DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

TO ACCOMPANY MAP MF-1853-E

# METALLOGENIC MAP OF VOLCANOGENIC MASSIVE-SULFIDE DEPOSITS IN PRE-TERTIARY ISLAND-ARC AND OCEAN-BASIN ENVIRONMENTS IN NEVADA

By Maureen G. Sherlock

## VOLCANOGENIC MASSIVE-SULFIDE MAP SERIES

Edited by R.L. Earhart

## EDITOR'S NOTE

The metallogenic map of volcanogenic massive-sulfide occurrences in Nevada is one of several planned or published preliminary and interim products of a study of the distribution and setting of volcanogenic massive sulfides in the western United States. "Volcanogenic massive sulfides" refers to occurrence types that are inferred to be associated with the development of ancient volcanic arcs or with rift systems in a mainly subaqueous environment. Three types of massive-sulfide deposits are shown on this map: (1) Cyprus-type massive-sulfide deposits associated with mafic volcanic rocks of an ophiolite sequence, (2) kuroko-type massive-sulfide deposits associated with felsic and intermediate volcanic rocks of an island-arc environment, and (3) Besshi-type massive-sulfide deposits associated with oceanic sedimentary rocks of an uncertain, but probably rift, tectonic environment.

The distribution of favorable host rocks for massive-sulfide deposits and the lithotectonic terranes in which they occur are also shown on the map. The host rocks shown are not necessarily formal stratigraphic units, and they may contain several lithologic types. They are shown here to delineate areas that may be prospective for undiscovered massive-sulfide deposits.

## INTRODUCTION

Two massive-sulfide deposits are mined in Nevada. The largest is the Rio Tinto (Mountain City) copper deposit in Elko County which produced 1,110,000 tons of ore that averaged 9.7 percent copper (Coats and Stephens, 1968). The Big Mike copper deposit in Pershing County, which produced 100,000 tons of ore that averaged 10.5 percent copper, is smaller but has been studied extensively (Rye and others, 1984). The Rio Tinto deposit is in carbonaceous shale of the Valmy Formation of Ordovician age of the Roberts Mountains terrane (Roberts terrane of Silberling and others, 1987); volcanic rocks are not closely associated with the ore body but occur within the Valmy Formation at many exposures in Nevada. The Big Mike deposit is in carbonaceous cherts and argillites directly above pillow basalts in the Havallah sequence of Silberling and Roberts (1962) of Late Devonian to early Late Permian age (Stewart and others, 1986) of the Golconda terrane. Fifteen prospects for massive-sulfide deposits in Nevada occur in felsic and intermediate volcanic rocks of Mesozoic age in the Jackson terrane and Walker Lake terrane.

The general type of massive-sulfide deposit is described as a stratabound (stratiform), lenticular accumulation of massive pyrite and copper-, lead-, and zinc-bearing sulfide ore minerals; sulfide content characteristically is greater than 60 percent, and chalcopyrite, sphalerite, and galena are the primary ore minerals. Modern interpretation and descriptions generally agree that the deposits were formed in a submarine environment at or near the site of active volcanic and (or) hydrothermal activity. Three deposit model types are distinguished in Cox and Singer (1986) as (1) Cyprus massive-sulfide (Singer, 1986a), (2) kuroko massive-sulfide (Singer, 1986b), and (3) Besshi massive-sulfide (Cox, 1986a) deposits. These models represent distinct geologic environments: the Cyprus type is associated with oceanic rift basalts preserved in ophiolite terrane; the kuroko type is associated with island-arc felsic to intermediate volcanics; and the Besshi type is associated with marine basaltic and sedimentary rocks in an uncertain tectonic environment.

Nevada contains many rock types that host volcanogenic massive-sulfide deposits elsewhere in the world; these potential host rocks occur in pre-Tertiary terranes. The Rio Tinto and the Big Mike massive-sulfide deposits occur in the Paleozoic Roberts Mountains and Golconda terranes that are thought to originate as a back-arc basin or oceanic basin, rise, and slope accumulations

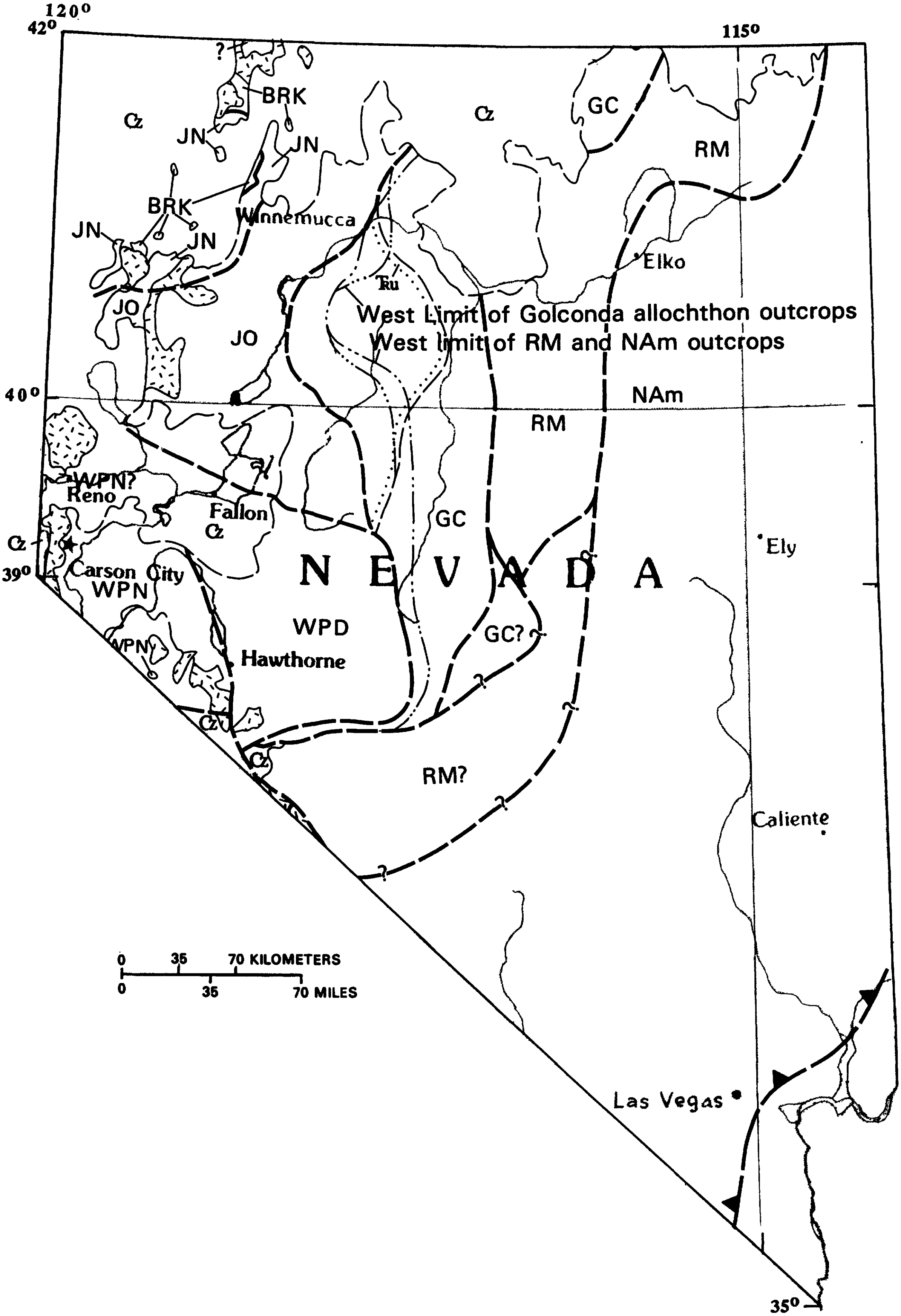


Figure 1—Lithotectonic terrane map of Nevada (slightly modified from Silberling and others, 1987).

