U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

To accompany the

Preliminary Geologic Map of the Snow Gulch Quadrangle, Humboldt and Lander Counties, Nevada

by

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with a section on

Radiolarians in the Ordovician Valmy Formation and Devonian Scott Canyon Formation

by

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and a section on

Helicoprion sp. from the Pennsylvanian and Permian Antler Peak Limestone, Lander County, Nevada

by

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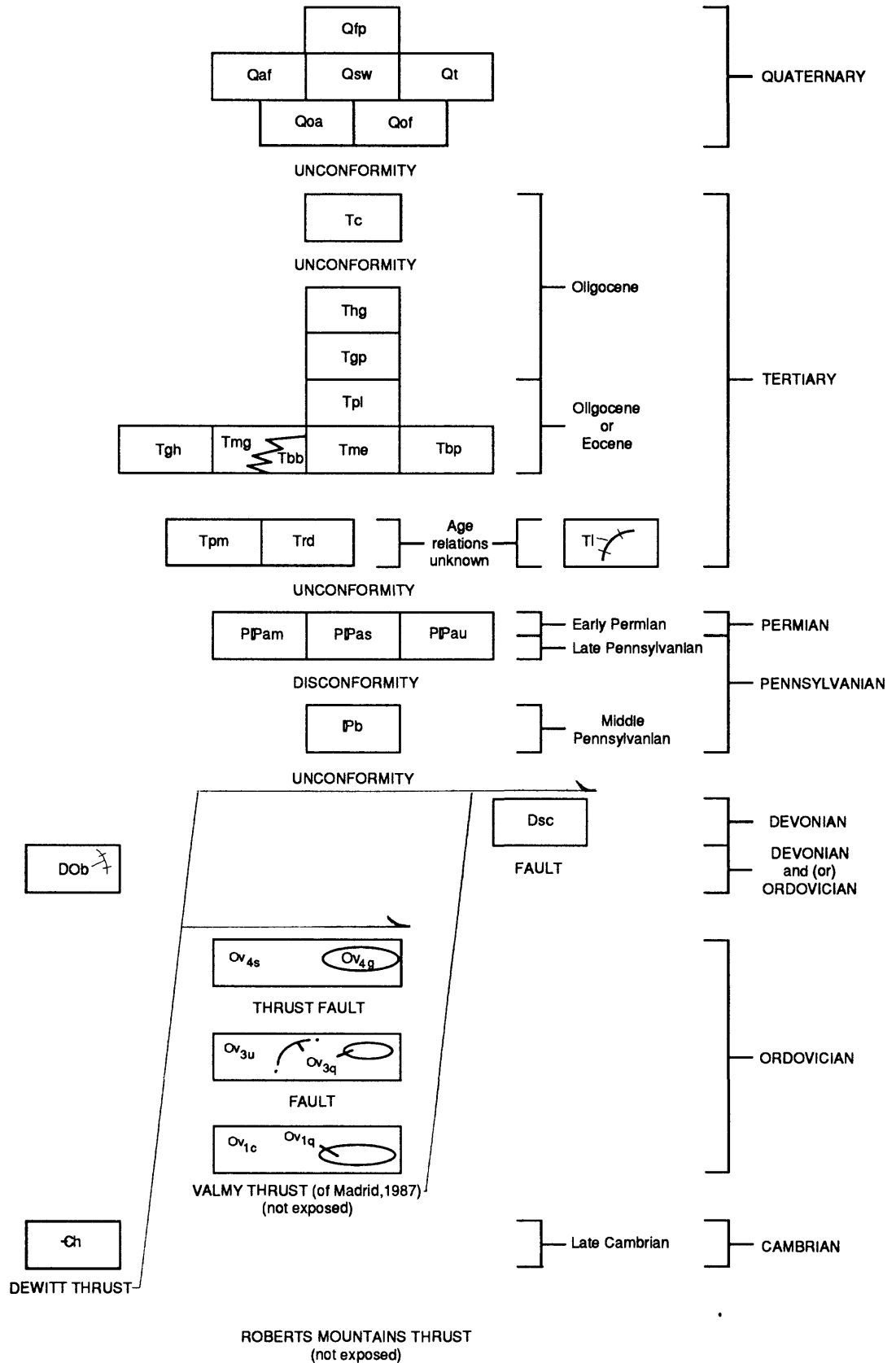
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CORRELATION OF MAP UNITS

	Qfp	
Qaf	Qsw	Qt
	Qoa	Qof

UNCONFORMITY — QUATERNARY

Tc

UNCONFORMITY

Thg

Tgp

Tpl

Tgh	Tmg / Tbb	Tme	Tbp

Oligocene

Oligocene or Eocene

TERTIARY

Tpm	Trd

Age relations unknown

Tl

UNCONFORMITY

PIPam	PIPas	PIPau

Early Permian — PERMIAN
Late Pennsylvanian

DISCONFORMITY

Pb

Middle Pennsylvanian — PENNSYLVANIAN

UNCONFORMITY

Dsc — DEVONIAN

FAULT

DEVONIAN and (or) ORDOVICIAN

DOb

Ov4s	Ov4g

THRUST FAULT

Ov3u	Ov3q

FAULT

Ov1c	Ov1q

VALMY THRUST (of Madrid,1987)
(not exposed)

ORDOVICIAN

€h

DEWITT THRUST

Late Cambrian — CAMBRIAN

ROBERTS MOUNTAINS THRUST
(not exposed)

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DESCRIPTION OF MAP UNITS

Qfp   **Flood plain deposits (Quaternary)**--Includes silt, sand, and clay
             deposits along the flood plain of the Humboldt River

Qaf   **Younger alluvium and fanglomerate deposits (Quaternary)**--
             Locally includes some flood deposits at various places confined narrowly
             along major drainages emanating from the areas of exposed bedrock in the
             quadrangle

Qt   **Talus deposits (Quaternary)**

Qsw   **Slope wash deposits (Quaternary)**

Qoa   **Older alluvium (Quaternary)**--Confined largely to relatively narrow
             drainages in mountainous areas of the quadrangle. Probably equivalent in
             age to older fanglomerate deposits (Qof)

Qof   **Older fanglomerate deposits (Quaternary)**--Contacts approximately
             located using large-scale color aerial photographs. Age relative to younger
             alluvium and fanglomerate deposits determined by degree of dissection and
             relative superposition of drainages. Probably equivalent in age to older
             alluvium (Qoa)

Tc   **Caetano Tuff (Oligocene)**--Pinkish-gray crystal lithic ash-flow tuff
             present as erosional outflow-facies-remnant of regionally extensive,
             approximately 34.5-Ma (recalculated from McKee and Silberman, 1970)
             Caetano Tuff of Gilluly and Masursky (1965). Crops out only near the
             southeast corner of the quadrangle in SE 1/4 sec. 22, T. 32 N., R. 44 E.
             The tuff farther to the south contains three lithologic units (Roberts, 1964):
             a lower poorly welded, grayish orange-to pale-pink biotite crystal tuff; a
             dark gray to black, welded hornblende-biotite-quartz vitrophyre; and an
             upper partly devitrified welded tuff. These three units are not subdivided on
             the accompanying map. The upper parts of the unit generally weather to
             rounded, exfoliated forms. The tuff has been tilted gently to the east, in
             places as much as 10° to 15°, in the general area around the promontory at
             Elephant Head immediately to the south of the quadrangle (Roberts, 1964;
             Theodore and Jones, 1992)

Thg   **Hornblende granodiorite porphyry of the Overlook claim area
             (Oligocene?)**--Crops out only in the area of the Overlook claims (in SE
             1/4 sec. 17, T. 32 N., R. 44 E.) as a narrow dike emplaced into Oligocene
             granodiorite porphyry and rocks of the Upper Cambrian Harmony

Formation. Weathers to ochre red-brown angular blocks as opposed to rounded, knobby exposures of nearby Oligocene granodiorite porphyry. Fresh exposures are generally light gray. Includes roughly 10 to 15 volume percent propylitically altered hornblende phenocrysts, as much as 1 mm long, set in a relatively fresh cryptocrystalline quartz-plagioclase matrix (typically as much as 60 to 70 volume percent). Matrix averages approximately 0.02 mm in grain size. Other phenocrysts, as much as 15 to 30 volume percent of the rocks, are partially resorbed quartz, glomeroporphyritic clots of variably altered plagioclase (as much as 5 mm in long dimension), and sparse propylitically altered books of biotite. Hornblende phenocrysts now consist of sundry mixtures of chlorite, epidote, sphene, and opaque minerals

