GEOLOGY OF THE BEND ZINC-LEAD-SILVER MASSIVE SULPHIDE PROSPECT SOUTHEASTERN BRITISH COLUMBIA* (83D/1)

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INTRODUCTION

The Bend massive sulphide body is conformably hosted by metasedimentary rocks of the Park Ranges in the Rocky Mountains (Figure 2-7-1). The deposit outcrops in the Cummins River canyon on McNaughton Lake and in a roadcut 3.5 kilometres to the northwest. Mineralization in the Cummins River canyon was first discovered during construction of the Big Bend Highway and claims were staked by highway workmen in 1949 (Oliver, 1985). These claims lapsed and in 1966 The Consolidated Mining and Smelting Company of Canada, Limited (Cominco Ltd.) staked 45 claims as the Bend group. Cominco retains 12 of the original claims covering the canyon zone.

The Bend showing is exposed on the north and south walls of the Cummins River canyon, but flooding to the 750-metre elevation by the Mica hydroelectric dam has partly submerged the showings. Detailed mapping of a 100-metre section (Figures 2-7-2 and 2-7-3) centred on the prospect was completed by the senior author over a four-day period in June 1985 (Reddy, 1986).

REGIONAL GEOLOGY

The Cummins River area is dominantly underlain by Proterozoic miogeosynclinal rocks (Höy *et al.*, 1984) that form a thick, conformable stratigraphic succession on the western limb of the Porcupine Creek anticlinorium (Figure 2-7-1); the units strike northwest and dip southwest. These sedimentary rocks have been metamorphosed to amphibolite of garnet-staurolite-kyanite grade. The region exhibits well-defined metamorphic isograds that trend northwest with grade increasing toward the southwest (Craw, 1978).

The Late Cambrian Gog and Middle Cambrian Chancellor Groups overlie the Hadrynian Miette Group in the property area. Two of three formations in the Chancellor Group, Kinbasket and Tsar Creek, outcrop in the Cummins River canyon. The Tsar Creek Formation hosts the sulphide showing; the stratigraphic section from hangingwall to footwall described here is entirely within this formation.

Many of the layers in the Tsar Creek Formation are tightly folded with axial planes striking northwest and dipping steeply southwest (Dodson, 1971). The Early Cambrian age is based on fossils in equivalent unmetamorphosed strata to the south of the map area, near Sullivan River (Fyles, 1960). There are no volcanic rocks in the immediate area of Cummins River.

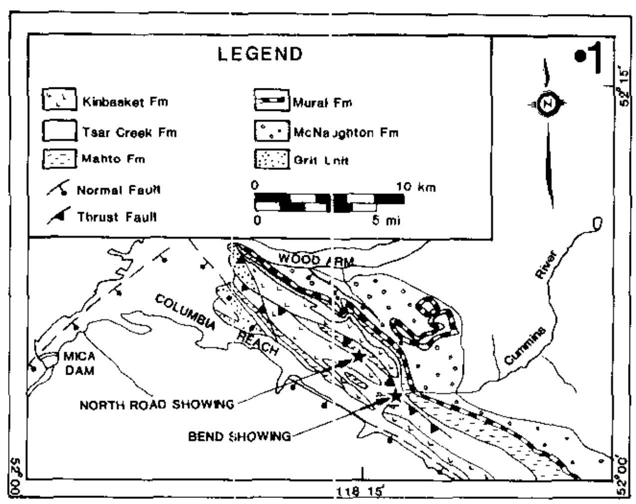

Figure 2-7-1. Regional geology of the Bend property, Cummins River canyon area (after Simony *et al.*, 1980). Geology is shown only for the area surrounding the North Road and Bend showings. The northwest-trending axis of the Porcupine Creek anticlinorium passes approximately through point 1.

LOCAL GEOLOGY

The 100-metre exposure examined along shoreline in the Cummins River canyon is a conformable sedimentary sequence within the Tsar Creek Formation (Figure 2-7-3). Foliation and bedding attitudes are similar and strike northwest and dip southwest, but foliation dips more steeply than bedding. This relationship, structural vergences, and elemental and compositional zoning in the sulphide deposit, indicate that the units are upright. Simony *et al.* (1980) mapped an overturned anticline-syncline pair in the canyon; the section studied is apparently on the east limb of the syncline.

Host rocks to the sulphide deposit are metamorphosed clastics, chert, and argillites. The footwall, the sulphide zone, and the hangingwall are described below and in Figure 2-7-2.