Figure 1—Continued

## EXPLANATION

| | |
|---|---|
| Cz | Cenozoic deposits |
| | Postaccretion granitic rocks |
| | Accreted terranes—Arranged alphabetically by map symbol |
| BRK | Black Rock terrane |
| GC | Golconda terrane |
| JN | Jackson terrane |
| JO | Jungo terrane |
| RM | Roberts Mountains terrane |
| | Walker Lake terrane |
| WPD | Paradise subterrane |
| WPN | Pine Nut subterrane |
| | Nonaccretionary continental rocks |
| NAm | North America—Continental rocks of North America not accreted during Phanerozoic time |
| TRu | Late Triassic overlap—Postaccretion overlap relation shown by line of small dots along depositional overlap contact |
| | Terrane-bounding fault—Dashed where approximately located |
| | Postaccretion or postamalgamation contact—Includes both depositional and intrusive contacts and faults that are not terrane boundaries. Dashed where contact is with Cenozoic deposits |
| | Belt of low-angle cordilleran thrust faults—Approximate east limit |

(Stewart and others, 1986; Oldow, 1984a). Small volcanogenic massive-sulfide prospects in the western part of Nevada are in the Jackson and Walker Lake terranes that contain pre-Tertiary, predominantly Mesozoic, volcanic rocks that are thought to have originated as volcanic island arcs (Russell, 1984; Silberling and others, 1987; Oldow, 1984b). The Rio Tinto deposit is classified as a Besshi-type massive-sulfide-deposit, the Big Mike deposit is classified as a Cyprus-type massive-sulfide deposit, and the small prospects in the western terranes are classified as kuroko-type massive-sulfide deposits. Other massive-sulfide deposits may be unrecognized or unclassified because of overprinting by intense hydrothermal mineralization of Tertiary age.

I have used some of the features ascribed to volcanogenic massive-sulfide deposits by Hutchinson (1973), Franklin and others (1981), and Lydon (1984) and summarized in Cox and Singer (1986) to select the deposits and prospects shown on the map and listed in table 1. These features are: (1) occurrence of pyrite, chalcopyrite, sphalerite, and galena either as lenticular concordant massive bodies or as stockwork systems, such as are known to underlie massive ore bodies in many places in (2) pre-Tertiary age host rocks that either are volcanic or contain a substantial volcanic-derived sedimentary component that (3) formed in a submarine environment. The coincidence of these three features permits the assumption that the deposit may be syngenetic in origin and formed by volcanic processes.

Silberling and others (1987) lithotectonic terranes (fig. 1) are used to group the pre-Tertiary rocks. Using their terrane definitions, the map outlines areas that contain volcanic rocks that are presumed to have been formed in an ocean-basin or island-arc environment. Table 2 lists the stratigraphic units that correlate with the terranes outlined on the map. Estimates of east-west extension in the Great Basin in Miocene time range from 20 to 100 percent. This extension would affect the distribution pattern of the terranes; correction for this extension would compress the terranes a like amount, giving different patterns of distribution. No attempt has been made to restore the extension.

## GOLCONDA TERRANE

The Golconda terrane is comprised of two dissimilar groups of rocks. Upper Paleozoic (Devonian to mid-Permian) pelagic and turbiditic sedimentary rocks and pillow lavas compose the Golconda allochthon. Triassic subaerial felsic volcanic rocks and carbonate and clastic sedimentary rocks unconformably overlie the older rocks and compose the late Triassic overlap. Only the rocks of the Golconda allochthon are suitable host rocks for massive-sulfide deposits.

The Golconda allochthon extends in a curved-S pattern from northeastern Nevada to western Nevada and attains its fullest width and stratigraphic continuity in north-central Nevada. It includes many formally named stratigraphic sequences throughout its extent (table 2) that are correlated with the Havallah sequence, which has been interpreted to have been formed in a deep ocean-basin environment (Stewart and others, 1977; Brueckner and Snyder, 1985) or, alternatively, in a back-arc-basin environment (Miller and others, 1984). Where the stratigraphic succession is well known, the lower part of the sequence is characterized by basalt pillow lava that is Late Devonian or Early Mississippian in age in northeastern Nevada and that could be as young as Permian in north central Nevada (Stewart and others, 1986). The association of pillow lava and chert suggests ophiolite sequences in the allochthon. The allochthon is interpreted to have been thrust into its present position along the Golconda thrust during the Triassic (Silberling and others, 1987). Recent studies by Stewart and others (1986) indicate that the entire sequence is a structural accumulation of thrust-repeated sedimentary and volcanic rocks that are Late Devonian to Permian in age, but are most commonly Mississippian and Pennsylvanian in age. Scattered exposures of serpentinite occur in the southern part of the Golconda terrane; these outcrops lie along or near the trace of the old continental margin as defined by a line connecting $^{87}Sr/^{86}Sr$ values of

0.706 from analysis of plutonic rocks (Kistler, R.W., in press; R.W. Kistler, oral and written commun. 1988).

The Big Mike Cyprus-type massive-sulfide copper deposit (No. 17, map and table 1) occurs in the Havallah sequence of the Golconda terrane at the north end of the Tobin Range in north-central Nevada. One other, the Ground Hog prospect (No. 16, map and table 1), occurs in the Toiyabe Range in central Nevada.

The Big Mike deposit was recognized as a massive sulfide during its period of exploration and development. The following is a summary of the significant characteristics, which are described in detail by Snyder (1977) and Rye and others (1984): The Big Mike consists of one main lens-shaped ore body, approximately 250 ft long, 160 ft wide, and 49 ft thick; other small lenses, all less than 25 ft in length, were found during mining. Both high-angle and low-angle faults offset the rocks in the mine area. The ore contains three types of sulfide occurrences: (1) **framboidal pyrite,** locally containing interstitial secondary copper sulfide (djurleite) thought to have replaced original chalcopyrite; (2) **massive pyrite ore,** composed principally of pyrite and lesser amounts of chalcopyrite and a little sphalerite; and (3) **stringer mineralization,** consisting of veinlets of quartz that contain pyrite, carbonate, sericite, and some chalcopyrite and sphalerite. The massive pyrite ore and the framboidal pyrite are restricted to carbonaceous chert and argillite; the stringer mineralization occurs in both the underlying and overlying pillow basalts. The massive pyrite ore has been affected by supergene mineralization; the secondary copper sulfides, djurleite and digenite, occur throughout the ore lens, and covellite and other copper alteration minerals (native copper, cuprite, chrysocolla, and malachite) occur in the upper part of the ore lenses. The mineralized stringer zone in the footwall pillow basalt is intensely oxidized. No secondary alteration of chalcopyrite was observed in either the stringer zone in the hanging-wall pillow basalts or in the mineralized interstices in the footwall pillow basalt. Manganiferous cherts and jasper, locally cut by hematite-bearing quartz veins, occur in the rocks stratigraphically above the ore deposit. Supergene alteration also resulted in a gossan zone in the metavolcanic rocks below the ore deposits that extended as far as 30 ft below the surface.

