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ZIPPA MOUNTAIN WOLLASTONITE SKARNS, ISKUT RIVER MAP AREA (104B/11)

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INTRODUCTION

Skarns associated with the Zippa Mountain Igneous Complex of the Iskut River area are unusual for their high wollastonite contents. They are the focus of British Columbia's only active wollastonite exploration venture. Wollastonite is increasingly sought as an industrial mineral for the ceramics, paint, steel and automobile industries. Much recent demand stems from its utility as a replacement for asbestos and as a strength additive in industrial plastics. This report summarizes results of recent mapping of two wollastonite skarn deposits on the east flank of the syenitic Zippa Mountain pluton. We argue that the skarns resulted from extensive fluid infiltration into marble xenoliths in the pyroxenite border phase of the intrusion. The final stages of infiltration and skarn formation postdate the incorporation of the xenoliths into the intrusion. The apparent lack of wollastonite skarn around the other two intrusive phases of the Zippa Mountain Igneous Complex may stem from their lower heat contents.

ZIPPA MOUNTAIN IGNEOUS COMPLEX AND ASSOCIATED ROCKS

The Zippa Mountain Igneous Complex is located in the Iskut River map area of northwest British Columbia (inset in Figure 1), 5 kilometres south of the Iskut River and 32 kilometres upstream from its confluence with the Stikine River. It is composed of three Late Triassic intrusions, the Zippa Mountain, Mount Raven and Seraphim Mountain plutons, closely associated in space and time (Figure 1).