Tgp   **Granodiorite porphyry (Oligocene)**--Most widely exposed of the various intrusive units in the quadrangle and generally best exposed as rounded knobby hill-forming dikes and elongate masses along ridgetops. Many emplaced along north-striking faults. Commonly gray on fresh surfaces, but in places deeply weathered to various shades of drab pale orange. Locally contains conspicuous 2- to 4-cm-wide euhedral K-feldspar phenocrysts and subrounded "eyes" of quartz bipyramids, together making up as much as 15 volume percent of the rocks. Large books of primary biotite are partly altered to chlorite. Groundmass mostly aphanitic, but may contain fairly abundant partially chloritized needles of hornblende. Some dikes show contact metamorphic aureoles at least 30 to 50 m wide. Primary hornblende in granodiorite porphyry from SW 1/4 sec. 21, T. 32 N., R. 44 E., near the south edge of the quadrangle, yielded 35.4 ± 1.1-Ma age by potassium-argon method (McKee, 1992). Similar appearing dike at south end of Lone Tree Hill, approximately 10 km to the northwest of the quadrangle, yielded potassium-argon ages of 39.4 ± 1.2 Ma and 36.3 ± 1.3 Ma on biotite and hornblende respectively (E.H. McKee, written commun., 1993)

Tpl   **Porphyritic leucogranite (Oligocene or Eocene)**--Most of this unit is confined to a relatively large composite body, including porphyritic monzogranite and porphyritic tonalite phases, that crops out in the south-central part of the area near the south edge of the quadrangle (Theodore and others, 1992). Exposures commonly weather to smooth slopes marked by light-yellowish-white to locally grayish white colors as a result of the overall low color index of the unit. Some of the coarse-grained porphyritic facies weather to a blocky landscape of angular

exposures reflecting presence of well-developed joints. Numerous satellitic bodies of the unit cannot be shown on the map because of their small size. Also, the two phases, each quite lithologically homgeneous, are not subdivided on the accompanying geologic map and include clinopyroxene- and (or) hornblende-dominant hypersolidus assemblages. The two dominant monzogranite and tonalite phases of the unit respectively include either a K-feldspar-rich or plagioclase-rich quench-textured groundmass. Porphyritic leucogranite, *sensu lato,* is associated genetically with widespread development of andradite-diopside skarn generally to the southeast of the large body (Theodore and Hammarstrom, 1991). Porphyritic leucogranite also appears to be genetically associated with gold mineralization at the Labrador gold-skarn deposit just south of the south edge of the quadrangle (Theodore and others, 1992). Primary hornblende from porphyritic leucogranite yields 37.7 ± 1.4-Ma age by potassium argon method (McKee, 1992). Porphyritic leucogranite is intruded by Oligocene granodiorite porphyry

Tgh　　**Granodiorite of hill 6010 (Oligocene or Eocene)--**Crops out as a number of small intrusive bodies in the southern part of the quadrangle mostly in SW 1/4 sec. 17, but also in a relatively large body that straddles the common border between sec. 18 and sec. 19, all in T. 32 N., and R. 44 E. The unit name is taken from a hill along which prominent exposures of the granodiorite are present in NE 1/4 sec. 19, and provide the basis for initial descriptions of the unit (Theodore and others, 1992). Petrographically very similar to Oligocene hornblende granodiorite of the Overlook claim area, but appears to be older than that unit. Generally, granodiorite of hill 6010 is a fine- to medium-grained altered granodiorite, of which the southern lobe of the largest body of this unit has been emplaced as a sill-like mass apparently astride a north-northeast trending hingeline of a minor fold in the adjoining Harmony Formation (Theodore and others, 1992). Actinolite-dominant alteration assemblages are strongly associated with this unit and the presence of similar alteration assemblages in some phases of Eocene or Oligocene porphyritic leucogranite suggest that granodiorite of hill 6010 is the same age as porphyritic leucogranite. Granodiorite of hill 6010 has not been dated radiometrically, but the unit is intruded by Oligocene granodiorite porphyry (Tgp) in SW 1/4 sec. 17, T. 32 N., R. 44 E.

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Large body of granodiorite of hill 6010 includes two undivided phases: a mostly hypidiomorphic-granular phase, including local porphyritic textures, and a predominantly porphyritic phase. Both phases are dominated by presence of dispersed needles of phenocrystic hornblende. Small body of this unit that crops out in SE 1/4 sec. 17, T. 32 N., R. 44 E., is the porphyritic variety, and shows gray-white fresh surfaces that weather orange red-brown, and includes less than 10 volume percent , approximately 0.5-cm-wide quartz bipyramids and 0.4- to-0.5-mm-long needles of hornblende set in an aplitic plagioclase-rich matrix. Igneous fabric of rock is cut by microveins of amphibole. As mapped in SE 1/4 sec. 17, the unit may include some minor dikes of Oligocene granodiorite porphyry. K-feldspar-stable alteration in the unit includes actinolite + sphene assemblages, essentially as replacements of primary hornblende. Feldspar-destructive alteration includes chlorite + sphene + actinolite assemblages at the sites of former primary mafic minerals, and a conversion of plagioclase to a brownish mat of clay(s) + white mica

Tmg   **Biotite-hornblende monzogranite of Bluff area (Oligocene or Eocene)**--Distinctive biotite-hornblende monzogranite that crops out in the general area of a craggy promontory termed "Bluff" on large-scale topographic maps of the mining district (Theodore and others, 1992) is present in an approximately 0.6 km^2 body that straddles the boundary between secs. 19 and 20, T. 32 N., R. 44 E., just to the north of Poorman's Gulch. A number of small similar bodies of biotite-hornblende monzogranite of the Bluff area are also present nearby in the surrounding wallrocks belonging to the Harmony Formation. Rocks of the unit generally are deeply weathered owing to relatively high proportions of modal biotite and hornblende imparting a color index of 20 to 25 to the unit. Porphyritic phases are also present in the unit, but are not designated separately on the accompanying map. Much of the biotite-hornblende monzogranite of the Bluff area is cut by quartz stockworks, individual veins of which are typically banded, planar, and continous for distances in the range 0.5 to 1.5 m. Emplacement of these quartz stockwork veins occurred both prior to and after development of the Oligocene or Eocene breccia pipe of the Bluff area which appears to be genetically associated with emplacement of biotite-hornblende monzogranite of the Bluff area (see below). Biotite-hornblende monzogranite of the Bluff area is intruded by both Oligocene or Eocene porphyritic leucogranite (Tpl) and by Oligocene granodiorite porphyry (Tgp). Primary hornblende from biotite-hornblende

monzogranite of the Bluff area yields a 39.0 ± 1.1-Ma age and a primary biotite from another sample yields a 39.3 ± 1.0-Ma age by the potassium argon method (McKee, 1992)

Tbb   **Breccia pipe of Bluff area (Oligocene or Eocene)--**Crops out in generally resistant and rugged exposures in an approximately 200- by 500-m portion of the Oligocene or Eocene biotite-hornblende monzogranite of the Bluff area (Tmg) (Theodore and others, 1992). Includes metasedimentary and sedimentary rocks from several formations, together with several types of igneous rock. Most common metasedimentary fragments are angular fragments of biotite hornfels of the Upper Cambrian Harmony Formation, replaced partly by K-feldspar along their margins. Fragments derived from either the Ordovician Valmy Formation or Devonian Scott Canyon Formation are also present. Igneous fragments include veined and unveined biotite-hornblende monzogranite of the Bluff area, rhyolite porphyry, and diabase, the latter probably equivalent in age to Devonian and (or) Ordovician basaltic dikes. Matrix of the breccia of Bluff area in places contains a magnetite-diopside-quartz-K-feldspar mineral assemblage, but the most common one is an amphibole-K-feldspar-sphene-quartz ± pyrite ± chalcopyrite(trace) assemblage. The presence of chalcopyrite is inferred from presence of local concentrations of secondary copper minerals in the breccia pipe. Emplacement of the breccia pipe of Bluff area appears to overlap, temporally, emplacement of quartz stockworks that are present in a small part of the breccia pipe, but are much more widespread in the nearby biotite-hornblende monzogranite of the Bluff area. Some outcrops in the breccia pipe show termination of quartz veins at fragment-matrix interfaces, and other outcrops show quartz veins that cut fragment-matrix interfaces

