Geology and Mineral Resources of the Reno 1° by 2° Quadrangle, Nevada and California

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By DAVID A. JOHN, JOHN H. STEWART, JAMES E. KILBURN, NORMAN J. SILBERLING, and LARRY C. ROWAN

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Geology and Mineral Resources of the Reno 1° by 2° Quadrangle, Nevada and California

By David A. John, John H. Stewart, James E. Kilburn, Norman J. Silberling, *and* Larry C. Rowan

Abstract

The geology and mineral resources of the Reno 1° by 2° quadrangle, Nevada and California, were studied by a team of geologists, geochemists, and geophysicists as part of the Conterminous United States Mineral Assessment Program (CUSMAP) of the U.S. Geological Survey between 1985 and 1990. This report summarizes the geology and metallic mineral resources in the Reno quadrangle.

Paleozoic(?) and Mesozoic metasedimentary and metavolcanic rocks are the oldest rocks exposed in the Reno quadrangle. They are divided into seven tectonostratigraphic terranes, most of which were previously established by other geologists for western Nevada. Principal tectonostratigraphic terranes are the Pine Nut, Jungo, Sand Springs, and Paradise terranes and some unassigned metavolcanic rocks; less areally extensive units are the Mountain Well sequence and Marble Butte rocks. The distribution of the Paleozoic(?) and Mesozoic metamorphic rocks is the result of polyphase tectonic transport both subparallel and perpendicular to the early Mesozoic continental margin.

Mesozoic plutonic rocks are divided into three groups that consist of Middle Jurassic volcanic arc-related granitoids, Middle Jurassic mafic plutonic rocks of the Humboldt complex, and mid- to Late Cretaceous granitoids of the Sierra Nevada batholith. The Jurassic granitoids appear to have been emplaced at significantly shallower depths than the Cretaceous granitoids and are associated with copper-iron mineralization of porphyry copper and copper and iron skarn types, whereas most mineralization related to the Cretaceous granitoids is the tungsten skarn type.

Cenozoic volcanic and sedimentary rocks are divided into three volcanic assemblages that represent different volcanic-tectonic environments. These are (1) the interior andesite-rhyolite assemblage consisting of silicic ash-flow tuffs and lesser amounts of intermediate composition lavas that range in age from about 31 to 20 Ma, (2) the western andesite assemblage whose rocks are lithologically similar to those of the Cascade volcanic arc and consist of intermediate composition lavas ranging in age from about 20 to 12 Ma, and (3) the bimodal basalt-rhyolite assemblage and associated sedimentary rocks consisting of mafic and silicic lavas and hypabyssal intrusions and extension-related sedimentary and alluvial deposits that range in age from 16 Ma to present. Several calderas associated with the interior andesite-rhyolite assemblage are identified in the eastern part of the quadrangle, and four major igneous centers related to the western andesite assemblage are identified in the south half of the quadrangle. Quaternary alluvial and basin-fill deposits cover much of the quadrangle.

Late Cenozoic structures developed during several periods of normal faulting and crustal extension and include a major zone of strike-slip faulting. Early to middle Miocene large-scale crustal extension, resulting in steeply tilted Tertiary rocks and rotation of high-angle normal faults to shallow dips, has been identified in several areas, notably in the southern Stillwater Range and along the south edge of the quadrangle from the northern Wassuk Range to near Carson City. A second period of more moderate extension, resulting in development of modern basin-and-range physiography, may have begun about 16 Ma and continues to the present. Much of the west half of the quadrangle lies within the Walker Lane Belt, a northwest-trending structural zone, which in the Reno quadrangle is characterized by northwest-striking right-lateral strike-slip faults at its northwestern and southeastern ends and by northeast-striking left-lateral oblique-slip faults in its central part.

Interpretative geophysical maps, including depth to Mesozoic bedrock, depth to shallow magnetic sources, and edges of magnetic bodies, were constructed to aid in interpreting shallow subsurface geology beneath basin fill and (or) Cenozoic volcanic rocks. These maps were used to (1) outline areas of shallow Mesozoic basement (<500 m below the surface) and extensions of Tertiary volcanic rocks beneath thin deposits of upper Cenozoic basin fill and (2) to outline areas permissive for various types of mineral deposits on the basis of subsurface extension of exposed geology.

About 20 types of metallic mineral deposits are present in the Reno quadrangle. The most important deposit types in terms of historical and (or) current production are adularia-sericite gold-silver, porphyry copper, tungsten skarn, iron skarn, and sediment-hosted gold deposits. Characteristics of

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known deposits are described, as well as characteristics of deposit types not known to be present in the quadrangle but considered potentially present. Broad areas are delineated for most deposit types that are permissive for the presence of undiscovered deposits. More areally restricted areas containing evidence for mineralization and thus considered favorable for undiscovered deposits are outlined for 10 deposit types including adularia-sericite gold-silver, quartz-alunite gold, porphyry copper, iron skarn, tungsten skarn, copper skarn, and zinc-lead skarn, polymetallic replacement, and several types of uranium deposits.

Nonmetallic minerals (for example, sand and gravel, limestone, diatomite, gypsum, salt), oil and gas, and geothermal energy resources are described briefly but are not evaluated in this report.

INTRODUCTION

The geology and mineral resources of the Reno 1° by 2° quadrangle, Nevada and California (fig. 1), were studied as part of the U.S. Geological Survey Conterminous United States Mineral Assessment Program (CUSMAP) between 1985 and 1990. In this report, the Reno 1° by 2° quadrangle is referred to as "the Reno quadrangle" or "the quadrangle." The project was an interdisciplinary study that encompassed geology, geochemistry, and geophysics. This report summarizes the studies completed as part of the project, discusses the geology of the Reno quadrangle as a background for the evaluation of metalliferous mineral resources, and discusses known and potential metalliferous mineral deposits in the quadrangle. Nonmetallic minerals, oil and gas, and geothermal energy resources are briefly discussed, although the potential for undiscovered resources of these commodities was not evaluated.

The Reno CUSMAP project included geologic mapping and compilation of a new geologic map at a scale of 1:250,000 (Greene and others, 1991), compilation of new gravity and aeromagnetic maps (Plouff, 1992; Hendricks, 1992), compilation of well-log data showing depth to bedrock, construction of interpretative gravity and aeromagnetic maps that show depth to Mesozoic basement, areas of magnetic sources, and edges of magnetic bodies, compilation of remote-sensing maps showing distribution of hydrothermal alteration and lineaments, characterization of mines and prospects by deposit type (John and Sherlock, 1991), K-Ar and Rb-Sr geochronology, geochemical sampling of mines, prospects, and hydrothermally altered areas, geochemical analyses of regional stream-sediment samples (Kilburn and others, 1990), geochemical studies of granitic rocks (John, 1992), and paleomagnetic studies. The overall scope of these studies is described briefly below, as are results of many of these studies as they relate to the mineral resource assessment. Several of these studies were done as part of, or in conjunction with, the Nevada State mineral assessment project conducted by the U.S. Geological Survey and the Nevada Bureau of Mines and Geology (Cox and others, 1990).

Results of the mineral resource assessment of the Reno quadrangle reflect our understanding of the geology and mineral resources at the time the assessment was completed (fall of 1990). Undoubtedly, some conclusions contained in this report may change as additional knowledge is obtained in the various scientific disciplines listed above. Several limitations on the conclusions of this study need to be kept in mind. In particular, limits on funding and personnel restricted the amount of fieldwork that could be conducted. Consequently, new geologic mapping was not completed in all areas identified as needing new mapping to produce a geologic map of uniform quality and detail, relatively few new geochemical data were gathered and a systematic stream-sediment sampling program was not undertaken, geophysical studies and field investigations of mines and prospects were not completed, and topical studies, such as characterization of granitic plutons, were not completed. Fieldwork of varying duration was undertaken from 1986 through 1989, and limited field checking was completed in 1990.

ACKNOWLEDGMENTS

Many individuals contributed to this study. Other people who served as members of the Reno CUSMAP team during at least of the project included W.J. Ehmann, B.A. Eisworth, L.A. Fraticelli, R.C. Greene, R.F. Hardyman, J.D. Hendricks, F.J. Kleinhampl, Donald Plouff, G.B. Sidder, D.B. Smith, and M.L. Sorensen. Many members of the U.S. Geological Survey Nevada State Mineral Assessment project, which was conducted at the same time as this study, contributed data and many ideas including B.R. Berger, R.J. Blakely, D.P. Cox, R.C. Jachens, S.D. Ludington, E.H. McKee, M.G. Sherlock, and D.A. Singer. In addition, W.C. Bagby, J.L. Doebrich, M.R. Hudson, A.C. Robinson, and T.G. Theodore, of the U.S. Geological Survey; H.F. Bonham, L.J. Garside, and J.V. Tingley, of the Nevada Bureau of Mines and Geology; J.E. Black of Kennecott; Kelly Cleur of Tennaco Minerals; Larry MacMaster of Asamera Minerals; and P.G. Vikre of ASARCO all contributed data and ideas.

BACKGROUND STUDIES

Geologic Mapping

The geologic map compiled for this study (Greene and others, 1991) is based on new mapping of approximately 30 percent of the quadrangle at 1:62,500 or larger scales and compilation of existing mapping for the rest of the quadrangle.

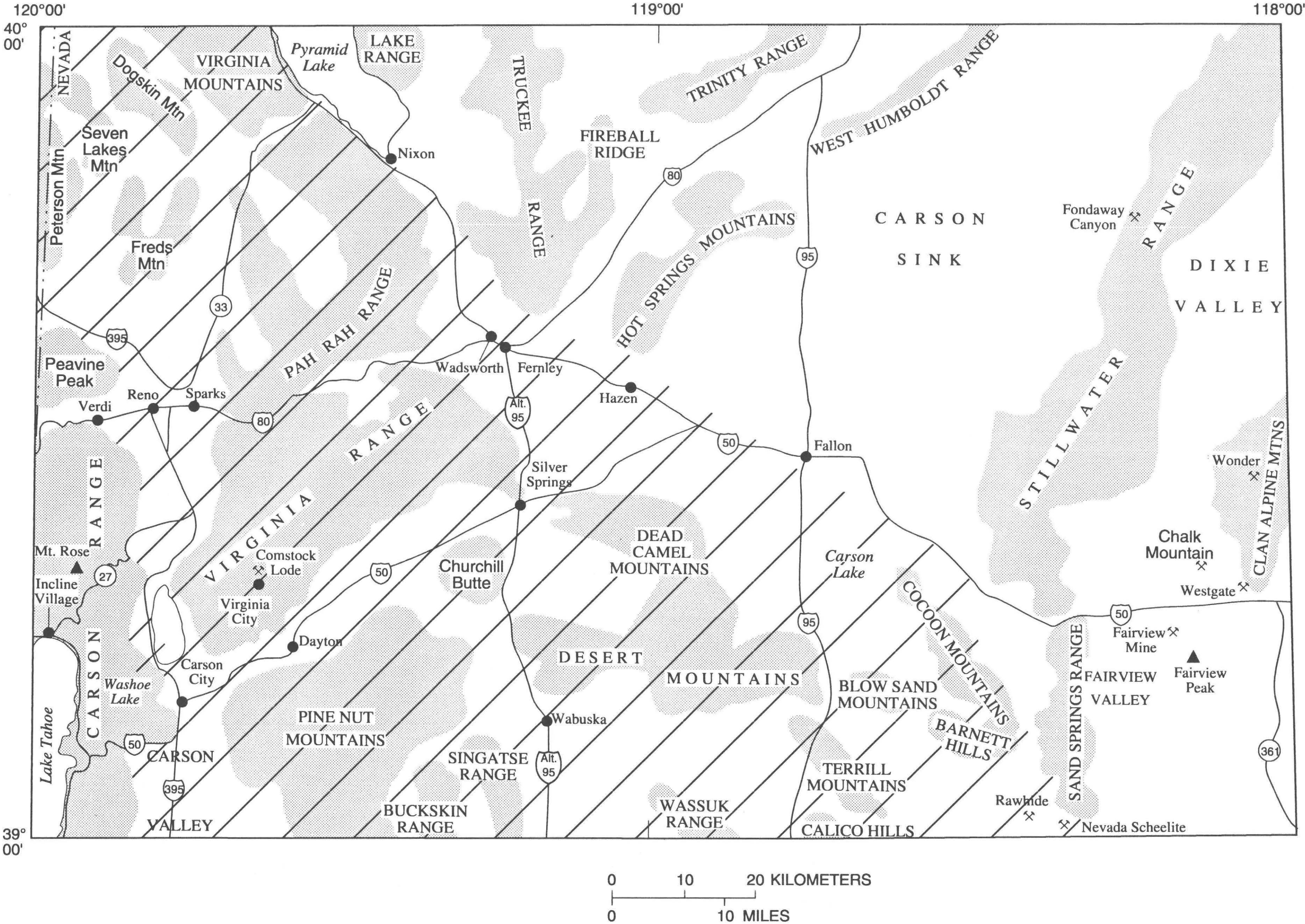


Figure 1. Index map showing location of geographic and cultural features in the Reno quadrangle, Nevada and California. Also shown is approximate outline of the Walker Lane Belt structural and physiographic zone (diagonal line pattern) modified from Stewart (1988).

Areas mapped as part of this study were mostly in the south half of quadrangle and included the northern Pine Nut Mountains, Churchill Butte, the Desert Mountains, the Dead Camel Mountains, parts of the Virginia Range, the Terrill Mountains, the Blow Sand Mountains, the Sand Springs Range, Fairview Peak, and the southern Stillwater Range (fig. 1). Much of the western part of the quadrangle has been mapped at a scale of 1:24,000 by personnel of the Nevada Bureau of Mines and Geology subsequent to publication of county reports for these areas (Moore, 1969; Bonham, 1969), and these maps were used to update the geologic maps in the county reports. Much of the north-central and northeastern parts of the quadrangle were not remapped and are only slightly modified from the maps in the Washoe and Storey Counties (Bonham, 1969) and Churchill County (Willden and Speed, 1974) reports. A simplified version of the new geologic map is included on plates 1-4.

Gravity Data

Gravity studies in the Reno quadrangle were based on data obtained from the National Geophysical Data Center (1984) supplemented by 275 data points obtained from the Nevada Bureau of Mines and Geology (Erwin, 1982) and 300 data points from Wahl and Peterson (1976). An additional 424 gravity stations were established by the U.S. Geological Survey in 1987–88. Redundant or mislocated data points were discarded. The remaining points were used to calculate terrain-corrected Bouguer gravity anomalies that were contoured at a scale of 1:250,000 to produce the final gravity map for the Reno quadrangle (Plouff, 1992).

An interpretative map showing depth to Mesozoic bedrock was produced by R.C. Jachens (unpub. data, 1988) for use in the Nevada State mineral assessment. This map was slightly modified by D.A. Ponce (written commun., 1991) using a different data set of gravity measurements. These maps were produced by an iterative procedure that divided the gravity field into two components: gravity produced by Cenozoic rocks and gravity produced by Mesozoic basement rocks; the thickness of Cenozoic rocks was estimated from differences in the two gravity components (Jachens and Moring, 1990). Jachens and Moring (1990) described the uncertainties associated with this procedure. We used the 500-m contour denoting depth to Mesozoic bedrock as shown on the revised map of D.A. Ponce as a maximum depth to which we projected the permissive areas and favorable tracts for mineral resources in areas of the quadrangle covered by Cenozoic deposits (fig. 2).

Aeromagnetic Data

A new aeromagnetic map of the Reno quadrangle (Hendricks, 1992) is based on data compiled by Hildenbrand and Kucks (1988) that they used to produce a digital aeromagnetic map for Nevada. The new aeromagnetic map was primarily used to locate possible unexposed Tertiary intrusions that may be indicated by strong magnetic highs or lows in areas of Tertiary volcanic rocks.

An interpretative map showing areas of shallow magnetic sources was compiled by R.J. Blakely (unpub. data, 1988) for the Nevada State mineral assessment and was modified by D.A. John using a more detailed geologic map. The map is based on aeromagnetic data that were collected by the National Uranium Resource Evaluation (NURE) Program along east-west flightlines spaced approximately 5 km apart and flown at constant elevation of approximately 120 m above the ground. The procedure for constructing the map is discussed by Blakely and Jachens (1991). The map allows semiquantitative estimates of depth to magnetic sources and can be used to identify areas where Tertiary volcanic rocks covered by late Cenozoic alluvial and sedimentary deposits are likely to be less than 500 m below the surface (fig. 3).

A map showing the edges of magnetic bodies was produced by R.J. Blakely (unpub. data, 1988) for the Nevada State mineral assessment. It is based on a procedure developed by Cordell and Grauch (1982, 1985) to identify edges of magnetic bodies. The procedure is described in detail in these papers and by Blakely and Simpson (1986). The procedure produces a map showing abrupt lateral changes in the magnetic field. This map allows interpretation of the subsurface extent of magnetic bodies, such as plutons, beneath alluvial cover and often is more precise in locating edges of magnetic bodies than simple aeromagnetic maps (Blakely and Simpson, 1986).

Isotopic-Dating Studies

New isotopic-dating studies mostly included dating by the K-Ar method of fresh Tertiary volcanic and plutonic rocks in the southern Stillwater Range and the area between Fernley and Yerington, which is about 1.5 km south of the Reno quadrangle. About 25 samples were dated as part of this project by E.H. McKee (unpub. data, 1990). In addition, several unpublished K-Ar age determinations of hydrothermal minerals collected from various mining districts in the Reno quadrangle have been completed as part of the U.S. Geological Survey-Nevada Bureau of Mines and Geology Cooperative Program and made available to this project (E.H. McKee, unpub. data, 1990). Rubidium and strontium isotopic compositions were measured for about 90 granitic rock samples from the Reno quadrangle and used to construct whole-rock isochrons for several granitic plutons (A.C. Robinson and D.A. John, unpub. data, 1990).