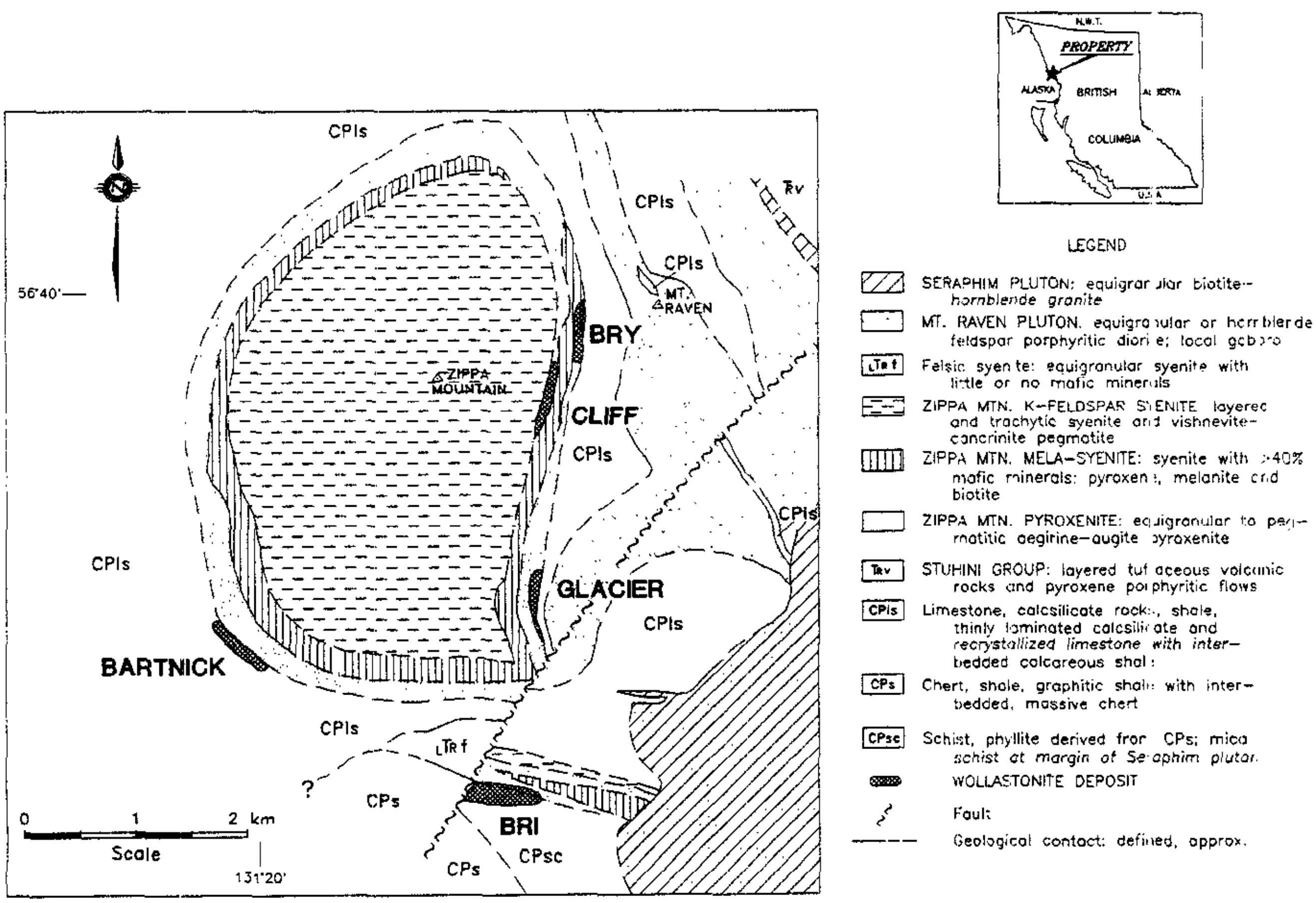

Fig. 1. Geology of the Zippa Mountain pluton and wollastonite skarns, after Lueck and Russell (1994).

The complex intrudes Paleozoic metasediments of the Stikine assemblage and Triassic volcanics of the Stuhini Group (Lueck and Russell, 1994). The Paleozoic strata are intensely folded, faulted and metamorphosed and display isoclinal, overturned and recumbent folds (Anderson, 1989). Regional metamorphic grade in the vicinity of Zippa Mountain is lower greenschist (Anderson, 1989).

The three plutons of the Zippa Mountain complex exhibit a diversity of chemical compositions despite their close spatial and temporal association. The following description of the complex derives from Lueck and Russell (1994). The Zippa Mountain pluton is a 3.5 by 5 kilometre elliptical laccolith consisting of a syenite core with border phases of mela-syenite and pyroxenite. The pluton is alkaline and strongly silica-undersaturated and is characterized by well developed planar mineral fabrics. The Mount Raven pluton is a fine-grained, equigranular hornblende diorite. It outcrops immediately east of the Zippa Mountain pluton and is characterized by the presence of pervasive gossan derived from the weathering of abundant pyrite. The Seraphim Mountain pluton is exposed southeast of the Mount Raven pluton and is a homogenous, equigranular hornblende biotite granite. Field relationships indicate that the Zippa Mountain pluton is the oldest of the three intrusions and the Seraphim Mountain pluton is the youngest. However, the earliest phases of the Mount Raven pluton predate the latest phases of the Zippa Mountain pluton. The close temporal relationship of the three plutons is also indicated by radiometric dating: an age of approximately 210 Ma is recorded by U-Pb in zircon from the Zippa Mountain pluton (M.L. Bevier, unpublished data cited in Lueck and Russell, 1994; Anderson *et al.*, 1993) and 213 ±4 Ma is recorded by K-Ar in hornblende from the Seraphim Mountain pluton (analysis GSC 90-40; R.G. Anderson in Hunt and Roddick, 1991).

Although all three plutons intrude limestone (the probable host of the skarns, Figure 1), the wollastonite skarns are restricted to the margins of the Zippa Mountain pluton. Five wollastonite localities have been identified to date. Two of these, the Cliff and Glacier deposits, were the focus of investigation during the 1995 field season; both lie within the pyroxenite border phase of the Zippa Mountain pluton. The Cliff deposit outcrops on the east margin of the pluton as a prominent west-facing, white cliff about 160 metres long and 100 metres high. The Glacier deposit is located approximately 1.6 kilometres south of the Cliff deposit and outcrops on a north-facing slope as a 300 by 50 metre exposure.

Igneous and metamorphic rocks are displaced by a fault which trends northeast and extends over 8 kilometres within the wollastonite property (Figure 1). This fault is significant because it truncates the southeast corner of the Zippa Mountain pluton and may offset wollastonite occurrences in that area.

WOLLASTONITE SKARN LOCALITIES

The Glacier and Cliff wollastonite occurrences are both composed of metasedimentary and skarn rocks enclosed in pyroxenite of the Zippa Mountain pluton. The two showings are lithologically similar and both appear to have formed by incorporation of marble and calcsilicate into pyroxenite. They differ, however, in that the Cliff occurrence consists of a single large screen while the Glacier outcrop contains many xenoliths that are highly dissected by pyroxenite dikes, veins and dikelets. Detailed maps of the Cliff and Glacier deposits are presented in Figures 2 and 3. The map units are described below.

