

Geology of an Ordovician Stratiform Base-Metal Deposit in the Long Canyon Area, Blaine County, Idaho

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METRIC CONVERSION FACTORS		
Multiply	By	To obtain
Miles	1.609	Kilometers
Feet	0.3048	Meters
Inches	2.54	Centimeters
Tons	1.016	Metric tons
Short tons	0.907	Metric tons
Troy ounces	31.103	Grams
Ounces	28.35	Grams

Geology of an Ordovician Stratiform Base-Metal Deposit in the Long Canyon Area, Blaine County, Idaho

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Abstract

In the Long Canyon area, Blaine County, Idaho, a stratiform base-metal-bearing gossan is exposed within a complexly folded and faulted sequence of Ordovician strata. The gossan horizon in graptolitic mudrock suggests preservation of bedded sulfides that were deposited by an Ordovician subaqueous hydrothermal system. Abrupt thickness changes and geochemical zoning in the metal-bearing strata suggest that the gossan is near the source of the hydrothermal system.

Ordovician sedimentary rocks at Long Canyon represent a coarsening-upward section that was deposited below wave base in a submarine depositional environment. The lowest exposed rocks represent deposition in a starved, euxinic basin and overlying strata represent a prograding clastic wedge of terrigenous and calcareous detritus. The metalliferous strata are between these two types of strata.

Strata at Long Canyon have been deformed by two periods of thrust faulting, at least three periods of normal faulting, and two periods of folding. Tertiary extensional faulting formed five subhorizontal structural plates. These low-angle fault-bounded plates truncate Sevier-age and possibly Antler-age thrust faults. The presence of gossan-bearing strata in the four upper plates suggests that there was only minor, although locally complex, stratigraphic displacement and rotation. The lack of correlative strata in the lowest plate suggests the displacement was greater than 2000 ft.

The metalliferous strata were exposed to surface weathering, oxidation, and erosion prior to and during deposition of the Eocene Challis Volcanic Group. The orientations of erosional canyons formed during this early period of exposure were related to the orientations of Sevier-age thrust faults, and stream-channel gravel was deposited in the canyons. During this and subsequent intervals of exposure, sulfidic strata were oxidized to a minimum depth of 700 ft.

Introduction

The Long Canyon area is along the northern margin of the Snake River Plain, approximately 8 mi northeast of the community of Carey, in secs. 20 and 29, T. 1 N., R. 22 E., Blaine County, Idaho (fig. 1). Closest road access to the property is via Road Canyon and a single track dirt road into Long Canyon.

The Long Canyon area is not in a formally recognized mining district and no recorded production has occurred in the area. Three short adits and a few shallow prospect pits are the only

visible records of historic exploration activity. These prospects explored sulfidic bull quartz veins. Several impressive stratiform gossans exposed in the area show no evidence of past prospecting.

The present study resulted from exploration efforts by Cominco American Resources Incorporated and included geologic mapping, soil and rock-chip geochemistry, geophysics, and drilling of three core holes totalling 1,664 ft.

Geology

Regional Geology

Strata exposed near Long Canyon occupy a structurally compressed part of a lower and middle Paleozoic sequence of hemipelagic, siliciclastic, and calcareous sedimentary rocks (Skipp and Sandberg, 1975) (fig. 2). Strata that can be correlated stratigraphically are exposed in places from the northern margin of the Snake River Plain on the south to the Clayton, Idaho area on the north (Umpleby and others, 1930; Anderson and others, 1950; Sandberg and others, 1975; Skipp and Hall, 1975; Skipp and Sandberg, 1975; Carter and Churkin, 1977; Batchelder and Hall, 1978; Carstensen, 1983; Hall, 1985). Hall (1985) named the part of this belt from Bellevue area north to the Salmon River area the central Idaho black-shale mineral belt. Rocks exposed in the Long Canyon area have been dated paleontologically as Middle to Late Ordovician (Claire Carter, oral commun., 1985). This indicates a partial stratigraphic correlation with lower Paleozoic strata described by Dover and others (1980) in the Trail Creek area 30 mi to the northwest. The location of the Long Canyon area near the northern margin of the Snake River Plain southeast of Bellevue logically makes it part of the central Idaho black-shale mineral belt described by Hall (1985).

Other Paleozoic sedimentary rocks in the Fish Creek Reservoir area include flysch deposits of the Mississippian Copper Basin Formation, which is a thick sequence of carbonate and siliciclastic rocks (Nilsen, 1977a, b), and the Middle Pennsylvanian-Lower Permian Wood River Formation (Skipp and Hall, 1975; Skipp and Sandberg, 1975). The lower Paleozoic strata are in structural contact with middle and upper Paleozoic rocks and are exposed in an erosional window which Skipp and Sandberg (1975) refer to as the Fish Creek Reservoir Window. Volcanic and volcanoclastic rocks of the Challis and Snake River Plain are in both depositional and structural contact with Paleozoic strata.