Paleomagnetic Data

Paleomagnetic samples of Tertiary volcanic and plutonic rocks in the southern Stillwater Range and southern

Sand Springs Range were collected and analyzed from about 50 sites by M.R. Hudson. These data supplement published paleomagnetic data from the northern Stillwater Range and Clan Alpine Mountains (Hudson and Geissman, 1987; 1991). These data also complement field and geochronologic data in restricting the timing of Tertiary extension in the southern Stillwater Range (John and McKee, 1991; John, in press).

Geochemical Data

Regional stream-sediment geochemical studies were limited to reanalysis of 960 stream-sediment samples collected during the NURE Program (Bennett, 1980). Analytical techniques and results are given in Kilburn and others (1990). Problems resulted because many samples were contaminated, and the sample coverage was not thorough or of uniform quality. Results of the regional geochemical study are discussed in the geochemical section.

About 800 rock samples collected from mines, prospects, and altered areas and about 90 samples of unaltered granitic plutons were chemically analyzed. Five groups of samples were collected and analyzed. These are (1) hydrothermally altered rocks collected during field checking of hydrothermal alteration detected by remote sensing by L.C. Rowan and others, (2) samples collected from dumps of mines and prospects primarily in the eastern and southern parts of the quadrangle by D.A. John and G.B. Sidder, (3) hydrothermally altered rocks collected during geologic mapping mostly in the southern Stillwater Range by D.A. John, (4) hydrothermally altered and unaltered granitic rocks and their wallrocks collected from throughout most of the quadrangle except the Sierra Nevada block by D.A. John, and (5) rocks collected in and around the Humboldt

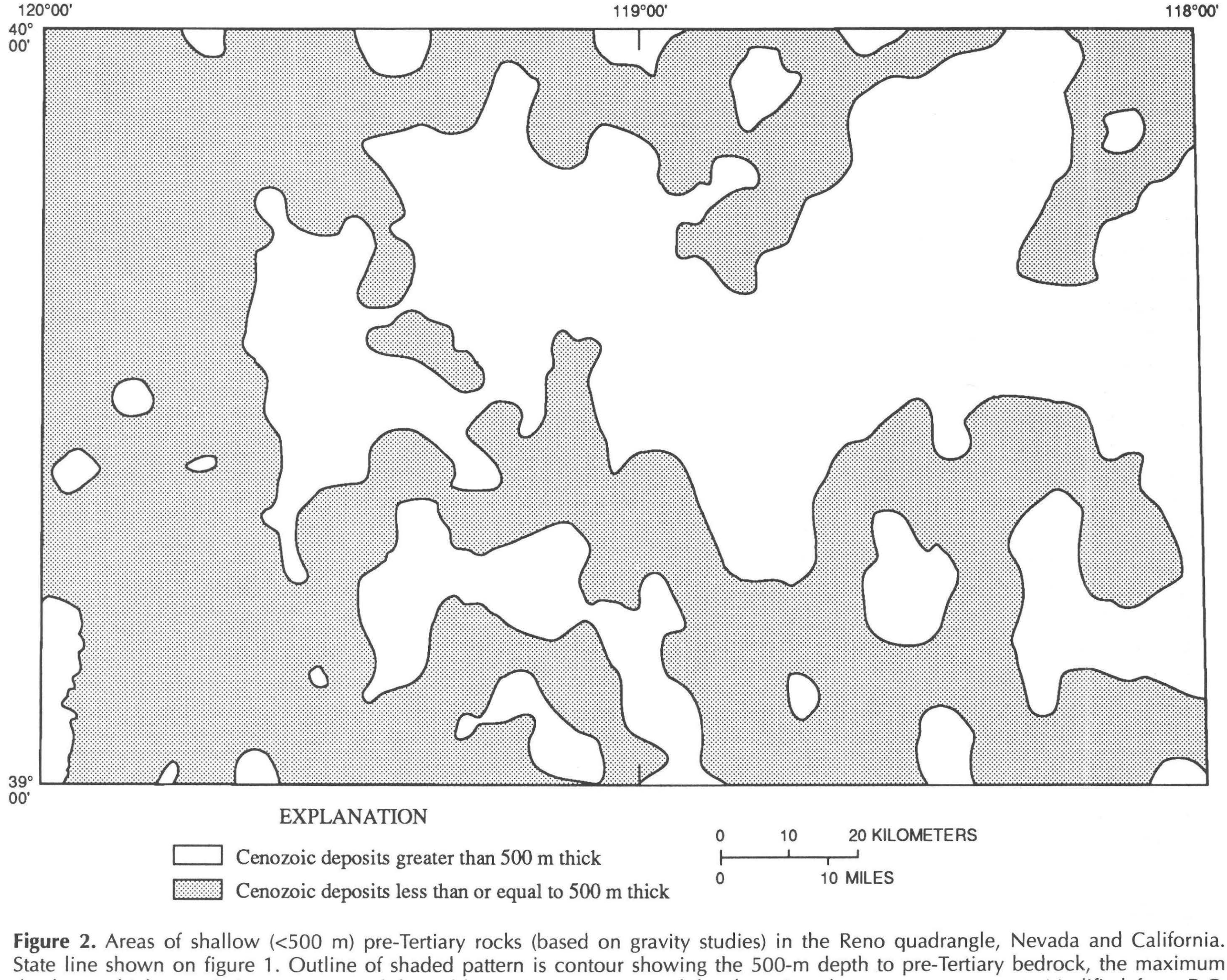


Figure 2. Areas of shallow (<500 m) pre-Tertiary rocks (based on gravity studies) in the Reno quadrangle, Nevada and California. State line shown on figure 1. Outline of shaded pattern is contour showing the 500-m depth to pre-Tertiary bedrock, the maximum depth to which permissive terranes and favorable tracts were projected for the mineral resource assessment. Modified from R.C. Jachens (unpub. data, 1988) and D.A. Ponce (unpub. data, 1991).

complex by G.B. Sidder and M.L. Zientek. Samples were collected to help characterize large areas of hydrothermal alteration and potential mineralization, to characterize plutonic rocks in the quadrangle, and to aid in interpreting the Humboldt complex.

Samples were analyzed either by induction-coupled plasma spectrometry (Crock and others, 1983) or by semiquantitative emission spectrographic methods (Grimes and Marranzino, 1968; Motooka and Grimes, 1976) for 40 or 33 elements, respectively. Samples were also analyzed for gold, tellurium, and thallium by the atomic-absorption method of Hubert and Chao (1985); for mercury using a modification of the methods of McNerney and others (1972) and Vaughn and McCarthy (1964); for arsenic, antimony, bismuth, cadmium, and zinc by the atomic-absorption technique of O'Leary and Viets (1986); and for tungsten by the colorimetric method of Welsch (1983). Major- and trace-element contents of fresh granitic rocks were analyzed by wavelength-dispersive X-ray fluorescence (Taggert and others, 1987) and energy dispersive X-ray fluorescence (Johnson and King, 1987), respectively.

Mines and Prospects Data

Data compiled for approximately 450 mines and prospects in the Reno quadrangle from a combination of published data, records in the U.S. Geological Survey Mineral Resource Data System (MRDS), field studies, and geochemical studies are included in John and Sherlock (1991). About 20 types of mineral deposits were identified in the Reno quadrangle (table 1) and about three-quarters

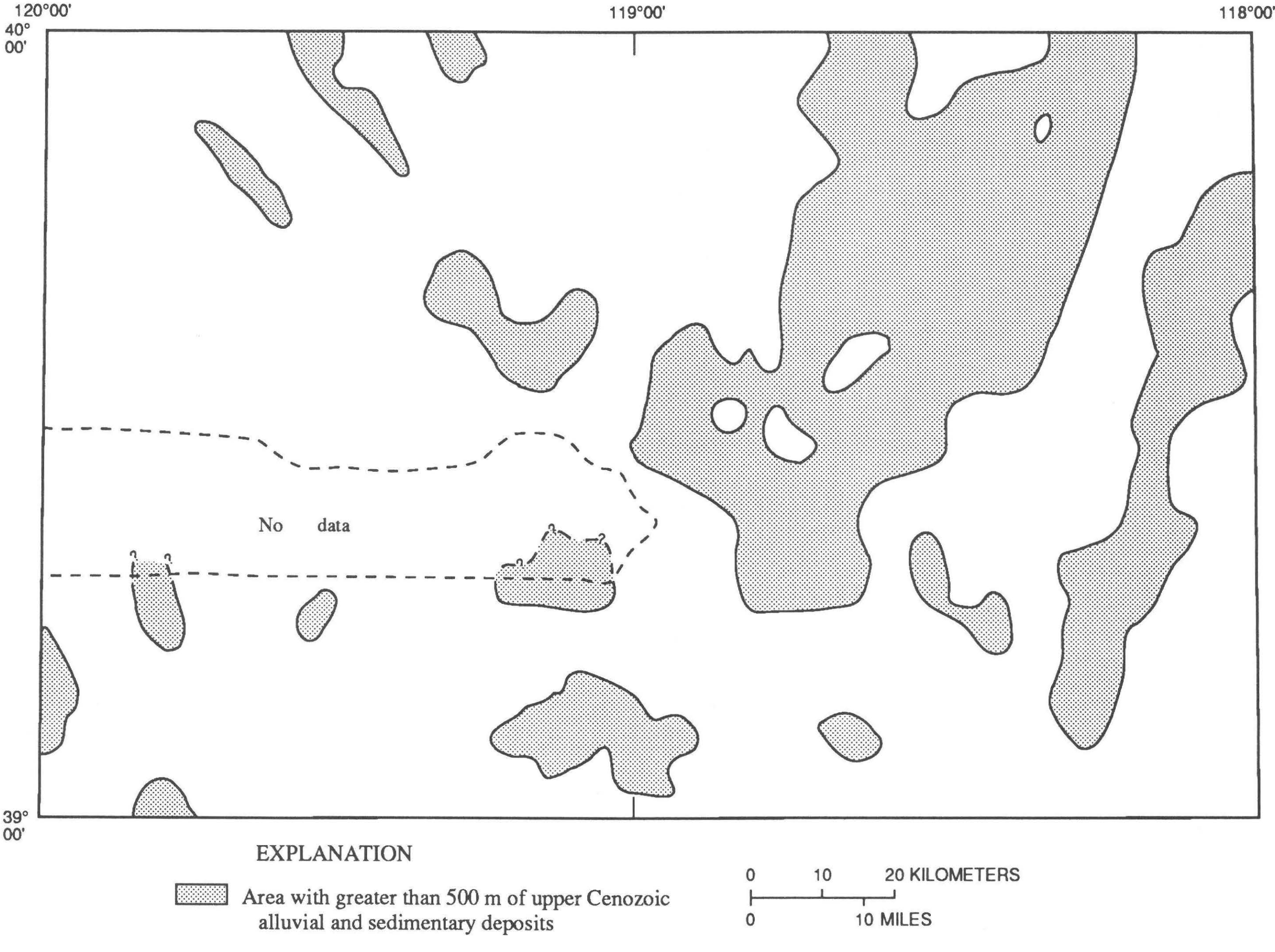


Figure 3. Areas with shallow magnetic sources (≤1 km) (as determined from NURE aeromagnetic data) beneath Cenozoic alluvial and sedimentary deposits in the Reno quadrangle, Nevada and California. State line shown on figure 1. Outline of shaded pattern is contour showing less than 1-km depth to magnetic sources and represents areas covered by upper Cenozoic sedimentary rocks and basin-fill deposits greater than 1 km thick. Dashed lines with query marks denote estimated extent of shallow magnetic sources. Query marks denote uncertain extent of shallow magnetic sources. Modified from R.J. Blakley (unpub. data, 1988).

of the known mines and prospects were classified by deposit type. Approximate locations of mining districts in the Reno quadrangle are shown in figure 4.

Remote-Sensing Data

A map showing the distribution of hydrothermally altered rocks was compiled through field evaluation of areas that were delineated in Landsat Thematic Mapper (TM) images (Rowan and others, in press). The visible and near-infrared (0.4 to 2.5 micrometers) reflectance spectra of hydrothermally altered rocks are commonly characterized by iron absorption in the short-wavelength region and hydroxyl absorption in the long-wavelength region. Iron absorption is due to the presence of iron oxide and hydroxide minerals produced by oxidation of metallic sulfide minerals. Hydroxyl absorption is related to clay and other hydroxyl minerals that form through alteration of feldspar and ferromagnesium minerals. The presence of these alteration minerals is shown on TM images using a combination of channels that enhance their absorption features. Because these minerals occur in some unaltered rocks, such as limonitic shale, field and laboratory evaluations were necessary to confirm the identification of hydrothermally altered rocks. Limitations of this method include the lack of alteration minerals that display these absorption features, obscuration by vegetation cover, and the spatial resolution of the TM images (30 m).

AREA DESCRIPTION

The Reno quadrangle encompasses about 19,300 km^2 between lat 39° and 40° N. and long 118° and 120° W. in western Nevada and extreme eastern California (fig. 1). More than 99 percent of the quadrangle lies in western Nevada with only a thin strip along the northwest boundary of the quadrangle lying in eastern California. Reno, Sparks, Carson City, and Fallon are the largest cities in the quadrangle and contain most of its population; the rest of the quadrangle is generally sparsely populated. Interstate

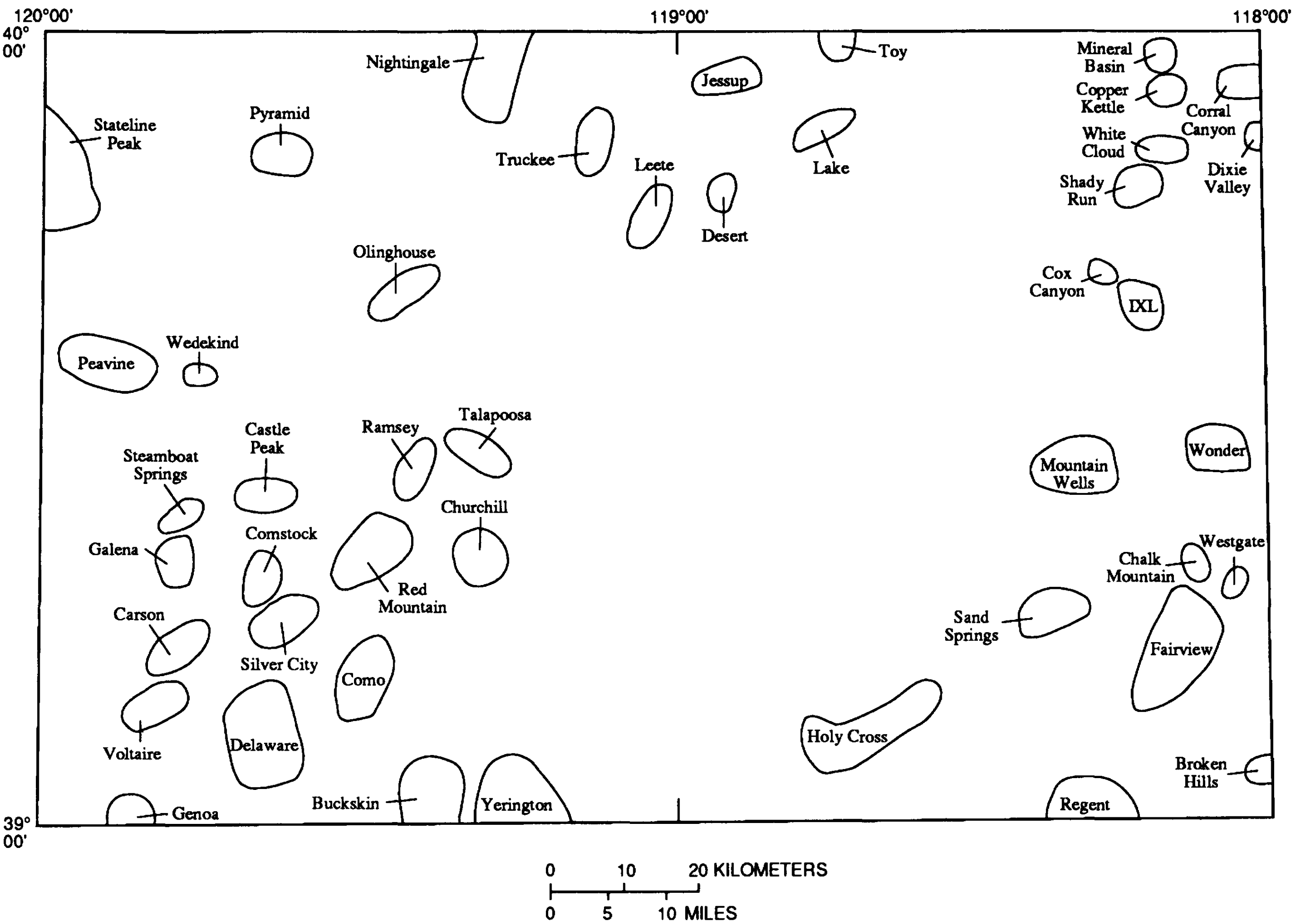


Figure 4. Approximate locations and boundaries of mining districts in the Reno quadrangle, Nevada and California. State line shown on figure 1.

80 runs east to west across the central and northern parts of the quadrangle, U.S. Highway 50 runs east to west across the central and southern parts of the quadrangle, and U.S. Highways 395, 95, and Alternate 95 run north to south through the western and central parts of the quadrangle. Numerous state and county roads, both paved and improved gravel, are present in the west half of the quadrangle, but relatively few roads are present throughout much of the eastern third of the quadrangle. Elevations range from about 1,025 m (3,360 ft) on the floor of Dixie Valley to 3,285 m (10,776 ft) at the summit of Mt. Rose.

