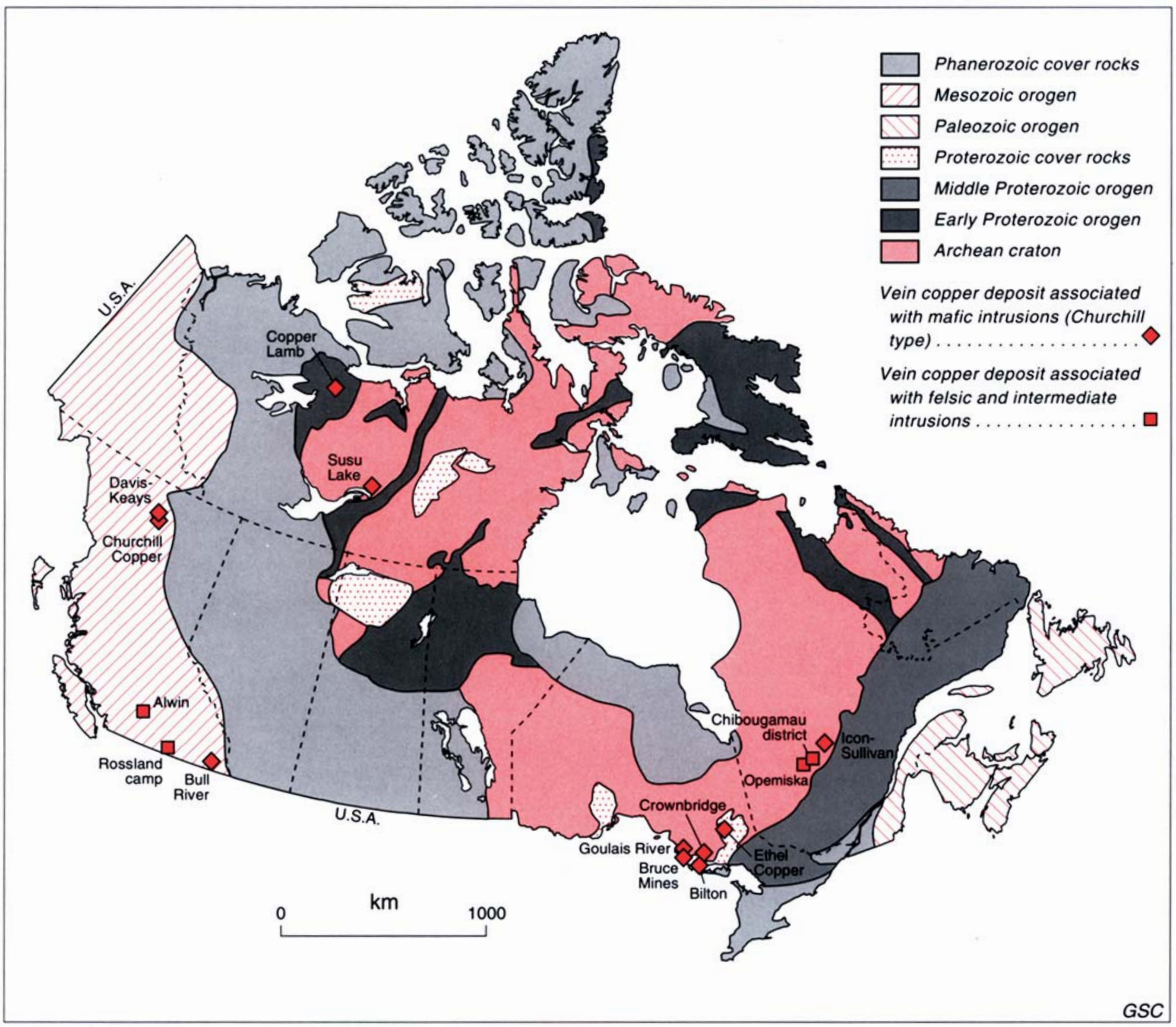


**Figure 17-1.** Distribution of selected vein copper deposits in Canada.

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**Table 17-1.** Production/reserves of selected Canadian and foreign vein copper deposits.