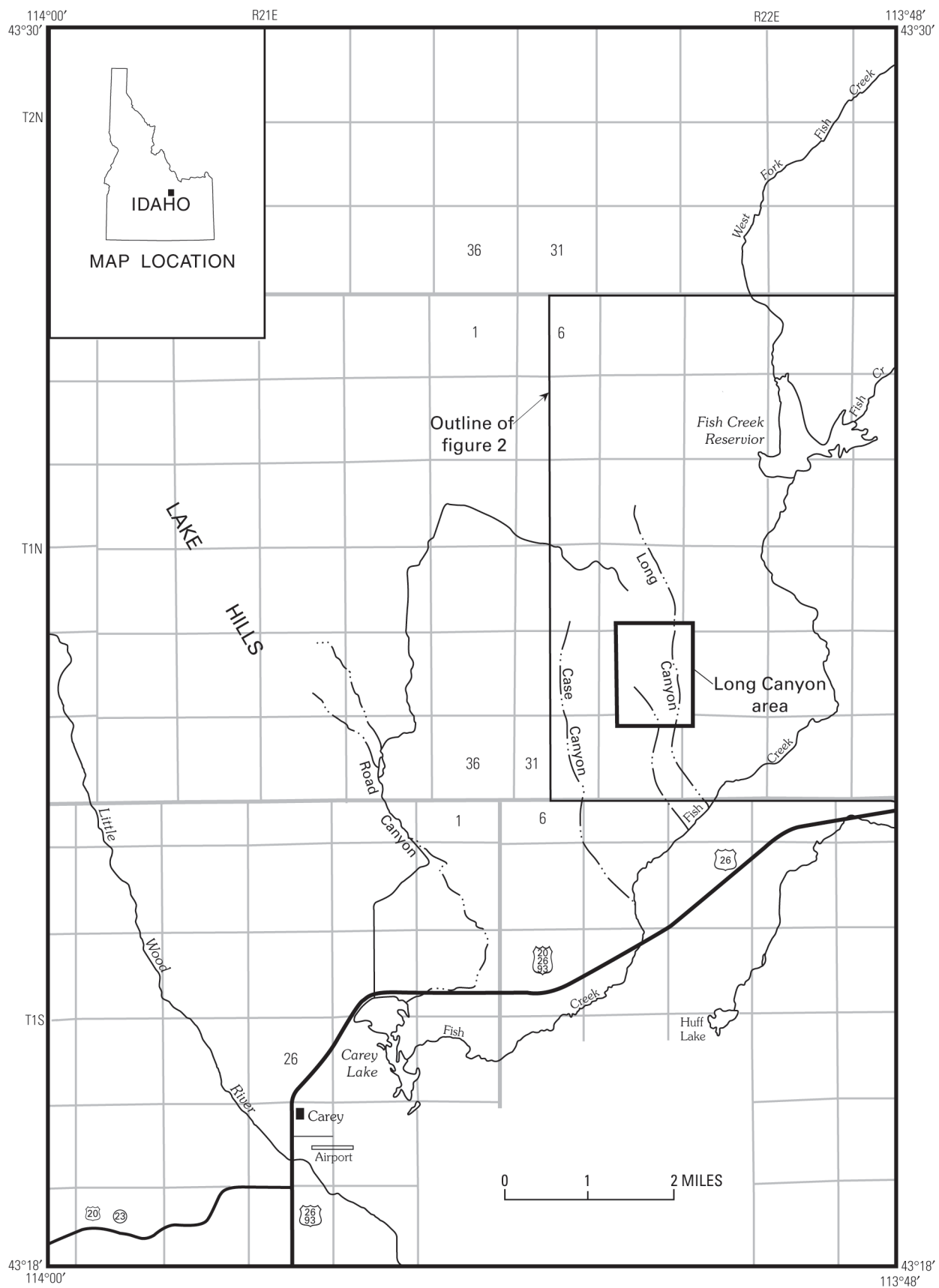
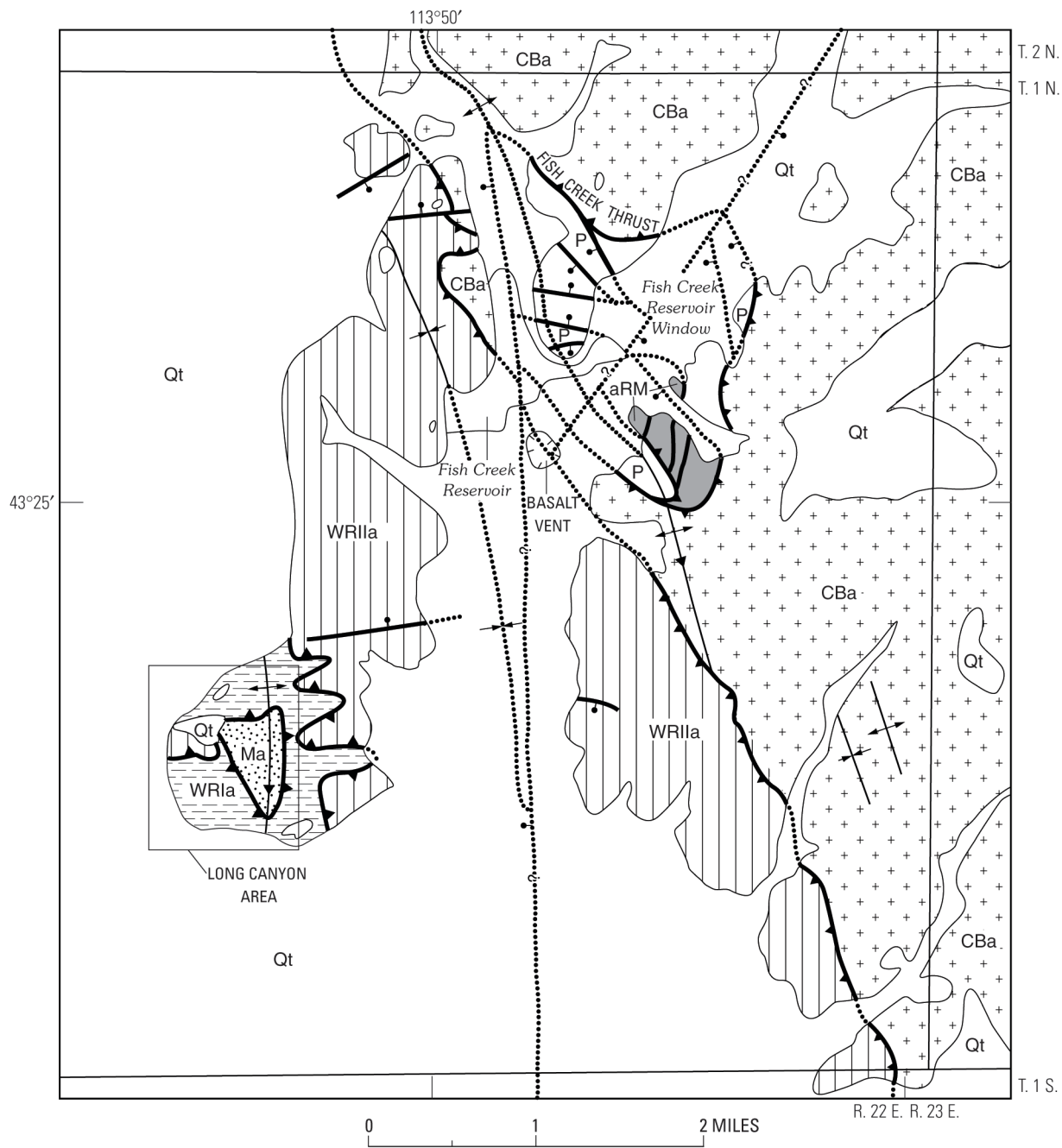