Tme   **Porphyritic monzogranite of the Elder Creek area (Oligocene or Eocene)--**Large number of small, generally potassic-altered intrusive bodies clustered in general area of Elder Creek. Associated genetically with emplacement of the approximately 5-km-wide Elder Creek porphyry copper system, the broad core of which is probably centered approximately in NW 1/4 sec. 1, T. 32 N., R. 43 E. Most porphyritic monzogranite of the Elder Creek area is present within the area of outcrop of quartz stockwork veins associated with the system. Includes undivided hornblende-biotite and biotite-only phases, both showing highly variable concentrations of phenocrystic quartz bipyramids. Presence of numerous pendants in porphyritic monzogranite suggests that current overall level of

exposure of the system probably approaches highest levels to which the system was emplaced in the crust. Locally abundant secondary copper minerals and locally intense flooding and stockwork veining by quartz result in almost complete obliteration of igneous fabric of the rocks. Quartz stockworks in some places, as near the portal to the Morning Star Mine, define well-developed "stars" in outcrops indicative of their being close to the center of the porphyry system. Many outcrops in general area of the center of the system also show abundant concentrations of secondary copper minerals, including blue and green varieties of chrysocolla, and secondary copper oxides, all formed in porphyritic monzogranite of the Elder Creek area and its adjoining wallrocks. Some outcrops of brecciated rock show development of slickensides on secondary-copper-bearing fractures indicative of post-mineral movement along prominent N. 45° W.-striking joints cutting porphyritic monzogranite. In addition, some exposures of brecciated rock include well-rounded fragments of biotite hornfels derived from protoliths of the Upper Cambrian Harmony Formation, and these brecciated rocks show infilling by porphyritic monzogranite and subsequent veining by additional copper-stained quartz veins. These relations suggest that some brecciation near the core of the porphyry system preceeded final circulation of fluids associated with development of the porphyry system.

Sample of primary biotite from porphyritic monzogranite obtained from NE 1/4 sec.2, T. 32 N., R. 43 E., yields 37.3 ± 0.7-Ma age by the potassium-argon method (Theodore and others, 1973).

Petrographic examination of approximately 20 samples of porphyritic monzogranite indicate quenched aplitic groundmass (average grain size in the range 0.06 to 0.12 mm) throughout the unit, which groundmass includes mostly quartz and K-feldspar, and minor amounts of biotite and hornblende. Plagioclase (An_{35-45}) is exclusively phenocrystic and K-feldspar is almost entirely confined to the groundmass suggesting that bulk of the quenching occurred just before evolution of the chemical composition of the magma(s) reached the cotectic between plagioclase solid solution and K-feldspar solid solution. Those samples containing phenocrystic K-feldspar show the K-feldspar to be approximately one-third to one-tenth the size of the plagioclase and also show a corresponding decrease in the amount of K-feldspar present in the groundmass. However, other samples

showing comparatively small volumes of groundmass (roughly 10 volume percent) do not show added presence of phenocrystic K-feldspar. Crystallization of primary biotite appears to have preceded that of hornblende except in those rocks showing relatively high concentrations of hornblende and, in places, hornblende and biotite continued to crystallize synchronous with development of groundmass. Porphyritic monzogranite showing abundant modal hornblende shows multiple generations of hornblende, including some that crystallized prior to final crystallization of biotite phenocrysts and some that is definitely secondary.

Classic indications of potassic alteration are reflected in predominant presence of feldspar-stable alteration assemblages indicated by (1) secondary biotite replacing primary hornblende and primary biotite, (2) quartz-K-feldspar ± biotite ± hornblende ± sphene in veins cross-cutting igneous fabric of porphyritic monzogranite, and (3) widespread presence of K-feldspar in alteration selvages along margins of quartz ± K-feldspar ± sulfide veins. Minor accessories include sphene (primary and secondary), apatite, and traces of allanite. Overall intensity of potassic alteration (mostly as replacement of hornblende by shreddy secondary biotite) decreases in narrow dikes of porphyritic monzogranite cropping out near the outer limit of quartz stockwork veins. Late-stage chlorite, primarily as a marginal alteration of primary and secondary biotite is generally sparse, although some rocks show complete replacement of primary biotite by chlorite, and a few other samples of porphyritic monzogranite show chlorite + K-feldspar + epidote + sphene veins. Throughout the porphyritic monzogranite, effects of intermediate argillic alteration (white mica + clay alteration of plagioclase and continued stability of K-feldspar) appear to be confined to areas close to some of the major post-mineral faults that cut the porphyry system, such as the Elder Creek fault. Additional details about the porphyry system are included in the section below titled "The Elder Creek Porphyry Copper System"

Tbp **Breccia pipe (Oligocene or Eocene)**--Small breccia pipe present in SE 1/4 sec. 1, T. 32 N., R. 43 E., near approximate outer limit of epigenetic alteration shown by recrystallization of feldspathic sandstone and quartz arenite of the Upper Cambrian Harmony Formation to biotite hornfels and (or) pyrite-bearing mineral assemblages and related to the Elder Creek porphyry system. Poorly exposed, but possibly as much as 30 m wide based on extent of breccia float on colluvium-covered slopes. Not

dated radiometrically, but inferred to be approximately the same age as porphyritic monzogranite of Elder Creek area. Includes poorly-sorted, matrix-supported fragments of dark gray chert and dark gray shaly argillite from Ordovician Valmy Formation. Additional fragments noted in thin section also include phyllic-altered felsite containing small phenocrysts of quartz, quartzarenite of the Valmy Formation, and phyllic-altered feldspathic arenite of the Harmony Formation. Dark-gray matrix includes variably comminuted fragments of all of the types of lithology listed above, and sparse development of secondary euhedral K-feldspar along narrow discontinuous quartz veins that course through the breccia. No widespread increase in alteration visible in outcrops close to the pipe

Tpm　**Porphyritic hornblende-biotite monzogranite (Tertiary)--Crops** out only as a cluster of small intrusive bodies in sec. 18, T. 32 N., R. 44 E., and shows a surrounding aureole of biotite hornfels that extends as much as 0.8 km from the largest exposed body of this unit. Part of the aureole in NW 1/4 sec. 18 includes conversion of some calcareous shale sequences of the Upper Cambrian Harmony Formation to diopside hornfels with surrounding selvages of chalcedonic quartz. Not dated radiometrically, but most likely Tertiary in age. Includes some related composite banded quartz veins that are planar and throughgoing as they extend through the igneous fabric of the unit. Phenocrysts include plagioclase (An$_{45}$), quartz (many showing continued crystallization after formation of quenched groundmass), biotite (red brown [optic Z-axis] in thin section), and pale gray-green hornblende (many altered to intergrowths of chlorite, calcite, and epidote). All K-feldspar is in the groundmass, which typically averages approximately 0.06 mm in grain size

Trd　**Porphyritic rhyodacite (Tertiary)--Crops** out only in a number of small inrusive bodies near the south-central border of the quadrangle in NE 1/4 sec. 24, T. 32 N., R. 43 E., and NW 1/4 sec. 19, T. 32 N., R. 44 E., and, as mapped, includes a small intrusive mass of rhyolite that crops out in SW 1/4 sec. 21, T. 32 N., R. 44 E., near the south edge of the quadrangle. Intensely altered, showing in thin section clouded oligoclase phenocrysts, heavily chloritized and carbonate-altered hornblende, and chloritized biotite. Also includes secondary sphene and secondary apatite, both noted in thin section to be concentrated at sites of former primary hornblende (Theodore and others, 1992). However, the surrounding feldspathic arenite of the Upper Cambrian Harmony Formation is not notably altered to similar propylitic assemblages. Two fairly large bodies of

rhyolite near the Little Giant Mine, approximately 1.5 km south of the south border of the quadrangle yielded 39.1 ± 1.0-Ma and 37.3 ± 1.1-Ma ages from primary biotite separates (McKee, 1992)

Tl **Lamprophyre (Tertiary?)**--Crops out only in SW 1/4 sec. 36, T. 33 N., R. 43 E. as an approximately 2- to 3-m-wide, brownish-black fine-grained dike emplaced into contact metamorphosed rocks of the Upper Cambrian Harmony Formation and cut by quartz-stockwork veins associated with the Oligocene or Eocene Elder Creek porphyry copper system. Relatively well exposed in shallow bulldozer cut. In thin section, found to be composed essentially of apparently compatible euhedral blue-green (optic Z-axis) hornblende (average grain size 0.1 mm), clouded plagioclase (approximately An_{60}), and dark brown (optic Z-axis) primary biotite--listed in order of declining abundance. Hornblende probably makes up about 60 volume percent of the rocks. Biotite includes 10- to 20-μm anhedral blebs of ilmenite, confirmed by scanning electron microscope (SEM), which in turn are mantled by thin rims of sphene. Biotite also includes some uncommonly small grains of zircon, approximately 0.2 μm wide. Extremely sparse K-feldspar in lamprophyre associated with late-stage hornblende-quartz veins. The lamprophyre falls into the calc-alkaline branch of the lamprophyre clan of Rock (1991), and should best be termed spessartite according to his classification scheme. Assumed to be Tertiary in age on the basis of lithologic similarity with some of the potassium-argon-dated Tertiary biotite and hornblende-biotite lamprophyres present in general area of Hancock Canyon in the Shoshone Range, approximately 25 km to the southeast of the quadrangle (E.H. McKee, oral commun., 1994)