IGNEOUS ROCKS

PYROXENITE

The pyroxenite border phase of the Zippa Mountain pluton weathers dark green and consists of fine-grained, dark green aegirine-augite (90%) and interstitial apatite (10%) with trace amounts of euhedral titanite and biotite (Lueck and Russell, 1994). Biotite usually occurs as millimetre-scale mica books within an aegirine-augite groundmass, and less commonly, as inclusions within poikilolitic pyroxene. Within the Glacier deposit, a biotite-rich pyroxenite unit can be mapped as a discrete irregular zone within the pyroxenite (Figure 2). It consists largely of biotite and pyroxene with minor amounts of interstitial potassium feldspar. Numerous pyroxenite dikes and dikelets, as narrow as 1 centimetre, cut virtually all skarn and metasedimentary units at the Glacier locality.

DIORITE

A diorite porphyry dike, 15 metres wide, crosscuts the skarn and Zippa Mountain plutonic phases in the Glacier deposit. It contains between 15 and 25% plagioclase phenocrysts up to 4 millimetres in diameter, set in an aphanitic groundmass. The phenocrysts and groundmass are strongly altered. The main phase of the dike weathers brown to orange and is represented by the rusty diorite unit on Figure 2. The origin of the diorite dike is uncertain, but it may be related to the Mount Raven pluton.

METASEDIMENTS

CALCSILICATE

Fine-grained green calcsilicate contains diopside and grossular garnet with varying amounts of biotite, melanite garnet, potassium feldspar and wollastonite. Grossular is concentrated in layers and pods 2 to 5 centimetres thick. These layers may be veins or sedimentary features. Biotite occurs within subparallel layers 0.5 to 4 millimetres thick and in pockets. The thin, parallel nature of these biotite layers suggests that they represent argillaceous beds within the original sediment.