FOOTWALL

The footwall of the sulphide lens consists of four rock types. From stratigraphically lowest to highest they are quartzite, siliceous dolomite, garnet biotite schist and garnet mica schist. The quartzite is bedded and composed of mostly recrystallized and strained quartz grains (85 per cent) with associated micas, garnet, tourmaline, and staurolite. It is at least 35 metres thick and extends beyond the section studied. The dolomite (80 per cent carbonate) is siliceous with up to 20 per cent quartz and minor micas. The garnet biotite schist, above the dolomite, is a 1-metre-thick layer containing porphyroblastic garnet and biotite crystals within a micaceous groundmass. The garnet mica schist, separated from the garnet biotite schist by a 3-metre-thick quartzite layer, is 11 metres thick and consists of subhedral porphyroblastic almandine garnets up to 1

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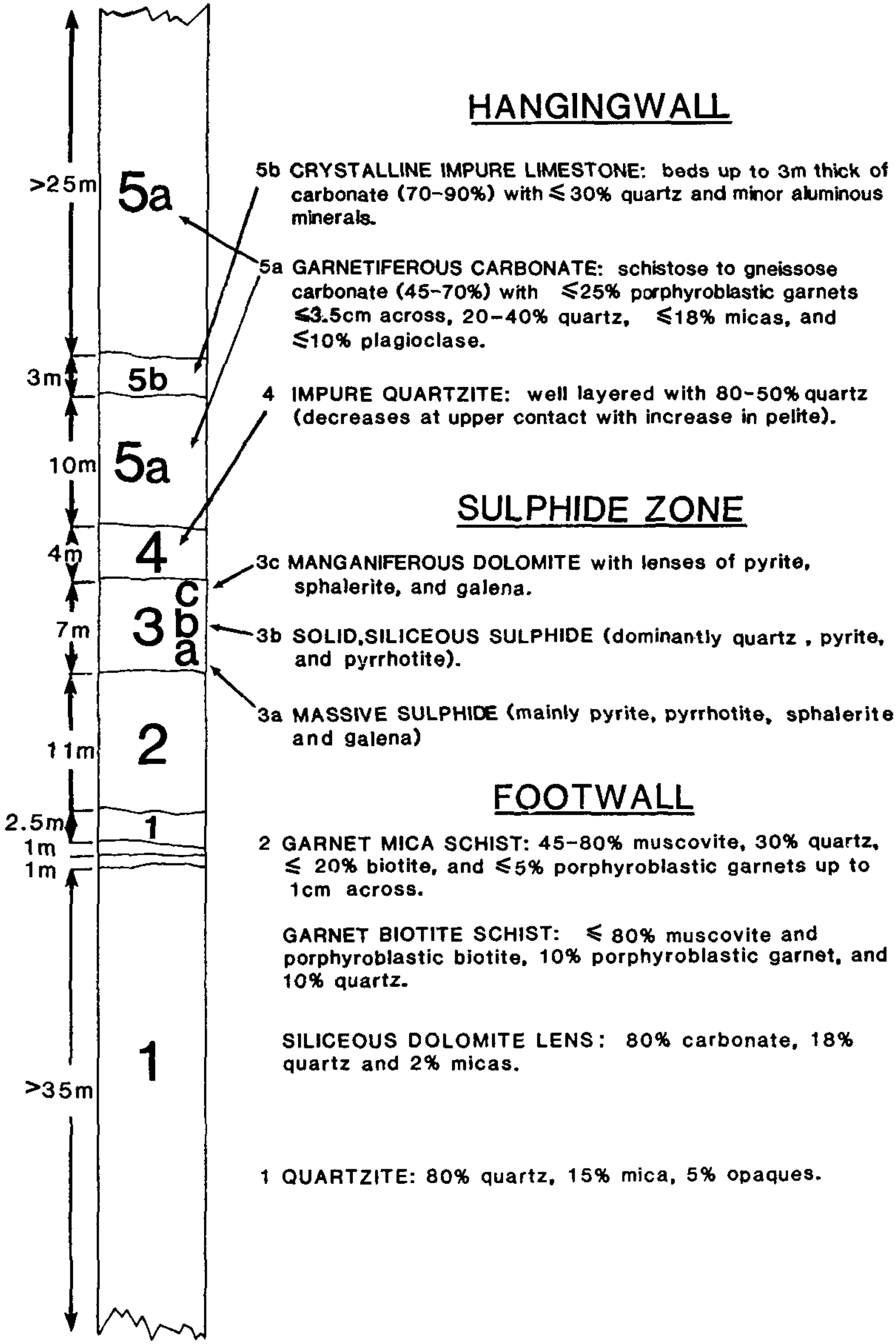

Figure 2-7-2. *Detailed stratigraphic column of the 100-metre section studied in the Cummins River canyon.* Unit numbers correspond to those in Figures 2-7-2 and 2-7-3.