Figure 1. Index map showing location of the Long Canyon area, Blaine County, Idaho.



EXPLANATION

Qt	Quaternary and Tertiary, undivided	▲▲?—	Thrust fault—Sawteeth on upper plate. Dotted where covered; queried where inferred
WRIIa	Wood River II allochthon	—●—	Steep fault—Bar and ball on down-thrown side. Dotted where covered; queried where inferred
WRIa	Wood River I allochthon	—↕—	Troughline of anticline—Showing direction of plunge and direction of dip of limbs. Dotted where concealed
Ma	Milligen(?) allochthon	—↕—	Crestline of syncline—Showing direction of dip of limbs. Dotted where concealed
aRM	Allchthon of the Roberts Mountains Formation		
+ CBa +	Copper Basin allochthon		
P	Parautochthon		

Figure 2. Map showing structural geology of the Fish Creek Reservoir window, Blaine County, Idaho.

In the Trail Creek area and the adjacent Warm Springs and Mineral mining districts, a thick basinal siliciclastic and clastic carbonate section represents the time interval from Ordovician through early Late Devonian (Carter and Churkin, 1977; Dover and others, 1980; Sandberg and others, 1975; Otto and Turner, 1987; Turner and Otto, 1988). These strata, which are lithologically similar to and are time correlative with the strata in the Long Canyon section, have a significant history of exploration for and production of base- and precious-metals. At the Triumph mine, the largest past producer in the Warm Springs district, bedded sulfide in argillite, calcareous argillite, limestone, and quartzite of the Lower to Upper Devonian Milligen Formation produced almost two million tons of ore at a grade of 11 percent combined zinc and lead, 0.08 ounces per ton of gold, and 7.5 ounces per ton of silver (Turner and Otto, 1995).

Other significant past producers and prospects in the Warm Springs and Mineral mining districts include the Mascot, Minnie Moore, and Homestake mines, all hosted in Devonian strata, and the Phi Kappa mine, hosted in Ordovician strata (Umpleby and others, 1930). Many of these mines and prospects are stratabound zinc-lead-silver deposits hosted by basinal strata that are lithologically similar to those exposed at Long Canyon.

Long Canyon Area Geology

Rocks of the Long Canyon area (fig. 3) consist of a structurally complex sequence of lower Paleozoic argillite, limestone, and sandstone and Tertiary and Quaternary volcanic rocks. Skipp and Hall (1975) and Link and others (1988) showed the upper Paleozoic Wood River Formation in structural contact with the lower Paleozoic sequence (fig. 2). The lower Paleozoic rocks, originally deposited in a continental slope environment of the early Paleozoic North American craton, were folded in Late Devonian to Early Mississippian time during Antler deformation (Turner and Otto, 1988). The rocks were folded and thrust faulted during the later Sevier tectonic event (Skipp and Hall, 1975; Skipp and Hait, 1977; Dover, 1981) and were normal faulted during the Tertiary. The combination of rapid facies changes, intersecting fold systems, complex fault geometries, and poor exposures has hindered measurement of an accurate stratigraphic section; however, figure 4 shows a measured section drawn on the basis of available field data.

Paleozoic Stratigraphy

Rapid facies changes recorded in the Paleozoic section exposed at Long Canyon make it difficult to correlate the tightly folded rock units across low- and high-angle faults. The few recognized stratigraphic directional indicators suggest that the rocks generally are not overturned but units have been repeated by folds and thrust faults. The preliminary stratigraphic section shown on figure 4 is based on the presence of similar rock sequences in each of the stratigraphically discordant structural plates (fig. 3). We interpret the repetitions in the section to be

bedding-subparallel thrust faults. The low-angle normal faults shown on the geologic map were mapped on the basis of brittle gouge, slickensides, and rock unit juxtaposition (fig. 3).