Antler sequence of Roberts (1964)--In this area near the southeast corner of the quadrangle consists of:

> **Antler Peak Limestone (Permian and Pennsylvanian)**--Divided into three parts, including two major interlayered facies (Theodore and Jones, 1992), all of which correlate with uppermost strata of the Antler Peak Limestone at its type section (Roberts, 1964). In SW 1/4 sec. 21, T. 32 N., R. 44 E., the Antler Peak Limestone is in fault contact with the underlying Middle Pennsylvanian Battle Formation, but at several other places in the Battle Mountain Mining District it has been shown by Roberts (1964) that these two formations form a disconformable stratigraphic succession. The age of the formation is well established from extensive collections of fossils described by Roberts (1964). Rocks of the formation comprise an east-dipping sequence that shows progressively shallower

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angles of dip from west to east across the limited area of outcrop on the map:

PPam   **Micrite-dominated facies**--Includes a typically well-exposed, carbonate-dominant facies composed of gray thick-bedded-to-massive micrite mottled by chert and including sandy to pebbly pelmicrite with chert clasts, dolomite, and biomicrite

PPas   **Siliclastite-dominated facies**--Includes a pale-grayish-orange to pale brown siliceous facies composed of carbonate-rich siltite interbedded with sandy siltite, sandstone, and dolomite. Rocks of this facies generally form smooth slopes with abundant platelike fragments that have weathered out. Recently, approximately 5-cm-wide unusual spiraled tooth crowns of an Edistid shark were found in this facies near the southeast corner of the quadrangle by Russell T. Ashinhurst, near the top of hill 5301 in SE 1/4 sec. 21, T. 32 N., R. 44 E. The implications of these tooth crowns are described in detail below in the section titled "Helicoprion sp. from the Pennsylvanian and Permian Antler Peak Limestone, Lander County, Nevada". The age of the strata that host the tooth crowns is Wolfcampian (Verville and others, 1986). As pointed out by these authors, the Wolfcampian fauna are the youngest fusulinids found in the Antler Peak Limestone

PPau   **Undivided part**--Poorly exposed

Pb   **Battle Formation (Pennsylvanian)**--Rocks in this area are mostly chert-pebble conglomerate that is correlative with the lower member of Roberts (1964). Crops out only in two nearby areas: (1) in a narrow fault-bounded block near the southeast corner of the quadrangle, and (2) in a small approximately 100-m-wide area at the Bailey Day Mine, which is in SW 1/4 sec. 21, T. 32 N., R. 44 E. Chert-pebble conglomerate in the first area also shows a short strike-length of its basal unconformity with the underlying Upper Cambrian Harmony Formation near the south edge of the quadrangle. Most of the rocks of the Battle Formation have been removed by recent gold-mining operations at the second area. Chert-pebble conglomerate is variably metamorphosed and altered by fluids associated with emplacement of numerous mineralized and unmineralized igneous rocks, many too small to show at the scale of the geologic map (Theodore and others, 1992). Near the north end of the narrow fault-bounded block, the unit contains some narrow sequences of thinly bedded calcareous quartzarenite and shale

ALLOCHTHON OF THE ROBERTS MOUNTAINS THRUST

Dsc   **Scott Canyon Formation (Devonian)**--Crops out in an approximately 0.6-km^2 fault-bounded block near the southwest corner of the quadrangle and recognized primarily on the basis of contained Devonian-age radiolarians at a locality in NW 1/4 sec. 22, T. 32 N., R. 43 E. (see section below titled "Radiolarians in the Ordovician Valmy Formation and Devonian Scott Canyon Formation"). Mostly black chert and argillite that is poorly exposed throughout much of the unit. Intensely recrystallized black chert and argillite of the unit comprises a window through the tectonically overlying Upper Cambrian Harmony Formation in NE 1/4 sec. 22, T. 32, R. 43 E, and the chert and argillite in the window is deformed highly and cut by abundant discontinuous veins of creamy-white quartz

DOb   **Basaltic dikes and sills (Devonian and (or) Ordovician)**--Confined almost entirely to the area of outcrop of Upper Cambrian Harmony Formation, and emplaced prior to major deformation associated with the Antler orogeny (Roberts, 1964). Assigned provisionally to the Ordovician and (or) Devonian periods because of known widespread mafic volcanism of these ages in the region. Narrow 1- to 8-m-wide, olive-green-to-gray, fine-grained, augite-bearing basaltic dikes and sills, as much as several 100 m long, showing chilled margins against enclosing sedimentary rocks of the Harmony Formation. In places well exposed, particularly along ridgelines, but where poorly exposed, location marked by subtle presence of 2- to 4-cm-wide angular chips on colluvium-covered hillsides. Locally include some sulfides (pyrite, chalcopyrite, and sphalerite) mostly contemporaneous with development of superposed propylitic or greenschist assemblages in the basaltic dikes and sills. Pyrite is commonly present as spongy mm-sized clots (some including sphene), as intergrowths among augite and plagioclase, and as tabular infillings among radiating splays of plagioclase. Some of the plagioclase is altered to albite. Where these basaltic dikes and sills crop out within outer limit of quartz stockworks associated with the Elder Creek porphyry copper system, they are intensely veined by quartz, and, in places, altered hydrothermally to actinolite ± chlorite ± secondary biotite mineral assemblages.

Petrographic examination of 12 thin sections shows most samples to include approximately 10- to 20-volume-percent phenocrysts of glomeroporphyritic plagioclase, ovoid clots of olivine (now altered completely to pale apple green chlorite), and augite that are as much as 1 to 2 mm wide. Augite also forms reaction rims around rare grains of quartz, affirming thereby to the silica undersaturated nature of these magmas. Microprobe analyses of augite in three

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samples shows them to be subcalcic augites (R.L. Oscarson, written commun., 1994). In places, the ovoid clots of chlorite contain 100- to 175-μm-wide euhedral crystals of spinel that show increased contents of iron towards texturally complex inclusions made up of augite + albite + chlorite ± biotite ± sphene composite assemblages, all verified by SEM. Microprobe analyses of spinel show them to contain roughly 28 to 36 weight percent Cr_2O_3 (R.L. Oscarson, written commun., 1994). Some chromium in spinel probably is derived from precursor chromian-olivine magmatic assemblages (M.G. Sawlan, oral commun., 1994). However, the proportion of spinel in some of the ovoid clots of chlorite suggests that all the chromium could not have been present in a chromian olivine of approximately the same size as the clots. Intergranular groundmass is mostly plagioclase, augite, and opaque minerals (mostly ilmenite) where unaltered. Roughly 50 percent of the samples examined show extensive alteration of augite to brownish (in thin section) fine-grained intergrowths of amphibole ± chlorite even at localities far removed from the widespread secondary alteration associated with Tertiary mineralization. Chalcopyrite, mostly as 10- to 20-μm-wide grains, is preferentially associated with chlorite. In addition, many of the large glomeroporphyritic clots of plagioclase in these altered samples are replaced by mattes of fine-grained white mica ± calcite

Valmy Formation (Ordovician)--In this area, consists of three tectonostratigraphic packets of rock:

> **Unit 4**--Equivalent to member 3 of Roberts (1964). Tectonically below unit 3 in this area. However, the apparent "normal" tectonostratigraphic succession farther to the southwest demonstrates that unit 4 is tectonically above unit 3 throughout much of the Battle Mountain Mining District (Roberts, 1964; Theodore, 1991). As such, unit 4 is structurally the highest package of the formation exposed in the mining district. Divided into:

Ov4s

> > **Shaly argillite and chert**--Generally a slope-forming subunit whose strata are in many places poorly exposed. Typically includes relatively thick sequences of bluish-gray-to-silvery argillite, locally as much as hundreds of meters thick and highly contorted, and thin-bedded black chert that in many exposed sequences weather to light gray or were bleached light gray during subsequent alteration. Subunit as a whole shows much more outcrop-scale deformation and internal disruption than unit 3. However, there are some exposures of relatively undeformed thick-bedded black chert in the unit, particularly near the trace of the fault at the base of the overthrust rocks belonging to unit 3,