The Ground Hog claim (No. 16, map and table 1) is little more than a prospect in silicified greenstone that had anomalous copper values detected in geochemical analysis. However, it is included because the geologic setting is correct for these types of deposits, the geochemical analysis (Kleinhampl and Ziony, 1985b, p. 242; see table 1) is permissive for this type, and the silicified zone could represent an exhalite zone or footwall stockwork in the original rocks before metamorphism and deformation.

The Golconda allochthon contains many local sites where pillow basalts and cherts are known to occur. Massive pyrite bodies occur within the terrane, and one such is reported to be located at the mouth of Mill Canyon on the west side of Battle Mountain (Ralph Roberts, 1988, oral commun.). Yet discoveries of massive-sulfide deposits that have significant copper or zinc grades are limited to the Big Mike so far as is now known. Bedded jaspers, jasperoid dikes, and sediment-hosted volcanogenic manganese accumulations (of the type described by Koski, 1986) may offer useful guides for massive-sulfide exploration (Snyder, 1977). Gossans led to the discovery of the Big Mike deposit and the Rio Tinto (in the Roberts Mountains terrane).

## JACKSON TERRANE

The Jackson terrane as shown on the map is composed of two terranes, the Jackson terrane and the Black Rock terrane that were originally depicted by Silberling and others (1987) as distinct terranes. The rocks assigned to the original definition of the Jackson terrane include Upper Triassic to Middle Jurassic rocks of the Happy Creek Volcanic Complex. These igneous rocks occur in the Jackson Mountains (Willden, 1963; Russell, 1984; Sorensen, 1986) and Pine Forest Range (Smith, 1973) and are an extrusive-intrusive complex of basaltic andesite, andesite, diorite, and quartz diorite dikes and lavas, autobreccias, and flow breccias. Similar metavolcanic rocks, shown on the state geologic map as Permian and Triassic (Stewart and Carlson, 1978), occur along the periphery of the Black Rock Desert.

The rocks assigned to the original definition of the Black Rock terrane include Mississippian to middle Triassic ocean-basin and island-arc rocks in isolated exposures in northwesternmost Nevada. It represents either a single original terrane of stratigraphically related but laterally variable rocks that have been brought together tectonically or a composite of different terranes. Silberling and others (1987) put this terrane together from isolated outcrops of different ages and lithologies. The Black Rock terrane is now considered to be part of the Jackson terrane (N.J. Silberling, oral commun., 1988) and is shown as such on the map. The Black Rock terrane, as originally defined, is composed of predominantly sedimentary rocks of volcaniclastic and deep oceanic nature -- cherts, argillites, and turbidites. Limestones that are interpreted to have been formed either on the continental platform, transported as part of submarine gravity slides from the continental shelf, or in the ocean basin occur in different exposures assigned to the terrane. The volcanic rocks originally assigned to the Black Rock terrane occur in two areas: (1) Quinn River, where they range from andesite to peridotite, although they are predominantly basalts and intrusive gabbro (Ketner and Wardlaw, 1981); and (2) in the Granite Range, where they are metabasalt and meta-andesite flows, breccias, and tuffs (Bonham, 1969). The metavolcanic rocks of the Black Rock terrane are patterned on the map the same as the Jackson terrane. Record of base-metal deposits within the Black Rock terrane, as originally defined, that fit the model for massive-sulfide deposits has not been found.

Record of base-metal deposits within the Jackson terrane that fit the model for massive-sulfide deposits exists. Small copper prospects in the Pine Forest Range (Nos. 1-3, map and table 1) contain some features that are suggestive for volcanogenic massive-sulfide type deposits. Recent studies within the southern Jackson Mountains (Sorensen and others, 1987; Hamilton, 1987) describe silver-copper and iron-copper prospects (Nos. 4-9, map and table 1) that are targets for exploration for volcanogenic massive-sulfide deposits. An association with magnetite deposits exists throughout the area, and all the deposits may be part of the same volcanogenic system. The copper-bearing prospects and small mines shown on the map and listed in the table are possibly kuroko-type massive-sulfide veins that contain base and precious metals; barite veins were also noted throughout the region (but are not shown on the map or listed in the table). These small prospects and mines may represent various morphological parts of a massive-sulfide system, such as bedded sulfide deposits in depressions, sulfide stringer veins associated with vent zones, and copper-rich sediments distal to the vent zone. Some, or all, may be fractured, faulted, remobilized, and redeposited within the volcanic sequence.

The Red Boy mine (No. 8, map and table 1) is one of the exploration targets for volcanogenic massive-sulfide deposits. The Red Boy mine produced a small tonnage of lead-zinc ore during the 1940's and in the 1980's (Hamilton, 1987). Rock types at the Red Boy mine area include andesite flows, tuffs, agglomerates, and breccias. Mineralized zones consist of disseminated pyrite and chalcopyrite, barite chemical sediment, massive gossan, quartz-sulfide veins, and siliceous lead-zinc clast supported breccia. Siliceous hematite veins and carbonate veins also occur. Ore minerals in the veins include pyrite, chalcopyrite, argentiferous galena, sphalerite, arsenopyrite, and magnetite. The occurrences at the Red Boy mine and vicinity were interpreted by Wescord Resources to be massive sulfides and exhalite horizons in a volcanogenic system which had vent areas to the northwest of the mine (Hamilton, 1987).

## JUNGO TERRANE

The Jungo terrane includes Upper Triassic and Lower Jurassic fine-grained terrigenous clastic rocks of the Auld Lang Syne Group (Burke and Silberling, 1973). These rocks are interpreted to have accumulated, perhaps as marine turbidity currents, in an ocean basin (Speed, 1978; Lupe and Silberling, 1985) after the emplacement of the Golconda allochthon. They contain no volcanic rocks. The southeast outcrops of the Jungo terrane contain mafic igneous rocks that have been interpreted as a lopolithic complex (Speed, 1976) or ophiolite (Erskine and Moores, 1984). Recent field investigations note a lack of intrusive contacts and metamorphic aureoles (Sidder, 1988; N.J Page, oral commun., 1987). These layered mafic rocks of the Humboldt Complex are gabbroic and basaltic in composition and texture and are associated with pure quartz sandstones of Jurassic age.

Record of base-metal deposits that fit massive-sulfide-deposit models in the sedimentary rocks of the Jungo terrane has not been found. Nickel-copper-cobalt prospects in the Cottonwood Canyon area of Churchill County are associated with the layered mafic igneous rocks of the Humboldt Complex. These prospects may be related to the Duluth Cu-Ni-PGE deposit type (Page, 1986) or to the volcanic-hosted magnetite deposit type (Cox, 19?6b) rather than volcanogenic massive-sulfide deposits (G.B. Sidder, oral commun., 1985). Therefore, neither the Humboldt Complex nor these prospects are shown on the map or on table 1.