The base of the stratigraphic section is dolomitic siltstone and sandstone (unit Os), which is overlain depositionally by cherty argillite and chert (unit Oca), which in turn grades vertically to argillite, siltite, and channelized quartzite (units Osh and Oq), and then to limestone and calcareous diamictite (unit Ol). The stratabound metal system at Long Canyon is at the transition from argillite and quartzite (units Osh and Oq) to the calcareous rocks (units Ol and Os) (figs. 3, 5).

Footwall Stratigraphy

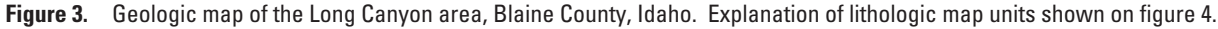
The exposed base of the lower Paleozoic section consists of a sequence (unit Os) of buff-colored dolomitic and calcareous sandstone, siltstone, and silty dolomite that weather to rusty colors (figs. 3, 4). These strata are characterized by relatively abundant bedding structures, including convolute beds, ripples, and planar laminations. We interpret these beds what Bouma (1962) called turbidites (Tbcde).

Black chert and cherty argillite (unit Oca) are in sharp, conformable contact with the underlying unit (Os). Unit Oca is exposed in the bottom of Long Canyon in the lowest structural plate as well as isolated thrust fault segments in higher structural plates (figs. 3, 5). The argillite is marked by few bedding structures and commonly has a near-bedding-parallel cleavage. Unit Oca contains as much as 50 percent structureless black chert.

A highly foliated argillite cataclasite in unit Oca (unit Ofa) is well exposed in the bottom of Long Canyon. In drill hole LC-3, the cataclasite is intersected between 165 and 200 ft (figs. 3, 5), indicating a minimum thickness of 35 ft. Contacts with the overlying and underlying cherty argillite (unit Oca) are gradational over intervals of several feet. The cataclasite exhibits a distinctive, intensely developed cleavage with abundant coplanar millimeter- to centimeter-scale tight, isoclinally folded quartz veins. Limbs of the isoclinal folds are parallel to the cleavage that defines the unit. The cleavage is parallel with a regional fabric in lower Paleozoic units of the Central Idaho black-shale belt.

Cherty argillite (unit Oca) grades upward to graptolitic, carbonaceous mudstone and siltstone (unit Osh). The latter strata are thin bedded and lack bedding structures; they were originally very carbonaceous, as indicated by the unoxidized carbonaceous centers of some of the larger pieces of float and from unoxidized parts of drill core. Poorly preserved graptolites, were collected by Cominco workers from the carbonaceous mudstone. The samples were analyzed by Claire Carter of the U.S. Geological Survey, who identified three species, *Climacograptus*, *Glyptograptus*, and *Orthograptus* and defined the age of as the mudstone and siltstone as Middle to Late Ordovician. The gossan-hosting section (unit Og) and correlative strata (units Ofc, Oc) are correlative with the upper parts of unit Osh (fig. 4).

Locally abundant coarse-grained massive quartzite beds and lenses (unit Oq) occur in the upper part of unit Osh (figs. 3-5). Some of the quartzite lenses are at and near the stratigraphic



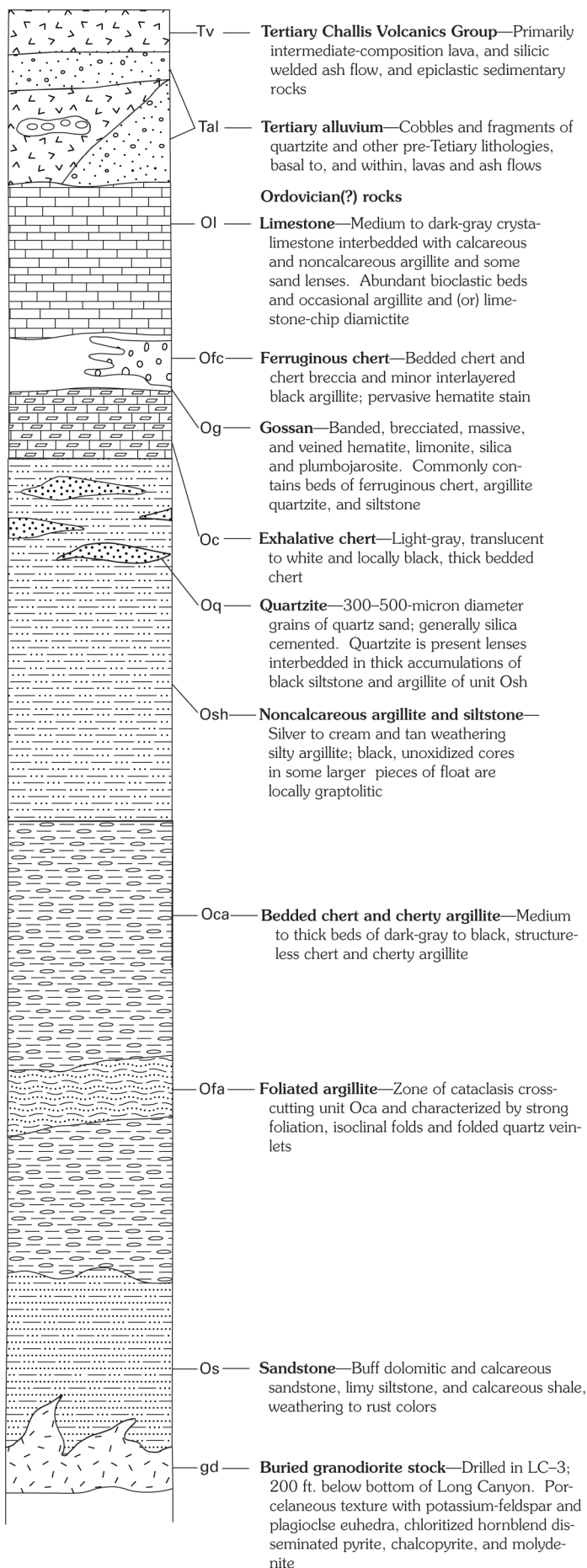


Figure 4. Composite stratigraphic column, Long Canyon area, Blaine County, Idaho.