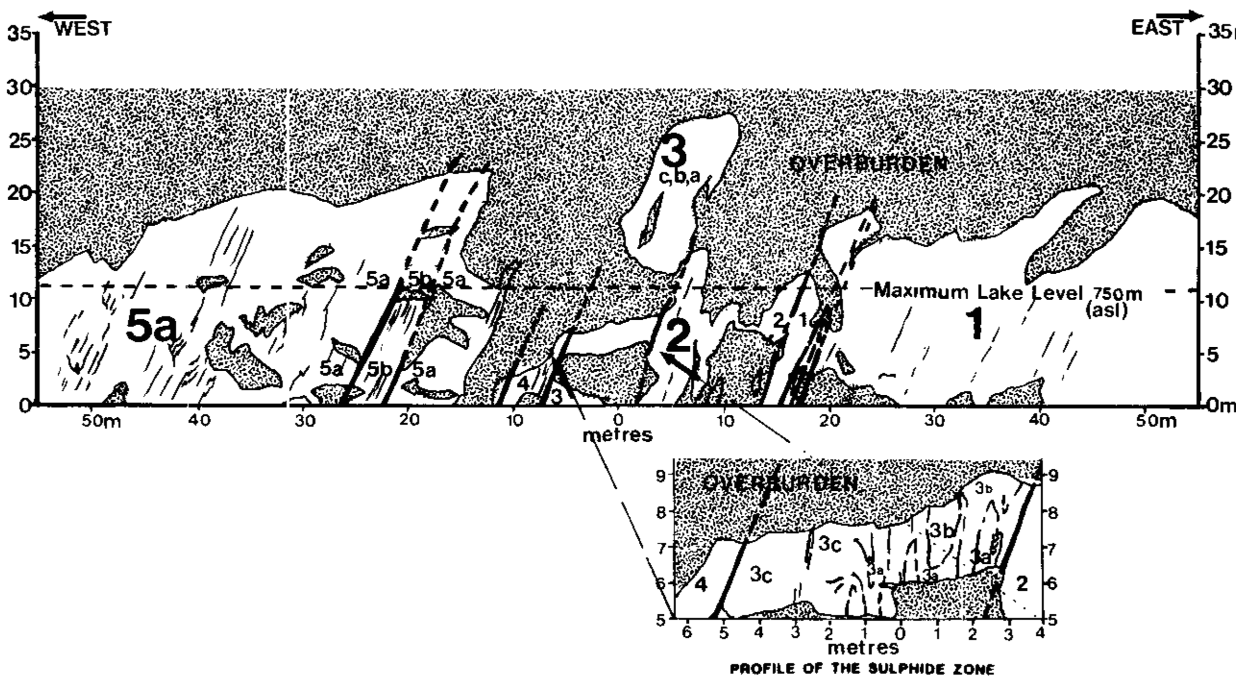

Figure 2-7-3. Profile of the Bend occurrence, Cummins River canyon. Zero on the vertical scale is the level of McNaughton Lake in June 1985; 11 metres is the maximum level of the lake. Unit numbers correspond to Figure 2-7-2.

centimetre in diameter associated with minor staurolite, kyanite and zoisite. Micas exhibiting strain-slip cleavage constitute 45 to 80 per cent of this unit which conformably underlies the sulphide zone.

SULPHIDE ZONE

The sulphide zone is a conformable layer within the metamorphosed argillite and quartzite host (Plate 2-7-1A). Intense deformation has preferentially folded the ductile sulphide layers (Plates 2-7-1B and 2-7-1C); this has hampered zoning studies. The mineralized zone can be divided into three units: massive sulphide, siliceous sulphide and mineralized manganiferous dolomite. The thickness of the combined sulphide layers is 5 metres at the detailed section, thickening down dip to 10 metres (Leask, 1981). Down dip the zone is submerged under the Mica Dam reservoir.