## ROBERTS MOUNTAINS TERRANE

The Roberts Mountains terrane (Roberts terrane of Silberling and others, 1987) includes early to middle Paleozoic deep-marine volcanic and sedimentary rocks of the Roberts Mountains allochthon and similar deep-marine, predominantly sedimentary rocks that may be authochthonous in the southern part of the terrane. Many different formational names are given to these rocks (table 2). Rock types are chert-argillite-greenstone sequences and clastic turbidites. The most geographically widespread names are the Ordovician Valmy and Vinini Formations, which are interpreted to be facies of each other. The Valmy Formation contains more volcanic rock. The map distinguishes those map units (Valmy Formation, Slaven Chert, which is now recognized as containing pillow lava in the Shoshone Range (C.T. Wrucke, oral commun., 1989), Scott Canyon Formation, and undifferentiated siliceous and volcanic rocks in northeastern Elko County) that contain abundant volcanic rocks from those in which volcanic rocks are notably sparse.

Silberling and others (1987) also include the upper Paleozoic, nonmarine to shallow-marine conglomeratic rocks of the overlap assemblage in the Roberts Mountains terrane; these formations (the Antler sequence of Silberling and Roberts, 1962, and correlated map units of Stewart and Carlson, 1978) were deposited unconformably on the Roberts Mountains allochthon before the emplacement of the Golconda allochthon. These rock units occur in different exposures than the deep-marine rocks and are not shown on this map.

Recent studies (see especially Madrid, 1987) suggest that the lower stratigraphic succession of the Roberts Mountains allochthon in most areas is characterized by pillow lava and other volcanic rocks; the upper stratigraphic succession is characterized by volcaniclastic and other clastic sedimentary rock types. Oldow (1984a) interprets the lithology and structure of the rocks included within the allochthon to represent oceanic basin, rise, and slope accumulations accreted to the continent as part of the obduction of an east-facing accretionary prism. Madrid (1987) suggests that the rocks composing the allochthon were deposited in a rift basin floored by Precambrian miogeoclinal continental rocks developed along the continental margin of North America. These rocks are now exposed in a series of thrust nappes.

The Rio Tinto (Mountain City) copper deposit (No. 18, map and table 1) is interpreted to be a massive-sulfide deposit of the Besshi type (Proffett, 1979; D.P. Cox and J.A. Briskey, oral commun., 1985). It occurs in the Ordovician Valmy Formation in the northernmost exposures of the Roberts Mountains terrane. Volcanic rock, in the form of pillow lava, diabase flows and sills, common in the Valmy is not found near the deposit, but it does occur in the outcrop area near Mountain City (Coats, 1968).

The ore forms disc-shaped lenses as much as 1,000 by 90 ft in shales and quartzite beds in the Valmy Formation (Coats and Stephens, 1968). Other smaller lenses occur both along strike and below the main lens. Mine workings are now inaccessible. The deposit was discovered by drilling through an exposed leached gossan (Crawford and Forbes, 1932a, b). The ore, consisting of massive pyrite and subordinate chalcopyrite, local sphalerite, and rare galena was strongly affected by supergene chalcocite, bornite, and covellite enrichment. Shales (phyllites) below the ore body contain the nonsulfide ore minerals cuprite, native copper, malachite, and azurite. The primary massive ore is associated with gray quartzose ore that is erratically silicified and cut by chalcopyrite and pyrite veinlets or completely silicified and coarsely banded and contains chalcopyrite and pyrite in streaks and blobs. Also associated is "banded white quartz ore" that is distinctly layered, pervasively silicified, and micro veined by quartz, pyrite, and chalcopyrite. Chloritic shales below the ore body contain lenticles of pyrite and chalcopyrite.

Other occurrences of syngenetic pyrite in stringers, pods, and disseminations reportedly occur at various localities throughout the terrane. One such stringer zone is located at the mouth of the Cottonwood Creek canyon on the south end of the Toiyabe Range (Cascaceli and others, 1986). A pyrite pod is located at Saval Ranch along Gance Creek on the east side of the Independence Mountains (Ralph Roberts, oral commun., 1988). These and other similar occurrences do not have sufficient copper mineralization associated with them to warrant a published written record.

## WALKER LAKE TERRANE

The Walker Lake terrane contains many rock units that include diverse lithologies and are assigned different formational names (table 2); most units are Mesozoic in age, some are upper Paleozoic in age. The rock types include marine carbonate, siliciclastic, and volcaniclastic rocks, marine and nonmarine volcanic flows and tuffs, and terrigenous clastic rocks and evaporites. The terrane is divided into the Paradise and Pine Nut subterranes based on depositional history and structural style (Silberling and others, 1987). Most of the volcanic and associated sedimentary rocks in both subterranes have been interpreted to have been formed in a marine volcanic-arc environment (Silberling and others, 1987; Oldow, 1984b, and Proffett and Dilles, 1984), although some rocks are interpreted to have formed subaerially (Speed, 1978, 1984; Proffett and Dilles, 1984). The units shown on the map are those which, in my interpretation, appear to have been formed in an island-arc environment. A number of small copper deposits occur in the Walker Lake terrane that have characteristics suggestive of a volcanogenic origin. These features include copper sulfide mineralization, stockworks, gossans, and host rocks permissive for the occurrence of kuroko-type massive-sulfide deposits (Singer, 1986b).

Scattered small prospects that contain disseminated copper minerals (Nos. 11-13, map and table 1) occur in metavolcanic rocks assigned to the Peavine sequence of westernmost Nevada by Bonham (1969). The Peavine sequence occurs on Peavine Peak and Petersen Mountain north of Reno and as small outcrops of roof pendants in Mesozoic granitic rocks and windows surrounded by Tertiary volcanic and sedimentary rocks along the western border of the state. These rocks, which may be part of the Pine Nut subterrane (Silberling and others, 1987), are predominantly andesitic to dacitic in composition, but basalt and rhyolite are common (Bonham, 1969). Pillow basalt, if present, is rarely preserved (Bonham, 1969, and Moore, 1969). The metallogenic history of this region is complicated by the overprint of Tertiary mineralization, indicated by bleaching and pyritization of both Tertiary and older rocks, and the presence of Tertiary epithermal deposits. Both Hill (1915) and Bonham (1969) point out that some deposits in the vicinity of Peavine Mountain are pre-Tertiary in age. Only pre-Tertiary deposits are included in table 1.

Two gossans suggestive of volcanogenic massive-sulfide origin occur in the southern part of the Pine Nut subterrane. One is a small prospect (No. 14, map and table 1) for copper oxides and sulfides in meta-andesite associated with an iron gossan. The other, a magnetite-bearing gossan (No. 15, map and table 1) in metadacite, was described by Hudson (1983), who suggested a volcanogenic origin. Other prospects in that region contain copper sulfide minerals in pre-Tertiary metavolcanic host rock, but they are not shown because evidence is insufficient to suggest volcanogenic origin. Silicic rocks, perhaps volcanic centers, are associated with some of the outcrop areas in the Pine Nut subterrane (Byron Berger, oral commun., 1988). However, the presence of gypsum deposits and welded tuffs in the rocks in the southern part of the Walker Lake terrane indicate that part of the Pine Nut subterrane is subaerial (Moore, 1969) and would not be permissive for massive-sulfide deposits. Detailed mapping by Proffett and Dilles (1984) and a broad regional summary by Dilles and Wright (1988) also indicate that some of the volcanic and associated sedimentary rocks are subaerial in origin. The map units containing these lithologies are not shown.