position of the metal-bearing strata of units Ofc and Og. This observation is based on the map distribution of quartzite and gossan lenses and the presence of centimeter-scale laminations of coarse-grained quartzite that are interbedded with the cherty ironstone of units Ofc and Og. The beds of quartzite range from a few centimeters to several meters in thickness. Grain size of the quartz sand is as large as 1 mm, but generally averages 0.5 mm. Bedding orientation criteria and bedding structures are generally absent in the quartzite.

Mineralized Sedimentary Rocks

Metal-bearing sedimentary strata, mapped as three spatially separate but temporally equivalent units (units Ofc, Oc, Og), correlate laterally with the upper part of the carbonaceous mudstone of unit Osh.

Thin- to thick-bedded chert (unit Oc) forms the stratigraphic footwall of the gossan (unit Og) and laterally equivalent parts of unit Ofc (figs. 3, 4). In general, thicker beds and a thicker section of chert underlie the thickest and best developed gossan. Thinner sections of unit Oc with thinner chert beds underlie ferruginous cherty ironstone of unit Ofc. The chert is internally textureless in hand specimen and contains very uneven and distinctive load structures. Thicker bedded chert has load structures as much as 1 ft in diameter and 6 in. thick, whereas the thinner bedded chert contains load structures as much as a few inches in diameter. Immediately below the gossan, white to flesh-colored, medium- to thick-bedded chert contains load casts on bedding surfaces. Downsection, the chert grades to darker colors and the abundance of load structures in chert beds decreases. A hydrothermal exhalative origin is suggested for unit Oc by the changes in lateral thickness, the occurrence of chert beds and load structures, the light color, and the spatial association with metal-enriched strata.

Gossans (unit Og), in some places more than 50 ft thick, are underlain by chert of unit Oc and overlain by limestone of unit Ol. Oxidation of high-sulfide cherty strata likely produced the cherty ironstone and gossan of units Ofc and Og. At some gossan outcrops, millimeter-scale laminations of quartz sand, silt, and clay are present in massive and laminated hematite. At other outcrops, the processes of oxidation of sulfides, dissolution, and in situ reprecipitation of iron oxides have destroyed bedding structures.

A tremolite- and magnetite-bearing carbonaceous argillite, weathering to silvery colors, is structurally below the gossan of unit Og on the west side of Long Canyon near a buried granodiorite intrusion. Its exact stratigraphic position with respect to the gossan is unknown because of structural complexities and poor exposure; at some outcrops argillite directly underlies the gossan strata. The presence of tremolite suggests that the protolith was calcareous argillite, unlike strata nearer the thicker gossan to the northwest (fig. 3). A granodiorite intrusion at the 200 ft depth in the nearby LC-3 drill hole likely caused the calcification.