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which chert shows 8- to 10 cm-wide intervals between parting surfaces along bedding. Near this fault, unit 4 includes some minor green chert interbeds with bioturbated black argillite. Overall amount of quartzarenite in the subunit is quite sparse, although some moderately sorted, medium sands are uncharacteristically quite immature because of high contents of organic-rich cement that includes abundant angular fragments of fine-grained quartz. Some exposures in the unit also include well-developed, penetrative rod-like structures formed by intersection of two sets of cleavage, and other 5- to 8-cm-wide beds of black chert show poorly developed, 1- to 2-cm-wide compaction structures on bedding surfaces, which compaction structures are common in chert of the formation. Close to the trace of the Dewitt thrust, some strata of the subunit apparently have been rotated into parallelism with the general attitude of the plane of the thrust

Ov₄g

Greenstone--Crops out only in one area as a small body of olive gray-to-grayish green, deeply weathered basaltic rock in NE 1/4 sec. 10, T. 32 N., R. 43 E., where it is cut off by rocks of the Upper Cambrian Harmony Formation in the upper plate of the Dewitt thrust. Poorly exposed but appears in part to be fragmental. Contact with adjoining gray-black chert of subunit Ov₄s shows presence of shearing. Includes some minor beds of gray micrite

Unit 3--Generally equivalent to member 2 of Roberts (1964). In this area, unit 3 has tectonically overridden unit 4 during the Antler orogeny along an approximately 3-km-long, northeast-striking overturned thrust fault. Divided into:

Ov₃u

Undivided part--Heterogeneous mixture of chert, argillite, shale, and quartzarenite. General presence of quartzarenite in the subunit can be used as diagnostic mapping criteria to separate these rocks from those of unit 4. Overall amount of quartzarenite present in the subunit appears to diminish from west to east, particularly in the area west-to-southwest of Elder Creek. Where black chert strata are well exposed, they define homoclinal sequences showing minimal amounts of tectonic disruption. Individual bedding surfaces of chert commonly show development of compaction structures and parting surfaces, the latter marked by thin seams of gray-to-gray-black argillite. Some argillite seams

may be as much as 1 cm wide. Includes some greenish-gray chert, some of the best exposures of which contain well-preserved radiolarians and are present near the upper bounding thrust in SE 1/4 sec. 3, T. 32 N., R. 43 E. Some gray shale strata in the subunit are as much as 1 m thick and contain less than 5 volume percent silt-sized detrital fragments. Petrographic examination of 10 thin-sectioned samples of quartzarenite reveals that these rocks are largely mature medium sands whose framework sites are occupied by more than 95 volume percent monocrystalline quartz. Framework feldspar was not noted in any of the thin-sectioned rocks. Chert cement is usually 5 volume percent or less, and, where altered or recrystallized, is replaced by variably complex quartz-quartz sutured grain boundaries. Where such altered rocks also have a "sanded" appearance in hand sample, the rocks in thin section show presence of secondary clay(s) ± white mica along the grain boundaries of the detrital quartz grains

Ov_{3q} **Quartzarenite**--Generally drab-gray resistant ridge-forming knobs that consist of massive-to-thick-bedded, brown-to-gray mature quartz sands. Petrographically similar to quartzarenite in undivided subunit

Unit 1--Equivalent to member 1 and part of the undifferentiated member of Roberts (1964). Crops out only in a narrow, fault-bounded block near the west-central border of the quadrangle in SW 1/4 sec. 27 and NW 1/4 sec. 34, T. 33 N., R. 43 E. Divided into:

Ov_{1c} **Chert and argillite**--Mostly poorly exposed thin-bedded gray-to-light gray chert and argillite including minor interbeds of quartzarenite. Some outcrops folded into small-scale folds whose fold axes plunge shallowly to the north

Ov_{1q} **Quartzarenite**--Resistant hill-forming knobs of massive-to-thick-bedded quartzarenite that appear to be floating tectonically in surrounding chert and argillite subunit

€h **Harmony Formation (Cambrian)**--Although rocks assigned by Whitebread (1994) to this formation in the East Range were considered by him to be pre-Mississippian in age, the rocks of the Harmony Formation in the Battle Mountain Mining District are still considered to be middle and late Late Cambrian in age as assigned by Roberts (1964). This conclusion is based on the presence of trilobites contained in rocks assigned to the formation near the

north end of the Hot Springs Range, 5 to 10 km west-northwest of the Osgood Mountains (Roberts and others, 1958; Hotz and Willden, 1964; C.A. Suczek, oral commun., 1992), and some additional evidence from field relations in the Battle Mountain Mining District. This additional evidence is well exposed near the mouth of Galena Canyon and elsewhere to the south of the Snow Gulch quadrangle (Jeff L. Doebrich, oral commun., 1993), and implies tectonic emplacement of rocks of the Harmony Formation during the Devonian, thereby precluding any age younger than Devonian for the rocks of the Harmony Formation. At Galena Canyon, volcaniclastic rocks and, in places, weakly pillowed basalts of the presumably mostly Devonian Scott Canyon Formation contain numerous clasts and blocks of poorly sorted feldspathic arenite of the Harmony Formation. In addition, some olistoliths of archaeocyathan-bearing Lower and Middle Cambrian limestone derived from an unknown source are also present widely in rocks of the Scott Canyon Formation near the locality . It seems likely to me that these olistoliths could also have been derived from the rocks of the Harmony Formation. Some of the olistolithic blocks of feldspathic arenite derived from the Harmony Formation are as much as 5 to 8 m wide and the largest of the limestone olistoliths in the same general area is as much as 100 m in length. Thus, rocks of the Harmony Formation must be older than marine volcanic rocks in a now recognized debris-flow unit of the Scott Canyon Formation that hosts them (Jeff L. Doebrich, oral commun., 1993). Moreover, occurrence of a wide expanse of in-place, generally topographically high Harmony Formation close to the locality of the feldspathic arenite clasts suggests that the leading edge of the overthrust Harmony Formation may also have been nearby that locality in Devonian time as a tectonically uplifted source for the clasts and blocks in the debris-flow unit of the Scott Canyon Formation. Some Ordovician-age limestone olistoliths are also known to be present in basaltic rocks of the Scott Canyon Formation, and the nearest radiolarian-dated mass of chert to the locality containing the olistolithic blocks of feldspathic arenite is Ordovician (L.B. McCollom, oral commun., 1993).

Weathers to smooth-rounded slopes, and commonly poorly exposed in many areas, especially on sides of hills. Mostly olive gray-green feldspathic arenite where unmetamorphosed and unaltered. Minor amounts of calcareous shaly hornfels present locally, and some of these sequences, where well within the outer alteration aureoles of large mineralized systems, show successive replacement by diopside- and garnet-bearing assemblages. Large tracts of this unit have been converted to variably sulfidized biotite

hornfels, generally in areas surrounding the Elder Creek porphyry copper
system, and near the southeast border of the quadrangle where a large
number of mineralized plutons are present. Where metamorphosed, rocks
of the formation are various shades of drab gray brown and subsequently
bleached yellowish white largely as a function of the prior amount of
iron sulfides introduced during development of the biotite hornfels. Locally
close to the trace of the Dewitt thrust, rocks of the Harmony Formation are
intensely sheared, and they show fabrics almost phyllonitic in appearance

———?—?   Contact--Queried where location uncertain

                      Faults--Showing dip. Arrows indicate sense of displacement.
                      Long dashed where approximately located; short dashed where
                      inferred; queried where uncertain; dotted where concealed

                                Normal fault-Bar and ball on downdropped block

                                Thrust fault-Sawteeth on upper plate

                                Low angle glide fault-Sawteeth on upper plate

                      Strike and dip of bedding

                                Inclined-Facing not always known with certainty

                                Vertical

                                Overturned

                                Horizontal

                      Folds--Showing trace of hinge line and plunge of axis; long
                      dashed where approximately located; short dashed where inferred;
                      queried where uncertain; dotted where concealed

                                Anticline

                                Syncline

                                Minor anticline, showing trend and plunge

                                Horizontal minor anticline, showing trend

                                Minor syncline, showing trend and plunge

                                Minor overturned fold, showing trend and plunge

                                Horizontal minor overturned fold, showing trend

                      Alteration

   Quartz vein--massive, white

                                Especially well-developed concentration of quartz stockwork
                                veins

                                Outer limit of abundant quartz stockworks--hachures on side
                                of quartz stockworks; dotted where concealed, queried
                                where uncertain

                                Approximate outer limit of epigenetic alteration mostly
                                shown by recrystallization of feldspathic sandstone and
                                quartz arenite of the Harmony Formation to biotite hornfels
                                and (or) pyrite $\pm$ pyrrhotite-bearing mineral assemblages--

