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Dear Dave:

I have been working slowly but surely on the material I collected at the mine in 1971, and after trying to examine features of all the pits where I sampled, finally began concentrating on Little Chief. This became rather trying, as the amounts of alteration present obscured the primary mineralogy to a large extent in my samples, but as of now I believe I have defined a reasonable answer to my thesis question: the basic mineralogy and sequence of skarn events and their relation to mineralization in Little Chief Mine. A summary of findings follows.

The basic mineralogy of silicates in the skarn zone was determined by the study of about 100 thin sections, with some of key minerals being prepared for more quantitative analysis. These thin sections, plus about 50 polished surfaces of skarn and ore were used in the formulation of a paragenetic sequence for the mine area. (attached sheet) Phases identified include: OPX, CPX(diopside and hedenbergite), gar (several color phases, much andradite), zoisite? (fine grained alteration of feldspar, pink in color), plagioclase, K-spar, green epidote, chlorite, talc, amphibole, biotite+ phlogopite, serpentine.

Opaque phases identified in polished surface include: pyrite, pyrrhotite, chalcopyrite, bornite, molybdenite, valleriite, intergrowths of bor-cpy, bor-digenite or cpy-digenite, bor-chalcocite, and the oxides magnetite, hematite or maghemite, goethite and possibily minor cassiterite(?) Tetrahedrite was observed at War Eagle in a late vein, and wolframite was found in a blast fragment of a quartz vein.

Major ore minerals at Little Chief are bornite, bor-chalcocite intergrowth, cpy and cpy veins. Limited exposures alon Middle Chief were also examined, and the major mineral appears to be cpy; likewise for dump samples from Valerie.

These phases have been divided into a sequence of skarn and skarn-ore events. Most of the massive skarn is believed to have resulted from a major bimetasomatic (after Korzinskii and others) event, caused by the differential migration of Mg, Fe, [illegible], Si and Al into the limestone and the migration of Ca, K and Na outward. This caused the formation of a zoned skarn in the contact zone with the following sequence:

Zoned Skarn Sequence

1) Marble ± pyroxene
2) Clinopyroxene + minor garnet and magnetite
3) Clinopyroxene + garnet (± garnet veins)
4) " + zoisite + garnet (± garnet veins)
5) K-spar + plagioclase + quartz ± magnetite and epidote
6) Granodiorite to diorite (± garnet and epidote veins)

Boundaries between zones aren't always distinct, and in particular the K-spar zone apparent in the southwest corner of the pit is not continuous and was not observed along LC-North fault or in poor exposures along the west wall of the pit. Thin section evidence points to the presence of an early clinopyroxene (Di?) and Orthopyroxene being replaced by later, granular clinopyroxene (Hd?) and andradite garnet, indicating Mg skarn minerals being superceded by later Fe-rich skarn.

Ore minerals, from available evidence, were introduced in two stages. Present in magnetite concentrations near original limestone boundaries as inclusions are cpy and cpy-bor or cpy-digenite grains, generally quite small (.1 - .01 mm) in size. These are believed to be early grains with chalcocite-bor or bor-cpy intergrowths since altered to cpy and digenite, in part by later mineralization involving fresh eutectic-type intergrowths of bor-chalcocite, which are larger in size and replace early magnetite grains or are molded onto them, and are most abundant in the pyroxene-rich zones 2 and 3. A later mineralizing event is chosen to explain the massive and vein-type cpy, py and pyrrhotite mineralization crosscutting or replacing other skarn phases and associated with the contact zones between granodiorite and skarn with garnet and epidote veins. Granodiorite and diorite near the contact also contains disseminated pyrite, with cpy in clots, while at more distant locations the granodiorite holds disseminated magnetite.

Both ore events are associated with a hydrous Fe alteration assemblage which includes actinolite, biotite, chlorite and especially epidote. Veins of bor-cpy are surrounded by a halo of epidote, and bor occurs with epidote crystals cutting pyroxene skarn along fractures. A few quartz-cpy-epidote veins with alteration halos of amphibole and chlorite also occur along the granodiorite contact in the west and northwest parts of pit.

The final events in the contact zone were hydrous alteration of preexisting skarn, possibly with the addition of Mg, to serpentine, talc, chlorite and spinel, also seemingly controlled by the footwall contact of skarn and granodiorite and the formation of calcite veins which cut all units in pit. Occasionally ore fragments occur in these veins, but their contribution is minor.

Secondary replacement of original Cu sulfides has occurred to a minor extent, with secondary cpy, chalcocite and digenite occurring in serpentinized areas, along with valleriite-pyrite. Valleriite surrounds bits of bor-cpy in serpentine, and where the whole rock has gone to serpentine, valleriite occurs with pyrite.

Late dikes of andesitic to basaltic composition cut through the skarn zone, although some are badly altered, indicating formation before end of skarn events.

To check the optically observed differences in clinopyroxene grains observed in the ore zone and along the contacts with granodiorite, a number of grains from these areas are being mounted for electron probe analysis. The several observed color phases of garnet, especially the vein garnet along the footwall contact, are also being analysed. A series of magnetite grains from massive and disseminated areas both in serpentine and in pyroxene are being analysed for Mn, Al, Cr, and Ni to check for possible ultramafic sources for the magnetite (or at least for the abundant Fe and Mg of the skarn zone). The two color phases of bornite will be probed for compositional variations if time allows.

I would appreciate any comments you might make on this inferred sequence, especially any zonal sequence of skarn minerals you may have observed in the hanging wall of the granodiorite-limestone contact from drilling. I don't recall if much ore was located above the limestone block or within it; I wouldn't expect much, but Andy showed me a chunk of development core from LCU 38, approx. 93', which showed finely laminated and contorted bornite-serpentine-carbonate, which may have been from the interior of the limestone block. Could you confirm this, and also indicate where this hole is in reference to the underground workings? I haven't seen this type of ore occurrence elsewhere.

Have you defined the nature of the ore zone in the Middle Chief area? In the trench exposures at the surface are marbles with disseminated silicates, probably pyroxene, and pyrrhotite after pyrite in alteration veined ground. This marble sits on top of massive magnetite, with malachite staining, and is cut by fractures carrying massive magnetite and minor chalcopyrite blebs. Near the old adit to the north, massive pyrite-pyrrhotite with chalcopyrite replacment cuts massive magnetite skarn. If a later ore event moved along this contact, I would expect veins of this high sulfur mineralization to be found along the contact at depth also.

Have you seen any evidence for a second intrusive event not associated with skarn in the Little Chief area? The presence of E-W trending fractures with cpy, NW-SE and NE-SW joints and the late E-W dikes could suggest a N-S compressional environment in LC Pit during some of ore deposition -- the contact may have been brecciated by shear due to compression parallel to the contact.

Is there any way I could get assay plans of the 2400 and 2600 levels in the pit, or assay sections along 5200E and 9200 and 9700N on LC grid? I could then see if ore grades show any seperable difference between contact zone and interior of massive skarn.

I will be in contact with you again as soon as my analyses are complete: Thank you for your patience.

Yours truly,

Dave Grabher

Paragenetic Sequence - Little Chief Mine