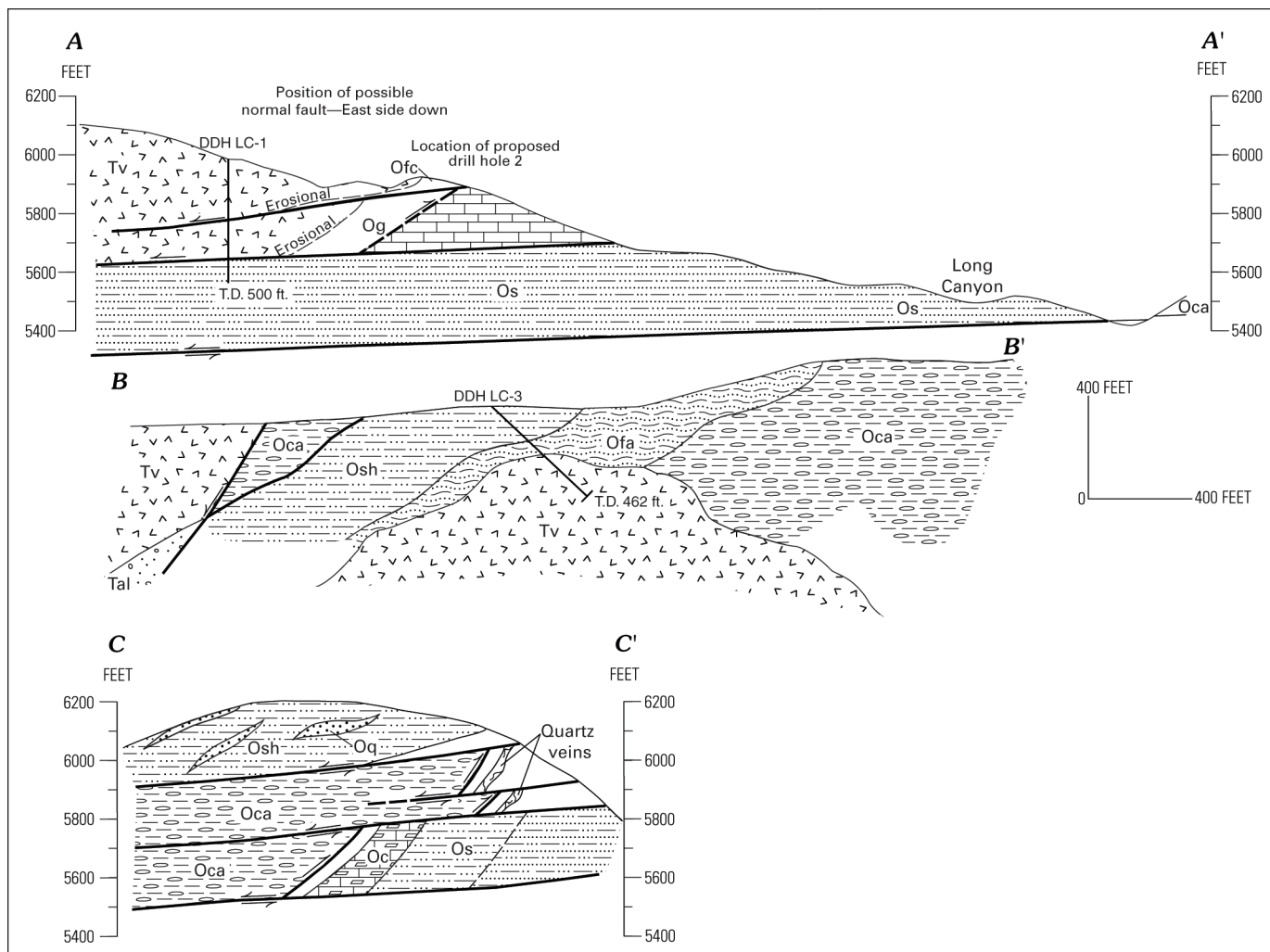


Figure 5. Geologic cross-sections A-A', B-B', and C-C', Long Canyon area, Blaine County, Idaho.

Surface rock-chip sampling and D-horizon soil sampling were conducted in gossans of unit Og. Samples collected near the gossans were analyzed for Cu, Pb, Zn, Au, Ag, and Ba, and show anomalous concentrations of Pb and Zn. Although scattered silver and copper values were detected, they are generally associated with epigenetic quartz veins in and near normal faults and probably not associated with the metalliferous strata of units Ofc or Og.

Lead concentrations in soil collected downslope from the gossans range from 150 to 1,000 ppm. These values decrease with distance from the gossan to a background level of 20-150 ppm. Lead concentrations in rock-chip samples collected from gossan exposures range from 2,000 to 3,000 ppm; locally they are higher. The lead in rock-chip samples is primarily plumbogjarosite.

Background concentrations of zinc in the Paleozoic strata range from 80 to 250 ppm. In soil samples, elevated levels of zinc form a broader dispersion halo than do elevated levels of zinc which are associated with the ferruginous chert of unit Ofc rather than the gossans. Concentrations of zinc in soil samples associated with unit Ofc typically range from 250 to 1,000 ppm; locally higher concentrations were measured. Soils developed on unit Og have zinc concentrations of 250-500 ppm. The area

of elevated zinc coincides with the ferruginous cherty strata and the low-angle faults that cut this part of the section indicating the possibility that zinc from the metal-bearing strata was remobilized along the structures.

Cherty and carbonaceous argillite of unit Osh grades laterally and upward to ferruginous chert and argillite (unit Ofc). The ferruginous chert contains a clastic component, including siltstone and fine- to medium-grained sandstone. Although unit Ofc is dominantly ferruginous chert, it includes gradations from massive, bedded silica ironstone to ferruginous mud-rich clastic rock. Local erratic distribution of the ferruginous chert and argillite (unit Ofc) may reflect structural dismembering of a single stratum or multiple and separate depositional lenses of those lithologies. Unit Ofc grades laterally into unit Og and represents a distal facies of the oxidized sulfidic strata.

Hanging-Wall Stratigraphy

Massive gray limestone, silty limestone, and limy diamictite (unit Ol) overlie carbonaceous argillite (unit Osh) and gossanous strata (units Og, Ofc) (figs. 3, 4). The limestone and silty limestone consist of a shelf-derived accumulation of carbonate

and abundant organic debris and fossil hash. Bedding structures are generally lacking in these strata, probably because of overprinting by S1 cleavage. Limy mud-matrix diamictite locally constitutes much of the limestone section and consists of mud-supported, rounded siliciclastic and carbonate clasts in a lime-mud matrix. All of the clasts are lithologies similar to nearby strata, suggesting local derivation. Thickness of the unit is unknown because of structural dismemberment.

Age Correlation

Skipp and Hall (1975) and Skipp and Sandberg (1975) mapped the Long Canyon area as part of the Devonian Milligen Formation. Although similar in lithology and vertical lithological progression to the Milligen, Middle to Late Ordovician graptolites (unit Osh) also exhibits a partial correlation with the Lower Ordovician to Middle Silurian Phi Kappa Formation of the Trail Creek area (Claire Carter, oral commun., 1995). The Phi Kappa Formation, as described by Carter and Churkin (1977), is an "unbroken succession from late Early Ordovician through latest Ordovician" that is only 200 m (656 ft) thick. Although some unit Osh strata are clearly Ordovician in age, higher parts of the section may also correlate with younger units, such as the Trail Creek or Milligen Formations, or with the unnamed Silurian and Devonian unit of Dover (1980). Because the mineralized strata of units Og, Ofc and Oc correlate laterally to unit Osh, we believe that the gossan strata are likely Ordovician in age.