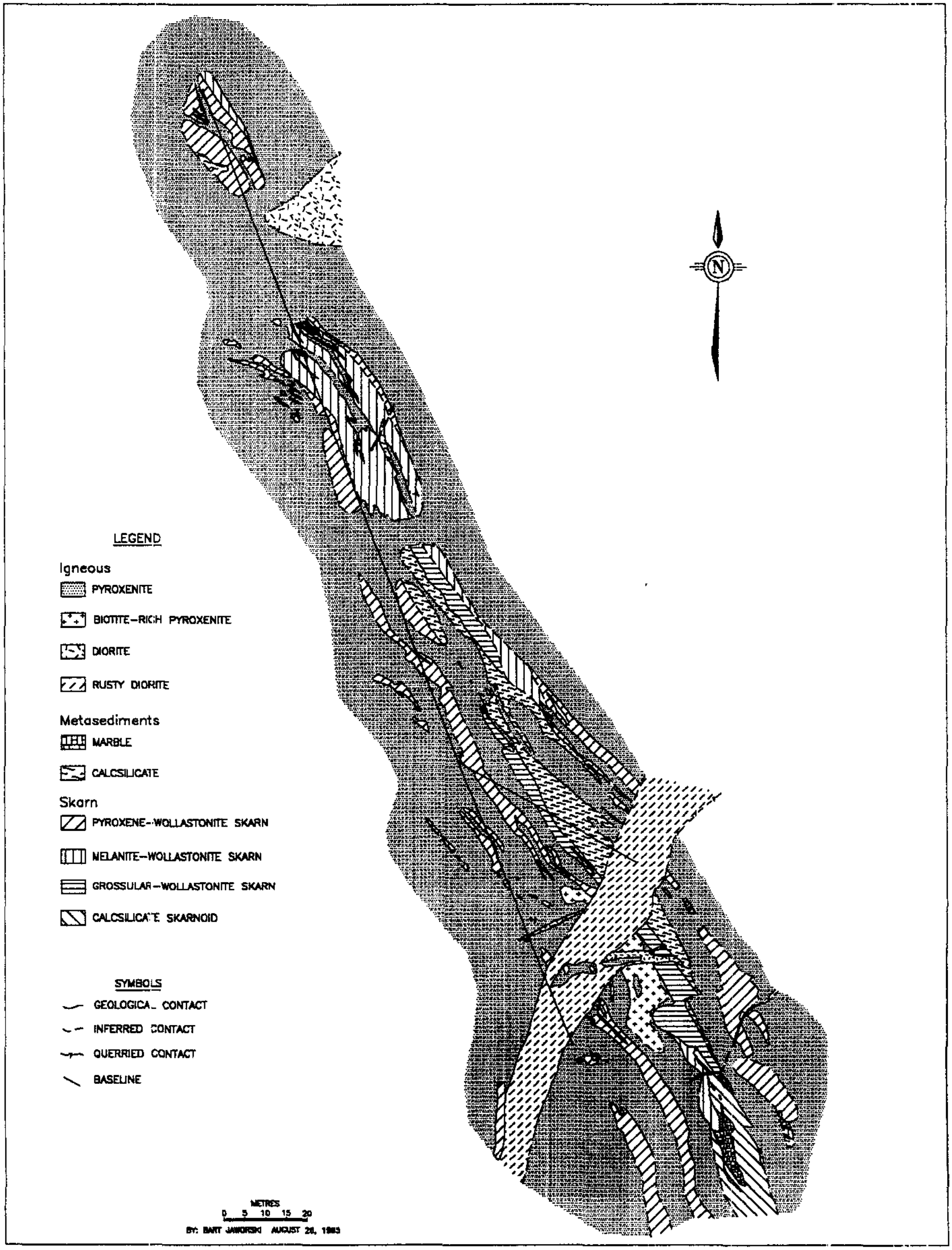

Fig. 2. Detailed geology of the Glacier wollastonite deposit.

MARBLE

Light green to grey marble outcrops in the southeastern end of the Glacier deposit. It is composed predominantly of recrystallized calcite, 1 to 2 millimetres in diameter, and probably represents a clean limestone protolith that was unreactive during metamorphism. It is locally characterized by millimetre-scale dark green laminations that probably contain fine-grained diopside.

WOLLASTONITE SKARN UNITS

Five map units are identified within the wollastonite skarn of the Cliff and Glacier localities, on the basis of texture and the relative abundances of accessory minerals. All units except the calcsilicate skarnoid contain between 50 and 95% wollastonite by volume. Pyroxene, melanite, and grossular-wollastonite skarn units are defined by the relative abundances of pyroxene, melanite garnet and grossular garnet. Two texturally distinct units were further distinguished in the field, based on grain size: the coarse wollastonite unit and the fine-grained calcsilicate skarnoid. The average grain size of skarn minerals is about 3 millimetres, but varies considerably between less than a millimetre in the calcsilicate skarnoid to 4 centimetres in the coarse wollastonite skarn.

PYROXENE-WOLLASTONITE SKARN

Light grey to cream-weathering pyroxene wollastonite skarn is the most abundant skarn unit in the Cliff and the Glacier localities. It contains abundant pyroxene (up to 45 volume % and on average 10%) with no visible garnet. Pyroxene occurs as fine-grained disseminated diopside within the wollastonite matrix and as wispy, light green layers of diopside. The fine, parallel-laminated nature of these layers and their consistent orientation, suggests they may reflect bedding within a protolith limestone such as is observed in the marble described above. The pyroxene-