I have not shown any massive-sulfide prospects in the Paradise subterrane of the Walker Lake terrane. Only part of the Mesozoic metavolcanic rocks in this subdivision are interpreted to be marine in origin and to be permissive for massive-sulfide deposits. The sparse descriptive information available about copper occurrences includes some features in common with peripheral parts of massive-sulfide deposits (such as stringers, disseminated sulfides, barite), but these deposits fit equally well into polymetallic vein, and (or) polymetallic replacement, copper skarn, or porphyry copper deposit types that are identified and considered permissive for this area (Orris and Kleinhampl, 1986).

## NORTH AMERICAN CRATON

The North American Craton is characterized by Precambrian and Paleozoic metamorphic, igneous, and sedimentary rocks. The Precambrian rocks include rock types that are interpreted to have been formed in a major eugeosyncline and associated magmatic arc (Stewart, 1980) and might host massive-sulfide deposits similar to those described for Arizona (Anderson and Guilbert, 1979; Donnelly and Conway, 1988) and New Mexico (Robertson and others, 1986). No identified copper-, lead-, or zinc-bearing prospects that contain characteristics of massive-sulfide deposits have been identified within the Precambrian of southeastern Nevada.

## CONCLUSIONS

Rocks that have an inferred depositional environment known to host the three main types of massive-sulfide deposits are common, widespread, relatively well exposed, and variously well studied in Nevada. Yet, only two recognized deposits of the massive-sulfide type are known in the state. Scattered occurrences of mineralization suggestive of underlying stringer mineralization are present, however, wide areas of permissive rock are unmapped and unexplored, and many undiscovered deposits could exist in Nevada.

## REFERENCES


Anderson, Phillip, and Guilbert, J.M., 1979, The Precambrian massive sulfide deposits of Arizona--a distinct metallogenic epoch and province: Nevada Bureau of Mines and Geology, Report 33, p. 39-48.

Bonham, H.F., 1969, Geology and mineral deposits of Washoe and Storey Counties, Nevada, *with* a section on industrial rock and mineral deposits by K.G. Papke: Nevada Bureau of Mines and Geology Bulletin 70, 140 p.

Brueckner, H.K., and Snyder, W.S., 1985, Structure of the Havallah sequence, Golconda allochthon, Nevada: Evidence for prolonged evolution in an accretionary prism: Geological Society of America Bulletin, v. 96, p. 1113-1130.

Burke, D.B., and Silberling, N.J., 1973, The Auld Lang Syne Group, of Late Triassic and Jurassic(?) age, north-central Nevada: U.S. Geological Survey Bulletin 1394-E, p. E1-E14.

Cascaceli, R.J., Wendell, D.E., and Hoisington, W.D., 1986, Geology and mineralization of the McGinness Hills, Lander County, Nevada: Nevada Bureau of Mines and Geology Report 41, p. 93-102.

Coats, R.R., 1968, Preliminary geologic map of the southwestern quarter of the Mountain City quadrangle, Elko County, Nevada: U.S. Geological Survey open-file map, scale 1:20,000.

_______1987, Geology of Elko County, Nevada: Nevada Bureau of Mines and Geology Bulletin 104, 112 p.

Coats, R.R., and Stephens, E.C., 1968, Mountain City Copper Mine, Elko County, Nevada, *in* Ridge, J.D., ed., Ore deposits of the United States, 1933-1967 (Graton Sales Volume), v. 2: New York, N.Y., American Institute of Mining Metallurgical, and Petroleum Engineers, p. 1074-1101.

Cox, D.P., 1986a, Descriptive model of Besshi massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 136.

_______1986b, Descriptive model of volcanic-hosted magnetite, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 172.

Cox, D.P., and Singer, D.A., Eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.

Crawford, A.L., and Forbes, D.C., 1932a, The Rio Tinto copper discovery near Mountain City, Nevada: Proceedings of the Utah Academy of Sciences, Arts and Letters, v. 9, p. 51-52.

_______1932b, Microscopic characteristics of the Rio Tinto, Nevada, copper deposit: The Mines Magazine, Colorado School of Mines Alumni Association, v. 22, no. 8, p. 7-9.

Dilles, J.H., and Wright, J.E., 1988, The chronology of early Mesozoic arc magmatism in the Yerington district of western Nevada and its regional implications: Geological Society of America Bulletin, v. 100, no. 5, p. 644-652.

Donnelly, M.E., and Conway, C.M., 1988, Metallogenic map of volcanogenic massive-sulfide occurrences in Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-1835-B, scale 1:1,000,000.

Erskine, M.C., and Moores, E.M., 1984, Ophiolitic belts of western Nevada, field and geophysical evidence

[abs]: Geological Society of America Abstracts with Programs, v. 16, no. 6, p. 503.

Franklin, J.M., Lydon, J.W., and Sangster, D.F., 1981, Volcanic-associated massive sulfide deposits: Economic Geology, 75th Aniversary Volume, p. 485-627.

Hamilton, M.M., 1987, Mineral resources of the South Jackson Mountains Wilderness Study Area, Humboldt County, Nevada: U.S. Bureau of Mines Mineral Land Assessment Open-File Report MLA-10-87, 93 p.

Hill, J.M., 1915, Some mining districts in northeastern California and northwestern Nevada: U.S. Geological Survey Bulletin 594, 200 p.

Hudson, D.M., 1983, Alteration and geochemical characteristics of the upper parts of selected porphyry systems, western Nevada: Reno, Nev., University of Nevada, Ph.D. dissertation, 229 p.

Hutchinson, R.W., 1973, Volcanogenic sulfide deposits and their metallogenic significance: Economic Geology, v. 68, p. 1223-1246.

Kay, Marshall, and Crawford, J.P., 1964, Paleozoic facies from the miogeosynclinal to the eugeosynclinal belt in thrust slices, central Nevada: Geological Society of America Bulletin, v. 75, p. 425-454.

Ketner, K.B., and Wardlaw, B.R., 1981, Permian and Triassic rocks near Quinn River Crossing, Humboldt County, Nevada: Geology, v. 9, no. 3, p. 123-126.

Kistler, R.W., in press, Chemical and isotopic characteristics of two different lithosphere types in the Sierra Nevada of California, *in* Anderson, J.L. ed., Cordilleran magmatism: Geologic Society of America Memoir 174.

Kleinhampl, F.J., and Ziony, J.I., 1985a, Geology of northern Nye County, Nevada: Nevada Bureau of Mines and Geology Bulletin 99A, 172 p.

_______1985b, Mineral Resources of northern Nye County, Nevada: Nevada Bureau of Mines and Geology Bulletin 99B, 243 p.

Koski, R.A., 1986, Descriptive model of volcanogenic Mn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 139.