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hachures in direction of alteration; queried where uncertain, dotted where concealed
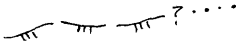
Approximate limit of epigenetic alteration mostly shown by recrystallization of feldspathic sandstone and quartz arenite of the Harmony Formation to chlorite, epidote, and (or) pyrite-bearing mineral assemblages--hachures in direction of alteration; dotted where concealed, queried where uncertain. Only present locally near outermost alteration visible in outcrop surrounding the Elder Creek porphyry copper system
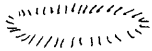
Skarn--Andradite-diopside skarn that crops out mainly in the general area of Oliogcene or Eocene porphyritic leucogranite (Tpl) near the southeast corner of the quadrangle

Presence of secondary copper minerals visible in outcrop

Mine dump

Placer workings

Fossil locality

Elder Creek Porphyry Copper System

It was not until the middle 1960s that the approximately 37-Ma Elder Creek porphyry copper system was first tested as a porphyry target. Many of the prominent concentrations of mineralized veins and mineralized faults in the area had already attracted significant exploration activity at a time when some of the earliest exploration targets in the mining district were first being assessed in the late 1800s and early 1900s (Roberts and Arnold, 1965). In this 5-km-wide system, many of the polymetallic veins and mineralized faults (such as those at the Morning Star Mine, the Big Pay Mine, the Gracie Mine, and the Ridge Mine, which are all polymetallic vein and fault occurrences) show minor amounts of gold in their production records. For example, during the six years for which metal extraction occurred between 1905 and 1938, the Morning Star Mine is reported to have produced approximately 194 oz gold from a total shipment of approximately 230 tons ore (Roberts and Arnold, 1965). The average

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copper content of the ore from the oxide-zone was about 4 weight percent. In addition, this particular mineralized occurrence is close to the inferred center of the Elder Creek porphyry system, whereas the Ridge and the Gracie Mines are located just inside the mapped outer limit of widespread iron sulfide epigenetic alteration associated with the porphyry system. These latter two mines, approximately 2 and 2.5 km, respectively, from the center of the system, are reported to have yielded a maximum total of 15 and 51 oz gold prior to 1939, during four years of production. In addition, the Ridge and Gracie Mines are each located close to the centers of two elongate aeromagnetic anomalies, each about 100 to 150 gammas (1 gamma = 1 nano-Tesla) magnetic field strength above local background, that are part of a donut-shaped pattern of anomalies that encompass the Elder Creek porphyry system (Battle Mountain Gold Company, unpub. data, 1994). These anomalies appear to be largely just interior to the outer limit of the introduction of pyrite ± pyrrhotite that surrounds the system. These anomalies also, in places, are purported to result partly from the presence of as much as several volume percent disseminated pyrrhotite in rocks of the Harmony Formation that are recrystallized to biotite hornfels.

Approximately 0.3 km south-southwest of the Ridge Mine, the position of the outer limit of iron sulfidation that surrounds the Elder Creek porphyry copper system seems to be a function partly of some intensely phyllic-altered and pyrite-veined Oligocene granodiorite porphyry. Emplacement of this pyrite-veined granodiorite porphyry may have been superposed onto rocks previously altered by the Elder Creek porphyry system. This occurrence (in NW 1/4 sec. 12, T. 32 N., R. 43 E.) is along a short mineralized segment of a fault that has the same strike as the 1.5-km-long mineralized structure that controls mineralization at the Ridge Mine. A few polished thin sections examined petrographically from the occurrence also show the presence of traces of disseminated chalcopyrite in the groundmass of phyllic-altered granodiorite porphyry. However, the several shallow workings at the occurrence most likely represent exploration efforts in the search for precious metals. Abundant quartz-pyrite veins cut granodiorite porphyry at the locality, and the fluid-inclusion signature of the vein quartz includes an absence of halite-bearing fluid inclusions and wide-ranging liquid-vapor proportions in two-phase fluid inclusions suggestive of boiling. These fluid-inclusion relations are in stark contrast to the halite-bearing fluid-inclusion signatures of quartz stockworks near the core of the Elder Creek porphyry copper system.

Silver:gold weight ratios from mineralized occurrences in the general area of the Elder Creek porphyry copper system appear to vary systematically across the system. The overall weight ratio of silver:gold in production data from the four above-listed mines ranges from a low value of approximately 2.1 at the Morning Star Mine to a high value of approximately 128 at the Big Pay and Ridge Mines. These changes in the values of the weight ratio of silver:gold

are consistent with the geographic positions of the four mineralized occurrences relative to the Elder Creek prophyry system in as much as they show dramatic increases of silver:gold toward the margins of the system. Actually, the Big Pay Mine is located along a mineralized north-striking fault roughly 0.4 km outside the outer limit of the introduction of pyrite ± pyrrhotite surrounding the porphyry system. However, the relatively low silver:gold weight ratios at the Morning Star Mine, which is situated near the center of the system, might also have been enhanced by the fact that the Morning Star Mine appears to be in the hanging wall or down-faulted block of the post-mineral Elder Creek fault. At moderate to extreme depths in the general area of the Morning Star Mine, there should be a corresponding increase in the silver:gold weight ratio in mineralized rocks, provided this system roughly duplicates geochemically other porphyry systems in the Battle Mountain Mining District. In the Copper Canyon area of the mining district, there is a notable decrease in the silver:gold ratio in a gold-silver zone that mantles a central copper-gold-silver zone near the core of the porphyry system there (Theodore and others, 1986). There may be additional mineralized rock with low silver:gold ratios in gravel-covered areas near the Morning Star Mine. Unfortunately, there do not appear to be calcareous strata favorable for repalcement-type mineralization in wallrocks immediate to the Eocene or Oligocene porphyritic monzogranite of the Elder Creek area comparable to those present at Copper Canyon. However, it is still possible that gravel-covered quartz stockworks near the core of the Elder Creek porphyry system, and in a geologic-geochemical environment similar to that at the Morning Star Mine, could comprise a gold target worthy of earnest exploration efforts. Such a target would be somewhat analogous to gold-bearing quartz stockworks present locally in the Copper Canyon area.

Duval Corporation was the first to test the Elder Creek porphyry system as a porphyry target by drilling three core holes in 1965 near the west border of sec. 6, T. 32 N., R. 44 E. These three core holes consequently were placed on the eastern margins of the system because of the land situation at the time (Joe Lamanna, written commun., 1994). In addition, the three holes were then part of a regional copper exploration program that was being conducted about the same time that the extent of the copper deposits at Copper Canyon and Copper Basin was being delineated by Duval Corporation (Sayers and others, 1968).

Rocky Mountain Energy, formerly a subsidiary company of Union Pacific, apparently was the next company to test the porphyry copper target in the Elder Creek area by drilling eight holes during 1968 (Patrick R. Wotruba, written commun., 1994). Six of the holes were located in W 1/2 sec. 1, T. 32 N., R. 43 E., another hole was drilled in the south-central part of sec. 36, T. 33 N., R. 43 E., and the last hole was drilled in NW 1/4 sec. 6, T. 32 N., R. 44 E.

Battle Mountain Gold Co. subsequently drilled an additional 40 holes in the Elder Creek area since they staked some additional claims there in 1985 (Joe Lamanna, written commun., 1994). However, all of this drilling by Battle Mountain Gold Co.was targeted toward discovery of economic gold mineralization peripheral to the porphyritic monzogranite of the Elder Creek area. The 40 drill holes were spread throughout secs. 1, 2, 11, and 12 of T. 32 N., R. 43 E.; and sec. 36 of T. 33 N., R. 43 E. Of the 40 holes, seven were drilled in sec. 36, five in sec. 2, six in sec. 11, 13 in sec. 1, and nine in sec. 12.

In early 1994, the pediment southeast of Elder Creek, considerably distant from the nearest exposed bedrock, was again being tested by drilling.

Radiolarians in the Ordovician Valmy Formation and Devonian Scott Canyon Formation

by

Benita L. Murchey

Bedded ribbon chert of the Valmy and Scott Canyon Formations contains abundant radiolarian remains. We collected eleven chert samples in which we observed radiolarians in hand-specimens. These samples were etched twice with five percent hydrofluoric acid, about twenty-four hours each time. The acid residue was examined with a binocular microscope.

Only two samples yielded biostratigraphically useful radiolarians. Six samples yielded poorly preserved, recrystallized, and flattened radiolarians. The acid residues of three samples from the Valmy Formation contain detrital quartz but no microfossils, possibly owing to recrystallization across fossil margins.

