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Copper Mineralization in the White Pine Deposit, Michigan

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Abstract

Copper mineralization in the White Pine deposit of the White Pine Copper Company, Ontonagon County, Michigan is restricted to a group of shaley siltstones and sandstones at the base of the Nonesuch formation and top of the Copper Harbor formation of late Keweenawan age. In the White Pine area Copper Harbor is made up of reddish brown arkosic sandstone, siltstone, and conglomerate with a thickness of possibly 3000'. Nonesuch formation, lying conformably on Copper Harbor, is predominantly a dark thin-bedded shaley siltstone, dark gray to black in the basal 100', alternating reddish brown and medium dark gray in the upper 350' to 500'. The contact between Nonesuch and the overlying Freda sandstone is generally indefinite, with a gradual change through the contact zone from grayish brown siltstone to reddish brown sandy siltstone and "red" sandstone.

The mineralized zone averages about 20' in thickness and is comprised of fine grained clastic rocks ranging from medium-to-coarse feldspathic sandstone through siltstone to a very finely laminated shale. Colors range from reddish brown through various shades of gray to black. More than half of the copper is associated with 4 dark gray shaley siltstone units whose aggregate thickness makes up one third or less of the total mineralized column, while relatively little copper is associated with the sandstones and light gray or reddish units.

The orebody lies in a broad gently dipping anticlinal structure frequently offset by faults. The largest known fault in the area, the White Pine Fault, has an estimated horizontal displacement of over one mile, with vertical displacement probably on the order of several hundred feet. Although copper mineralization is sometimes associated with faulting, especially in the neighborhood of the White Pine Fault, in gross respect there seems to be no definite relationship between faulting or warping and concentration of copper.

It is believed that the copper in the White Pine deposit was derived from copper-bearing middle Keweenawan lavas, which through weathering and erosion released copper in an oxidized state for transportation in ground water to a restricted basin in which reducing conditions prevailed. Precipitation of copper occurred either contemporaneously with sedimentation, or shortly thereafter, prior to consolidation of the sediments. After induration, tectonic activity caused minor redistribution of copper to effect concentrations both within and outside of the normal mineralized zone.

Introduction

The White Pine copper deposit is located (Plate 1) on the south limb of the Lake Superior syncline in Carp Lake Township, Ontonagon County, Michigan, 50 miles southwest of Houghton and 130 miles due east of Duluth, Minnesota. The orebody lies in a belt of upper Keweenawan sedimentary rocks which overly the middle Keweenawan Portage lake lava series of volcanic and sedimentary rocks. Native copper has been produced from various flows and sedimentary units of the lava series on the Keweenaw Peninsula for more than 100 years, and copper is known to occur in the series at many places around Lake Superior.

Regional Stratigraphy

The upper Keweenawan in the White Pine area (Plate 2, section on the left) is made up of several thousands of feet of clastic sedimentary rocks ranging from boulder conglomerate to shale. Immediately overlying the Lake Shore traps of the Portage Lake lava series is the Copper Harbor group of red to brown arkosic sandstones, siltstones, and conglomerates whose aggregate

thickness is probably about 3000'. The Copper Harbor group is overlain by about 500' of dark colored shales and siltstones which comprise the Nonesuch formation. The White Pine orebody lies in the basal 20' of the Nonesuch formation at the 3000' mark on the section. Overlying Nonesuch is Freda sandstone, generally a reddish-brown fine-grained sandstone which locally contains conglomerate, black shale, and red shale. The contact between Nonesuch and Freda is poorly defined, represented by a gradational change in color and grain size of the rock from one unit to the next. The thickness of the Freda sandstone along the Keweenaw Peninsula has not been determined, but must exceed 10,000'.