| Deposit | Production/reserves | Comments/references |
|---|---|---|
| **Vein copper deposits associated with mafic intrusions (Churchill type)** | | |
| ***Canadian deposits:*** | | |
| Churchill Copper (Magnum), British Columbia | 0.6 Mt; 2.9% Cu | Production 1970-75, plus reserves; British Columbia Ministry of Energy, Mines and Petroleum Resources, Minfile. |
| Davis-Keays, British Columbia | 1.9 Mt; 3.65% Cu | Proven and probable reserves; Canadian Mines Handbook 1990-91, p. 335. |
| Bull River, British Columbia | 0.5 Mt; 1.5% Cu<br>13.5 g/t Ag<br>0.27 g/t Au | Production 1972-74; British Columbia Ministry of Energy, Mines and Petroleum Resources, Minfile. |
| Copper Lamb, Northwest Territories | 5000 t; "high grade bornite ore" | Reserves; Kindle (1972). |
| Susu Lake, Northwest Territories | 0.13 Mt; 0.95% Cu | Reserves; Thorpe (1972). |
| Bruce Mines, Ontario | 0.4 Mt; 3% Cu | Production, 1847-1921; Shklanka (1969); Cu grade is approximate. |
| Crownbridge, Ontario | 0.4 Mt; 2% Cu | Reserves; The Northern Miner, 29 October, 1964. |
| Bilton, Ontario | 0.5 Mt; 1.7% Cu | Reserves; Pearson et al. (1985). |
| Goulais River, Ontario | 0.2 Mt; 2.35% Cu<br>0.26 g/t Ag | Reserves; Pearson et al. (1985). |
| Ethel Copper, Ontario | 7700 t; 1.2% Cu<br>10 g/t Ag<br>0.3 g/t Au | Production 1962-1967; Shklanka (1969). |
| Icon-Sullivan, Quebec | 1.4 Mt; 2.9% Cu | Production 1967-1975; Canadian Mines Handbook 1977-1978, p. 61. |
| **Vein copper deposits associated with felsic and intermediate intrusions** | | |
| ***Canadian deposits:*** | | |
| Alwin (OK), British Columbia | 1.2 Mt; 2.2% Cu<br>13 g/t Ag<br>0.2 g/t Au | Intermittent production 1916-1982, plus reserves; British Columbia Ministry of Energy, Mines and Petroleum Resources, Minfile. Gold grade based on historical production. |
| Rossland camp, British Columbia | 5.6 Mt; 1% Cu<br>16 g/t Au<br>21 g/t Ag | Production 1894-1941; Gilbert (1948). |
| Chibougamau district, Quebec | 40 Mt; 1.5-2% Cu<br>1-2 g/t Au | Production from Cu-Au veins in the Chibougamau district 1955-1992; Gobeil and Racicot (1984) and Canadian Mines Handbooks, 1984-1992. |
| Merrill Island (Canadian Merrill), Chibougamau, Quebec | 1.2 Mt; 2.25% Cu<br>0.46 g/t Au | Production 1958-1967; Gobeil and Racicot (1984). |
| Copper Rand, Chibougamau, Quebec | 16.3 Mt; 1.81% Cu<br>2.3 g/t Au | Production 1960-1989, plus reserves; Blais (1990). |
| Portage, Chibougamau, Quebec | 6.5 Mt; 1.75% Cu<br>2.7 g/t Au | Production 1960-1989, plus reserves; Blais (1990). |
| Devlin, Chibougamau, Quebec | 1.4 Mt; 2.25% Cu | Reserves; Campbell Resources Annual Report, 1983. |
| Corner Bay, Chibougamau, Quebec | 1.5 Mt; 4% Cu<br>0.34 g/t Au<br>14 g/t Ag | Reserves; Bertoni and Vachon (1984). |
| Opemiska, Quebec | 23.4 Mt; 2.2% Cu<br>1.6 g/t Au<br>9 g/t Ag | Production 1953-1978; Watkins and Riverin (1982) and Canadian Mines Handbooks, 1979-1992. |
| ***Foreign deposits:*** | | |
| Butte, Montana | 296 Mt; 2.5% Cu<br>68 g/t<br>0.3 g/t Au Ag | Production 1880-1964; Meyer et al. (1968); includes some production from lower grade, porphyry-type zones. |
| Magma, Arizona | 12.4 Mt; 5.69% Cu<br>66.2 g/t Ag<br>1.1 g/t Au | Production 1911-1964; includes some production from replacement deposits in limestone; Hammer and Peterson (1968). |
| Maria, Mexico | 0.47 Mt; 12.8% Cu<br>0.25% Mo<br>62 g/t Ag | Mineable reserves; Reuss and Ollivier (1992). |
| Dalcoath Lode, Cornwall, England | 0.35 Mt; 6-7.5% Cu | Production 1750-1905; Dines (1956); significant amounts of Sn were also produced from lower, Cu-poor parts of the vein system. |
| Quiruvilca district, Peru | >10 Mt; Cu-Pb-Zn-Ag ore | Production 1789-1990; Bartos (1990). |
| Akenobe, Japan | 17 Mt; 1.1% Cu<br>2.0% Zn<br>20 g/t Ag<br>0.4% Sn | Production 1935-1986; Shimizu and Kato (1991); In also present (T. Nakamura, pers. comm., 1994). |