GEOLOGY

The Reno quadrangle straddles two geologic and physiographic regions: the Sierra Nevada and the Basin and Range Province. About 90 percent of the quadrangle lies within the western part of the Basin and Range Province, an area of alternating basins separated by narrow, elongate ranges formed during late Cenozoic block faulting and crustal extension. The mountainous terrain of the Sierra Nevada encompasses only the Carson Range in the southwestern part of the quadrangle. The Basin and Range Province includes numerous northwest- to northeast-trending ranges and broad intervening basins including Carson Sink, Carson Lake, and Dixie Valley. The basins were covered by Lake Lahontan during Pleistocene glacial periods.

Previous geologic studies, which date from discovery of the Comstock Lode in 1859 and the 40th Parallel Survey in the 1860's (Richtofen, 1866; King, 1870, 1878), are too numerous to describe in detail. Important summaries of previous geologic studies are given in county reports for Washoe and Storey Counties (Bonham, 1969), Mineral County (Ross, 1961), Lyon, Douglas, and Ormsby (Carson City) Counties (Moore, 1969), Churchill County (Willden and Speed, 1974), and northern Nye County (Kleinhampl and Ziony, 1984, 1985). Other recent compilations of previous geologic studies in the Reno quadrangle include Hurley and others (1982) and Sidder (1986, 1987).

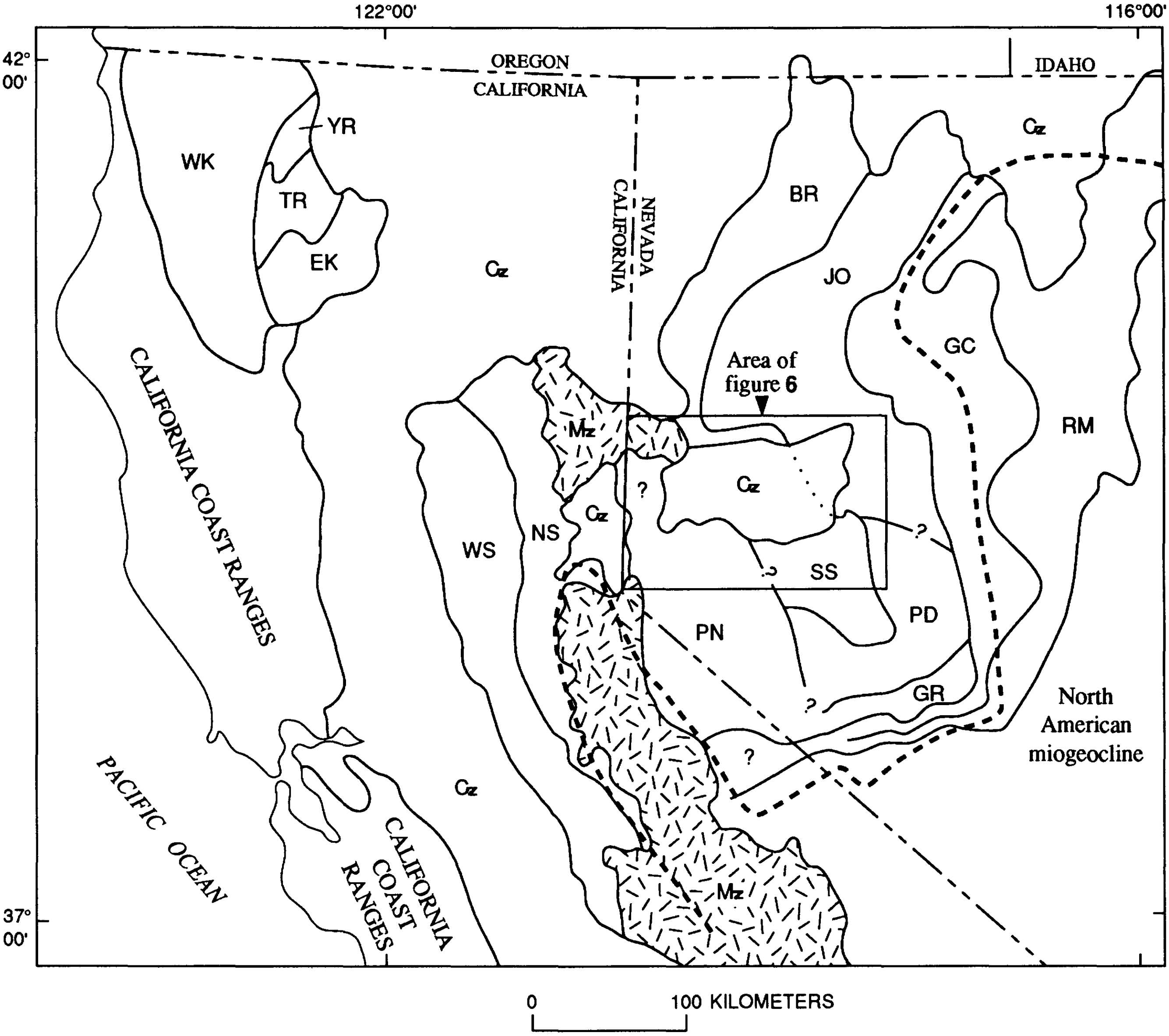
Three groups of rocks and deposits are present in the Reno quadrangle: (1) pre-Tertiary metasedimentary and metavolcanic rocks, (2) Mesozoic plutonic rocks, and (3) Cenozoic volcanic, sedimentary, and plutonic rocks and alluvial deposits. These groups of rocks and their tectonic evolution are discussed in the next section.

Pre-Tertiary Metavolcanic and Metasedimentary Rocks

Most scattered outcrops of pre-Tertiary metavolcanic and metasedimentary rocks in the Reno quadrangle can be assigned to one of the principal allochthons or tectonostratigraphic terranes previously established in western Nevada (Oldow, 1984; Silberling and others, 1987; Silberling, 1991) (fig. 5). For treating the predominant pre-Tertiary geologic elements of the quadrangle, these terranes provide useful first-order subdivisions. Some exposures in the Reno quadrangle, however, such as those composed wholly of undated metavolcanic rocks in the western part of the quadrangle, are stratigraphically and structurally too indistinct for terrane assignment. In addition, a few discrete exposures, although geologically distinct, have some unique characteristics unlike those known for the more extensive terranes and are thus treated separately. The inferred extent of pre-Tertiary tectonic terranes in the Reno quadrangle, extrapolating from the outcrops that are assigned to terranes, is shown on figure 6. At best, the boundaries between the terranes are poorly defined, and their configuration beneath the extensive Cenozoic cover in the central part of the quadrangle (Carson Desert and Carson Sink) is unknown. All pre-Tertiary metamorphic rocks except gabbroic rocks of the Jungo terrane are combined as one unit, JŦRsv, on the generalized geologic map (pls. 1-4).

The Jungo terrane (unit JO on fig. 5 and units JO_1 and JO_2 on fig. 6) underlies the northeastern part of the Reno quadrangle and also extends east and far to the north of the quadrangle in northwestern Nevada (fig. 5). It is characterized by an extraordinarily thick, mostly basinal marine sequence of fine-grained continentally derived clastic rocks exclusively of Norian (late Late Triassic) to Early Jurassic age. In the Clan Alpine Mountains, about 30 km east of the Reno quadrangle, the thickness of mainly pelitic Norian rocks of the Jungo terrane was estimated by Speed (1978) to exceed 5 km. Throughout its great thickness, quartz, along with ubiquitous, but subordinate amounts of feldspar and detrital mica, forms the principal framework grains in sandstones. Illitic clay and chlorite are the predominant pelitic components along with graphitic and ferric-oxide pigment. In addition to the fine-grained clastic rocks in the Jungo terrane, subordinate interstratified units of carbonate rocks are as thick as several hundred meters, and some of the terrigenous clastic rocks—especially those of Early Jurassic age—are calcareous. Strata older than Norian age are not exposed in the Jungo terrane, and its basement is unknown. Speed (1979) hypothesized that the Mesozoic strata of the Jungo terrane were deposited in a basin formed by the contraction and subsidence of a late Paleozoic arc complex; among other alternatives, they may have originally accumulated directly on oceanic crust formed by Triassic rifting. In any case, large-scale, partly isoclinal folds and related faults are pervasive in exposed rocks of the terrane, and the largely pelitic rocks characteristic of the terrane are a volumetrically large crustal component in direct relation to their great original thickness.

Mafic igneous rocks of gabbroic complexes form a significant part of the Jungo terrane and are shown sepa-



EXPLANATION

Tectonostratigraphic terrane boundary—Query denotes uncertain extent or position of terrane boundary; dotted where concealed

BR	Black Rock terrane	RM	Roberts terrane
EK	Eastern Klamath terrane	SS	Sand Springs terrane
GC	Golconda terrane	TR	Trinity terrane
GR	Gold Range terrane	WK	Terranes of western and central Klamath Mountains
JO	Jungo terrane		
NS	Northern Sierra terrane	WS	Terranes of western Sierra Nevada
PD	Paradise terrane	YR	Yreka terrane

Sr_i = 0.706 isopleth

Cz Cenozoic cover

Mz Mesozoic granitic rocks of Sierra Nevada batholith

Figure 5. Tectonostratigraphic terranes and geologic and structural features of western Nevada and northern California. Sr_i data from R.W. Kistler (written commun., 1988). Modified from Silberling (1991).

rately on figure 6 (unit JO_2). These rocks are at least in part Middle Jurassic in age and structurally overlie the Upper Triassic and Lower Jurassic sedimentary rocks of the Jungo terrane. In the northeastern corner of the Reno quadrangle, gabbro, related intrusive rocks, ultramafic segregates, and basalt of the Humboldt lopolith (Speed, 1976) intrude quartzite and associated sedimentary rocks of probable Jurassic age; together, these units, are thrust over the older strata of the Jungo terrane. The total thickness of mafic magmatic rocks forming the Humboldt complex was inferred by Speed (1976) to exceed 2 km. Another gabbroic complex of hornfelsic basalt and mafic intrusive rocks occurs at the margin of the Jungo terrane in the north-central part of the Reno quadrangle. It may be related to the Humboldt complex, but neither its age nor relation to surrounding pre-Tertiary rocks is known. Recent interpretation by Dilek and others (1988) of their informally named Humboldt complex as the ophiolitic basement of the lower Mesozoic strata of the Jungo terrane would seem to violate the known age and structural relations. Intrusion into the Jungo terrane during either initial tectonic contraction (Speed, 1976) or an episode of Middle Jurassic rifting is more plausible.

The Paradise terrane is only represented at the east boundary of the Reno quadrangle by isolated exposures at Chalk Mountain and Westgate. These outcrops are assigned to the Luning Formation and to the Volcano Peak Group of Taylor and others (1983), which are characteristic of this terrane southeast and south of the Reno quadrangle. Distinctive inner-platform "primary" dolostone of the Luning is in strong lithologic contrast with age-equivalent deep-marine flyschoid terrigenous clastic rocks in nearby outcrops of the Jungo terrane, as discussed by Willden and Speed (1974). The combined thickness of carbonate and calcareous fine-grained clastic rocks of the Upper Triassic Luning and uppermost Triassic to Lower Jurassic Volcano Peak is as much as 2,000 m. Older parts of the Paradise terrane in ranges just southeast of the Reno quadrangle (Silberling and John, 1989) are mainly volcanogenic rocks of intermediate to mafic composition whose exact thickness is unknown but greater than 1,000 m.

The Sand Springs terrane, exposures of which are present in the southeastern part of the Reno quadrangle, is characterized by ubiquitous volcanogenic rocks and a complex, partly metamorphic, Mesozoic tectonic history. It is a structurally composite terrane. Sparse occurrences of fossils within this terrane in and south of the Reno quadrangle are of Late Triassic and Early Jurassic age. Principal rock types, whose stratigraphic relations are largely unknown owing to the complex structure and scarcity of age data, include metapelitic rocks containing interstratified volcaniclastic sandstone and coarser grained rocks, turbiditic volcanogenic sandstone, marble, andesitic breccia, and massive basalt.

The Pine Nut terrane extends into the southwestern part of the Reno quadrangle from the south, and some of the undifferentiated metavolcanic rocks in the west-central part of the quadrangle may also belong to it. Outcrops assigned to the Pine Nut terrane preserve parts of a variable but generally coherent, distinctive, volcanic-rich lower Mesozoic sequence. Four mappable units, in ascending order are: (1) Middle and (or) Upper Triassic volcanic flows, breccia, and tuff of andesitic to rhyolitic composition and locally at least 1,000 m thick; (2) about 1,000 m of Upper Triassic limestone, which is mostly basinal in character, interstratified with volcanogenic rocks; (3) several hundred meters of Lower Jurassic tuffaceous sandstone, siltstone, thin-bedded impure limestone, and argillite; and (4) a great thickness of Middle Jurassic and possibly younger subaerial, intermediate volcanic rocks. Orthoquartzite, locally associated with gypsum, is present in places between the Jurassic sandstone and the overlying volcanic rocks, and this contact may be a regional unconformity. The Triassic and Lower Jurassic units of the Pine Nut terrane are grossly correlative with those forming the Luning Formation, Volcano Peak Group, and Dunlap Formation of the Paradise terrane southeast of the Reno quadrangle. The Pine Nut rocks, however, differ in being more basinal, much more volcanogenic, and in having a distinct tectonic history.

Several small isolated, distinctive exposures along the southwestern margin of the Jungo terrane are not assignable to any of the more extensive terranes represented in the Reno quadrangle. Marble Butte and another smaller nearby outcrop near Pyramid Lake in the northwestern part of the Reno quadrangle consist of a large volume of complexly deformed marbles whose protoliths possibly include evaporitic and eogenetic-secondary dolostone in addition to the more prevalent limestone. Besides the suggestion that these rocks were originally a carbonate sequence of unusual thickness and composition, their deformational history is more complex than that of nearby outcrops of the Jungo terrane and unassigned metavolcanic rocks. Lacking an obvious correlation with known lower Mesozoic successions, the Marble Butte rocks could be of late Paleozoic age and could represent the Black Rock terrane that forms the northwestern pre-Tertiary exposures in Nevada north of the Reno quadrangle (fig. 6, unit mb).

Another relatively small but distinctive unit is the Mountain Well sequence (MW, fig. 6), which is faulted against the Jungo terrane where it is juxtaposed on the Sand Springs terrane in the southern Stillwater Range. The undated, stratigraphically coherent Mountain Well sequence consists of metamorphosed dacitic lava flows and breccia, turbiditic orthoquartzite and pelite, and andesitic rocks. This compositional association is unlike any of those known in nearby terranes but suggests a Jurassic age.

The Mesozoic tectonic history of the terranes in the Reno quadrangle can be characterized as the structural collapse and imbrication of an early Mesozoic back-arc basin (Oldow, 1984). Structural juxtaposition of the various pre-Tertiary terranes and smaller allochthonous blocks resulted from strike-slip and thrust-fault displacements between terranes and from large-scale tectonic shortening on imbricate thrust systems within certain terranes such as the Sand Springs and Paradise terranes.

Triassic through Lower Jurassic rocks of the Pine Nut terrane underwent coaxial folding about northwest-trending axes prior to and during emplacement of 169- to 166-Ma granitic plutons (Dilles and Wright, 1988). An important, but unexposed transpressional fault—the Pine Nut fault (fig. 6)—was proposed by Oldow (1984) to extend into the Reno quadrangle and to bound the Pine Nut terrane on the east. Compared with that of the Pine Nut terrane, the structural history of Mesozoic rocks in terranes east of the Pine Nut fault is more complex and relates to the so-called Luning-Fencemaker thrust system (Oldow, 1984). In the Luning-Fencemaker thrust belt northwest-trending contractional structures of probable Cretaceous age are superimposed on northeast-trending folds and thrusts that resulted from large-scale Jurassic to Early Cretaceous northwest-southeast shortening of hundreds of kilometers. Rocks of the Sand Springs terrane underwent still earlier Middle Jurassic ductile deformation, possibly related to that of the Pine Nut terrane (Satterfield and Oldow, 1989). The Marble Butte rocks also appear to have been foliated prior to the initial phase of Luning-Fencemaker deformation. The outcrop pattern of juxtaposed, stratigraphically and structurally disparate, pre-Tertiary terranes in the Reno quadrangle thus resulted from polyphase tectonic transport both subparallel and perpendicular to the early Mesozoic continental margin. The greatest compositional contrast between tectonically juxtaposed pre-Tertiary rocks is present between the mainly terrigenous-clastic rocks of the Jungo terrane and the mostly volcanogenic, but partly correlative, rocks in terranes farther southwest as determined from exposed rocks. This boundary, although complicated by younger Mesozoic and Cenozoic structures, may have been a large-scale left-slip fault related to middle Mesozoic northwest-southeast contraction and thus originally an important high-angle discontinuity within the crust.

Pre-Tertiary metasedimentary and metavolcanic rocks serve as host rocks for many types of mineral deposits in the Reno quadrangle. Carbonate-bearing strata, which serve as host rocks for tungsten, copper, and iron skarn and polymetallic replacement deposits, are the most important pre-Tertiary metamorphic units in the Reno quadrangle. Carbonate rocks are relatively abundant in the Paradise, Sand Springs, and Pine Nut terranes, in shale and limestone of the Jungo terrane, and in the Marble Butte rocks (fig. 6). Carbonate strata are sparse to absent in undifferentiated metavolcanic rocks, the Mountain Well sequence, and gabbroic rocks of the Jungo terrane (fig. 6), and these units contain relatively few mineral deposits

Mesozoic Plutonic Rocks

Mesozoic plutonic rocks in the Reno quadrangle can be divided into three groups on the basis of age and composition (fig. 7). These are: (1) Middle Jurassic granitoids and related volcanic arc rocks (Yerington and Shamrock batholiths), (2) Middle Jurassic mafic plutonic rocks and cogenetic volcanic rocks (Humboldt complex), and (3) Late Cretaceous granitoids (Sierra Nevada batholith and related rocks). Characteristic features of these groups of plutonic rocks are described in the following sections.