Lupe, Robert, and Silberling, N.J., 1985, Genetic relationship between lower Mesozoic continental strata of the Colorado Plateau and marine strata of the western Great Basin: significance for accretionary history of Cordilleran lithotectonic terranes, p. 263-272 *in* Howell, D.G., ed., Tectonostratigraphic terranes of the Circum-Pacific Region: Circum-Pacific Council for Energy and Mineral Resources, Earth Science Series, no. 1, 581 p.

Lydon, J.W., 1984, Ore deposit models - 8. Volcanogenic massive sulphide deposits, part 1: a descriptive model: Geoscience Canada, v. 11, no. 4, p. 195-202.

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

Miller, E.L., Holdsworth, B.K., Whiteford, W.B., and Rodgers, D., 1984, Stratigraphy and structure of the Schoonover sequence, northeastern Nevada: Implications for Paleozoic plate-margin tectonics: Geological Society of America Bulletin, v. 95, p. 1063-1976

Moore, J.G., 1969, Geology and mineral deposits of Lyon, Douglas, and Ormsby Counties, Nevada: *with* a section on industrial mineral deposits by N.L. Archbold: Nevada Bureau of Mines and Geology Bulletin 75, 45 p.

Oldow, J.S., 1984a, Spatial variability in the structure of the Roberts Mountains allochthon, western Nevada: Geological Society of America Bulletin, v. 95, p. 174-185.

_______1984b, Evolution of late Mesozoic back-arc fold and thrust belt, northwestern Great Basin, U.S.A.: Tectonophysics, v. 102, p. 245-274.

Orris, G.J., and Kleinhampl, F.J., 1986, Preliminary mineral resource assessment of the Tonopah 1° by 2° quadrangle, Nevada: U.S. Geological Survey Open-File Report 86-470, 23 p. plus appendices and maps.

Page, N.J, 1986, Descriptive model of Duluth Cu-Ni-PGE, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 16.

Proffett, J.M., Jr., 1979, Ore deposits of the western United States: a summary: Nevada Bureau of Mines and Geology Report 33 [Papers on mineral deposits of western North America], p. 13-32.

Proffett, J.M., and Dilles, J.H., 1984, Geologic map of the Yerington district, Nevada: Nevada Bureau of Mines and Geology Map 77, scale 1:24,000.

Robertson, J.M., Fulp, M.S., and Daggett, M.D., III, 1986, Metallogenic map of volcanogenic massive-sulfide occurrences in New Mexico: U.S. Geological Survey, Miscellaneous Field Studies Map MF-1853-A, scale 1:1,000,000.

Russell, B.J., 1984, Mesozoic geology of the Jackson Mountains, northwestern Nevada: Geological Society of America Bulletin, v. 95, p. 313-323.

Rye, R.O., Roberts, R.J., Snyder, W.S., Lahusen, G.L., and Motica, J.E., 1984, Textural and stable isotope studies of the Big Mike cupriferous volcanogenic massive sulfide deposit, Pershing County, Nevada: Economic Geology, v. 79, p. 124-140.

Sidder, G.B., 1987, A report on work in progress for the Reno 1° x 2° CUSMAP project, Nevada, *with* additional bibliography: U.S. Geological Survey Open-File Report, 87-656, 22 p.

Silberling, N.J., Jones, D.L., Blake, M.C., Jr., and Howell, D.G. 1987, Lithotectonic terrane map of the western conterminous United States: U.S. Geological Survey Miscellaneous Field Studies Map MF-1874-C, scale 1:2,500,000

Silberling, N.J., and Roberts, R.L., 1962, Pre-Tertiary stratigraphy and structure of northwestern Nevada: Geological Society of America Special Paper 72, 58 p.

Singer, D.A., 1986a, Descriptive model of Cyprus massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 131.

_______1986b, Descriptive model of kuroko massive sulfide, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 189.

Smith, J.G., 1973, Geologic map of the Duffer Peak quadrangle, Humboldt County, Nevada: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-606, scale 1:48,000.

Snyder, W.S., 1977, Origin and exploration for ore deposits in upper Paleozoic chert-greenstone complexes of northern Nevada: Stanford, Calif., Stanford University, Ph.D. dissertation, 159 p.

Sorensen, M.L., 1986, Geologic map of the South Jackson Wilderness Study Area, Humboldt County, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-1829, scale 1:48,000

Sorensen, M.L., Plouff, Donald, Turner, R.L, and Hamilton, M.M., 1987, Mineral resources of the South Jackson Mountains Wilderness Study Area, Humboldt County, Nevada: U.S. Geological Survey Bulletin 1726 B, 14 p.

Speed, R.C., 1976, Geologic map of the Humboldt lopolith and surrounding terrane, Nevada: Geological Society of America Map and Chart Series MC-14, scale 1:80,000.

_______1978, Paleogeographic and plate tectonic evolution of the early Mesozoic marine province of the western Great Basin, p. 253-270, *in* Howell, D.G., and McDougall, K.A., eds., Mesozoic Paleogeography of the Western United States, Pacific Coast Paleogeography Symposium 2, Annual Convention of the Pacific Section of the Society of Economic Paleontologists and Mineralogists, Sacramento, Calif., 1978, 573 p.

Speed, R.C., 1984, Paleozoic and Mesozoic continental margin collision-zone features: Mina to Candelaria, Nevada traverse (field trip 6): Geological Society of America, Western Geological Excursions, v. 4, p. 66-80.

Stewart, J.H., 1980, Geology of Nevada: Nevada Bureau of Mines and Geology Special Publication 4, 136 p.

Stewart, J.H., and Carlson, J.E., 1978, Geologic map of Nevada: U. S. Geological Survey, map scale 1:500,000.

Stewart, J.H., Carlson, J.E., and Johannesen, D.C. 1982, Geologic map of the Walker Lake 1° by 2° quadrangle, California and Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-1382-A, scale 1:250,000.

Stewart, J.H., MacMillan, J.R., Nichols, K.M., and Stevens, C.H., 1977, Deep-water upper Paleozoic rocks in north-central Nevada--a study of the type area of the Havallah Formation: p. 337-347, *in* Stewart, J.H., Stevens, C.H., and Fritsche, A.E., eds., Paleozoic Paleogeography of the Western United States, Pacific Coast Paleogeography Symposium 1, Annual Convention of the Pacific Section of the Society of Economic Paleontologists and Mineralogists, Bakersfield, Calif., 502 p.

Stewart, J.H., Murchey, Benita, Jones, D.L., and Wardlaw, B.R., 1986, Paleontologic evidence for complex tectonic interlayering of Mississippian to Permian deep-water rocks of the Golconda allochthon in Tobin Range, north-central Nevada: Geological Society of America Bulletin, v. 97, p. 1122-1132.

Whitebread, D.H., 1986, Generalized geologic map of the Tonopah 1° by 2° quadrangle, Nevada: U.S. Geological Survey Open-File Report 86-462, scale 1:250,000.