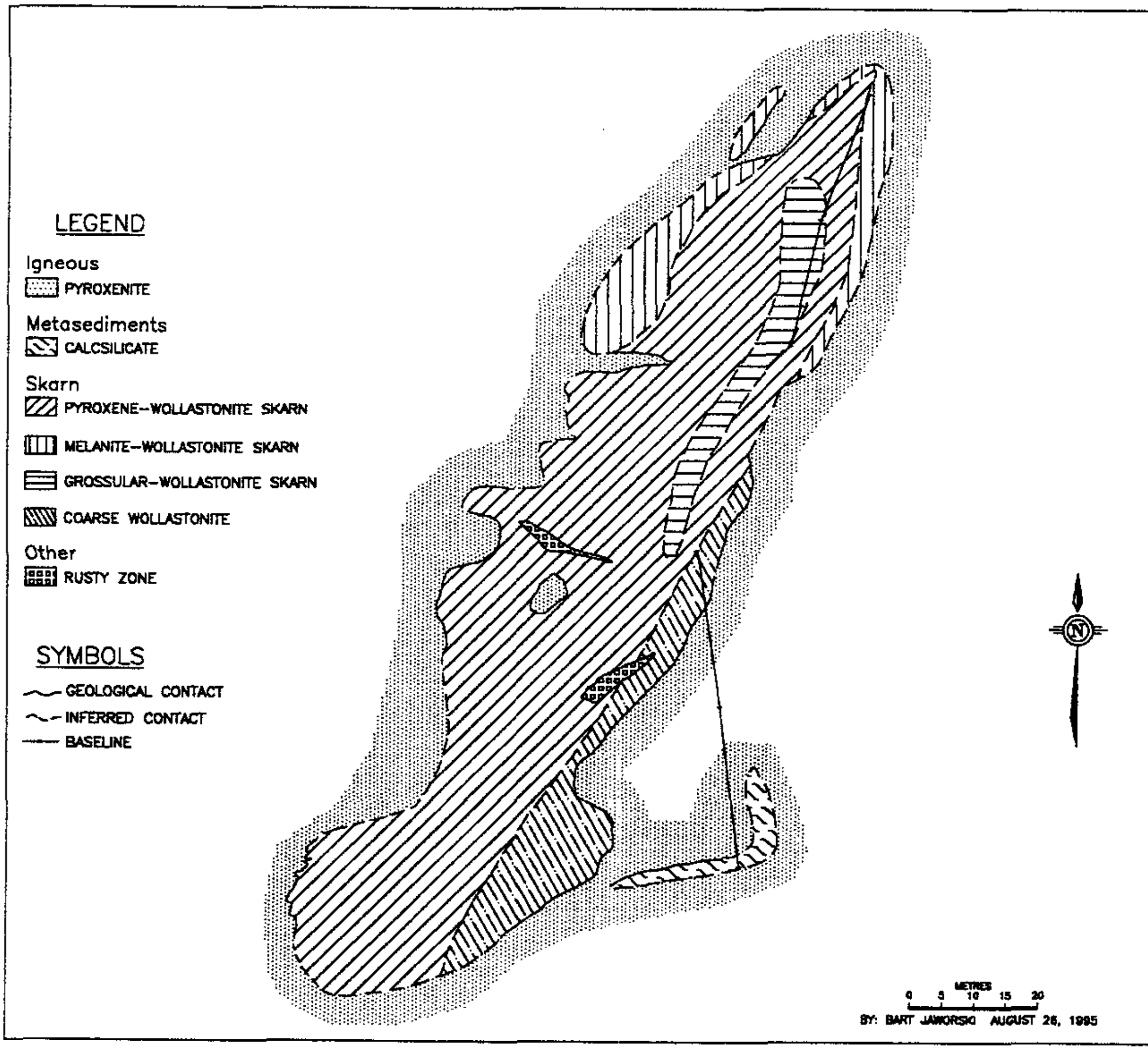

Fig. 3. Detailed geology of the Cliff wollastonite deposit.

wollastonite skarn is commonly dissected by pyroxenite dikelets. In places it becomes difficult to distinguish between diopside stringers of probable sedimentary origin and pyroxenite dikelets of igneous origin.

MELANITE-WOLLASTONITE SKARN

Melanite-wollastonite skarn contains up to 20% black, fine to coarse-grained melanite garnet, with or without pyroxene. Typical skarn contains about 10% melanite, 3% pyroxene and 87% wollastonite. Locally, pyroxene abundance approaches 15%. Preferential weathering of wollastonite gives the rock a warty, light to dark grey appearance. Melanite garnet occurs as disseminated crystals within the wollastonite and as irregular millimetre-scale stringers. The skarn is locally brecciated; fragments of melanite-poor skarn are surrounded by wollastonite containing abundant disseminated melanite. Melanite commonly contains microscopic inclusions of calcite and diopside.

GROSSULAR-WOLLASTONITE SKARN

This cream to pink-weathering unit is characterized by the presence of 5 to 10% grossular garnet in a wollastonite matrix and the absence of pyroxene. Grossular occurs in centimetre-scale layers and disseminated throughout. It locally contains up to 15% melanite.

COARSE WOLLASTONITE SKARN

Massive, white outcrops of coarse wollastonite skarn consist predominantly of coarse-grained, randomly oriented wollastonite. The rock typically contains less than 5% of the accessory phases pyroxene, grossular and/or melanite. Titanite is locally present in haloes around potassium feldspar veins.