Middle Jurassic Arc-Related Rocks

Middle Jurassic plutonic rocks crop out in the southern part of the quadrangle in the Pine Nut Mountains, the Buckskin, Singatse, and Wassuk Ranges, and possibly in the Calico Hills (fig. 7). Other exposures of Jurassic(?) granitic rocks consist of a small altered granitic pluton on the east side of Copper Valley along the north-central edge of the quadrangle, a composite pluton on Fireball Ridge, a small dioritic pluton at the north end of the Hot Springs Mountains, and several small exposures of granodiorite and diorite near the Dayton iron deposit and the Iron Blossom Prospect about 15 km northeast of Dayton (fig. 7 and pl. 1). The large exposures of Jurassic granitic rocks in the southern part of the Reno quadrangle are the northern part of a Middle Jurassic (from about 172 to 165 Ma) island-arc sequence that is extensively exposed farther south in the adjacent Walker Lake quadrangle and well described by Dilles (1984, 1987), Dilles and Wright (1988), and Proffett and Dilles (1984). Several Jurassic plutons are exposed in the Reno quadrangle including parts of the Yerington and Shamrock batholiths, the Sunrise Pass pluton, and numerous hypabyssal porphyry intrusions related to the volcanic rocks of Fulstone Spring (Castor, 1972; Hudson and Oriel, 1979; Dilles and Wright, 1988; J.H. Stewart, unpub. mapping, 1989). Volcanic rocks cogenetic with the Yerington and Shamrock batholiths are also preserved locally in the Buckskin Range and Pine Nut Mountains (Dilles and Wright, 1988). The Jurassic plutonic and volcanic rocks constitute remnants of island arcs that were formed along the western margin of North America (Dilles and Wright, 1988).

Jurassic plutonic rocks in the Reno quadrangle range in composition from diorite to granite, although the largest exposures are primarily granodiorite and granite (Dilles, 1987) using the I.U.G.S. classification (Streckeisen, 1976). Silica contents vary from about 56 to 70 weight percent SiO_2 and most rocks contain 60 to 68 weight percent

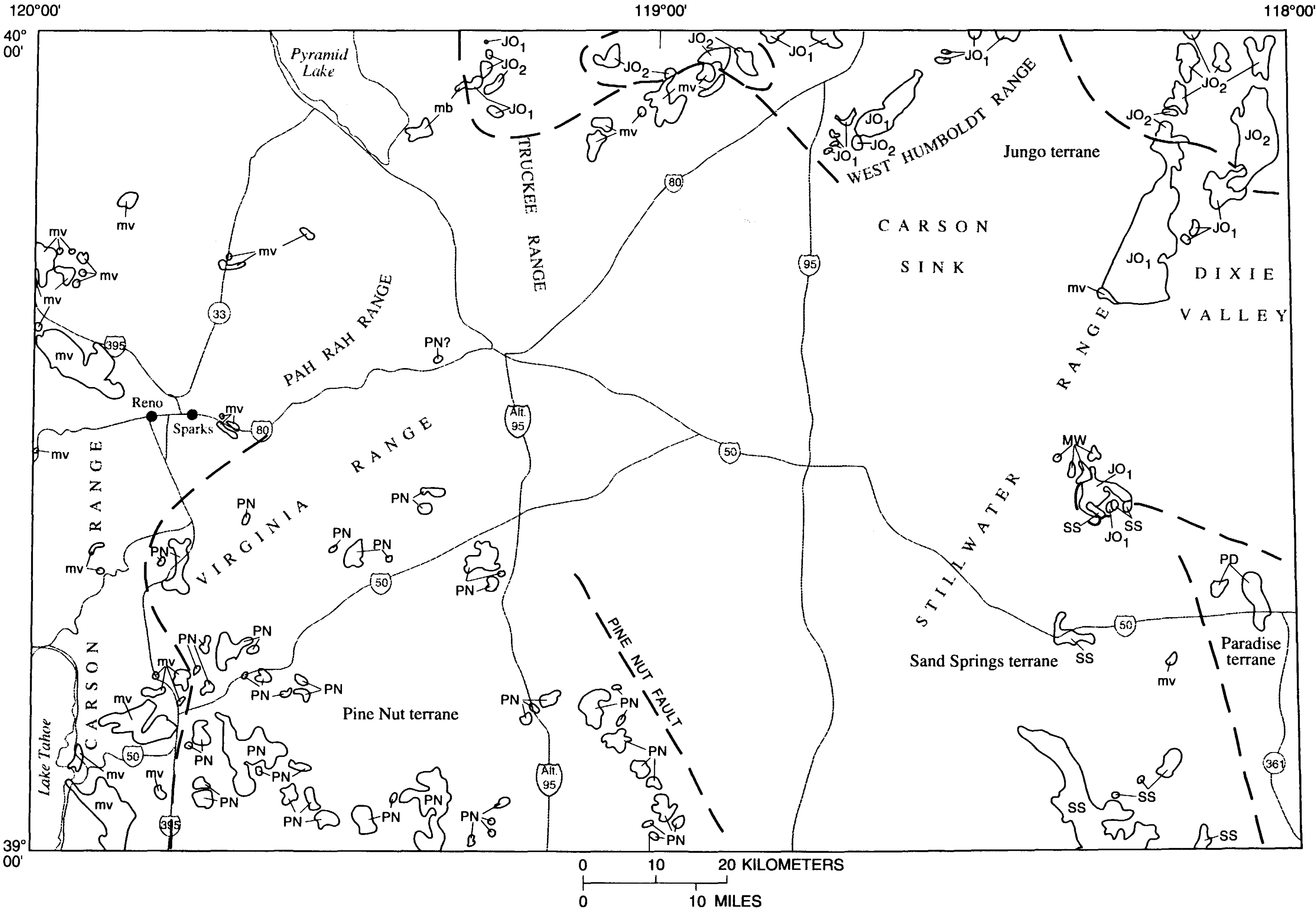


Figure 6. Inferred extent of known tectonostratigraphic terranes in the Reno quadrangle, Nevada and California, and assignment of outcrop areas to these terranes. State line shown on figure 1.

SiO_2. The Jurassic igneous rocks constitute a high-K calc-alkaline series typical of island arcs (fig. 8*A*; Dilles, 1987). Textures of the plutonic rocks vary from medium-grained, coarsely porphyritic to porphyroaphanitic. Most of the diorite bodies and the Yerington batholith are fine-grained, equigranular rocks. Both the Shamrock batholith and the Sunrise Pass pluton have multiple intrusive phases including porphyritic phases that contain scattered potassium feldspar megacrysts. Exposures of the volcanic rocks of Fulstone Spring (Castor, 1972; Dilles and Wright, 1988) in the Reno quadrangle are primarily hypabyssal porphyry intrusions. High-salinity (halite-bearing) fluid inclusions are ubiquitous in igneous quartz crystals in the Jurassic granitoids; their presence suggests the plutons were emplaced at relatively shallow depths (≤5 km; see John, 1989).

Hydrothermal alteration of the Jurassic granitoids is widespread and locally pervasive. Several types of alteration are present including clinopyroxene, actinolite, biotite, and local sodic-calcic alteration assemblages that contain various hydrothermal minerals including combinations of biotite, sodic plagioclase, sericite, clinopyroxene, actinolite, epidote, sphene, specular hematite, garnet, and scapolite (Carten, 1986; Battles and Barton, 1989; Battles, 1991; D.A. John, unpub. data, 1990). Large outcrops of pyroxene+epidote+specular hematite+garnet endoskarn are present in the Shamrock batholith at the south end of Mineral Peak in the Pine Nut Mountains, and large areas of bleaching and clinopyroxene alteration are present in the Sunrise Pass pluton at the north end of Mineral Peak. Porphyry intrusions associated with the volcanic rocks of Fulstone Spring are commonly intensely biotitized or epidotized. Bleached selvages (albitic(?) alteration of plagioclase) around epidote±pyroxene±actinolite veins are common throughout much of the Shamrock batholith and the Sunrise Pass pluton. Hydrothermal alteration of the Jurassic granitoids sharply contrasts with hydrothermal alteration of Cretaceous and Tertiary granitoids in the quadrangle, which generally lack sodic-calcic, clinopyroxene, and actinolite alteration assemblages.

Ore deposits associated with the Jurassic granitic rocks include two porphyry copper systems in the Yerington batholith at the north end of the Singatse Range (MacArthur deposit and Bear and Lagamarsino Prospects), iron skarn in the Buckskin Range (Minnesota Iron Mine), and iron-copper skarn in the Calico Hills (pl. 1). Two other porphyry copper deposits related to the Yerington batholith are present just south of the Reno quadrangle in the Yerington Mining District (Yerington and Ann Mason deposits). Copper skarns are also associated with the Yerington batholith, although all known copper skarn deposits are present south of the Reno quadrangle. Iron skarns at the Dayton iron deposit and the Iron Blossom Prospect are associated with a Jurassic(?) granodiorite pluton (Roylance, 1966). Copper skarns at the Copper Queen and Hard-to-Find Mines are associated with an altered Jurassic(?) pluton (Copper Valley pluton) along the north-central edge of the quadrangle, and weak porphyry copper-type alteration and copper skarns are associated with a composite Jurassic(?) pluton on Fireball Ridge (Harlan, 1984).

EXPLANATION

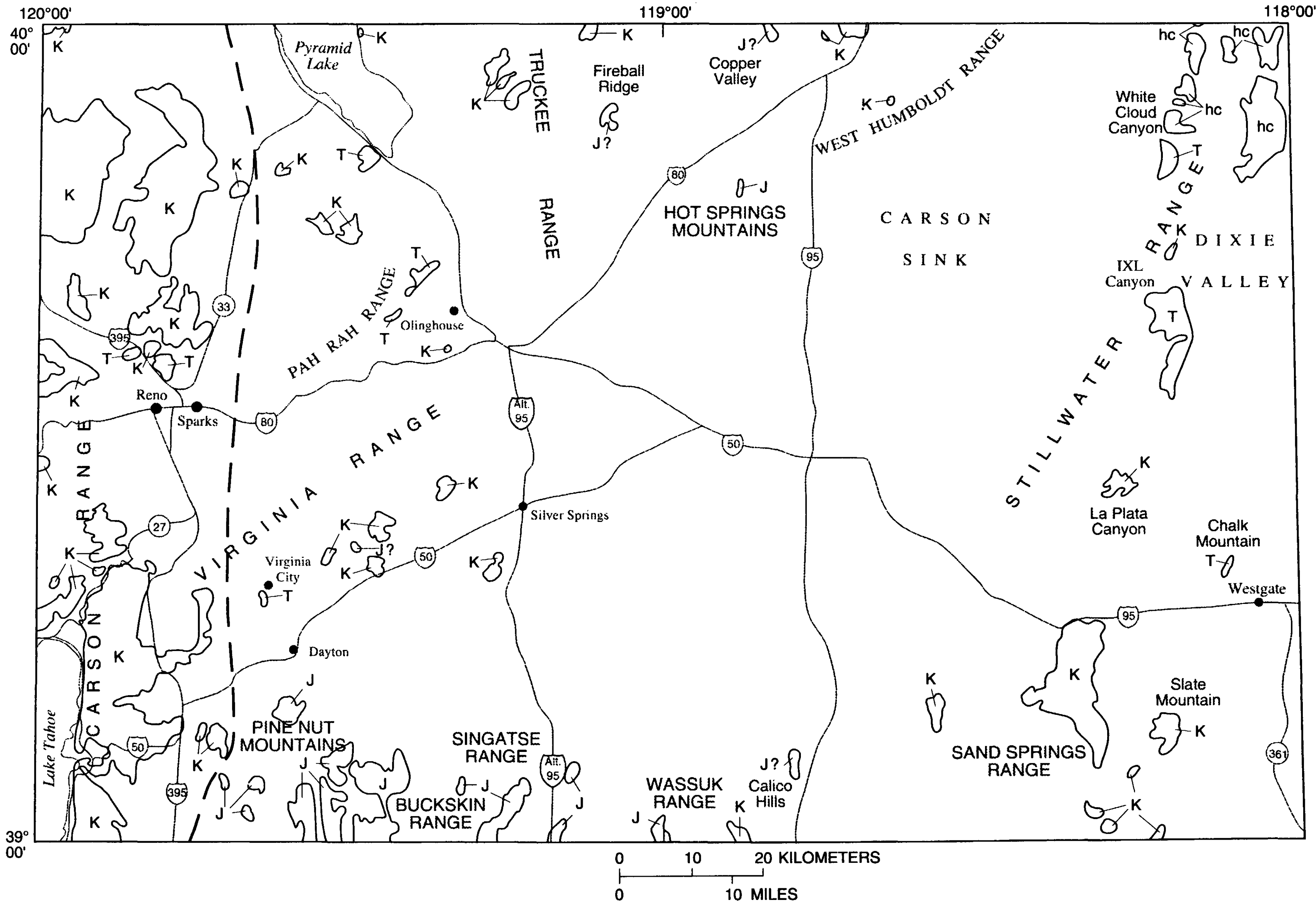
PN	Pine Nut terrane—Query denotes uncertain terrane assignment
SS	Sand Springs terrane
PD	Paradise terrane
MW	Mountain Wells sequence
	Jungo terrane—Divided into:
JO_1	Shale and limestone
JO_2	Gabbroic complexes—Includes mafic volcanic rocks
mb	Marble Butte rocks
mv	Metavolcanic rocks, undivided
— —	Boundary of terrane or rock unit—Approximately located
?	Uncertain terrane assignment

Figure 6. Continued.

Middle Jurassic Mafic Igneous Rocks

Middle Jurassic (165-150 Ma) mafic plutonic and volcanic rocks crop out in the Stillwater and West Humboldt Ranges in the northeastern corner of Reno quadrangle (unit JO_2, fig. 6). They form the southern part of the Humboldt complex, a layered mafic intrusive complex, and locally preserved cogenetic mafic volcanic rocks. The igneous rocks primarily consist of gabbroic intrusive rocks and overlying basaltic rocks (Speed, 1976). The origin of the Humboldt complex and the tectonic environment of its emplacement are not clearly understood (see the "Pre-Tertiary Metavolcanic and Metasedimentary Rocks" section).

Large areas of the western part of the Humboldt complex have undergone intense hydrothermal alteration resulting in scapolite- and albite-rich assemblages, notably in the Buena Vista Hills (Speed, 1976). The scapolite-rich zones locally contain iron deposits that are present as magnetite and hematite veins and breccia zones and as replacements of scapolite-altered rocks (Reeves and Kral, 1955; Willden and Speed, 1974). Copper and nickel in veins that fill fractures and faults are also present in and along the margins of the Humboldt complex in the Table Mountain Mining District east of the Reno quadrangle (Willden and Speed, 1974).



EXPLANATION

T Tertiary pluton

K Cretaceous pluton

J Jurassic pluton

hc Humboldt complex

Figure 7. Granitic rocks of various ages in the Reno quadrangle, Nevada and California. State line shown on figure 1. Dashed line denotes eastern limit of Sierra Nevada batholith.

Cretaceous Granitoids

Cretaceous (approximately 125 to 80 Ma) granitic plutons are widely distributed in the Reno quadrangle, particularly in the western part where they form much of the Carson Range and much of the pre-Tertiary bedrock north and northwest of Reno (fig. 7) and constitute the eastern edge of the Sierra Nevada batholith. Other large exposures of Cretaceous granitic rocks (fig. 7) are present in the Sand Springs and southern Stillwater Ranges, Slate Mountain, the Truckee Range east of Pyramid Lake, and along U.S. Highway 50 between Dayton and Silver Springs.

The Cretaceous granitoids are generally medium- to coarse-grained biotite-hornblende granite and granodiorite. Silica contents range from about 59 to 77 weight percent SiO_2 with most between 62 to 72 percent; they tend to be more silica rich than the Jurassic granitic plutons. Potassium and zirconium contents are notably lower and aluminum content is generally higher than for the Jurassic granitic rocks (fig. 8). Coarsely porphyritic textures are common, whereas porphyry phases are uncommon. In contrast to Jurassic and Tertiary plutonic rocks, coeval volcanic rocks are absent near the Cretaceous plutons; their absence suggests deeper parts of the Cretaceous plutons are exposed than either the Jurassic or Tertiary plutonic rocks. That deeper parts of the Cretaceous plutons are exposed is also suggested by their generally coarser grained, more equigranular textures, the absence of high-salinity fluid inclusions, which are ubiquitous in the Jurassic granitic plutons (see John, 1989), and the abundance of tungsten skarns associated with them (see Newberry and Einaudi, 1981).

There generally is little hydrothermal alteration evident in exposures of Cretaceous granitic plutons. Weak deuteric or propylitic alteration, manifested by partial chloritization of mafic minerals and weak sericite or clay alteration of feldspars, is widespread but generally not strongly developed. Several areas, notably parts of the La Plata Canyon pluton in the southern Stillwater Range and a pluton in the central Sand Springs Range, contain stockwork quartz+pyrite+sericite±fluorite veins that resemble alteration associated with low-fluorine (quartz monzonite-type) porphyry molybdenum deposits.

Most mineral deposits associated with Cretaceous plutons are tungsten skarns, including the Nevada Scheelite deposit at the south end of the Sand Springs Range and the St. Anthony Mine in the Toy District. The tungsten skarn deposits are contained in Triassic and Jurassic carbonate rocks near contacts with Cretaceous granitoids. Polymetallic vein and simple antimony deposits are locally present in the plutons. In addition, K-Ar dating of muscovite thought to be genetically associated with the sediment-hosted gold deposit at Fondaway Canyon suggests that this deposit formed during the Late Cretaceous and is possibly related to an unexposed Cretaceous pluton (Russell and others, 1989; P.G. Vikre, oral commun., 1990).