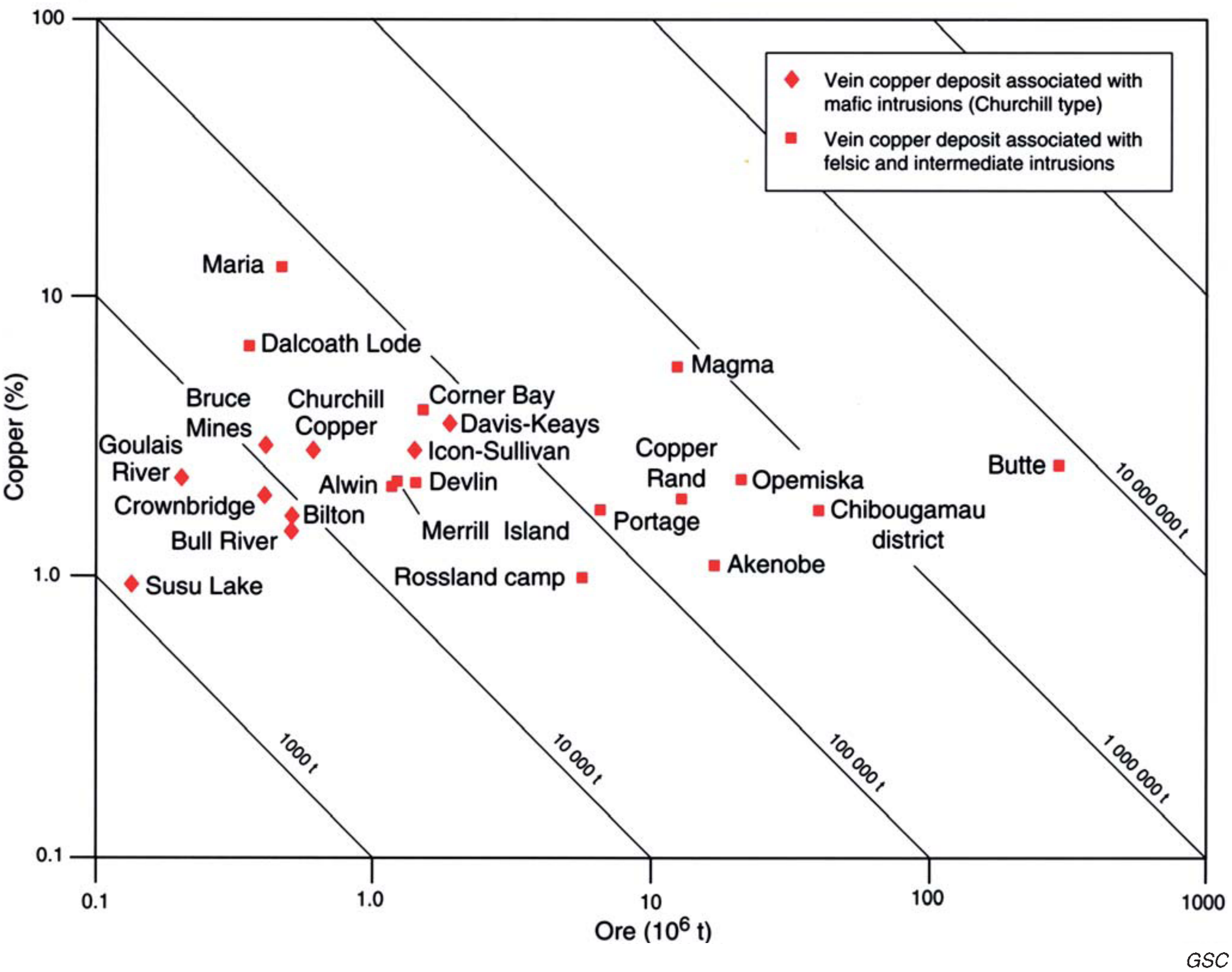


**Figure 17-2.** Grade versus tonnage diagram for vein copper deposits (data from Table 17-1).

**Figure 17-3.** Cliff face in the Gataga River area, northeastern British Columbia showing a typical diabase dyke swarm cutting Proterozoic sedimentary rocks; Churchill-type veins occur in the same or related fault and fracture systems as the dykes. GSC 1994-707 and 1994-708 (composite)

southeast side by a steep northeast-trending fault related to the Grenville Front; mafic rocks may have been present southeast of the mine area but have been removed or obscured by Grenvillian metamorphism and deformation.

Felsic and intermediate intrusion-associated vein copper deposits characteristically occur in subduction-related contintental- and island-arc settings, typically in areas of high-level felsic and intermediate intrusions and especially those associated with porphyry copper deposits (e.g., Alwin, British Columbia; Butte, Montana; Magma, Arizona; and Morococha, Peru). Although the vein copper-gold deposits of the Chibougamau and Opemiska mining camps are mainly in differentiated mafic intrusive rocks, the deposits are closely associated with, and probably genetically related to, felsic plutonic rocks (Sinclair et al., 1994; Robert, 1994). The copper-gold deposits of the Rossland camp, British Columbia are associated with monzonitic plutonic rocks (Dunne and Höy, 1992).

## Age of host rocks and ore

Vein copper deposits and their host rocks range in age from Archean to Recent. The ores are epigenetic and in many cases are much younger than their host rocks.

## Associated rocks

Country rocks for vein copper deposits are diverse and depend on the particular geological settings in which the deposits occur. Churchill-type deposits typically occur in clastic sedimentary rocks and mafic igneous rocks such as diabase or gabbro (e.g., Churchill Copper and Bruce Mines). Vein copper deposits associated with felsic and intermediate intrusions occur in a wide variety of host rocks, including layered mafic intrusive rocks (e.g., Chibougamau and Opemiska deposits), felsic plutonic rocks (e.g., Alwin, British Columbia; Butte, Montana), metamorphic and sedimentary rocks (e.g., Magma, Arizona), and volcanic rocks (e.g., Quiruvilca, Peru; Akenobe, Japan).