CALCSILICATE SKARNOID

A greenish white, fine-grained unit that outcrops at the south end of the Glacier deposit is distinguished from other skarn units by its fine grain size and from calcsilicate metasediment by its skarn mineralogy. Thin section examination reveals that it contains 5 to 10% coarse melanitic garnet in a fine-grained matrix of potassium feldspar, garnet (andradite?) and apatite, with or without diopside and wollastonite. Apatite is locally abundant, up to 20%. Calcite is common but appears to be related to fracturing and retrograde alteration.

VEINS

Metasediments, wollastonite skarn and pyroxenite are cut by several generations of veins that cannot be depicted at map scale. The oldest veins appear to be associated with latest stages of crystallization of the pyroxenite while the youngest veins crosscut all lithologies. They are described below in chronological order, as determined from crosscutting relationships.

POTASSIUM FELDSPAR VEINS

Irregular, centimetre-scale potassium feldspar veins cut metasediments and wollastonite skarn. They commonly contain euhedral, medium to coarse-grained titanite, melanite and pyroxene, with minor amounts of apatite (5%); however, they are highly variable and are locally composed of pure potassium feldspar. Melanite locally displays oscillatory zoning that overgrows cores of grossular garnet. These veins are crosscut by melanite-apatite veins.

MELANITE-APATITE VEINS

Melanite-garnet commonly occurs with apatite and less commonly with pyroxene in centimetre-scale irregular veins. Melanite is usually medium to coarse-grained and is surrounded by fine-grained apatite. These veins commonly cut skarn and calcsilicate, and usually occur within cores of pyroxenite dikes or spatially associated with pyroxenite.

QUARTZ AND CALCITE VEINS

Two sets of randomly oriented, monomineralic veins, one containing calcite, the other quartz, cut metasedimentary, igneous, and skarn units. The planar veins are 0.5 to 3.5 centimetres wide. Their relative age is unknown because crosscutting relationships between the two vein sets were not observed.

ZONING

Despite the complex pattern of skarn types in the two deposits, there is a consistent zoning in skarn mineralogy between outcrops and at different scales. Map-scale zonation (tens of metres) is generally parallel to the long dimension of the xenoliths, and may reflect control of alteration and/or fluid flow by sedimentary composition (Figures 2 and 3). Both deposits are cored by grossular-wollastonite skarn, and pyroxene-wollastonite skarn is generally found surrounding this core. At the Glacier deposit, pyroxenite-wollastonite skarn lies along the edges of many of the largest xenoliths and occurs as trains of isolated xenoliths on the margins of the deposit. Most of the screen at the Cliff deposit is composed of pyroxene-wollastonite skarn which completely surrounds the grossular-wollastonite unit. However, some zoning appears to crosscut lithologic boundaries. For example, melanite-wollastonite skarn wraps around the north end of the Cliff deposit (Figure 3) although there is no evidence for isoclinal folding within the screen. Individual xenoliths are also rimmed by melanite-rich zones that appear, at least in part, to be replacements (Photo 1). The complex skarn zoning in the Glacier deposit also suggests that it is not entirely controlled by sedimentary lithology. In the centre of the deposit, grossular and melanite-wollastonite skarn are truncated by calcsilicate. Similarly, the complex zoning of marble, calcsilicate skarnoid and grossular and melanite-wollastonite skarn at the south end of the Glacier deposit is probably controlled, in part, by infiltration. This is corroborated by field observations that skarn zonation cuts across bedding inferred from centimetre-scale laminations.

PROCESSES OF SKARN FORMATION

Our observations suggest that the wollastonite skarns formed by fluid infiltration into carbonate xenoliths in the margin of the Zippa Mountain pluton. The close spatial association of skarn and pluton, and the similarities between skarn and igneous mineral assemblages, suggest that the infiltrating fluids derived from the pluton. However, the sedimentary composition of xenoliths undoubtedly influenced skarn formation. Below we list the evidence for infiltration and lithologic control of skarn formation and briefly discuss the relative timing of skarn-forming processes.