Cenozoic Volcanic, Intrusive, and Sedimentary Rocks

A complex sequence of Cenozoic volcanic, shallow intrusive, and sedimentary rocks rests unconformably on Mesozoic granitic and metamorphic rocks in the quadrangle. Locally the basal part of this sequence is a thin veneer of undated sandstone and conglomerate. In the Yerington area, these deposits are as thick as 120 m in a large paleovalley (Proffett and Proffett, 1976) cut into Mesozoic rocks. These undated clastic deposits conceivably could be early Tertiary in age although a more likely interpretation is that they are only slightly older than overlying ash-flow tuffs, which regionally are as old as 31 Ma. Thus, the hiatus in the rock record at the Mesozoic-Cenozoic unconformity may range from the Late Cretaceous to the middle Tertiary.

The Cenozoic rocks in the Reno quadrangle can be assigned to three main lithologic-tectonic assemblages that have been distinguished over a large part of the Western United States (Cox and others, 1990; Christiansen and Yeats, in press). These assemblages are (1) an interior andesite-rhyolite assemblage consisting of silicic ash-flow tuffs and local lava flows and shallow intrusions of intermediate to rhyolitic composition (31 to 20 Ma), (2) a western andesite assemblage consisting of andesitic and dacitic lava flows (20 to 12 Ma) that is a part of early magmatic-arc volcanism associated with the Cascade volcanic belt, and (3) a bimodal basalt-rhyolite assemblage and associated sedimentary rocks (16 Ma to present day) related to extensional tectonic events.

Interior Andesite-Rhyolite Assemblage (31-20 Ma)

Rocks of the interior andesite-rhyolite assemblage in the Reno quadrangle consist of widespread silicic ash-flow tuffs and related rocks. In the Great Basin region of Nevada and Utah, this assemblage consists mostly of voluminous ash-flow tuffs formed during a south to southwestward sweep of volcanism (Best and others, 1989). Various hypotheses have been proposed to account for widespread andesite-rhyolite assemblage rocks in western North America. One hypothesis is that volcanism resulted from a shallow-dipping subduction zone (Snyder and others, 1976) or subparallel imbricate subduction zones (Lipman and others, 1971) that extended far inland beneath the North American lithospheric plate and initiated volcanism over a broad inland region. Coney and Reynolds (1977) and Coney (1987) emphasized a slowdown in convergence rates between the North American and Farallon Plates at about 40 Ma that caused steepening of a shallow-dipping crustal slab, relaxation of compressive stresses, and related extension and volcanism. Wernicke and others (1987) indicated that stresses inherent in the North American Plate rather than plate interactive forces may have been controlling factors in the tectonomagmatic evolution of this volcanism. They hypothesized that extension is localized in areas that were overthickened by previous crustal shortening, and that volcanism followed shortly after extension. Gans and others (1989) also related volcanism and extension, but they hypothesized that magmatism and associated extension was related to a flux of mantle-derived basalt into the crust.

In the northwestern part of the Reno quadrangle, silicic ash-flow tuffs and related volcanic rocks of the interior an-

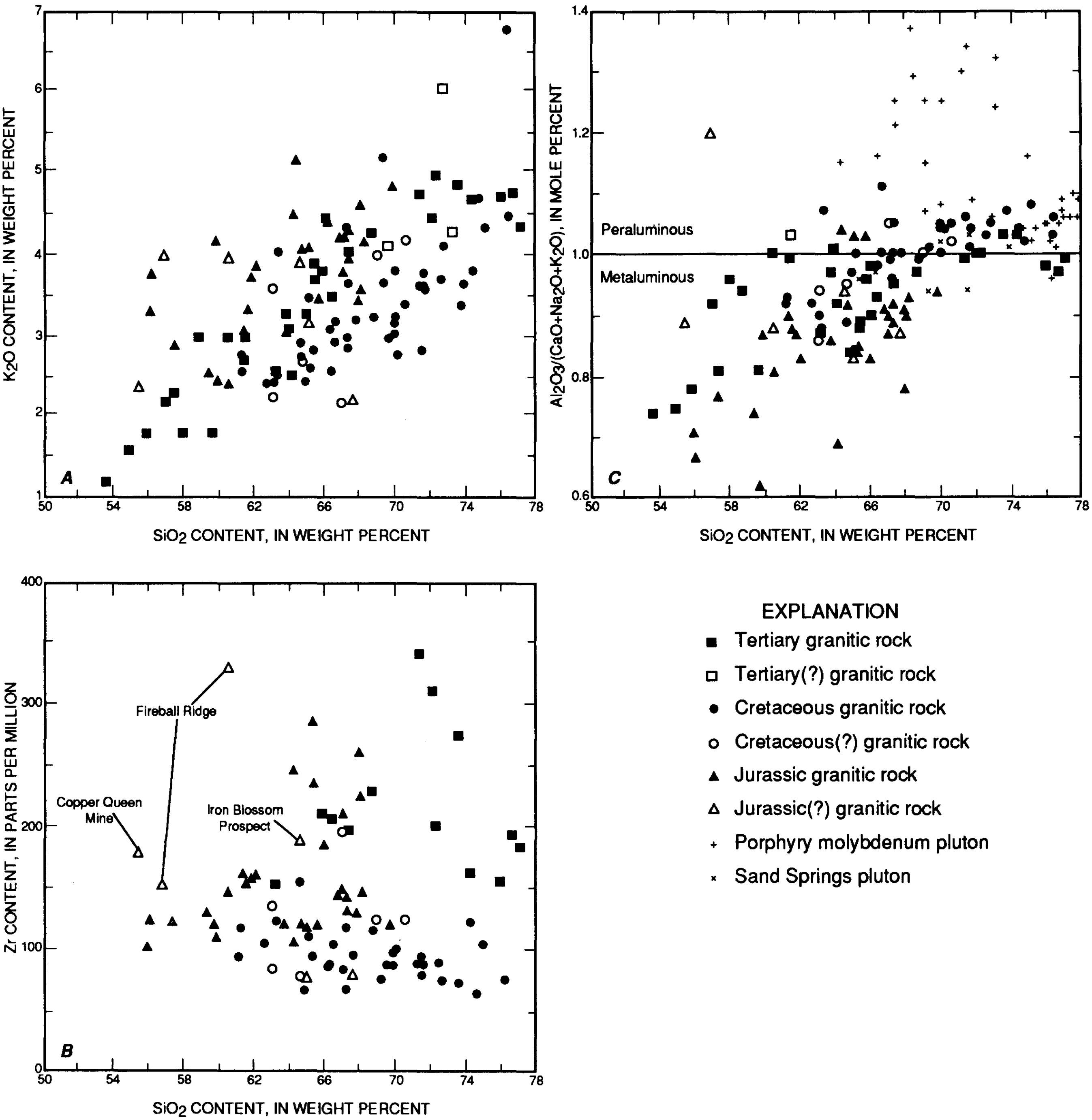


Figure 8. Chemical variation diagrams for granitic rocks in the Reno quadrangle, Nevada and California. All analyses normalized to 100 percent volatile-free. Samples from undated plutons assigned most probable age (queried) on the basis of field relations, metallogeny, and (or) comparison of geochemical data with plutons of known ages. Data from Thompson and White (1964), Wallace (1975), Hudson (1977), Lee (1984), M.L. Silberman (written commun., 1990), and John (1992). *A*, SiO_2 versus K_2O. *B*, SiO_2 versus Zr. *C*, SiO_2 versus $Al_2O_3/(CaO+Na_2O+K_2O)$ (mole percent). Data for plutons related to low-fluorine porphyry molybdenum systems from Westra and Keith (1981) (calc-alkaline type) and Mutschler and others (1981) (quartz monzonite type).

desite-rhyolite assemblage (unit Tt, fig. 9) are present extensively in the Seven Lakes Mountain, Dogskin Mountain, Virginia Mountains, and Pah Rah Range (Deino, 1985; Bonham 1969; H.F. Bonham and L.J. Garside, oral commun., 1990). In the southwestern part of the quadrangle, they are present in the Virginia Range and Pine Nut Mountains, north and east respectively of Carson City, and in the Buckskin and Singatse Ranges (Proffett and Proffett, 1976; Bingler, 1978). In the northeastern part of the quadrangle, they are exposed in the Stillwater Range, Louderback Mountains, and Clan Alpine Mountains (Willden and Speed, 1974; Hudson and Geissman, 1987; John and McKee, 1991; John, in press; Hardyman and others, 1988). In the southeastern part of the quadrangle, they are exposed in the Terrill Mountains, Fairview Peak area, and in the easternmost part of the quadrangle (Willden and Speed, 1974).

The main part of the silicic ash-flow tuff unit consists of a sequence of rhyolitic to dacitic tuffs that are locally at least 800 m thick. Sequences in individual areas generally consist of 5 to 10 individual ash flows that can be distinguished in the field by their different phenocryst contents. Individual ash flows typically show vertical zonation from vitrophyric basal parts to devitrified upper parts, commonly with vapor-phase alteration in the uppermost part. In the western and central parts of the quadrangle, the ash-flow tuffs are mainly outflow sheets that erupted from unknown vents and covered large areas; for example, the Nine Hill Tuff covered as much as 16,000 km^2 (Deino, 1985). In the eastern part of the quadrangle, ash-flow tuffs are present both as relatively thin outflow sheets (Hudson and Geissman, 1987) and intracaldera accumulations as thick as 3 km such as in the southern Stillwater Range (John and McKee, 1991; John, in press) and in the Clan Alpine Mountains along and east of the east border of the quadrangle (Hardyman and others, 1988). The ages of these ash-flow tuff sequences where they are most well studied range from about 31 to 23 Ma in the Seven Lakes Mountain area (Deino, 1985), from about 28 to 22 Ma near Carson City (Bingler, 1978), from about 28 to 24 Ma in the Yerington area (Proffett and Proffett, 1976), and from about 28 to 24 Ma in the southern Stillwater Range (John and McKee, 1991; John, in press).

Andesitic and dacitic lava flows, or lava flows and plugs of intermediate or silicic composition, are locally interstratified with, or intruded into, the ash-flow tuffs. These rocks are fairly widespread in the northeastern Terrill Mountains (Willden and Speed, 1974), southern Stillwater Range (John and McKee, 1991; John, in press), and in the southeasternmost part of the quadrangle (Willden and Speed, 1974).

Western Andesite Assemblage (20 to 12 Ma)

Andesitic and dacitic lava flows and related rocks of the western andesite assemblage are thick and widespread in a west-northwest-trending belt of outcrops across the southern part of the Reno quadrangle (fig. 10). These rocks are a part of an elongate north-south trending belt of magmatic-arc rocks in the western United States related to the early development of the Cascade magmatic arc. The rocks of the Cascade Arc are interpreted to have resulted from volcanism along a steeply dipping subduction zone (Coney, 1987). Subduction-related andesitic and dacitic volcanism of the western andesite assemblage was cut off progressively northward as the western margin of North America was converted to a transform boundary by the initiation of the Mendocino triple junction, its northward migration, and the development of the San Andreas Fault (Snyder and others, 1976). In the Reno quadrangle, this cut-off of subduction-related andesitic-dacitic volcanism took place at approximately 12 Ma.

Andesitic and dacitic rocks of the western andesite assemblage in the Reno quadrangle consist of the thick, widespread Alta and Kate Peak Formations in the western part of the quadrangle, the andesite of Lincoln Flat in the Singatse Range in the south-central part of the quadrangle, an unnamed widespread andesite unit in the Cocoon Mountains and adjacent areas in the southeastern part of the quadrangle, and local andesitic units elsewhere.

The Alta Formation in the Peavine Peak area, Virginia Range, and northern Pine Nut Mountains consists of a locally thick sequence of hornblende or pyroxene andesite, trachyte, and basalt lavas, flow breccias, and laharic breccias and pyroclastic rocks. The formation is commonly propylitically altered, and north of Reno and in the Virginia Range it contains abundant quartz-alunite ledges (Bell and Bonham, 1987; Vikre, 1989). The Alta Formation is reported to be 820 m thick in the Virginia City area of the Virginia Range (Calkins, 1944, p. 12), but it thins markedly in all directions away from there (Bonham, 1969). The Alta Formation contains a unit of volcaniclastic sedimentary rocks (Sutro Member) in the Virginia City area in the southwestern part of the Virginia Range (Thompson and White, 1964). The rocks of the Alta Formation range in age from about 20 to 16 Ma (Silberman and McKee, 1972; Vikre and McKee, 1987).

The Kate Peak Formation conformably overlies, and may locally interfinger with, the Alta Formation in the western part of the Virginia Range and in the northern Pine Nut Mountains (Thompson and White, 1964; J.H. Stewart, unpub. mapping, 1986–87). In the eastern part of Virginia Range and in Pah Rah Range it apparently conformably overlies the Pyramid sequence of Bonham (1969), and in the northern Carson Range it unconformably overlies Mesozoic granitic rocks in most places.

The Kate Peak Formation is a distinctive dacite with abundant large (3-5 mm) plagioclase phenocrysts, minor amounts of pyroxene or hornblende, and rare amounts of biotite. Although much of the formation is dacitic, compositions of its volcanic rocks range from andesite to rhyolite.

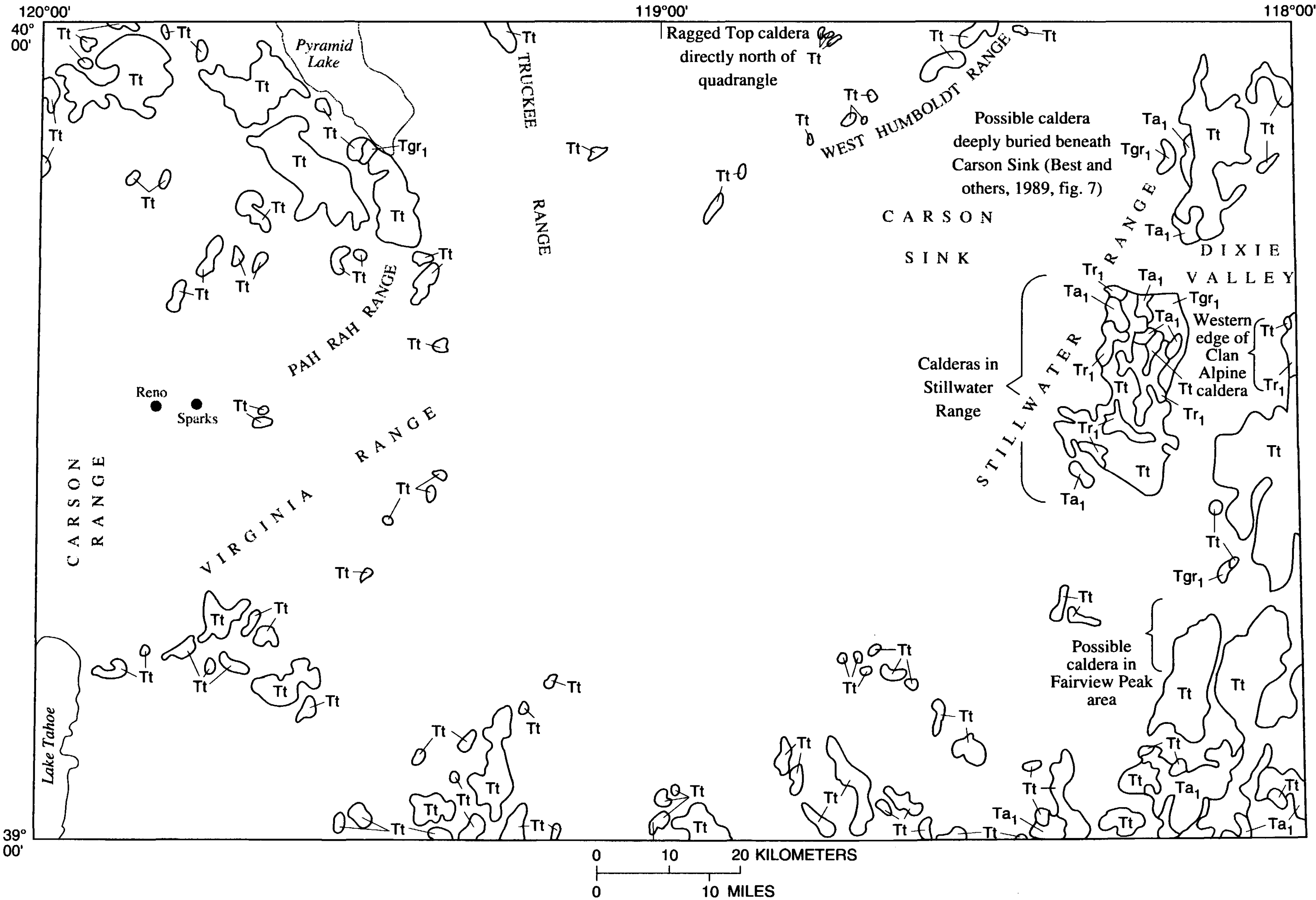


Figure 9. Oligocene and Miocene (31 to 20 Ma) rocks of interior andesite-rhyolite assemblage in the Reno quadrangle, Nevada and California. State line shown on figure 1.

The dacite is present as lava flows, flow and laharic breccias, and intrusions. In much of the Carson Range, Virginia Range, and Pine Nut Mountains, it is composed of an assemblage of flow domes; large composite volcanoes may have been present near Virginia City, Como, and Ramsey as indicated by the presence of these intrusions (fig. 10). The Kate Peak Formation is compositionally similar (Whitebread, 1976) to the Alta Formation, although it is somewhat more silicic. The Kate Peak Formation contains sedimentary sequences as thick as 900 m of shale, siltstone, and volcaniclastic sandstone and conglomerate in the eastern Virginia Range, which were included in the Desert Peak Formation by Rose (1969), and it contains a thinner sequence of sedimentary rocks in the northern Pine Nut Mountains (J.H. Stewart, unpub. mapping, 1987–1988)

The andesite of Lincoln Flat consists of hornblende-bearing andesite and dacite lava flows, flow breccia, and lahars separated from an underlying thick sequence of ash-flow tuffs by an erosional unconformity. The andesite of Lincoln Flat is reported to be as much as 1,500 m thick in the Yerington area (Proffett and Proffett, 1976)

A moderately widespread unit of andesite is present below a capping basalt in the Cocoon Mountains and adjacent areas in the southeastern part of the Reno quadrangle. Little is known of this unit except that it has been dated at 18.1 Ma (Willden and Speed, 1974; converted to new constants using Dalrymple, 1979). Andesitic and dacitic lavas approximately 15 Ma are also present below a capping basalt in the southern Stillwater Range (John and McKee, 1991; John, in press).