Tertiary Rocks

Andesite flow rocks, welded rhyolite lapilli ash-flow tuff, and epiclastic sedimentary rocks (unit Tv) exposed in the Long Canyon area are part of a regionally extensive sequence of the Challis Volcanic Group that erupted from nearby sources (figs. 3-5). The andesite flow rocks are both aphyric and plagioclase-porphyritic. Individual flows, as thick as 50 ft, covered the entire area prior to late Tertiary erosion. The rhyolite lapilli ash-flow tuff is a single cooling unit approximately 20 ft thick that is interlayered with andesitic lavas. The ash flow deposits likely erupted from a vent 4 mi west of Long Canyon near the Little Wood River. A sequence of epiclastic sedimentary rocks of unknown thickness interbedded with the andesite lavas represents deposition and emplacement in a Challis-age fluvio-lacustrine drainage system. These poorly indurated strata include tuffaceous sandstone, siltstone, and mudstone.

A laterally extensive sequence of well-rounded, coarse-grained, gravel beds and local accumulations of fanglomerate underlie and are interbedded with the Challis lavas (unit Tal, figs. 3, 4). The temporal and spatial relations between the coarse gravel deposits and the epiclastic sedimentary rocks are unclear. The gravel deposits generally contain volcanic detritus, suggesting that deposition occurred after the first eruption of Challis lavas, although in places gravel deposits are found at the base of the volcanic pile. Extensive gravel and conglomerate deposits of similar age are present north and northeast of Long Canyon in the upper Fish Creek drainage.

High-energy streams that drained a source area to the north deposited the Tertiary conglomerate. Similar and thicker clastic deposits of the same age are known to occur in upper Fish Creek Valley to the north and northeast. The position of the gravel with respect to surrounding bedrock exposures indicates deposition in an area of high relief, similar to that in the region today. Surface oxidation coincidental with this erosional event or a later event reached a minimum depth of 700 ft, as seen in drill hole DDH C-2.

Crystalline rocks exposed at Long Canyon include dikes of quartz-porphyry rhyolite and andesite. A Tertiary or younger age for the dikes is demonstrated by their presence in low-angle fault breccia that cuts Eocene-age volcanic rocks.

A diamond drill hole collared on the floor of Long Canyon intersected and drilled 200 ft into an altered and mineralized porphyritic granodiorite stock (fig. 4). The age of this stock is unknown; however, its texture and mineralogy are similar to those of Late Cretaceous stocks in the Wood River area to the north. The only surface expression of the intrusion is minor development of a calc-silicate mineral assemblage in nearby calcareous strata. The granodiorite has a porcellaneous hypabyssal texture, with phenocrysts of hornblende, plagioclase, and potassium feldspar in an aphanitic groundmass. Alteration of the stock includes chloritization of hornblende and white clay alteration of feldspars and groundmass. Pyrite, chalcopyrite, sphalerite, and molybdenite are disseminated throughout the rock in trace amounts; locally samples from the stock yield assays of more than 2,100 ppm Zn, 1,600 ppm Cu, 200 ppm Mo, and 5 ppm Ag.

Structure

Two folding events and several generations of thrust faulting and normal faulting complicate the geology of Long Canyon. Poor exposure hinders an understanding of the structural geology.

Folds

Argillite exposed at Long Canyon records two folding events. A refolded, intensely developed S1 cleavage characterizes the older of these. The folded cleavage, described by Sandberg and others (1975), Skipp and Hall (1975), and Turner and Otto (1988), cuts bedding at a low angle and locally forms axial planes to tight, isoclinal folds in bedding. Although pervasive in the argillite, the cleavage is best developed in the cataclastic zone that defines the foliated argillite of unit Ofa. Regional-scale folds associated with the early cleavage are not documented but may be present. The pervasive S1 cleavage is similar in style and occurrence to cleavage described by Otto and Turner (1987) and Turner and Otto (1988), attributed by them to the early Paleozoic Antler tectonic event.

The second folding event resulted in tight folds with S1 cleavage and bedding. Locally, the later folding event created an S2 fracture cleavage that crosses S1 at a high angle. The F2 folds are commonly seen in outcrop, but regionally the F2 folds lack

definition primarily because of superimposed faulting and poor exposure. One such regional anticline is on the floor of Long Canyon (fig. 3); it repeats the stratigraphic section over a limb-to-limb distance of 3,000 ft. The inverse repetitions of strata and fluctuations in the attitude of bedding and cleavage suggest the presence of other megascopic F2 folds. This style of folding and related thrust faulting has been described previously and is generally recognized as Mesozoic in age (Skipp and Hait, 1977; Dover, 1980; Otto and Turner, 1987; Burton and Link, 1989; Link and Mahoney, 1989).

Faults

Thrust faults of probable Mesozoic age, low-angle normal faults of Tertiary age, and high-angle faults of Tertiary age are present in the long Canyon area. Thrust faults of early Paleozoic age may be present, but their presence is not documented.

Thrust faults of probable Mesozoic age, present throughout the area, have multiple orientations. They generally strike north to northwest and dip 30°–45° to the west. The faults form boundaries between stratigraphic domains of different bedding and cleavage orientation. The northwest-trending faults bound strata that have a northwest-southeast structural strike, whereas the north-trending faults bound strata that have a north-south structural strike. The difference in orientation of these structures may be a function of one of the following: (1) two temporally unique faulting events, (2) later folding of one fault set, or (3) differential rotation by Tertiary low-angle normal faults. Geologic mapping suggests that there was rotation of thrust fault segments across Tertiary low-angle normal faults (fig. 3). The thrust faults are locally identified by indurated fault gouge and by repetition of the stratigraphic section. Some structures bifurcate, forming fault-bounded duplexes that are particularly common in units Og and Ol.