The massive sulphide layer lies immediately above the garnet mica schist of the footwall. Siliceous sulphide layers alternate with and are interfolded in the crumbly sulphides and overlying manganiferous dolomite. The massive sulphide consists mainly of pyrite, but grades into a siliceous sulphide layer that is dominantly quartz, garnet and carbonate. "Ore" minerals, in order of abundance are: pyrite, pyrrhotite, sphalerite, galena and magnetite, with minor arsenopyrite and chalcopyrite. Pyrite generally occurs as subhedral porphyroblasts up to 3 millimetres across or as annealed masses showing foam texture. Galena and chalcopyrite have been mobilized and are often found in cracks and pressure shadows of pyrite and spessartine (*see* following) garnet grains. Minor amounts of barite are reported, but none was observed in the detailed section and barium analyses do not show high values. The grade of the Bend sulphide occurrence is estimated at 3 per cent zinc, 1 per cent lead, and less than 16 grams silver per tonne.

Manganese dolomite is "chocolate weathering" due to manganese oxide coatings. The dolomite is cream to brown in colour and contains mica-rich layers. Lenses of massive pyrite, sphalerite, and galena occur within it.

The North Road Zone of sulphides (Figure 2-7-1) outcrops about 3.5 kilometres northwest of the Bend Canyon Zone. The two zones may be at the same stratigraphic level (Leask, 1981). Certainly the mineral assemblage and grades are similar, but the sulphides are mostly hosted by dolomite in the North Road occurrences. If the sulphide layer is continuous between the two outcrops, a strike length of at least 3.5 kilometres is indicated and significant tonnage potential exists.

HANGINGWALL

The hangingwall is a conformable sequence of quartzite, garnetiferous carbonate, and impure crystalline limestone. The manganiferous dolomite at the top of the sulphide zone has a sharp contact with a 4-metre-thick quartzite bed (Plate 2-7-1D). The quartzite decreases in quartz content and becomes a micaceous schist at the top of the unit. A garnetiferous carbonate overlies the quartzite and represents the remainder of the section studied. Numerous impure crystalline limestone lenses and layers, mostly less than 1 metre thick, occur within this unit (one layer is 3 metres thick). The garnetiferous carbonate consists of modal percentages of carbonate (45 to 70 per cent), quartz (20 to 40 per cent), garnets (up to 25 per cent), and plagioclase (up to 10 per cent). The euhedral, porphyroblastic almandine (*see* following) garnets are up to 3.5 centimetres in diameter.

GARNET COMPOSITION

Garnets were examined with a scanning electron microscope to determine changes in composition with respect to position in the stratigraphic section. The garnets sampled were from a 12-metre section extending from the footwall through the sulphide zone and into the hangingwall. The lowest garnet sample from the footwall (Figure 2-7-4A) is almandine $[Fe_3Al_2(SiO_4)_3]$. Within the sulphide zone (Figures 2-7-4B and 2-7-4C) and in the hangingwall (Figure 2-7-4D) the garnets are almost entirely spessartine $[Mn_3Al_2(SiO_4)_3]$.

Investigations of the change in compositions of almandine garnets with respect to temperature indicate that weight per cent MnO