Bimodal Basalt-Rhyolite Assemblage and Associated Sedimentary Rocks (16 Ma to Present Day)

Rocks of the bimodal basalt-rhyolite assemblage and associated sedimentary rocks are widely distributed in the Reno quadrangle (fig. 11). This assemblage has been interpreted (Christiansen and Lipman, 1972; Noble, 1972) to be related to regional extension in the Basin and Range Province that allowed deep basaltic magmas to be tapped and rhyolitic magmas to be produced by local melting of crustal rocks. The extension also produced fault-bounded sedimentary basins that initially may have extended over

EXPLANATION

Tt	Ash-flow tuffs (Miocene and Oligocene)
Ta_1	Andesite and dacite lava flows (Miocene and Oligocene)
Tr_1	Rhyolitic flows, domes, and shallow intrusive rocks (Miocene and Oligocene)
Tgr_1	Granitic rocks (Miocene and Oligocene)
———	Contact

Figure 9. Continued

large parts of the Reno quadrangle and have been overprinted by more restricted basins related to present-day basin-and-range structure. The cause of widespread extension in the Basin and Range Province has been interpreted in the following ways: (1) oblique extensional fragmentation in a broad region of right-lateral movement related to differential motion between the North American and Pacific Plates (Atwater, 1970), (2) back-arc extension (Scholz and others, 1971), and (3) extension related to crustal overthickening and thermal heating by igneous activity (Wernicke and others, 1987). The eruption of the bimodal basalt-rhyolite assemblage in the Reno quadrangle in part overlaps in time the eruption of volcanic rocks of the subduction-produced magmatic-arc rocks of the western andesite belt; this relation indicates that subduction-related and extension-related volcanism are partly coeval in the quadrangle.

Rocks of the bimodal basalt-rhyolite assemblage in the quadrangle have been divided into many regional and local units. Bonham (1969) proposed the informal name "Pyramid sequence" for the oldest rocks of this assemblage and applied this term to rocks widely exposed in southern Washoe and Storey Counties. The term is also applied to rocks in Churchill County (Greene and others, 1991). The Pyramid sequence is a widespread unit as thick as 1,000 m of basalt, basaltic andesite, and andesite lava flows, flow breccias, and mudflow breccias and associated sedimentary rocks. Rhyolite lava flows, flow breccias, tuffs, domes, and shallow intrusive rocks are locally present within this sequence. The Pyramid sequence in Truckee River canyon underlies the Kate Peak Formation of the western andesite assemblage, but isotopic ages of 16 to 14 Ma on the Pyramid sequence in part overlap the 15- to 12-Ma age of the Kate Peak Formation and indicate that the two units are partly coeval.

Volcanic rocks of the bimodal basalt-rhyolite assemblage that overlie the Kate Peak Formation, and locally are coeval with the Kate Peak Formation, consist of basalt, basaltic andesite, andesite, and localized rhyolite. These rocks cover large areas of the west-central, north-central, south-central, southeastern, and northeasternmost parts of the quadrangle (fig. 11). The basalt, basaltic andesite, and andesite flows generally dip gently and commonly form widespread flat-topped plateaus or mesas. Rhyolitic lava flows, domes, and shallow intrusive rocks are associated with the basalt, basaltic andesite, and andesite, and they are most abundant in a zone extending south-southeastward from the Virginia Range east of Reno into the east-central part of the quadrangle (fig. 11). These rhyolites are part of the Lahontan Reservoir and Desert Mountains Structural and Volcanic Zones (figs. 11 and 12) described in the "Cenozoic Structures" section. Most rocks of the bimodal basalt-rhyolite assemblage range in age from about 14 Ma to 6 Ma. Volcanic rocks younger than 6 Ma (units QTb, QTr, fig. 11) consist of local basalt flows,

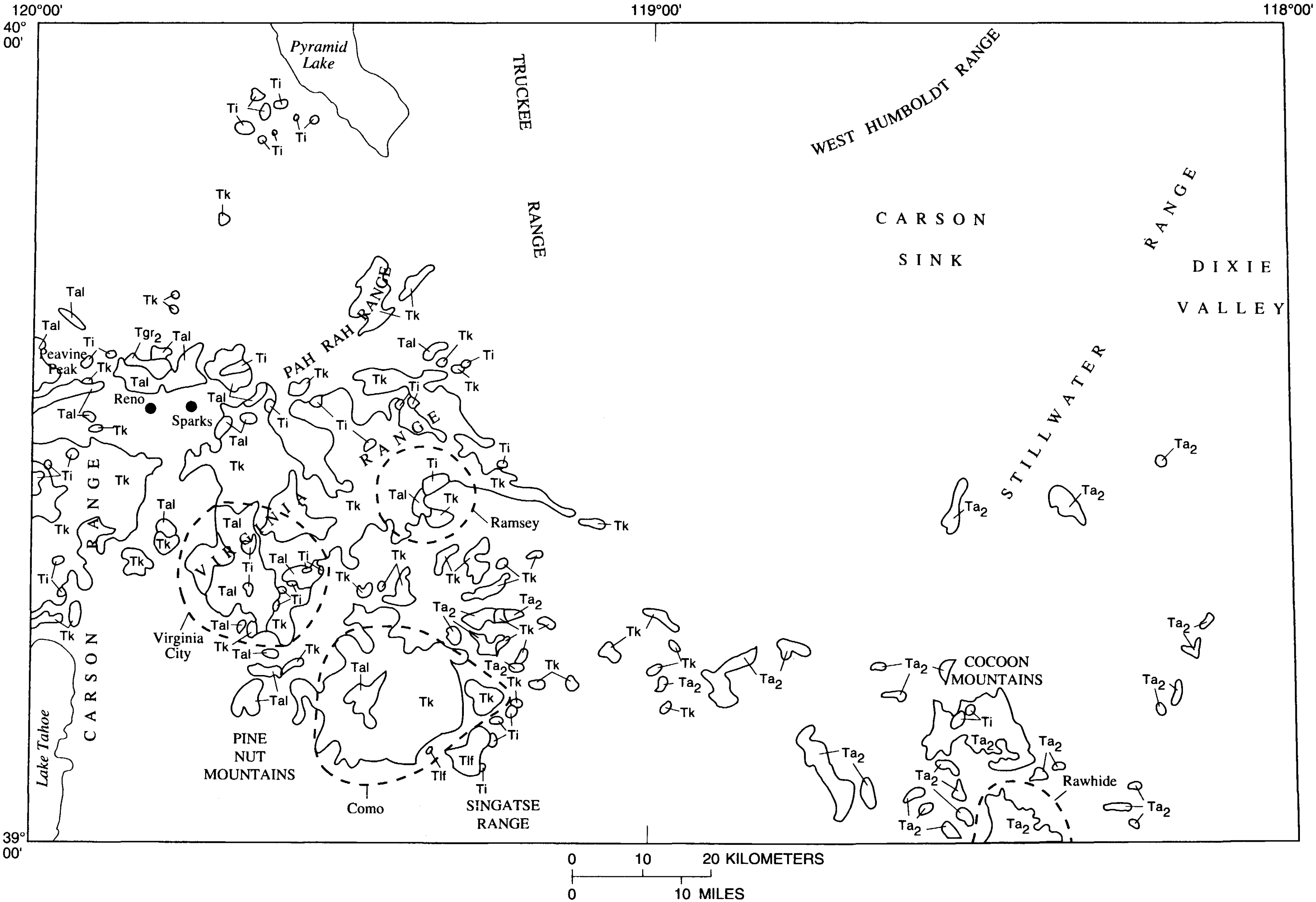


Figure 10. Miocene (20 to 12 Ma) rocks of western andesite assemblage in the Reno quadrangle, Nevada and California. State line shown on figure 1.

cinder cones, and maars and rhyolitic lava flows and domes. Volcanic rocks younger than 6 Ma are present in a east-northeast-trending zone from the Virginia Range on the west to the Carson Sink on the east (fig. 11).

Lacustrine and fluvial sedimentary deposits ranging in age from 16 to 6 Ma are widespread in the quadrangle. They are interstratified with volcanic rocks of the Pyramid sequence and younger basalt and basaltic andesite of the bimodal basalt-rhyolite assemblage, as well as with the Kate Peak Formation. Some individual sedimentary units that are part of the bimodal basalt-rhyolite assemblage in one area appear to extend into other areas where they are part of the western andesite assemblage. Sedimentary rocks younger than 6 Ma consist mostly of alluvial valley fill that is generally thin (<1 km) in areas west of a line (the eastern limit of the Walker Lane Belt) extending from Pyramid Lake in the northern part of the quadrangle southeastward through Rawhide in the southern part of the quadrangle (fig. 1). Northeast of this line, upper Cenozoic alluvial deposits (<6 Ma?) are locally thick and at least 2 km thick in Carson Sink (Hastings, 1979) and Dixie Valley (Anderson and others, 1983).

Tertiary Granitic Plutons

Tertiary granitic plutons are widely scattered in the Reno quadrangle cropping out in the Stillwater and Virginia Ranges, on the southwest side of Pyramid Lake, on Peavine Peak, and at Chalk Mountain and Westgate (fig. 7). The largest Tertiary granitic plutons are in the Stillwater Range and include the IXL and White Cloud Canyon plutons. Other Tertiary granitic plutons include the Davidson Granodiorite near Virginia City, the Guanomi stock on the southwest edge of Pyramid Lake, small diorite bodies in the Peavine Mining District, granitic dikes in the Olinghouse Mining District, and granitic rocks exposed at Chalk Mountain. Most Tertiary granitic plutons are present in deeply eroded volcanic piles; the IXL pluton represents the roots of a tilted caldera complex (John and McKee, 1991; John, in press) and the Davidson Granodiorite probably represents the roots of a stratovolcano (Vikre, 1989). Tertiary granitic plutons are metaluminous and have silica contents ranging from 55 to 77 weight percent SiO_2. Potassium content is slightly lower than the Jurassic plutons and notably higher than Cretaceous plutons (fig. 8*A*).

Strong hydrothermal alteration and base- and precious-metal mineralization are commonly associated with Tertiary granitic plutons. Sericitic alteration and stockwork quartz veins containing low-grade copper and molybdenum values are present in the Guanomi stock and represent a porphyry copper-molybdenum system (Bonham, 1969; Wallace, 1975; Satkoski and Berg, 1982). Large areas of advanced argillic, argillic, and sericitic alteration and gold mineralization are associated with Tertiary intrusions in the Peavine and Wedekind Mining Districts (Bonham, 1969; Hudson, 1977), and copper-gold mineralization in Tertiary volcanic rocks in the Pyramid Mining District may be related a to granitic stock underlying the district (Wallace, 1975). Gold-silver veins are associated with granitic dikes in the Olinghouse Mining District (Bonham, 1969; Geason, 1980). Copper skarns and polymetallic veins are associated with Tertiary granitoids of the Stillwater Range in the Shady Run and IXL Mining Districts (Vanderburg, 1940; Willden and Speed, 1974). Polymetallic replacement and vein deposits at Chalk Mountain and Westgate are related to Tertiary granitic plutons (Bryan, 1972).

EXPLANATION

Tk	Kate Peak Formation and related rocks, undivided (15 to 12 Ma, Miocene)
Ta_2	Andesite and dacite lava flows (20 to 12 Ma, Miocene)
Ti	Hypabyssal intrusive rocks (20 to 12 Ma, Miocene)
Tgr_2	Granitic rocks (20 to 12 Ma, Miocene)
Tal	Alta Formation and related rocks, undivided (20 to 16 Ma, Miocene)
Tlf	Andesite of Lincoln Flat (19 to 14 Ma, Miocene)
———	Contact
- - -	Volcanic center

Figure 10. Continued

Cenozoic Structures

The Cenozoic structural history of the Reno quadrangle before 31 Ma is unknown, because Cenozoic rocks older than about 31 Ma are unrecognized in the quadrangle. Presumably, the region was relatively high and undergoing erosion during the early part of the Cenozoic.

Cenozoic structures during of eruption of widespread ash-flow tuffs (31 to 20 Ma) of the interior andesite-rhyolite assemblage in the quadrangle consist of a few recognized calderas (fig. 9) and an area of large-scale extension in the southern Stillwater Range (fig. 12). Calderas (fig. 9) identified or interpreted to be in or near the Reno quadrangle are (1) three calderas in the Stillwater Range (John and McKee, 1991; John, in press), (2) a caldera complex in the Clan Alpine Mountains along and directly east of the east border of the quadrangle (Hardyman and others, 1988), (3) a problematic caldera in the area of thick tuff in the Fairview Peak area, (4) an even more problematic caldera, or group of calderas, in an area of thick tuff in the southeastern part of the quadrangle, (5) a caldera directly north of the north border of the quadrangle (Ragged Top caldera, Heggeness, 1982), and (6) a proposed caldera deeply buried under alluvial fill somewhere in the Carson Sink area

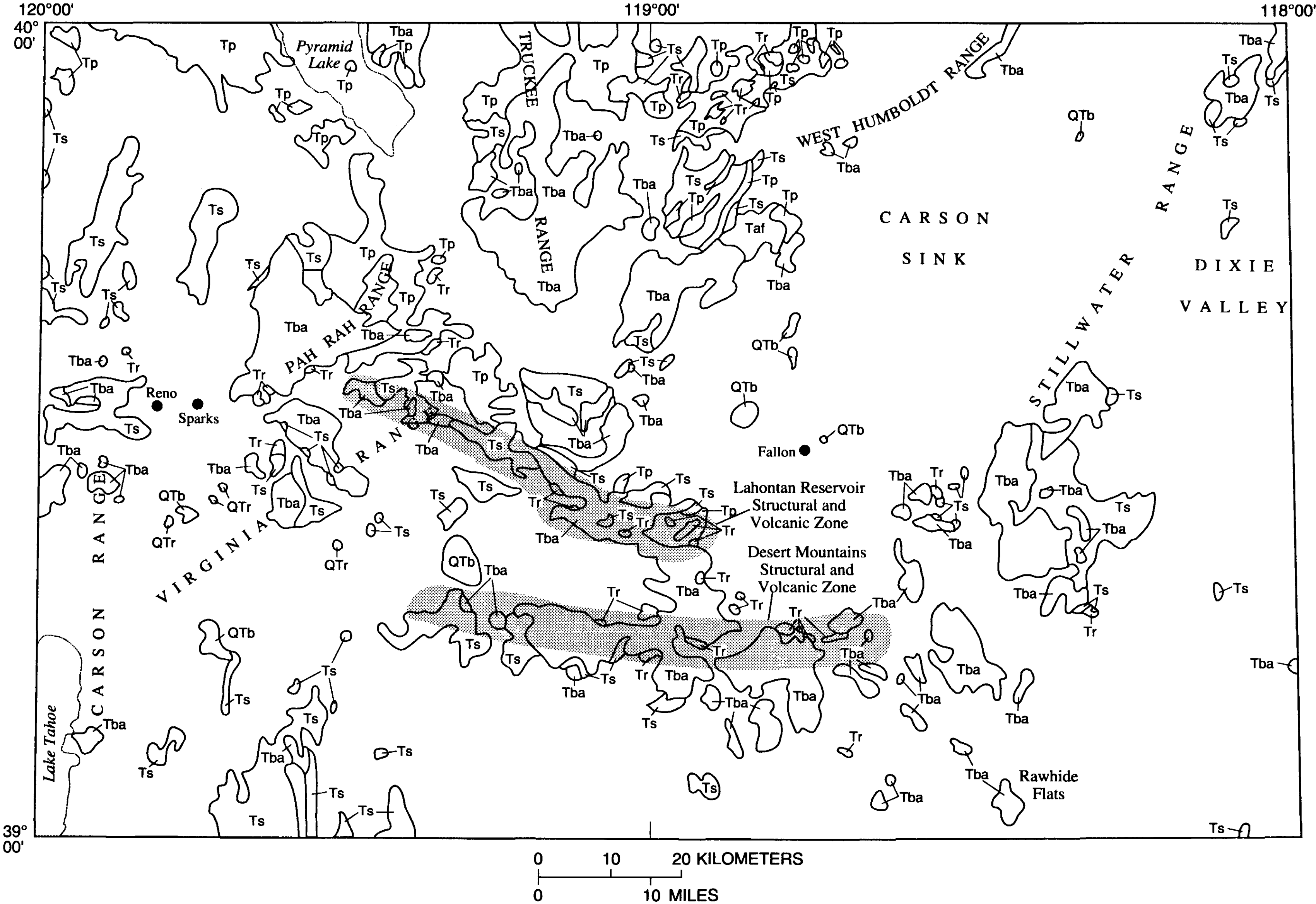


Figure 11. Miocene to Quaternary (16 Ma to present day) volcanic rocks of bimodal basalt -rhyolite assemblage and associated sedimentary rocks, and location of Lahontan Reservoir and Desert Mountains Structural and Volcanic Zones in the Reno quadrangle, Nevada and California. State line shown on figure 1.

(Best and others, 1989, fig. 7). The widespread distribution and fairly uniform thicknesses of individual ash flows in the western part of the quadrangle suggest that topographic relief there was generally low, and as a corollary, there was probably very little tectonic activity during deposition of the ash-flow tuffs. In the southern Stillwater Range, however, intracaldera ash-flow tuffs (as young as about 24 Ma) from three calderas were tilted to an almost vertical position before and during emplacement of 25- to-22 Ma rhyolite to dacite domes and dikes (John and McKee, 1991; John, in press). The tilting is probably related to local large-scale east-west extension (John and McKee, 1991; John, in press).