## Form and size of deposits

Deposits range from simple veins to anastomosing and reticulate veins (Fig. 17-4), vein sets, vein breccia, local stockworks, and horsetails. Individual veins and vein sets can be tens to hundreds to thousands of metres long and from less than one metre to tens of metres wide. Vertical extent of Churchill-type veins in northeastern British Columbia ranges from at least 150 m for the Churchill Copper deposit (Fig. 17-5 and 17-6) to more than 500 m for the Eagle vein system of the Davis-Keays deposit (Preto, 1971). The vertical extent of vein copper deposits associated with felsic and intermediate intrusions ranges from 250 m for the Alwin deposit (W.J. McMillan, 1972) to nearly 1400 m for the Anaconda vein system at Butte (Meyer et al., 1968). The copper-gold deposits of the Chibougamau camp are massive to disseminated, lenticular sulphide zones that occur within steeply-dipping shear zones several kilometres long, hundreds of metres wide, and extending to depths of 1000 m or more (Guha et al., 1983; Archambault et al., 1984).

Individual high-grade ore shoots within veins are structurally controlled, and typically occur where veins change attitude, as at the Churchill Copper deposit (Carr, 1971). At the Icon-Sullivan deposit, high-grade massive sulphide ore was localized in the vicinity of structural terraces or "rolls" in the flat-lying host rocks (Troop and Darcy, 1973). Distribution of ore minerals within ore shoots is typically irregular and may be disseminated, banded, patchy, or massive; disseminated to massive ore minerals may be present in adjacent altered host rocks.

## Mineralogy

In most Churchill-type vein copper deposits, chalcopyrite is the principal ore mineral; bornite, tetrahedrite, covellite, and galena are present in some deposits in minor amounts. Pyrite is the main associated gangue mineral; others include pyrrhotite, quartz, calcite, dolomite, ankerite, and hematite.