One of the samples with biostratigraphically useful radiolarians (USGS fossil accession number MR 8677) is from the Valmy Formation in the North Peak quadrangle, in SE 1/4 sec. 3, T. 32 N., R. 43 E., approximately 0.8 km west of the the border with the Snow Gulch quadrangle. The sample was obtained near the base of a steeply dipping 15 m section of bedded chert overlain by quartzarenite. The chert beds in the lower part of the section are about 0.5 m thick and contain spectacular compactional mounds approximately 0.3 m in diameter and rising up to 10 cm above the bedding surface. The chert is black when fresh but weathers to white and green. The sample residue contains poorly preserved spheroidal radiolarians, some of which retain a few simple spines. The spines are slender and circular in cross-section. While spines of this type are long-ranging in the fossil record, the absence of more robust bladed spines are an indication that the sample is pre-Middle Devonian, probably Ordovocian, which is consistent with previous age determinations of graptolites in clastic strata of the Valmy Formation. The radiolarian genera

cannot be identified because of the absence of preserved pore structure or internal structure. The sample residue also contains a few oxyhexactine (Class Hexactinellida) and oxea sponge spicules. The absence of co-occurring demosponge spicules suggests that the spicule source was a deep, low-energy environment.

The other sample (USGS fossil accession number MR 8684) with useful radiolarians is from the Scott Canyon Formation which is exposed in a window through the tectonically overlying Valmy and Harmony Formations in NE 1/4 sec. 22, T. 32, R. 43 E., near the southwest corner of the Snow Gulch quadrangle. In outcrop, the chert is black, not very vitreous in appearance, and heavily veined. The acid residue contains spheroidal radiolarians with slender, bladed spines. The three blades on each spine intersect at angles of 120 degrees. They extend the length of the spine and are constant in width and thickness except at the spine tip where they intersect in a point. Although some Silurian radiolarians have spines in which the base is bladed, the length-wise spines present in this sample are characteristic of Devonian and younger radiolarians. As in the previously described sample from the Valmy Formation, the absence of preserved pore structure and internal structure precludes the identification of genera. Sponge spicules in the sample include oxyhexactine and oxypentactine forms (Class Hexactinellida) but not demosponge forms. The spicules, whether in situ or redeposited, probably had a relatively deep, low-energy source.

Helicoprion sp. from the Pennsylvanian and Permian Antler Peak Limestone, Lander County, Nevada

by

Rex Alan Hanger, Ellen E. Strong, and Russell T. Ashinhurst

The enigmatic spiral tooth-whorl of *Helicoprion* is a rare and significant fossil of Permian age rocks worldwide. The teeth represent the only preserved portion of a shark-like fish of unknown dimensions. Occurrence of a single, symphysial whorl of *Helicoprion* sp. in Lander County, Nev. confirms the Permian age of the upper portion of the Antler Peak Limestone, and the open marine connections during the Permian between North America and coeval island arcs to the west.

Morphologic terminology follows Wheeler (1939) and Bendix-Almgreen (1966). The specimen is deposited in the University of California Museum of Paleontology (UCMP).

SYSTEMATIC PALEONTOLOGY

Family Helicoprionidae Bendix-Almgreen, 1966

Genus *Helicoprion* Karpinsky, 1899

Helicoprion sp.

Description -- The symphysial whorl of UCMP specimen 140632 consists of 1.5 volutions and is broken off at both juvenile and adult ends (fig. 1). The maximum preserved diameter (tooth crown tip to tooth crown tip) is 100.35 mm. Description is compromised by the fact that the enclosing rock is broken so that most of the specimen is split laterally, and several tooth crown are broken off at the shaft and missing. 47 tooth crowns are preserved in one volution. For a well-preserved tooth at approximately 1 volution, the volution height (V) is 20.2 mm, the shaft height (S) is 2.3 mm, with an S/V ratio of 0.11. No serration denticles are preserved.

Location -- From UCMP Locality V94012, in western Lander County, Nevada, which is found on the Snow Gulch, Nevada, 7.5-minute U. S. Geological Survey quadrangle, 1991 version. Township/Range coordinate is T. 32 N., R.44 E., in NE 1/4 of SE 1/4 of section 21. The specimen occurs in pale brown siltite of the siliclastite-dominated facies of the Antler Peak Limestone.

Comparison -- Several workers (Bendix-Almgreen, 1966; Siedlecki, 1970) have noted the very strong similarities of all described *Helicoprion* species. Unfortunately, *Helicoprion* fossils are always found as isolated specimens, not populations. The possibility exists that much of the published species diversity of the genus actually reflects the range of morphologic variation of very few, or even a single species. Because of this taxonomic imprecision and the taphonomic destruction of UCMP 140632, specific taxonomic placement is not possible. For S/V ratio and number of tooth crowns/volution, UCMP 140632 is most like Wheeler's (1939) specimen #1001 of *Helicoprion nevadensis*, from the Koipato Formation of the Humboldt Range, less than 200 km from UCMP Locality V94012. As reported by Wheeler (1939), the holotype of *Helicoprion nevadensis* apparently was collected from a tuffaceous shale approximately 1,000 m below the top of the Rochester Trachyte of the Triassic Koipato Group in the Humboldt Range, Nev., or roughly from about the middle of the Koipato Group. However, this specimen of *Helicoprion nevadensis* is considered by Silberling (1973) not to have been originally obtained from the Koipato Group in the Humboldt Range because of discrepancies between lithology of rock fragments attached to the fossil and the diagnostic lithologies found in the Koipato Group.

BIOSTRATIGRAPHY

The biostratigraphic utility of *Helicoprion* as an Early Permian biozone indicator (Wheeler, 1939; Teichert, 1940) has been overstated. The genus is now found in Wolfcampian through Guadalupian age strata, or their global correlatives. There are no unequivocal occurrences in either Carboniferous or post-Guadalupian Permian age strata.

UCMP Locality V94012 occurs between strata containing fusulinid foraminifera (Verville et al., 1986). The several species of *Schwagerina* confirm a Wolfcampian age for UCMP 140632, consistent with the established geologic range of *Helicoprion*.

BIOGEOGRAPHY

The genus *Helicoprion* has a worldwide distribution, with species described from Russia (Karpinsky, 1899; Obruchev, 1953, for summary), Japan (Yabe, 1903; Araki, 1980), Laos (Hoffet, 1933), Australia (Teichert, 1940), Spitsbergen (Siedlecki, 1970), Arctic Canada (Nassichuk and Spinosa, 1970; Nassichuk, 1971), British Columbia, Alberta (Logan and McGugan, 1968), Idaho, Wyoming (Hay, 1907, 1909; Williams and Dunkle, 1948; Bendix-Almgreen, 1966), Nevada, California (Wheeler, 1939; Larson and Scott, 1955; this report) West Texas (Kelly and Zangerl, 1976; Chorn, 1978), and Mexico (Mulleried, 1940), Thus, *Helicoprion* is found within rocks of many Permian benthic faunal provinces (see for example, Yancey, 1975; Bambach, 1990). Collectively, these provinces span polar to equatorial latitudes in both hemispheres, a remarkable distribution, even for a nektic organism, suggesting that temperature was not a limiting factor for *Helicoprion*.

Caution must be exercised in using *Helicoprion* for North American terrane analysis. The joint occurrence of *Helicoprion* in autochthonous Nevada (Wheeler, 1939; Larson and Scott, 1955; Roberts and others, 1958; this report) and in the allochthonous Northern Sierra terrane of McCloud Belt faunal affinity (Harwood, 1992; Miller, 1987) should not be taken as evidence of original paleogeographic proximity of the McCloud Belt to North America during the Permian. Presence of the nektic *Helicoprion* in both areas is evidence for open marine conditions between North America and the McCloud Belt arc(s) but cannot resolve the problem of longitudinal separation.

References cited

Araki, H., 1980, The discovery of the fossil genus *Helicoprion*, a chondrichthian, from Kesennuma City, Miyagi Prefecture, Japan: Journal of Geological Society of Japan, Journal, v. 86, no. 2, p.135-137. [In Japanese]

Bambach, R.K., 1990, Late Paleozoic provinciality in the marine realm, *in* W.S. McKerrow and C.R. Scotese, eds., Palaeozoic Palaeogeography and Biogeography: London, Geological Society Memoir Number 12, p. 307-323.

Bendix-Almgreen, S.E., 1966, New investigations on *Helicoprion* from the Phosphoria Formation of South-East Idaho, U.S.A.: Biologiske Skrifter Danske Videnskabernes Selskab, v. 14, no. 5, p. 1-54.

Chorn, J., 1978, *Helicoprion* (Elasmobranchii, Edestidae) from the Bone Spring Formation (Lower Permian) of West Texas: University of Kansas Paleontological Contributions, Paper 89, Fossil Fish Studies, p. 2-4.

Gilluly, James, and Masursky, Harold, 1965, Geology of the Cortez quadrangle, Nevada, with a section on Gravity and aeromagnetic surveys by D.R. Mabey: U.S. Geological Survey Bulletin 1175, 117 p.