Basal Nonesuch Stratigraphy

The center section of Plate 2 describes the basal 50' of Nonesuch formation and indicates by histogram the association of copper mineralization with certain stratigraphic units. The ore zone comprises two distinct shaley units separated by non-mineralized sandstone and resting more-or-less conformably on non-mineralized Copper Harbor sandstone. The lower mineralized zone, designated locally as Parting shale averages about 8' in thickness and ranges in copper content from about 15 to over 30 pounds copper per ton (0.75 to plus 1.5% Cu). The upper mineralized zone, designated locally as Upper shale, ranges from less than 1' to more than 7' and from less than 15 to more than 80 pounds copper per ton (minus 0.75 to plus 4% Cu). The two mineralized units are remarkably similar lithologically and presumably represent cyclic deposition in a restricted basin area. They are separated by sandstone, designated locally as Upper sandstone, which ranges from less than 1' to more than 10' in thickness in the mine area. Upper sandstone ranges from fine-grained red-shaley siltstone to massive coarse-grained brownish-gray to greenish feldspathic sandstone, and normally averages about 4 pounds copper per ton (0.2% Cu).

Parting Shale Stratigraphy

Distribution of copper in the Parting shale (Plate 2, section on right) is closely associated with specific and easily identified units, and sampling for assay is now normally controlled by lithologic rather than by arbitrary, engineered intervals. Parting shale ranges in color from reddish-brown through gray to black, and in texture from sandy laminated shale to massive siltstone. The major copper concentrations are in the dark gray to black units regardless of texture, while the red and brown units never contain copper in commercially significant amounts.

Underlying Parting shale is a gray to greenish sandstone which ranges from 5 to 10' in thickness and which represents the uppermost unit of the Copper Harbor sandstone. This unit, designated Lower sandstone forms the floor of the mine and is generally not mineralized by more than a few pounds of copper per ton (0.1 to 0.25% Cu) for a few inches to a foot immediately below Parting shale. At the base of Parting shale there frequently occurs a red shale parting or group of red shale laminae which comprises the contact between the Nonesuch formation and the Copper Harbor sandstone.

The Parting shale is made up of 9 distinct lithologic units each of which is characteristically mineralized over wide areas. The lowest unit, (Plate 3) resting on Lower sand is a transition zone made up of thin, light gray, fine- to medium-grained sand layers and lenses separated by black shale laminae. Its thickness in the mine area is about 6" and its copper content about 40 pounds per ton (2% Cu). Overlying transition is a thinly laminated dark gray shaley siltstone whose thickness ranges from 6" to over 1 1/2' and whose copper content ranges from about 40 to 80 pounds per ton (2% to 4% Cu). Thinly laminated is overlain by a 2" black, extremely finely laminated shale whose average copper content is about 40 pounds per ton (2% Cu). This group of shaley beds comprises 15 to 25% of the total Parting shale thickness and carries 35 to 45% of the total Parting shale copper content.

Overlying the basal shaley units of the Parting shale is a group of 3 massive siltstones whose aggregate thickness is about 3'. At the base of the group is a 1/2" calcareous layer which is extremely persistant over wide areas. The calcareous layer is immediately overlain by reddish massive siltstone, 6" thick, which averages less than 2 pounds copper per ton (0.1% Cu). Red massive is overlain by a brownish to medium gray massive siltstone,

about 1' thick, which averages about 6 pounds copper per ton (0.3% Cu). Brown massive is in turn overlain by dark gray massive to thinly laminated siltstone whose thickness ranges from about 1' to slightly over 2', and whose copper content averages about 50 pounds copper per ton (2.5% Cu). This unit is the most variable of all beds in the Parting shale, both in thickness and copper content, and shows distinct signs of having been disturbed by pre-consolidation slumping or flow. This group of massive siltstones aggregate about 40% of the total thickness and copper content of the Parting shale. Over 90% of the copper in the group, however, is in the upper dark gray portion.