The principal ore minerals in vein copper deposits associated with felsic and intermediate intrusion-associated vein copper deposits are more varied and include chalcopyrite, bornite, chalcocite, enargite, tetrahedrite-tennantite, bismuthinite, molybdenite, sphalerite, native gold, and

**Figure 17-4.** Typical anastomosing quartz-carbonate-chalcopyrite-pyrite-specularite vein (Churchill type) exposed in outcrop beside Highway 17 about 40 km west of Iron Bridge, Ontario. GSC 202516E

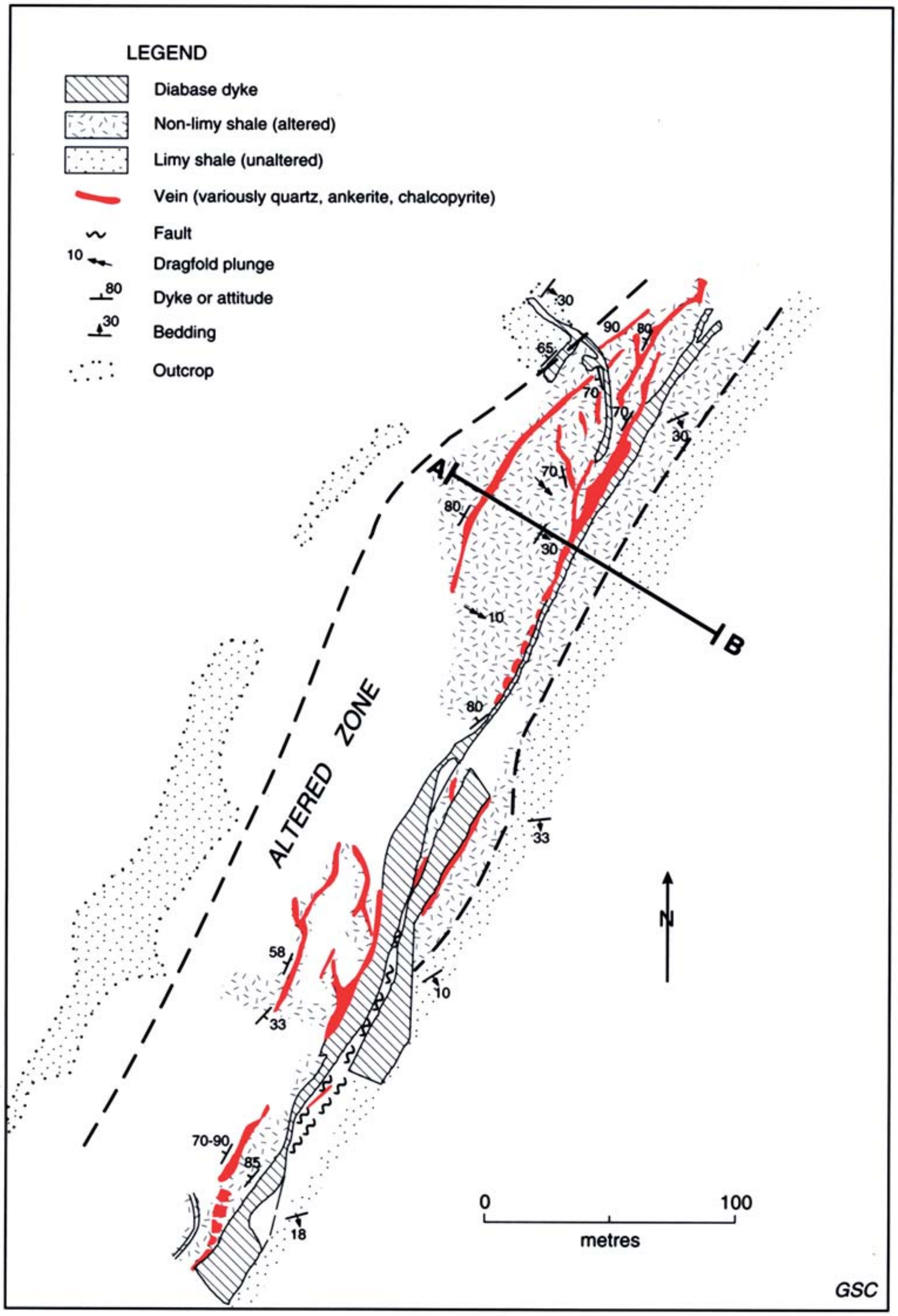


**Figure 17-5.** Surface geological map of the north part of the Churchill Copper (Magnum) vein system (adapted from Carr, 1971).