Rocks of the western andesite assemblage (20 to 12 Ma) were erupted from many small and probably a few large volcanic centers across the southern part of the quadrangle. A large composite volcano is indicated in the Como area (fig. 10) by the large circular outcrop pattern of the Kate Peak Formation (fig. 10), a radial fault pattern in the eastern part of this outcrop area (Greene and others, 1991), abundant small intrusions and hydrothermally altered areas in the presumed central part of the volcano, and a vaguely defined central vent area. Similar large volcanic complexes may be present in the Virginia City (fig. 10; Vikre, 1989) and Ramsey areas (fig. 10), where rocks of the western andesite assemblage are thick, highly altered, and cut by large hypabyssal intrusions. In the Ramsey area, rocks of the western andesite assemblage are also characterized by a disrupted circular topographic pattern. However, dacite of the Kate Peak Formation in many areas outside of these volcanic centers appears to have been emplaced as many small flow domes. In addition, a large center of volcanic activity is present in a 10-km-diameter area near the Regent Mining District in the southernmost part of the Reno quadrangle and the northernmost part of the adjacent Walker Lake 1° by 2° quadrangle (fig. 10; Ekren and Byers, 1986)

Overlapping in part with the time of eruption of the western andesite assemblage, and continuing after eruption of these rocks, structural extension dominates the tectonic history of the Reno quadrangle. This extension probably began about 16 Ma judging from the age of the oldest widespread, presumably extension related, sedimentary deposits in the quadrangle. Initially, east-west extension occurred in the southern part of the quadrangle from the Wassuk Range on the east to near Carson City on the west (fig. 12). This extension is characterized by closely spaced (1 to 2 km) normal faults that originally were steeply dipping but were subsequently rotated to a nearly horizontal position during continued extension (Proffett, 1977). The amount of extension is estimated to be more than 100 percent in the Yerington area and to have started during eruption of the andesite of Lincoln Flat (19 to 17 Ma). However, most of the extension probably took place after eruption of this unit but prior to eruption of 11- to 8-Ma basalts, and in areas farther west before eruption of the Kate Peak Formation (15 to 12 Ma).

Numerous sedimentary basins developed in the Reno quadrangle from 16 to 6 Ma. At times basalt and basaltic andesite lava flows erupted onto and spread out across these basins. The detailed distribution of the sedimentary basins is not clearly understood, but some must have been large. The Pyramid sequence (16 to 14 Ma), for example, of basalt and andesite and minor amounts of sedimentary rocks is widespread in the western part of the quadrangle and appears to represent deposition across a broad plain with only local volcanoes or elevated areas. The widespread distribution of younger basalts and andesites (11 to 6 Ma) in the south-central part of the quadrangle suggests an equally widespread basin or plain. During the 16- to 6-Ma time span, extension probably produced these widespread sedimentary basins but the amount of extension, based on the general low dips of rocks of this age, was much less than the large-scale extension and resulting stratal tilting that took place from 19 to 11 Ma in the Yerington area. However, local tilting of as much as 30° since the middle Miocene has been documented (Vikre, 1989).

Starting perhaps about 6 Ma, the deformational style in the quadrangle changed and the present-day physiography began to develop. The time of initiation of this change, which may have been gradual, is difficult to determine precisely; however, the age of the youngest widespread basalt flows appears to be about 6 Ma, and they have been extensively modified by faulting that at least locally is related to the development of the present-day basins and ranges. The young faulting and basin development appears to have been overprinted on the older, more widespread basins; parts of older basins dropped to form the deepest parts of present-day basins, and other parts were uplifted to form segments of mountain blocks. The

EXPLANATION

QTr	Rhyolitic flows, domes, and shallow intrusive rocks (Quaternary and Tertiary, 6 Ma or less)
QTb	Basalt (Quaternary and Tertiary, 6 Ma or less)
Tba	Basalt, basaltic andesite, and andesite (Tertiary, 16 to 6 Ma)
Tr	Rhyolitic flows, domes, and shallow intrusive rocks (Tertiary, 16 to 6 Ma)
Ts	Sedimentary rocks (Tertiary, 16 to 6 Ma)
Tp	Pyramid sequence of Bonham (1969) (Tertiary, 14 to 16 Ma)
Taf	Ash-flow tuff (Tertiary, 16 to 6 Ma)
	Contact
	Structural and volcanic zone

Figure 11. Continued

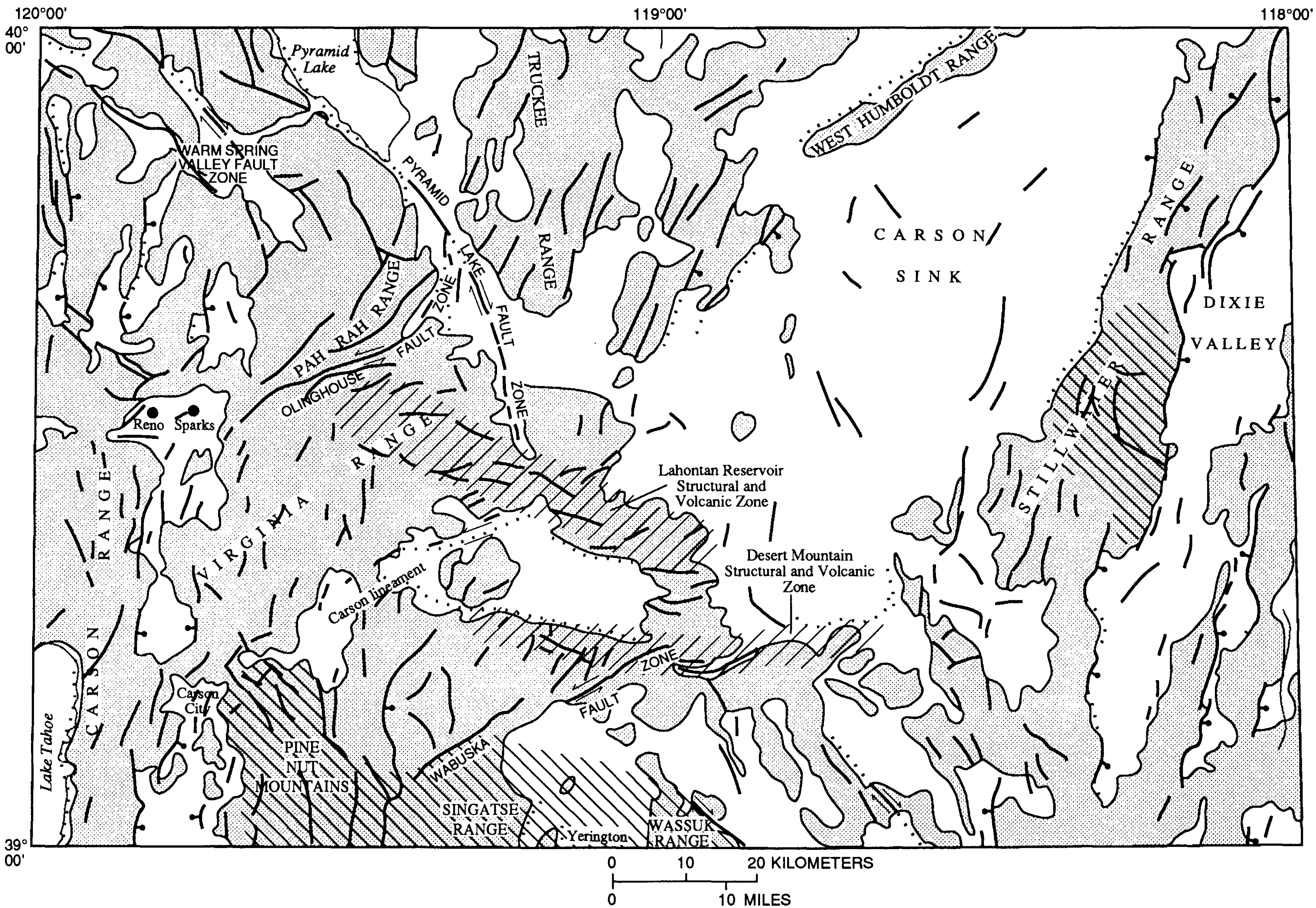


Figure 12. Principal Cenozoic structural features in the Reno quadrangle, Nevada and California. State line shown on figure 1.

young faulting has taken place mainly along widespread, generally north-south-trending, master faults (fig. 12) and many lesser faults, all related to the development of present-day basin-and-range topography. Direction of modern extension varies from approximately east-west along the south edge of the quadrangle in the Wassuk and Singatse Ranges and the Pine Nut Mountains to northwest in the Dixie Valley region (fig. 12; Zoback, 1989).

Strike-slip faulting has been an important element in the late Cenozoic tectonic history of the Reno quadrangle. The western part of the quadrangle is part of the Walker Lane Belt (fig. 1), a northwest-trending structural zone about 700 km long and 100 to 300 km wide characterized by northwest-trending right-lateral faults and northeast-trending left-lateral faults (Stewart, 1988). In the Reno quadrangle, the Walker Lane Belt is characterized by northwest-trending right-lateral faults of the Warm Springs Valley and the Pyramid Lake Fault Zones (fig. 12); to the south, by the northeast-trending left-lateral, or presumed left-lateral, Olinghouse and Wabuska Faults and the Carson Lineament (fig. 12; Stewart, 1988); and by unnamed right-lateral, or presumed right-lateral, faults in the southernmost part of the quadrangle (fig. 12). Bonham (1969) suggested a cumulative right-lateral displacement of 32 km across the Warm Springs Valley, Pyramid Lake, and related faults in the northwestern part of the quadrangle on the basis of the apparent offset of the northern outcrop of upper Oligocene and lower Miocene ash-flow tuffs, although he indicates that this estimate is highly conjectural. Presumed historical movement on the Olinghouse Fault Zone is left-oblique slip (Sanders and Slemmons, 1979), but estimates of total left-slip on the Olinghouse Fault Zone, as well as the Carson Lineament, have not been made. Left-lateral offset of 4 km on the Wabuska Fault Zone is suggested by the apparent offset of Mesozoic metavolcanic rocks on the south side of the Desert Mountains. The timing of strike-slip movement in the Reno quadrangle is poorly understood, but movement may have occurred at various times throughout the late Cenozoic, as determined by the age of Walker Lane structures in the Walker Lake 1° by 2° quadrangle to the south (Ekren and Byers, 1984; Hardyman and Oldow, 1991). The youngest movement on these structures in the Reno quadrangle is Quaternary and some is historic (Bell, 1984; Bell and Katzer, 1990).

Two unusual zones of east-southeast-trending faults and volcanic rocks are present in the south-central part of the Reno quadrangle. The northern zone (the Lahontan Reservoir Structural and Volcanic Zone, figs. 11 and 12) is well defined and characterized by a broad zone of east-southeast-trending faults, a concentration of rhyolitic lava flows and flow domes, and by an elongate east-southeast-trending distribution of basalt and andesite lava flows. The distribution of the basalt of the Lousetown Formation in the eastern Virginia Range (Rose, 1969) clearly shows this elongate east-southeast distribution, as does an unnamed hornblende andesite flow unit near Lahontan Reservoir (J.H. Stewart, unpub. mapping, 1987–88). The southern zone, the Desert Mountains Structural and Volcanic Zone, is less well defined but is characterized by east-southeast-trending faults and a concentration of rhyolitic lava flows and flow domes (figs. 11 and 12). Rhyolitic rocks within these two zones range in age from 14.4 to 8.3 Ma (E.H. McKee, written commun., 1988). The Lousetown Formation is undated where it is present along the trend of the Lahontan Reservoir zone, but in the western Virginia Range the age of this formation is 9.7 to 6.9 Ma (Dalrymple and others, 1967; Silberman and McKee, 1972; Morton and others, 1980; Fultz and others, 1984). The age of the unnamed hornblende andesite flow unit near Lahontan Reservoir is 6.7 Ma (E.H. McKee, written commun., 1988). Thus movement on faults in the Lahontan Reservoir and Desert Mountains Structural and Volcanic Zones may have occurred from about 14.4 to 6.7 Ma, if emplacement of the volcanic rocks was coeval with movement on the faults. The type of movement along faults in these zones is unknown.

EXPLANATION

- Quaternary alluvium
- Outcrop area
- Contact
- High-angle fault—Bar and ball on downthrown side; dotted where concealed
- Strike-slip fault—Arrows show direction of relative movement; dotted where concealed
- Fault zone, lineament, or structural and volcanic belt
- Area of large-scale extension (19 to 11 Ma in Yerington area and 24 to 23 Ma in southern Stillwater Range)

Figure 12. Continued

Relation of Cenozoic Volcanism and Tectonism to Mineral Deposits

Most mineral deposits formed during Cenozoic time in the Reno quadrangle consist either of epithermal precious metal deposits associated with volcanic and hypabyssal intrusive rocks or base and precious metal deposits associated with granitic rocks. However, for most individual deposits, the relation between the regional volcanic-tectonic setting and mineralization remains unclear.

Volcanic-hosted epithermal gold-silver deposits are the most important metallic mineral deposits in the Reno quadrangle, as discussed in the section "Mineral Deposits of Tertiary Age." These deposits are present in numerous mining districts hosted primarily by the western andesite and interior andesite-rhyolite assemblages, and a large number are hosted by the Kate Peak Formation (table 2). Deposits dated by K-Ar methods range in age from about 23 to 6(?) Ma, although the ages of most deposits are between about 16 to 10 Ma (table 2) and active hot-spring systems, such as Steamboat Springs, may be forming future epithermal deposits, as emphasized by White (1981). An unusually large percentage of the volcanic-hosted gold-silver deposits in Nevada are present in the Walker Lane Belt, as first noted by Silberman and others (1976), although the relation, if any, of Walker Lane tectonics to the genesis of precious-metal deposits remains ambiguous (John and others, 1989). Deposits in the Reno quadrangle do not appear to be structurally controlled by large faults of the Walker Lane Belt with the exception of deposits in the Olinghouse Mining District, which formed along the northeast-trending Olinghouse Fault (Bonham, 1969; Geasan, 1980). There is not an obvious relation between orientation of controlling structures and age of mineralization (table 2). There also does not appear to be a correlation between areas of early Miocene crustal extension and epithermal mineral deposits, a relation that has been noted farther south in the Walker Lane Belt (John and others, 1989). In fact, areas in the Reno quadrangle where large-scale, pre-middle Miocene extension has been documented (fig. 12) are notably devoid of known epithermal deposits. Detailed structural studies of many mining districts have not been completed; thus the suggestion by Seedorff (1991) that virtually all Tertiary mineral deposits in the Great Basin are related to extension cannot be evaluated. Most epithermal deposits in the Reno quadrangle are spatially associated with hypabyssal intrusions and (or) volcanic centers (table 2; figs. 9 and 10). However, the genetic relation of these intrusions to formation of mineral deposits beyond acting as heat sources remains ambiguous (see Vikre, 1989).

Cenozoic base- and precious-metal deposits are scattered across the Reno quadrangle. Known types of deposits include copper skarn, polymetallic replacement, polymetallic vein, porphyry copper, and zinc-lead skarn(?). In addition, base metal-rich veins that were primarily mined for their precious metal content may represent the upper parts of large porphyry systems (for example, Pyramid Mining District, Wallace, 1975, 1979). Most of these base-metal deposits are associated with small granitic to dioritic stocks that are part of the interior andesite-rhyolite and western andesite assemblages and range in age from about 30 to 13 Ma.

GEOCHEMICAL STUDIES

Regional Stream-Sediment Geochemistry

A regional geochemical study was conducted to aid in evaluating known as well as undiscovered mineral resources of the Reno quadrangle. This regional study was conducted to identify and evaluate, at a relatively low cost, favorable geochemical provinces with respect to possible mineral occurrences and provide some geochemical signatures of specific geologic and geophysical features. It was based on the reanalysis of stream-sediment samples initially collected as part of the NURE Program (Bennett, 1980). The NURE Program was established in 1973 to assess uranium resources and identify favorable areas for detailed uranium exploration throughout the United States. The reanalysis of NURE samples from the Reno quadrangle allowed the presence of certain elements to be determined that were not included in the NURE study and also made it possible to corroborate the original NURE findings (Bennett, 1980).

A total of 960 stream-sediment samples was collected for the NURE Program from March through June 1979. This sample medium provides a representative composite of the transported material of a stream or drainage basin; its composition is ideally dominated by the predominant geologic units bordering the drainage. The NURE sampling protocol called for gathering samples at a nominal density of one site per 18 km^2. The sediment was dried in an oven at ≤110 °C, then sieved, and the fraction <149 μm (-100 mesh) was blended and retained for analysis (Bennett, 1980). Comparison of chemical analyses of stream sediments can reveal changes in bedrock geology and geochemistry and indicate extensive areas of exposed mineralized rock. Analyses were carried out by the semiquantitative emission spectrographic method described by Grimes and Marranzino (1968) and Motooka and Grimes (1976). In addition, samples were analyzed by more sensitive and precise techniques for specific elements of interest. These include gold, tellurium, and thallium by the atomic-absorption method of Hubert and Chao (1985); mercury using a modification of the methods of McNerney and others (1972) and Vaughn and McCarthy (1964); arsenic, antimony, zinc, bismuth, and cadmium by the atomic-absorption technique of O'Leary and Viets (1986); fluorine by the specific ion method described by Hopkins (1977); and tungsten by the colorimetric method of Welsch (1983). Concise descriptions of the sampling methods and analytical techniques used, along with tabulated geochemical data and a sample locality map, are found in Kilburn and others (1990).