The thrust faults cut the sulfidic strata of units Og and Ofc (figs. 3, 5) and controlled development of a pre-Challis-age drainage system. The canyons that formed along the traces of the structures served as sites of deposition for Challis-age gravel. Many of the gravel fragments are rock types that are present in the Long Canyon area, suggesting that the gravel was locally derived.

Thrust faults of early Paleozoic age have not been conclusively identified. The cataclastic zone (unit Ofa, figs. 3–5) is an intensely developed area of S1 cleavage that is believed to have formed during the earliest recorded deformation. Other isolated outcrops of S1-parallel cataclastic argillite are in areas of stratigraphic repetition. Those cataclastic rocks may be the products of contractional movement during Antler tectonism, as described by Turner and Otto (1988).

Tertiary-age high-angle and low-angle normal faults are present throughout the area. Low-angle normal faults dominate the structural style and generally are older than the high-angle faults.

Four low-angle extensional faults separate five subhorizontally oriented and laterally continuous structural plates (fig. 3). The lowest structural plate crops out only in the bottom of Long Canyon, and the higher plates crop out on adjacent hillslopes and ridgetops (figs. 3, 5). The low-angle faults typically dip

2°–10° to the west and southwest; however, their present dip may result from downwarping of the Snake River Plain. In areas where detailed geologic maps are available, mapped low-angle structures demonstrate a southeast-northwest direction of transport similar to that described in the Hailey area by Turner and Otto (1988). The smallest of the known low-angle faults has a minimum of 600 ft displacement; the larger faults likely moved greater distances. The lowest exposed low-angle fault juxtaposes dissimilar rocks throughout the area, suggesting a total displacement of more than 2000 ft. Intraplate, low-angle faults of small displacement are present locally. One such fault cuts the gossan on the west side of Long Canyon and has a hanging-wall displacement of approximately 200 ft to the southwest (fig. 3). Gouge zones with subhorizontal slickensides across which rocks show lithological discontinuity are visible in low-angle faults. Breccia zones of the low-angle faults are typically rubbly and unconsolidated; sample recovery is poor in drill hole intersections and recessive weathering occurs along surface exposures. Gouge zones of the larger faults are as thick as 50 ft. The breccia zones serve as ground-water courses, as demonstrated by the loss of drilling fluids and by differential oxidation between the fault breccia and wallrock.

High-angle normal faults cut the low-angle faults and have two orientations, north-south and east-west. The north-south faults predate the east-west structures. The best example of a north-south fault separates Paleozoic strata from Tertiary volcanic rocks along the western margin of the Paleozoic outcrop belt (fig. 3). This fault has a west-side-down geometry of unknown displacement. The north-south faults are Eocene or younger in age because they cut Eocene volcanic rocks. These faults are geometrically similar to Neogene faults that bound the Wood River graben to the north.

East-west structures identified in the southern part of the area define the northern margin of the Snake River Plain. These faults juxtapose Paleozoic and Tertiary stratigraphy, cut north-south faults, and show a south-side-down sense of movement.

Discussion

A coarsening- and thickening-upward lower Paleozoic stratigraphic section at Long Canyon in Blaine County, Idaho is believed to be a remnant of a prograding, sub-wave-base depositional system. The following preliminary interpretation fits available data and published models of prograding submarine fan complexes (Walker, 1981).

The exposed base of the Long Canyon section consists of an unknown thickness of dolomitic sand and siltstone (unit Os). Chert and cherty argillite (unit Oca) record the initiation of pelagic and siliceous chemical sedimentation in a starved, euxinic, sub-wave-base depositional environment. Carbonaceous argillite (unit Osh) overlying the cherty section records encroachment of a distal, active depositional environment. This environment is suggested by thick accumulations of thin, planar-bedded mudstone lacking current-generated bedding structures and by the presence of graptolites. We interpret these strata to be similar to distal Tde turbidites described by Bouma (1962). Higher in the section, the distal Tde turbidites are interspersed

with sandstone of unit Oq, which represents a feeder system to a prograding clastic wedge. The sandstone strata include channel sandstone lenses and local overbank accumulations of thin-bedded sandstone laminae in the argillite.

Deposition of calc-turbidites of unit Ol demonstrates the end of the low-energy sedimentation represented by unit Osh. The shelf-derived limestone was deposited as channel diamictite and as laterally continuous sheets. Where bedding structures are preserved, the limestone units are Tbcde calc-turbidites (Bouma, 1962) that were deposited in an active high-energy environment. The calc-turbidites of unit Ol are exposed at the top of the Long Canyon section.

Gossan horizons at Long Canyon are between the top of the argillaceous strata of unit Osh and the bottom of the calcareous turbidites of unit Ol; they form unit Og and parts of unit Ofc. Bedding structures and clastic-bedding thicknesses in the metaliferous strata suggest that the depositional environment during formation of the strata was similar to that attributed to unit Osh. The metal-bearing parts of the units are stratabound in some places and stratiform in other places. The metals may have been introduced as original chemical sediment, during later diagenesis, or as replacement of lithified rocks during emplacement of the granodiorite stock. Association of mud-matrix diamictite, hydrothermal chert, and stratiform textures in metal-enriched rocks suggests mineralization was syngenetic or early diagenetic. The lateral correlation of metalliferous strata with unit Osh suggests an Ordovician age for the mineralization.

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