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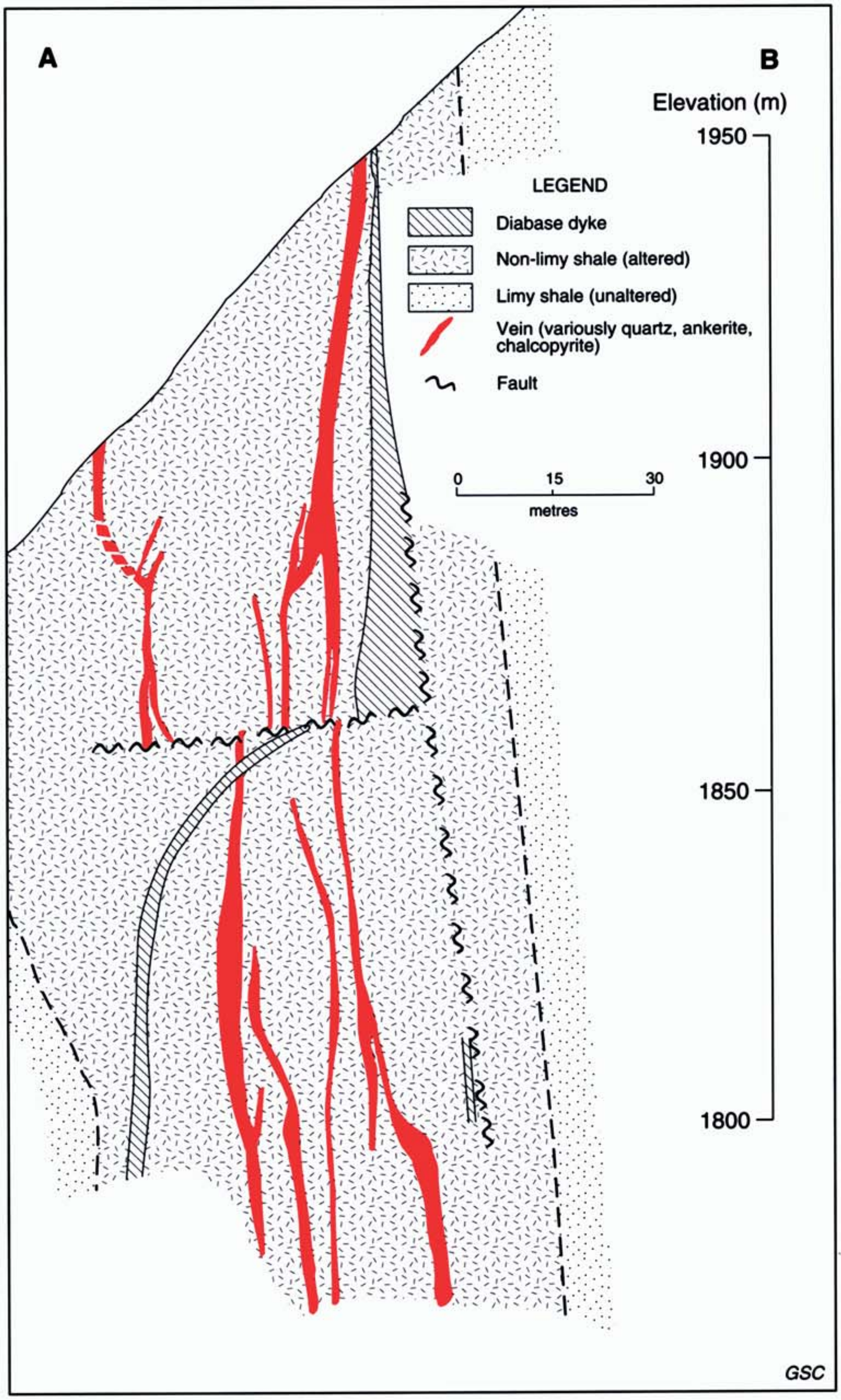


**Figure 17-6.** Vertical cross-section A-B of the Churchill Copper (Magnum) vein system (adapted from Carr, 1971). Location of the cross-section is shown in Figure 17-5.

electrum. Associated gangue minerals include pyrite, pyrrhotite, magnetite, hematite, quartz, K-feldspar, epidote, calcite, ankerite, siderite, chlorite, sericite, and clay minerals.