Willden, Ronald, 1963, General geology of the Jackson Mountains, Humboldt County, Nevada: U.S. Geological Survey Bulletin 1141-D, 65 p

**Table 1.** Possible volcanogenic massive-sulfide deposits in Nevada

[Mes., Mesozoic; Pal., Paleozoic. Elements are Ag, silver; As, arsenic; Au, gold; Ba, barium; Co, cobalt; Cu, copper; Fe, iron; Mn, manganese; Mo, molybdenum; Pb, lead; Sb, antimony; Zn, zinc]

| Locality No. | Name | Latitude Longitude | Age | Host-rock lithology | Mode of occurrence | Elements | Remarks |
|---|---|---|---|---|---|---|---|
| | | | | **Jackson terrane** | | | |
| 1 | Moose group.......... | 41°31'48"N. 118°50'02"W. | Mes. | Andesite | Underground... | Cu, Ag, Au | Oxidized copper minerals associated with gold and silver in quartz veins in volcanics. |
| 2 | Cove Meadow......... | 41°33'51"N. 118°48'25"W. | Mes. | Andesite | Surface and underground. | Cu, Au, Ag | Tabular near-surface oxidized ore body in shear zone; stringer and disseminated. Silicified, chloritized, associated limonite and magnetite gangue. Grades of hand-sorted ore: 2.83% to 7.5% Cu; 0.005 to 0.010 oz Au; 1.875 to 3.3 oz Ag from 46 and 42 tons. |
| 3 | Yellow Dog and Hapgood prospects. | 41°33'25"N. 118°34'15W. | Mes. | Andesite | Surface........... | Cu, Au, Ag | Free gold, chalcopyrite, copper oxides in prospects with other sulfides at depth; associated with kaolinization, Mn staining, and gossan. |
| 4 | Bold prospect.......... | 41°16'02"N. 118°21'57"W | Mes. | Andesite | Underground.... | Cu, Au, Fe | Disseminated chalcopyrite, galena, and pyrite in quartz veins in volcanics. |
| 5 | Jackson Creek prospect. | 41°19'07"N. 118°30'19"W | Mes. | Andesite | Surface and underground. | Cu, Co, Ag, Au | Copper-bearing stringer quartz veins; sulfide-bearing zones containing mineralized veins. Hematite, chalcopyrite, and others. Sulfides remobilized and redeposited in limestone units. Geochemical analyses indicate values in gold, silver, copper, and nickel and cobalt. Geophysical anomalies indicate massive sulfide potential at depth under thrust sheet. In part interpreted to be vent zone. Active exploration target for volcanogenic massive-sulfide deposits in 1986. Includes Harrison Grove, Humboldt King, Jackson Queen mines, which are in sedimentary rocks in thrust sheets above the Happy Creek Volcanic Complex. |

**Table 1.** Possible volcanogenic massive-sulfide deposits in Nevada--Continued

| Locality No. | Name | Latitude Longitude | Age | Host-rock lithology | Mode of occurrence | Elements | Remarks |
|---|---|---|---|---|---|---|---|
| 6 | Avalanche prospect.... | 41°15'26"N. 118°32'20"W. | Mes. | Andesite | Surface.......... | Ag, Cu, Pb | Silver- and copper-bearing veins near with felsic intrusive rock; geochemical analysis indicates values as high as 35 ppm Ag and 12% Cu. |
| 7 | Clover prospect........ | 41°14'19"N. 118°31'11"W. | Mes. | Andesite | Surface.......... | Au, Cu, Pb | Sulfide veins near small alkalic granitic intrusive body. Pyritic alteration. Geochemical analysis indicates values as high as 99 ppm Ag, .40% Cu, and 3% Pb. |
| 8 | Red Boy mine.......... | 41°12'49"N. 118°31'20"W. | Mes. | Andesite | Surface and underground. | Au, Ag, Cu, Pb, Zn | Massive-sulfide deposits and carbonate veins containing chalcopyrite, argentiferous galena and sphalerite. Former producer, small tonnage. Gossans and siliceous boxwork present. Geochemical analysis indicates values as high as 5 ppm Au, 500 ppm Ag, 0.13% Cu, 10% Pb, and 7% Zn. |
| 9 | Red Star prospect...... | 41°11'49"N. 118°31'49"W. | Mes. | Andesite | Surface.......... | Fe, Cu | Veins of magnetite and hematite; wallrock contains values in base metals. Geochemical analysis indicates values as high as 53% Fe in vein deposits and 0.20 ppm Au, 1 ppm Ag, 0.41% Cu, and 14% Fe in altered wallrock. Drilled in 1958 for iron; explored in 1986 for massive-sulfide deposits. |
| 10 | Gilbert and Stroud..... | 41°02'60"N. 118°31'53"W. | Mes. | Andesite | Underground.... | Au, Cu | Gold-copper deposit in Happy Creek Volcanic Complex. |
| 11a | Prospect (N. end Freds Mountain). | 39°47'43"N. 119°50'53"W. | Mes. | Metavolcanics | Surface.......... | Cu | Disseminated copper sulfides. |
| 11b | Comstock Eureka..... | 39°47'37"N. 119°50'06"W. | Mes. | Metavolcanics | Surface.......... | Cu, Au | Quartz vein. |
| 12 | Antelope................ | 39°44'05"N. 119°59'52"W. | Mes. | Dacitic meta-volcanic. | Surface and underground. | Cu, Ag, Au | Selected samples assayed 2% to 10% Cu; described as quartz vein. |

**Table 1.** Possible volcanogenic massive-sulfide deposits in Nevada--Continued

| Locality No. | Name | Latitude Longitude | Age | Host-rock lithology | Mode of occurrence | Elements | Remarks |
|---|---|---|---|---|---|---|---|
| | | | | **Walker Lake terrane** | | | |
| 13 | Red Metals mine....... | 39°36'42"N. 119°56'53"W. | Mes. | Meta-andesite | Surface and underground. | Cu, Au | Overlapping lenses containing oxidized copper sulfide minerals derived mainly from bornite. |
| 14 | United Mining Co..... | 39°04'14"N. 119°35'44"W. | Mes. | Metavolcanics | Underground.... | Cu | Iron gossan present. |
| 15 | Minnehaha gossan..... | 38°50'00"N. 119°35'00"W. | Mes. | Dacitic meta-volcanic. | Surface........... | Cu, Pb, Zn, Mo, As | Strataform massive limonite gossan; occurs in fragmental dacite unit. |
| | | | | **Golconda terrane** | | | |
| 16 | Ground Hog and other claims. | 38°57'04"N. 117°19'07"W. | Pal., Mes. | Greenstone | Surface and underground. | Cu, Au, Ag, Sb, Mn, Ba | Ore along linear zone; rocks are silicified, slightly argillized, and locally pyritized. Ore minerals are oxidized and coat fractures. Geochemical analysis of rock yields 0.18 and 0.04 ppm Au; 1 ppm Ag, 150 ppm Zr, 700 ppm Ba, and 0.28 ppm Hg; geochemical analysis of mineralized fracture coatings yield 0.24 and <0.02 ppm Au, 1.5 ppm Ag, 2,000 ppm Cu, 300 ppm Sb, 150 ppm Mn, and 5,000 ppm Ba. |
| 17 | Big Mike mine......... | 40°32'33"N. 117°33'35"W. | Pal. | Greenstone | Surface........... | Cu | Stratiform massive-sulfide deposit. Ore is entirely within a faulted, thin cherty carbonaceous argillite; stringer zones occur in underlying and nearby pillow basalt. Gossan, jasper, and manganiferous chert occur. |