Harwood, D.S., 1992, Stratigraphy of Paleozoic and Lower Mesozoic rocks in the Northern Sierra terrane, California: U. S. Geological Survey Bulletin 1957, 78 p.

Hay, O.P., 1907, A new genus and species of fossil shark related to *Edestus* Leidy: Science, New Series, v. 26, no.653, p. 22-24.

-----1909, On the nature of *Edestus* and related genera, with descriptions of one new genus and three new species: Proceedings of the U.S. National Museum, v. 37, p. 43-61.

Hoffet, J.H., 1933, Etudes geologiques sur le contre de l'Indochine entre Tourane et le Mekong: Service Geologique de l'Indochine Bulletin, v. 20, no. 2, p. 1-154. [In French]

Hotz, P.E., and Willden, Ronald, 1964, Geology and mineral deposits of the Osgood Mountains quadrangle, Humboldt County, Nevada: U.S. Geological Survey Professional Paper 431, 128 p.

Karpinsky, A., 1899, Uber die Reste von *Edestiden* und die neue Gattung *Helicoprion*.: Verhandlung Russisch-Keiserling Mineralogische Gesellschaft zu St. Petersburg, Series 2, v. 36, no. II, p. 361-376. [In German]

Kelly, M.A., and Zangerl, 1976, *Helicoprion* (Edestidae) in the Permian of West Texas: Journal of Paleontology, v. 50, no. 5, p. 992-994.

Larson, E.R., and Scott, J.B., 1955, *Helicoprion* from Elko County, Nevada: Journal of Paleontology, v. 29, p. 918-919.

Logan, A., and McGugan, A., 1968, Biostratigraphy and faunas of the Permian Ishbel Group, Canadian Rocky Mountains: Journal of Paleontology, v. 42, no. 5, p. 1123-1139.

Madrid, R.J., 1987, Stratigraphy of the Roberts Mountains allochthon in north-central Nevada: Stanford, California, Stanford University, Ph.D. dissertation, 341 p.

McKee, E.H., 1992, Potassium argon and $^{40}Ar/^{39}Ar$ geochronology of selected plutons in the Buckingham area, *in* Theodore, T.G., Blake, D.W., Loucks, T.A., and Johnson, C.A., Geology of the Buckingham stockwork molybdenum system and surrounding area, Lander County, Nevada: U.S. Geological Survey Professional Paper 798-D, p.D36-D40.

McKee, E.H., and Silberman, M.L., 1970, Geochronology of Tertiary igneous rocks in central Nevada: Geological Society of America Bulletin, v. 81, no. 8, p. 2317-2328.

Miller, M.M., 1987, Dispersed remenants of a northeast Pacific fringing arc: Upper Paleozoic island arc terranes of McCloud Belt faunal affinity, western United States: Tectonics, v. 6, p. 807-830.

Mullereid, F.K.G. 1945. El edestido, *Helicoprion*, en contrado por primera vez en Mexico, en el estado de Coahuila: Ciencia Revista Hispano-America de Ciencias Puras y Aplicadas, v. 6, p. 208-211. [In Spanish]

Nassichuk, W.W., 1971, *Helicoprion* and *Physonemus*, Permian vertebrates from the Assistance Formation, Canadian Arctic Archipelago: Geological Survey of Canada, Bulletin 192. p. 83-93.

Nassichuk, W.W., and Spinosa, C., 1970, *Helicoprion* sp., A Permian elasmobranch from Ellesmere Island, Canadian Arctic: Journal of Paleontology, v. 44, no. 6, p. 1130-1132.

Obruchev, D.V., 1953, A study of the edestids and the work of A.P. Karpinsky: Trudy Paleontologischkogo Instituto, Akademia Nauk SSSR, v. 45, p. 1-88. [In Russian]

Roberts, R.J., 1964, Stratigraphy and structure of the Antler Peak quadrangle, Humboldt and Lander Counties, Nevada: U.S. Geological Professional Paper 459-A, p. A1-A93.

Roberts, R.J., and Arnold, D.C., 1965, Ore deposits of the Antler Peak quadrangle, Humboldt and Lander Counties, Nevada: U.S. Geological Survey Professional Paper 459-B, 94 p.

Roberts, R.J., Hotz, P.E., Gilluly, James, and Ferguson, H.G., 1958, Paleozoic rocks in north-central Nevada: American Association of Petroleum Geologists Bulletin, v. 42, no. 12, p. 2813-2857.

Rock, N.M.S., 1991, Lamprophyres: Glasgow, Blackie; New York, Van Nostrand Reinhold, 285 p.

Sayers, R.W., Tippett, M.C., and Fields, E.D., 1968, Duval's new copper mines show complex geologic history: Mining Engineering, v. 20, no. 3, p. 55-62.

Siedlecki, S., 1970, A *Helicoprion* from the Permian of Spitsbergen: Norsk Polarinstitutt Arbok, 1968, p 36-54.

Silberling, N.J., 1973, Geologic events during Permian-Triassic time along the Pacific margin of the United States, in Logan, A., and Hills, L.V., eds., The Permian and Triassic Systems and their mutual boundary: Calgary, Alberta, Alberta Society Petroleum Geology, p. 345-362.

Teichert, C., 1940, *Helicoprion* in the Permian of Western Australia: Journal of Paleontology, v. 14, no. 2, p. 140-149.

Theodore, T.G., 1991, Preliminary geologic map of the North Peak quadrangle, Humboldt and Lander Counties, Nevada: U.S. Geological Survey Open-File Report 91-429, 10 p., 1 sheet (1:24,000).

Theodore, T.G., Blake, D.W., Loucks, T.A., and Johnson, C.A., 1992, Geology of the Buckingham stockwork molybdenum deposit and surrounding area, Lander County, Nevada, with a section on: Potassium-argon and $^{40}Ar/^{39}Ar$ geochronology of selected plutons in the Buckingham area by E.H. McKee, and a section on Economic geology by T.A. Loucks and C.A. Johnson, and a section on Supergene copper deposits at Copper Basin by D.W. Blake, and a section on Mineral chemistry of Late Cretaceous and Tertiary skarns by J.M. Hammarstrom: U.S. Geological Survey Professional Paper 798-D, p. D1-D307.

Theodore, T.G., and Hammarstrom, J.M., 1991, Petrochemistry and fluid-inclusion study of skarns from the northern Battle Mountain mining district, Nevada, in Aksyuk, A.M., and others, eds., Skarns--their genesis and metallogeny: Athens, Greece, Theophrastus Publications, p. 497-554.

Theodore, T.G., Howe, S.S., Blake, D.W., and Wotruba, P.R., 1986, Geochemical and fluid zonation in the skarn environment at the Tomboy-Minnie gold deposits, Lander County, Nevada: Journal of Geochemical Exploration, v. 25, p. 99-128.

Theodore, T.G., and Jones, G.M., 1992, Geochemistry and geology of gold in jasperoid, Elephant Head area, Lander County, Nevada: U.S. Geological Survey Bulletin 2009, 53 p.

Theodore, T.G., Silberman, M.L., and Blake, D.W., 1973, Geochemistry and potassium-argon ages of plutonic rocks in the Battle Mountain Mining District, Lander County, Nevada: U.S. Geological Survey Professional Paper 798-A, p. A1-A24.

Verville, G.J., Sanderson, G.A., and Drowley, D.D., 1986, Wolfcampian fusulinids from the Antler Peak Limestone, Battle Mountain, Lander County, Nevada: Journal of Foraminiferal Research, v. 16, no. 4, p. 353-362.

Wheeler, H.E., 1939, Helicoprion in the Anthracolithic (Late Paleozoic) of Nevada and California, and its stratigraphic significance: Journal of Paleontology, v. 13, no. 1, p. 103-114.

Whitebread, D.H., 1994, Geologic map of the Dun Glen quadrangle, Pershing County, Nevada: U.S. Geological Survey Miscellaneous Investigations Series, Map I-2409, 1 sheet [scale 1: 48,000].

Williams, J.S., and Dunkle, D.H., 1948, Helicoprion-like fossils in the Phosphoria Formation: Geological Society of America Bulletin, v. 59, p. 1362.

Yabe, H., 1903, On a Fusulina-Limestone with Helicoprion in Japan: Journal Geological Society of Tokyo, v. 10, no. 113, p. 1-13.

Yancey, T.E., 1975, Permian marine biotic provinces in North America: Journal of Paleontology, v. 49, p. 758-766.

Figure 1

Helicoprion sp. from the Antler Peak Limestone. UCMP 140632 (X1.1).