### Zoning

Zoning of minerals or metals may be present in large deposits or districts associated with felsic and intermediate intrusions. In the Rossland camp, three zones were defined by Thorpe (1967): 1) a central zone of massive pyrrhotite veins with minor chalcopyrite; 2) an intermediate zone with a diverse sulphide mineralogy dominated mainly by pyrrhotite and chalcopyrite; and 3) an outer zone comparable to the intermediate zone, except for the addition of galena, tetrahedrite, boulangerite, and abundant sphalerite. The copper grade and copper-to-gold ratio of the Rossland deposits increased outward from the central zone. Three crudely concentric zones have also been delineated at Butte: 1) a central copper zone which includes a molybdenite zone at depth; 2) an intermediate zone of copper with minor zinc; and 3) a peripheral zone of silver, zinc, and manganese (Sales, 1914; Meyer et al., 1968). In the Quiruvilca district, Peru, copper-rich deposits form a central core with lead-zinc-silver zones at the periphery (Bartos, 1990).

### Alteration

Principal types of alteration in Churchill-type vein copper deposits appear to be carbonatization and silicification. At Churchill Copper, limy strata have been altered to non-limy rocks by decalcification which has left abundant graphite in the host rocks and ankerite as metacrysts and replacement zones; pyrite is also present in places as seams and disseminated zones that are roughly conformable to bedding in the host strata (Carr, 1971; Preto, 1971). In the vein copper deposits north of Lake Huron, such as Bruce Mines and Crownbridge, breccia fragments in the veins are typically silicified and hematitized (Pearson, 1979).

Sericitization and chloritization are the principal alteration types in vein copper deposits associated with felsic to intermediate intrusions. Granodioritic rocks that border the Alwin copper vein, for example, have been intensely altered to sericite and clay minerals; chlorite is present in places and massive pods of epidote occur locally adjacent to ore zones (W.J. McMillan, 1972). The copper-gold veins of the Chibougamau camp occur in extensively sericitized anorthositic rocks with abundant siderite, ankerite, and magnetite in some of the deposits. Chlorite, chloritoid, and actinolite occur in close proximity to some ore zones (Eckstrand, 1963; Allard, 1976).

## DEFINITIVE CHARACTERISTICS

Churchill-type deposits are characterized by structural control, occurrence in predominantly extensional tectonic settings (rift and failed rift zones) and association with mafic intrusive rocks. Vein copper deposits associated with felsic and intermediate intrusions are also characterized by structural control, and are distinguished from Churchill-type deposits by their association with high level, felsic and intermediate intrusive rocks, particularly those associated with porphyry copper deposits, and by their occurrence in predominantly subduction-related continental- and island-arc settings.

## GENETIC MODEL

Vein copper deposits are a diverse and relatively understudied group of deposits for which no single, well constrained genetic model exists. For Churchill-type deposits, Kirkham (1973) proposed a model based the occurrence of the deposits in regions of crustal extension where passive upwelling of mafic magmas has occurred, as reflected by numerous mafic dykes. In such environments, water entrained in country rocks, or meteoric water that migrated to depth, could have been heated by the mafic magmas. The heated waters selectively extracted copper from the ascending magmas and/or the country rocks and subsequently deposited the copper in cooler, favourable structural environments at higher levels in the crust.

Genetic models for vein copper deposits associated with felsic and intermediate intrusions reflect either prograding or retrograding evolution of the deposits. Prograding evolution in base metal lode deposits is indicated by a paragenetic sequence of vein-filling minerals that reflects a temporal increase in sulphidation state (i.e., later deposition of minerals with increasing sulphur-to-metal contents), accompanied by pervasive wall rock alteration characterized by increasing hydrogen ion activity (i.e., strong sericitic and/or advanced argillic alteration) (Bartos, 1989). Prograde deposits form at moderate to deep levels in the crust (>3000 m below the paleosurface), mainly from magmatic-hydrothermal fluids expelled from the associated intrusions, but also by deep hypogene leaching and enrichment of copper-bearing protore by meteoric waters (e.g., Butte; Brimhall, 1979). According to Bartos (1989), vein copper deposits associated with porphyry copper deposits are typically prograde.