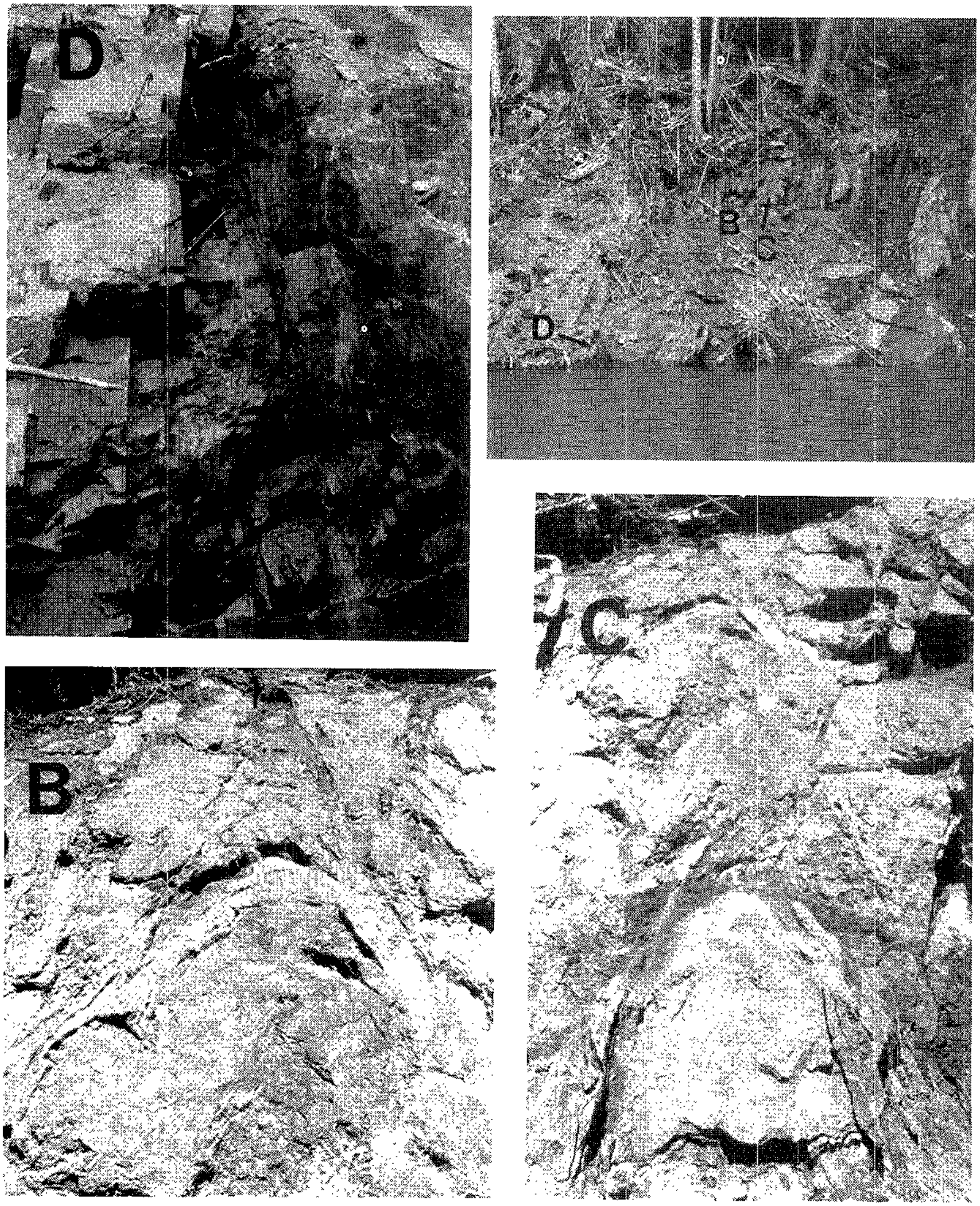

Plate 2-7-1A, B, C, D. Photographs of the Bend massive sulphide showing looking north. A = general view of showing as exposed in the Cummins River canyon; B and C = fold forms in siliceous and sulphide-rich layers; D = quartzite hangingwall over manganiferous dolomite.