Perhaps the most striking evidence for an infiltration origin for the wollastonite skarn is the exceptional wollastonite purity. Most skarn contains greater than 70% wollastonite by volume and no calcite or quartz. Without fluid infiltration, formation of wollastonite from calcite marble by the reaction calcite + quartz -> wollastonite + CO_2 is limited by quartz content. Thermally driven wollastonite formation should therefore produce calcite-wollastonite marbles with generally low wollastonite abundances. The presence of almost pure wollastonite skarn requires either that the protolith was a 1:1 molar mixture of calcite and quartz, or that some chemical components were introduced into the skarn by fluid infiltration. The purity of wollastonite and general lack of calcite at Zippa Mountain suggests that skarn formation resulted, at least in part, from reaction of calcite with metasomatically introduced SiO_2 to produce wollastonite.

An infiltration origin for the skarns is also supported by the zonation and overprinting relationships of melanite-bearing skarns. At the north end of the Cliff deposit, melanite-wollastonite skarn wraps around the screen. Melanite-rich alteration is also observed around individual small xenoliths at the Glacier deposit (Photo 1). Melanite-wollastonite skarn at the south end of the Glacier deposit appears to grade into marble and/or grossular-wollastonite skarn. Overprinting relationships also support a replacement origin for melanite: individual melanite crystals are cored by diopside or grossular.

There is also significant evidence for some lithologic control of skarn formation. Skarn zoning at the two deposits is generally elongate parallel to bedding and the long axes of the xenoliths. For example, the distribution of coarse wollastonite skarn at the Cliff deposit may be controlled by the original extent of a very pure calcite marble. Similarly, the distribution of calcsilicate, calcsilicate skarnoid, grossular-wollastonite skarn, and melanite-wollastonite skarn at the Glacier deposit may reflect original sedimentary features. Together they define a continuous band that strikes north-northwest across the entire deposit. The complex zoning in the Glacier deposit probably resulted from local control by heterogeneous metasediments on fluid flow and resulting metasomatism.

Both wollastonite skarn deposits examined to date at Zippa Mountain are contained in xenoliths of carbonate

Photo 1. Outcrop of wollastonite skarn xenoliths in the Glacier deposit. Pencil flare for scale; view is to the east. Note the dark rinds of melanite alteration ringing the xenoliths and melanite alteration along fractures in the large xenolith.

metasediments within the pyroxenite border phase of the pluton. It is likely that at least some fluid infiltration postdated the incorporation of xenoliths into the pluton. Complete enclosure of xenoliths by melanite alteration requires that the alteration postdate dismembering of the sedimentary rocks (Photo 1). The large-scale zonation of melanite-wollastonite skarn at the Cliff deposit also suggests that skarn formation postdated incorporation of the screen into the pluton. Xenoliths continued to disintegrate after incorporation, as evidenced by fracture-related melanite alteration in the interior of the xenolith pictured in Photo 1. In fact, the lack of concentric zoning in xenoliths at the Glacier deposit probably resulted from continued fracturing, diking, and assimilation.

IMPLICATIONS

Wollastonite skarns have not been found associated with the Mount Raven and Seraphim Mountain plutons. Identification of the factors critical to skarn formation at Zippa Mountain therefore may aid future exploration for wollastonite in British Columbia. Wollastonite skarn formation requires: a calcite-rich protolith and a high SiO_2 content (either inherited from the protolith or introduced by fluid infiltration), and one or both of high temperature and low CO_2 activity (*e.g.*, Greenwood, 1967). Wollastonite can form at low temperatures if the CO_2 activity is very low, or at high CO_2 activities if the temperature is very high. All three plutons of the Zippa Mountain igneous complex meet the first two criteria. They intrude limestones and probably exsolved silica-bearing aqueous fluids. The Mount Raven and Seraphim Mountain plutons contain magmatic biotite and/or hornblende and are quartz normative. The Zippa Mountain pluton contains magmatic biotite and is silica undersaturated (Lueck and Russell, 1994). Despite this, fluids from the Zippa Mountain pluton carried sufficient dissolved silica to drive wollastonite skarn formation. However, syenite and pyroxenite of the Zippa Mountain pluton were probably emplaced at higher temperatures than granite and diorite of the other plutons. Incorporation of marble xenoliths into the margin of the intrusion would also raise their temperature relative to intact wallrocks outside the intrusion. A critical factor for wollastonite skarn formation at Zippa Mountain may have been the unusually high temperatures resulting from emplacement of syenite coupled with the incorporation of marble xenoliths into the pyroxenite border phase.

ACKNOWLEDGMENTS

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NOTES