**Table 1.** Possible volcanogenic massive-sulfide deposits in Nevada--Continued

| Locality No. | Name | Latitude Longitude | Age | Host-rock lithology | Mode of occurrence | Elements | Remarks |
|---|---|---|---|---|---|---|---|
| **Roberts Mountains terrane** | | | | | | | |
| 18 | Rio Tinto mine......... | 41°48'43"N.<br>115°58'50"W. | Pal. | Shales | Underground.... | Cu | Massive-sulfide deposit. Ore occurs as disc-shaped lenses stratigraphically restricted to a zone of black and gray shale (metamorphosed to phyllite) with associated minor quartzite lenses. The massive ore consists of an intimate mixture of quartz, pyrite, chalcopyrite, with rare sphalerite; parts of the ore are banded. Supergene copper are well developed. |

**Table 2.** Correlation of terranes with stratigraphic units

| Age | Stratigraphic units | Lithology | Reference |
|---|---|---|---|
| | | **Golconda terrane** | |
| Mississippian........ | Msv (=Goughs Canyon and Inskip Fms.). | Siliceous and volcanic rocks: altered pillow lavas, coarse volcanic breccias, clastic limestone, and minor amounts of sandstone, shale, and chert (Goughs Canyon Fm.); quartzite, conglomerate, slate, limestone, chert, and greenstone (Inskip Fm.). | Stewart and Carlson (1978). |
| Permian to Devonian | PMh (=Schoonover, Reservation Hill, Farrel Canyon, Pumpernickel, Havallah, Pablo (in part), and Excelsior (in part) Fms.). | Chert, argillite, shale, greenstone, and minor amounts of siltstone, sandstone, conglomerate, and limestone. | Do. |
| Permian (formerly considered to be Ordovician). | Os (=Willow Springs Fm.). | Dark greenish-gray chert, amygdaloidal andesite, pillow lava, rare quartzite. | Kay and Crawford (1964). |
| Mesozoic, Paleozoic, Ordovician to Cambrian. | Pzub, Pzdi, O€ub, MzPzs. | Serpentine and ultramafic volcanic rocks; porphyry, diabase, peridotite. | Kleinhampl and Ziony (1985a); Whitebread (1986). |
| | | **Jackson terrane** | |
| Upper Triassic to Middle Jurassic. | Happy Creek igneous complex. | Basaltic andesite and andesite, diorite to quartz diorites. | Russell (1984). |

**Table 2.** Correlation of terranes with stratigraphic units--Continued

| Age | Stratigraphic units | Lithology | Reference |
|---|---|---|---|
| | | **Jackson terrane--continued** | |
| Permian or older..... | Happy Creek Volcanic Series. | Meta-andesite, tuff-breccia, tuff and andesite, sedimentary rocks, volcaniclastic sedimentary rock, graywacke and hornfels, limestone and marble. | Smith (1973). |
| Permian or older..... | Happy Creek Volcanic Series. | Andesite, basalt, and trachyte to dacite; graywacke. | Willden (1963). |
| Triassic to Permian.. | ₨Pvs............... | Volcanic flows and breccias, chiefly andesitic in composition, tuffs, sparse sandstone, and graywacke. | Stewart and Carlson (1978). |
| | | **Roberts Mountains terrane** | |
| Cambrian............ | €sc (=Scott Canyon Fm.). | Chert, shale, greenstone, sparse limestone, and quartzite. | Stewart and Carlson (1978). |
| Ordovician to Devonian. | Os (=Vinini, Palmetto (in part) and Comus Fms.).<br>Se (=Elder Sandstone).......<br>Ss (=Fourmile Canyon and Noh Fms.).<br>Dsl (=Slaven Chert).........<br>Ds (=Cockalorum and Woodruff Fms.).<br>DOs (=Valmy, Vinini, Noh, and Valder Fms.; Agort Chert, Tiser Limestone; North Fork sequence) | Shale, chert, and minor amounts of quartzite, greenstone, and limestone. | Do.<br><br><br><br><br>Coats, 1987 |
| Ordovician........... | Osv (=Valmy, and Palmetto (in part) Fms.). | Siliceous and volcanic rocks: chert, shale, quartzite, greenstone, and minor amounts of limestone. | Stewart and Carlson, 1978 |
| Devonian (Ordovician) to Cambrian. | D€sv (undivided siliceous assemblage). | Chert, shale, argillite, siltstone, quartzite, and greenstone. | Do. |

**Table 2.** Correlation of terranes with stratigraphic units--Continued

| Age | Stratigraphic units | Lithology | Reference |
|---|---|---|---|
| | | **Walker Lake terrane** | |
| Mesozoic and (or) Paleozoic. | MzPzs, Pzsp................. | Serpentinite; associated carbonate rocks. Inclusions of probable tectonic slices of sedimentary rocks. | Stewart and Carlson (1978) and Stewart, Carlson and Johannesen (1982). |
| Jurassic to Triassic.. | JTRsv (includes Peavine sequence). | Shale, sandstone, volcanogenic clastic rocks, and locally thick carbonate units. Metavolcanic rocks, regionally and thermally metamorphosed flows, breccias, and pyroclastics, ranging from basalt to rhyolite in composition. | Stewart and Carlson (1978).<br>Bonham (1969). |
| | | Paradise subterrane | |
| Permian.............. | Pbd (=Black Dyke Fm.)..... | Mafic volcanic breccia, intercalated volcanogenic sedimentary rocks, lava, dikes, and plugs. | Stewart, Carlson, and Johannesen (1982). |
| Triassic.............. | TRv (=volcanic rocks)....... | Lava flows and breccias of intermediate composition; minor volcaniclastic sandstone and conglomerate; includes intrusive rocks of possible Jurassic age in the Gillis Range. | Do. |
| Triassic.............. | TRlv (=limestone and volcanic rocks). (Rocks formerly assigned in part to the Luning Fm. and the Pamlico Fm.). | Limestone, volcanogenic sedimentary rocks, and volcanic rocks of intermediate and siliceous composition; minor amounts of shale, argillite, and hornfels. | Do. |
| | | Pine Nut subterrane | |
| Jurassic to Permian. | JPvs............................ | Lava flows of intermediate composition and silicic tuffs, and flows; includes some areas that may correlate to the Black Dyke Fm. and some that are elsewhere included in the Jurassic to Triassic volcanic and sedimentary rocks, undivided. | Stewart, Carlson, and Johannesen (1982). |

**Table 2.** Correlation of terranes with stratigraphic units--Continued

| Age | Stratigraphic units | Lithology | Reference |
|---|---|---|---|
| | | Pine Nut subterrane--continued | |
| Triassic | Ꞧv (=volcanic rocks)......... | Andesite and rhyolite flows, breccias, and sediments in the Singatse Range (Rb-Sr isochron age of 215 Ma) | Stewart, Carlson, and Johannesen (1982). |
| Upper Triassic....... | Ꞧlv (=limestone and volcanic rocks Oreana Peak Fm.). | Thick-bedded limestone and marble, minor dolomite, and intercalated tuff breccia, lapilli tuff, greenstone, welded tuff, tuffaceous sandstone, and calcareous quartz sandstone. | Do. |
| | | **North American Craton** | |
| Precambrian.......... | Xm............................ | Metamorphic rocks, gneiss schist, and gneissic granite, hornblendite, migmatite, pegmatite, and marble. | Stewart and Carlson (1978). |