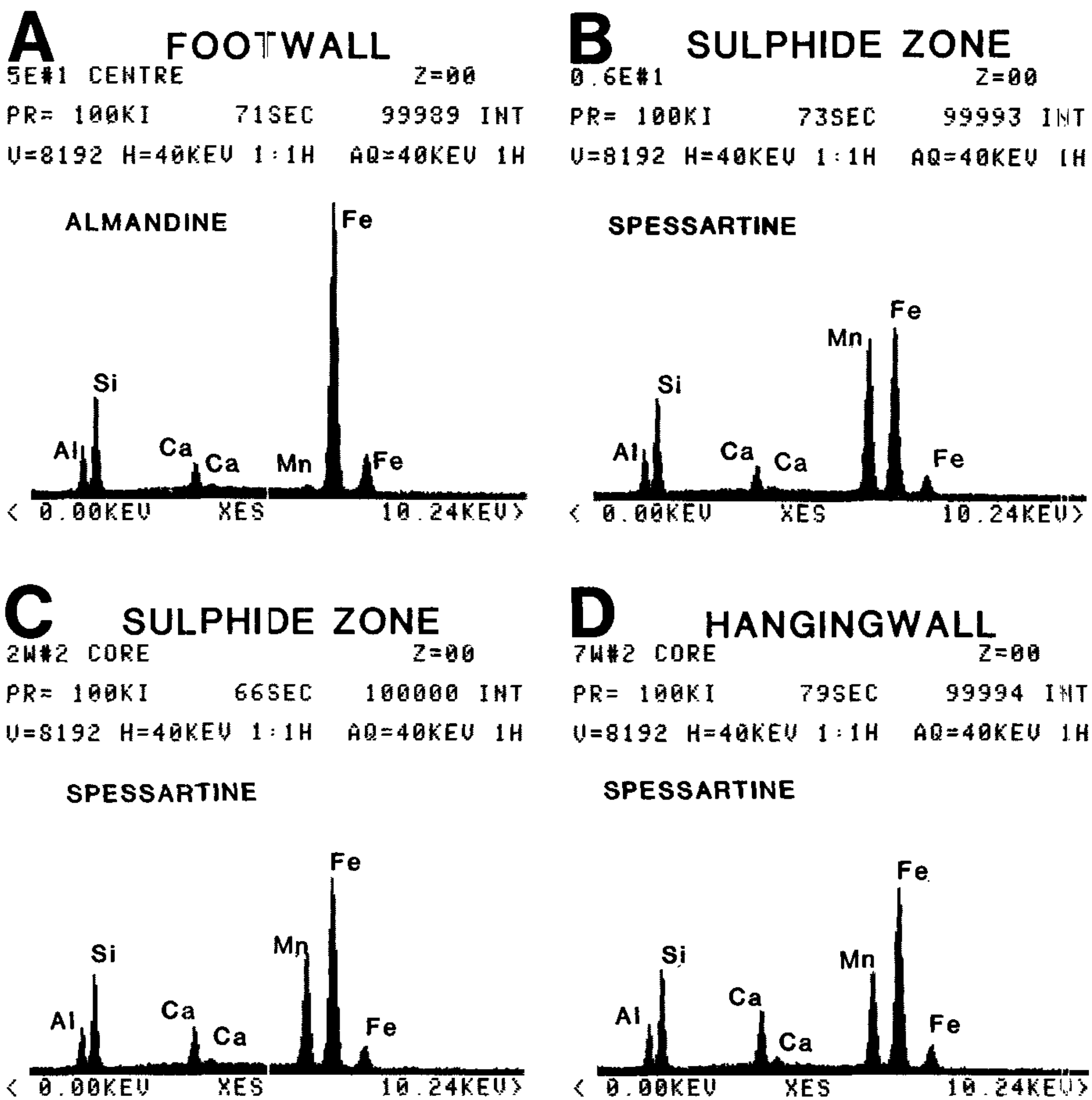

Figure 2-7-4A, B, C, D. Scanning electron microscope analyses of garnets defining the elemental constituents and relative amounts of elements present. Figure 2-7-4A is an almandine garnet [$Fe_3Al_2 (SiO_4)_3$] from the footwall. Figures 2-7-4B and 2-7-4C (sulphide zone), and 2-7-4D (hangingwall) are spessartine garnets [$Mn_3Al_2 (SiO_4)_3$].

and FeO decrease and increase respectively with an increase in temperature (Miyashiro, 1973). Although metamorphic grades, and therefore temperatures, in the Cummins River area increase regionally from east to west, the limited distance between samples suggests that the changes in MnO and FeO content of garnets observed in the Canyon Zone are related to the original bulk composition of the host rocks. Specifically, the manganese-rich garnets probably reflect a manganiferous exhalite horizon associated with and immediately above the sulphide layer. This capping manganiferous exhalite is coincident with other younging directions.

LEAD ISOTOPE DATA

Lead isotope analyses from the North Road Zone, probably stratigraphically equivalent to the Canyon Zone, are: $^{206}Pb/^{204}Pb = 18.204$, $^{207}Pb/^{204}Pb = 15.612$, $^{208}Pb/^{204}Pb = 37.996$. This gives a Hadrynian-Cambrian age as modelled on the shale curve (Godwin and Sinclair, 1982).

DISCUSSIONS AND CONCLUSIONS

The Bend occurrence is a stratiform, synsedimentary, exhalative massive sulphide body that was formed within the unstable cratonic margin of North America in the Early Paleozoic (Hadrynian-Cambrian). Original host lithologies include shale, chert, pelitic chert and manganiferous carbonate units consistent with deposition in a "starved basin" (Eckstrand, 1984).

The metalliferous sediments were probably deposited from dense, metal-rich brines derived from compaction of the sedimentary pile. Such brines exhaled onto the sea floor can be denser than sea water, in which case the solutions would pond in major depressions (Gustafson and Williams, 1981). Other chemical sediments, such as the iron and manganese-rich metamorphosed chert above the Bend sulphides, are commonly associated with the end of sulphide deposition.

Several structural events have resulted in folding of the host units and the sulphides. Metamorphism has reconcentrated galena, chalcopyrite and pyrrhotite into low pressure areas. Regionally, the deposit is on the east limb of a major anticlinorium. Within the Cummins River canyon the deposit is right-side-up on the east limb of a syncline. The stratigraphic younging direction from east to west is supported by structural criteria and by changes in the composition of garnets.

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