Overlying the massive beds, in some places unconformably, is a 3 1/2 to 4' group of shaley siltstones. The lower half of this unit is made up of a series of narrow beds each of which grades upward from medium gray massive siltstone to dark gray shale. Massive siltstone may occur locally up to 6" or more in thickness. The average copper content of the entire zone is about 15 pounds per ton (.75% Cu), and it is customary to find that the shaley portions are more highly mineralized than the massive portions. Overlying the widely laminated zone is a group of beds quite similar in most respects except that the shaley tops of the individual graded beds are red rather than dark gray, so that the unit has a distinctive red-and-gray banded appearance. Red-and-gray averages less than 2 pounds copper per ton (0.1% Cu) through an average thickness of about 1 1/4'.

Structure and Mineralization

The White Pine Deposit is bounded on the northwest and southeast by outcrop, on the southwest by the White Pine Fault, and on the northeast by cessation of exploratory drilling. The orebody lies on an asymmetric anticlinal structure formed both by gentle bending of beds and by displacement and tilting of the beds by faulting. The White Pine Fault, a reverse fault with relative displacement down on the southwest side, is a right-hand tear fault with horizontal displacement probably exceeding one mile. Minor faulting related to the White Pine Fault extends away from the White Pine Fault in a northerly direction with vertical displacements of up to 50' or more and two prominent strike directions of N20W and N60W.

Copper occurs at White Pine primarily as extremely fine-grained disseminated chalcocite. Possibly 12% of the total copper occurs as native copper in fine disseminations, wires, blebs, and thin sheets. Native copper seems to occur most commonly in the contact zone between the thinly laminated siltstone and the black extremely finely laminated shale in the basal units of Parting shale, and in the dark gray massive siltstone in the center of Parting shale. Trace amounts of bornite, chalcopyrite, and pyrite are known to occur; and silver, presumably as native silver, occurs in commercially recoverable quantities.

Over most of the explored area mineralization trends in individual beds of both Parting shale and Upper shale, and trends of total copper content do not appear to be related to faulting or other structural features. Control seems more clearly to be affected by lithologic and stratigraphic features, and as these features vary for individual beds, mineralization characteristics also vary. Two notable exceptions, which do not include a significant portion of the total copper known, are considered directly related to faulting. First, copper mineralization occurs in the Upper and Lower sandstones adjacent to the White Pine Fault; and second, copper and chalcocite occur in joints and thin veinlets in the shales, possibly over the entire orebody. Detailed sampling of the Parting shale in both faulted and non-faulted portions of the orebody has not indicated, however, that any significant variation in total copper content exists between faulted and non-faulted Parting shale in any given area.

Summary

It appears that copper in the White Pine deposit was emplaced in the basal units of the Nonesuch formation contemporaneously with or shortly after deposition of the sediments in which now constitute Parting and Upper shales. Remarkable uniformity of mineralization exists in shaley units a few feet thick underlying an area measurable in tens of square miles, with little relationship between mineralization trends and areal structure. Copper occurs predominantly in the finer-grained shaley rocks in which there is no obvious evidence of alteration. The copper content of the shaley laminated beds at the base of Parting and Upper shale varies inversely with sandiness, and copper is rarely found in appreciable amounts in the sand immediately underlying Parting or Upper shale.

Origin

The burden of evidence suggests that copper in the basal Nonesuch may have been derived from middle Keweenawan lavas. Through processes of weathering and erosion, copper in the lavas was successively oxidized and taken up in ground and surface waters for ultimate transportation in solution to a restricted basin area on the broad surface of the Copper Harbor sandstone. The chemical environment in the restricted basin was such that copper could be reduced and precipitated in the muds on the basin bottom. Copper in solution in ground water within the Copper Harbor sandstone could have been carried up into the basin waters or muds upon elevation of the water table by regional tilting or compaction of the sand. At some time after consolidation of the sediments tectonic activity brought about the present structural configuration, and redistribution of a small portion of the copper occurred, to produce concentrations of hydrothermal copper in sandstone along the White Pine Fault and in joint and fissure fillings in the shales.

Augusta, Maine
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