Retrograding evolution is indicated by temporal decrease in sulphidation state of vein-filling minerals and wall rock alteration characterized by decreasing hydrogen ion activity (i.e., maximum intensity of alteration occurs prior to significant base metal deposition). Retrograde deposits form mainly at shallow to moderate levels in the crust (approximately 200 to 3000 m below the paleosurface) from hydrothermal systems that have had a significant input of ground water. Such deposits tend to have a high component of lead and zinc, and in some cases grade outward to precious metal deposits (Bartos, 1989).

Deposits such as Alwin and copper-gold veins in the Chibougamau area are closely related to porphyry copper deposits, although they may have formed in different structural settings and may be superimposed on, or peripheral to, the porphyry deposits. The Alwin deposit, for example, occurs in the core of the Guichon Creek batholith in the vicinity of the Highland Valley porphyry copper deposits. A close association between the copper-gold deposits of the Chibougamau mining camp and felsic dykes of the Chibougamau pluton is evident, and preliminary observations suggest the deposits may be related to low-grade, porphyry-type copper-molybdenum deposits (Sinclair et al., 1994; Robert, 1994). The copper-gold veins are in strongly foliated, sericitic shear zones, however, and have a complex history that includes deformation and remobilization (e.g., Guha et al., 1983; Tessier and Hodgson, 1994).

The origin of the Opemiska veins is less certain as no porphyry deposits have been identified in the area. They could be related to the nearby Opemiska pluton (Duquette, 1970), which would account for the presence of minor tungsten and molybdenum, but alternative hypotheses involving leaching of metals from the associated host rocks (Derry and Folinsbee, 1957; Watkins and Riverin, 1982) and metamorphism of volcanic-associated vein-type deposits (R.H. McMillan, 1972) have been proposed.

## RELATED DEPOSIT TYPES

Churchill-type vein copper deposits are probably related to silver-cobalt-arsenic veins at Cobalt and Thunder Bay, Ontario and the Camsell River area, Northwest Territories (see subtype 14.1, "Arsenide vein silver-cobalt"). Deposits related to vein copper deposits associated with felsic and intermediate intrusions include high sulphidation gold-copper veins (e.g., El Indio, Chile), copper-bearing skarn and manto deposits, and porphyry copper deposits.

Also related to vein copper deposits associated with felsic and intermediate intrusions are polymetallic vein and replacement deposits such as Tintic, Utah; Central City, Colorado; and Cerro de Pasco, Peru. Other related deposits include precious metal veins which grade into base metal veins and vein copper deposits at depth, as in the Banská Štiavnica-Hodruša district, Carpathian Mountains, Slovakia (Štohl and Lexa, 1993) and iron-copper-mercury veins, such as the Droždiak and Hrubá veins of the Rudňany district, Slovakia, which are currently mined primarily for iron but which have produced signficant amounts of copper, silver, and mercury (Varček, 1967).

## EXPLORATION GUIDES

Exploration guidelines for vein copper deposits include the following:

1. Rifted Proterozoic sedimentary successions characterized by diabase dykes and gabbro bodies may contain copper veins of the Churchill type.
2. Ore shoots may be localized along dilational bends within veins, and high grade sulphide shoots may cut lower grade sulphide-quartz-carbonate parts of veins as in the Icon-Sullivan deposit (Troop and Darcy, 1973).
3. Vein copper deposits associated with felsic and intermediate intrusions may be mineralogically zoned, on both vein and district scales.
4. Primary geochemical dispersion aureoles in host rocks (mainly Cu) are likely to be limited in Churchill-type copper veins but may be more extensive in vein copper deposits associated with felsic and intermediate intrusions. Secondary dispersion halos in overburden and stream sediments may help identify target areas at regional and local scales.
5. Electromagnetic surveys can be used to trace favourable structures such as faults or fracture zones, and may help outline areas of high concentrations of sulphides in veins.

## ACKNOWLEDGMENTS

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## Authors' addresses

R.V. Kirkham
Geological Survey of Canada
100 West Pender Street
Vancouver, B.C.
V6B 1R8

W.D. Sinclair
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario
K1A 0E8

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