Several areas contain geochemical anomalies that appear to delineate specific rock types or mark element enrichments typically associated with hydrothermal mineralization in the Reno quadrangle (fig. 13). In most instances, however, the integrity of the sediment samples are clearly linked to factors, briefly related below, which render them suspect and any attempt to integrate them into a coherent regional geochemical picture would be inadvisable and probably misleading. Factors that clouded the regional geochemical study include: (1) preferential gathering of samples along major thoroughfares (U.S. Interstate 80 and other highways), secondary roads (State highways), active or abandoned railroads, and a host of dirt roads and jeep trails, which resulted in the detection of numerous geochemical anomalies mostly related to commerce or traffic associated with mining activity; (2) a sampling scheme that excluded critical areas (for example, large parts of the Pah Rah and Virginia Ranges) and mining regions such as the Fairview and Ramsey Mining Districts from the survey; and (3) the actual character of the quadrangle itself, encompassing 45 mining districts and literally hundreds of mines and prospects (Sidder, 1986; John and Sherlock, 1991), which collectively generate many geochemical anomalies that can effectively mask pertinent element concentrations and (or) their origins.

With these caveats in mind, a prudent though limited overview regarding certain element enrichments is possible. In some instances, geochemical anomalies coincide with mining districts, appear to characterize several unaltered rock types, and possibly define two small areas showing trace-element signatures possibly linked to some previously undocumented mineralization. Of the 45 mining districts in the Reno quadrangle (fig. 4), only 16 seem to be associated with designated element anomalies determined in the reanalyzed NURE samples (table 3). Of these, only the Mountain Wells, Comstock, and IXL Mining Districts have prominent geochemical signatures, and the lack of conspicuous geochemical anomalies in and around the other mining districts is perplexing.

In the Reno quadrangle, both beryllium and the mafic suite of cobalt-chromium-nickel and, less consistently, zinc show a general affinity for particular rock types to which they are commonly associated. Most of the anomalous beryllium (2 to 20 ppm), for example, turns up near the east edge of the quadrangle along the western flank of the Clan Alpine Mountains and the southern part of the

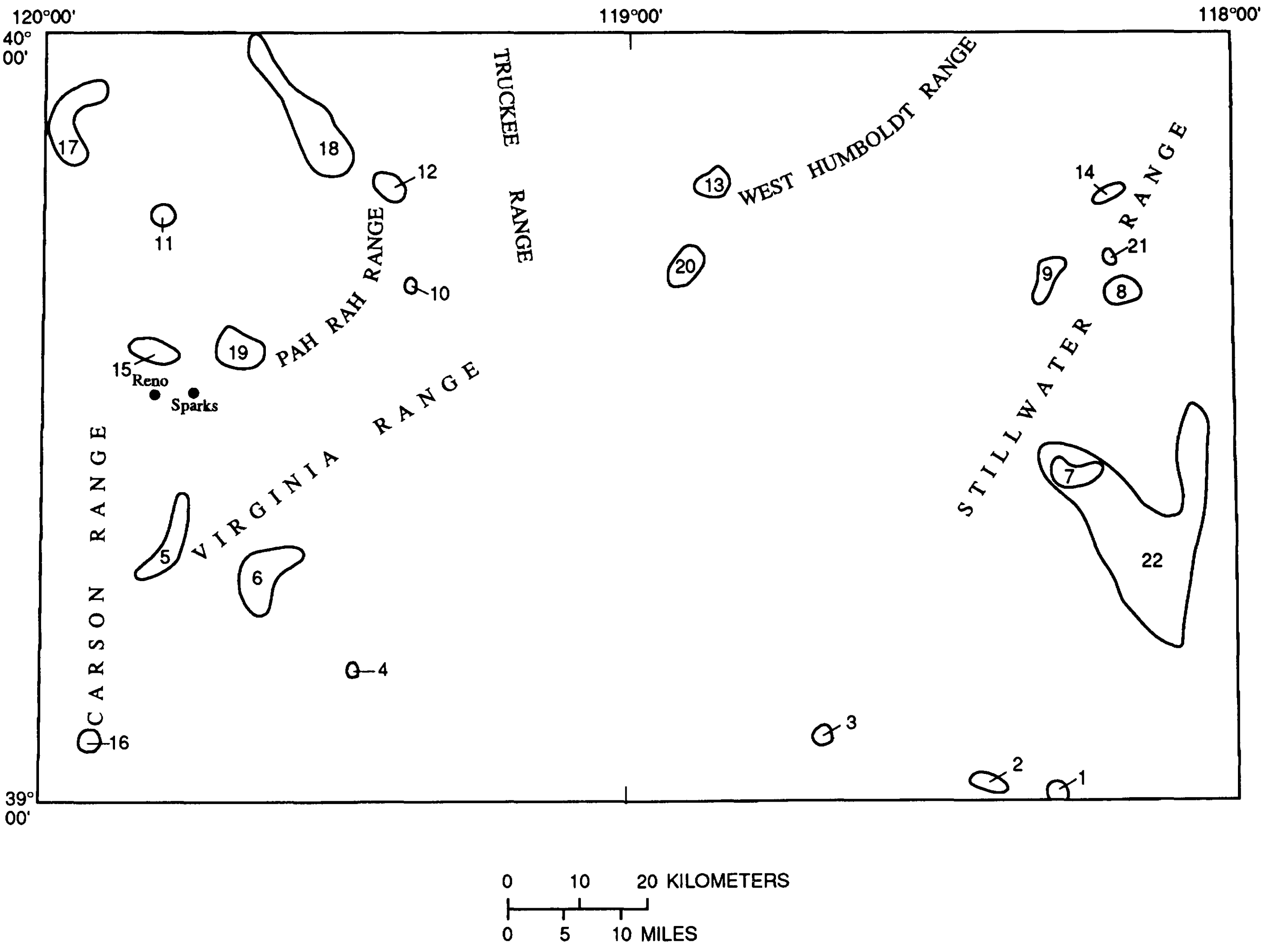


Figure 13. Locations of geochemical anomalies detected in stream-sediment samples in the Reno quadrangle, Nevada and California. State line shown on figure 1. Numbers correspond to locations described in table 3.

Stillwater Range associated with Tertiary ash-flow tuffs (anomaly 22, fig. 13). Although beryllium is geochemically compatible with rhyolitic rocks, this enrichment is present mostly within the confines of the U.S. Naval Electronic Warfare Training Area and contamination from beryllium alloys used in explosives and other military hardware is a distinct possibility. In addition, beryllium anomalies were detected in small areas in the northwestern part of the quadrangle in Red Rock Valley and on the west side of the Truckee River below Virginia Peak and Pah Rah Mountain. The Red Rock Valley region (anomaly 17, fig. 13) is largely dominated by Mesozoic granitic rocks and, to a lesser extent, by Tertiary ash-flow tuffs and volcanic rocks of the Pyramid sequence. Anomaly 10 (fig. 13) is present in or near a north-trending fault zone also in Tertiary ash-flow tuffs. Elements composing the mafic suite (cobalt-chromium-nickel±zinc) are individually scattered throughout the quadrangle with concentrated occurrences mostly limited to the northwestern part of the quadrangle including the southeastern side of the Hot Springs Mountains (anomaly 20, fig. 13), the Pyramid Lake region (anomaly 18, fig. 13), and the area southwest of Spanish Springs Peak (anomaly 19, fig. 13). The anomalies are associated with nearby Tertiary basalts and probably are little more than chemical manifestations of these mafic units.

With regard to undocumented mineralization, solitary but interesting geochemical anomalies were found on the eastern side of the Stillwater Range immediately north of the IXL Mining District and in the southwestern corner of the quadrangle between Lake Tahoe and Duane Bliss Peak in the Carson Range. Anomaly 21 (fig. 13), consisting of arsenic-silver-beryllium-nickel, is present near a fault zone in Triassic shale, sandstone, and siltstone. The trace-element signature though only containing some of the elements, is comparable to that of the Mottini Mine copper skarn deposit (arsenic-silver-tungsten-beryllium-cadmium-zinc-barium-nickel) several kilometers to the south. Anomaly 16 (fig. 13), consisting of arsenic-antimony-silver-molybdenum-lead-cadmium-zinc, is present in altered Tertiary andesitic rocks on the western flank of the Carson Range. Although both anomalies contain a geochemical signature consistent with hydrothermal mineralization known to be present in the region, their origin is unclear.

Geochemistry of Hydrothermally Altered Rocks

About 800 rock samples from mines, prospects, and altered areas were chemically analyzed. Five groups of samples were collected and analyzed. These are (1) hydrothermally altered rocks collected from areas of hydrothermal alteration detected previously by remote sensing; (2) samples collected from dumps of mines and prospects primarily in the eastern and southern parts of the quadrangle; (3) hydrothermally altered rocks collected during geologic mapping mostly in the southern Stillwater Range; (4) hydrothermally altered granitic rocks and their wallrocks collected throughout most of the quadrangle except from the Sierra Nevada; and (5) rocks in and around the Humboldt complex.

Samples were collected to help characterize the types of mineralization present in altered areas, mines, and prospects. In particular, the samples provide data on large areas of hydrothermal alteration that were not sampled systematically or detected by the regional stream-sediment samples and allow element characterization of minerals present in many small prospects where it was not obvious what commodities had been prospected. Samples from the Humboldt complex were collected to help evaluate the potential for platinum group elements (PGE). Samples from skarns were collected to test for the presence of gold in addition to base metals. Results of the chemical analyses from several areas are described briefly in sections about "Mineral Deposits of Mesozoic Age" and "Mineral Deposits of Tertiary Age."

REMOTE-SENSING STUDIES

The locations of hydrothermally altered rocks that were mapped from Landsat TM images and verified through field and laboratory evaluations are shown in figure 14. The altered rocks constitute areas that range in size from one TM picture element (30 m) to several square kilometers. The largest area encompasses the Peavine and Wedekind Mining Districts near the western margin of the quadrangle (A, fig. 14). The rocks are mainly limonitic, argillized Tertiary andesitic rocks and granodiorite porphyry and Mesozoic metavolcanic rocks. Locally, silicified rocks form resistant outcrops within the broad area of soft argillized rocks.

In the Virginia Range, hydrothermally altered rocks are widespread. The largest areas are located near Washington Hill, Geiger Grade, and the Ramsey Mining District (B, C, and D, respectively, fig. 14). Bleached, argillized Tertiary volcanic rocks are predominant in all three areas. Andesitic lava and pyroclastic rocks of the Alta Formation are widespread in the Geiger Grade area, whereas Kate Peak Formation andesitic lavas and pyroclastic rocks and andesite porphyry underlie the other two areas. Other large areas of hydrothermally altered rocks are present in the Buckskin and Singatse Ranges (E, fig. 14), the Olinghouse Mining District (F, fig. 14), and the Guanomi Mine area (G, fig. 14). Several moderately large areas are present in the eastern part of the quadrangle, especially near the Wonder and Regent (Rawhide) Mining Districts (H and I, respectively, fig. 14).

Several clusters of small closely spaced areas of hydrothermally altered rocks are noteworthy because this

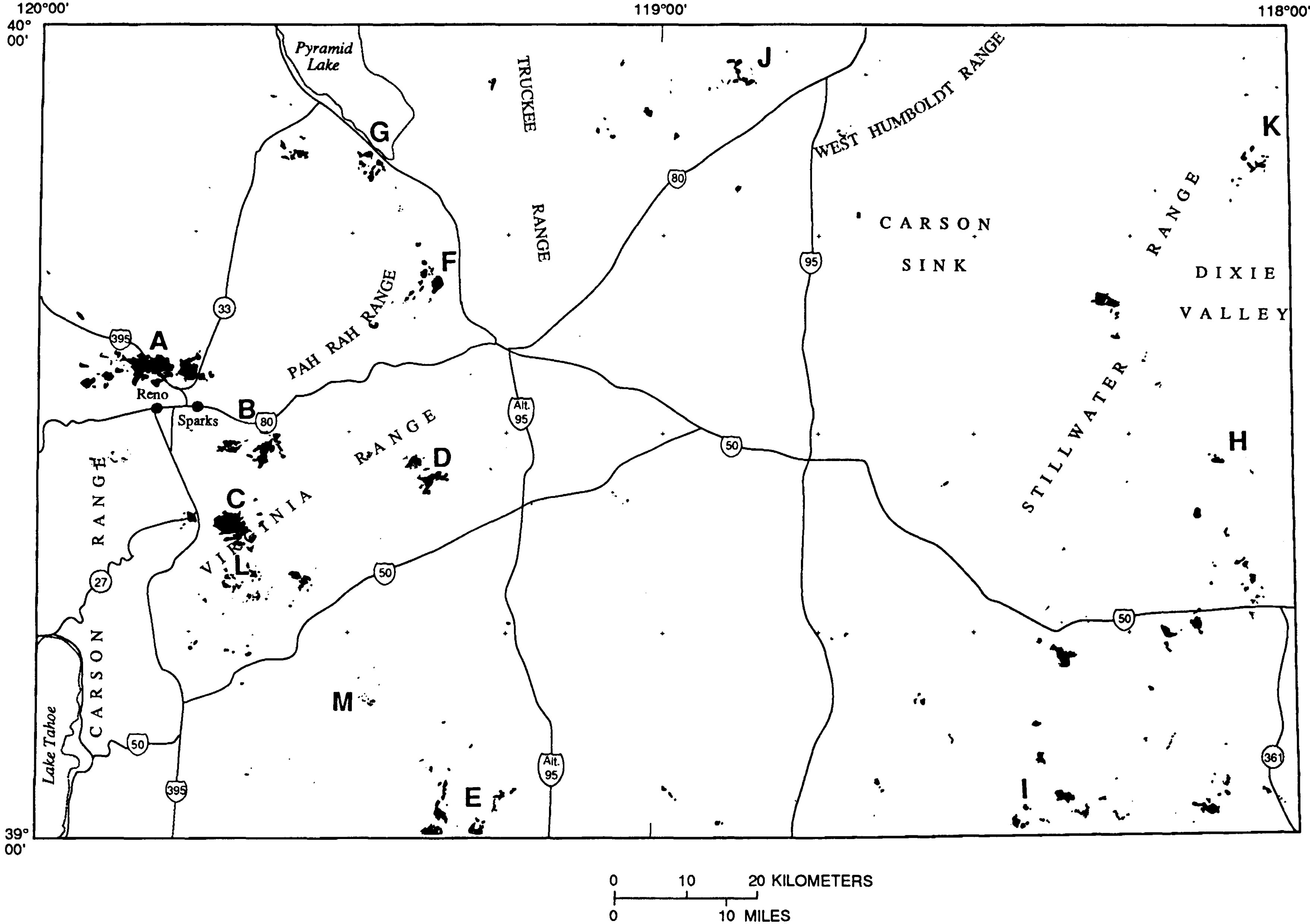


Figure 14. Areas of hydrothermal alteration (black spots) detected by remote sensing using Landsat TM images in the Reno quadrangle, Nevada and California. State line shown on figure 1. Areas labeled A-M are discussed in text.

pattern occurs for two different reasons. Some clusters, such as those near the Jessup and Dixie Valley Mining Districts (J and K, respectively, fig. 14), reflect small discontinuous areas of alteration. However, in other areas, including the Comstock and Como Mining Districts (L and M, respectively, fig. 14), this pattern is due to only local observation of the altered rocks because of vegetation cover. Such variations emphasize the limitation that vegetation cover places on thematic mapping of hydrothermally altered rocks.

MINERAL RESOURCES

Introduction

This assessment reviews known metalliferous mineral deposits and evaluates the potential for undiscovered metalliferous mineral deposits in the Reno quadrangle. Nonmetallic minerals, oil and gas, and geothermal energy resources are described briefly but not evaluated. The assessment generally follows the methodology initially developed for the Alaska Mineral Resource Assessment Program (AMRAP) of the U.S. Geological Survey, which consists of delineating areas according to the types of deposits that may be present, building grade and tonnage models that describe the deposit types, and estimating the numbers of undiscovered deposits (Singer, 1975; Singer and Cox, 1988; Menzie and Singer, 1990). However, no subjective probabilistic estimates of the numbers of undiscovered deposits were made for reasons discussed below. Mineral deposits and occurrences, defined in the section "Definitions," of the Reno quadrangle were classified by deposit types (see table 1) generally following the ore deposit models in Cox and Singer (1986). The characteristics of known deposits and occurrences are described by deposit type. Other types of deposits that are not known to occur in the quadrangle but may be present are also discussed. Grade and tonnage models for most of these deposit types are contained in Cox and Singer (1986) and in Bliss (1992). Areas where undiscovered deposits may be present are delineated for many deposit types (pls. 1-4). Two types of areas are delineated: (1) permissive terranes consisting of broad areas where the possibility of specific types of deposits occurring cannot be ruled out, and (2) favorable tracts consisting of smaller areas within permissive terranes where indications that ore-forming processes, such as hydrothermal activity, have taken place and indicate that a specific deposit type or group of related deposit types may be present.

No attempt was made to estimate numbers of undiscovered deposits in the Reno quadrangle, as has been done in other AMRAP and CUSMAP studies (for example, Richter and others, 1975; Singer and others, 1983; Peterson and others, 1983) for several reasons. These are (1) lack of sufficient geologic and geochemical data to make quantitative estimates, (2) lack of sufficient understanding of the genesis of several deposit types, (3) lack of or inconsistencies in grade and tonnage models for several deposit types, and (4) uneasiness with the methodology of quantitative estimates of undiscovered deposits.

Many deposit types present in the Reno quadrangle are either poorly characterized or the deposit model is poorly understood. For example, the Fondaway Canyon deposit in the northern Stillwater Range is the only known sediment-hosted gold deposit in the Reno quadrangle. It is located more than 50 km away from the nearest sediment-hosted gold deposit and more than 150 km away from the large deposits along the Carlin trend, and many aspects of the geology, geochemistry, tectonic setting, and origin are not clearly understood at Fondaway Canyon. In addition, many aspects about the genesis of sediment-hosted gold deposits remain unclear and controversial. We delineated a broad area as permissive for undiscovered sediment-hosted gold deposits (pl. 2), but we do not believe that we sufficiently understand or have enough detailed data to estimate the number of undiscovered deposits within this broad area.

The genesis of several other deposit types identified during our studies, such as iron endoskarn (or stockwork magnetite) deposits associated with the Jurassic Humboldt complex, is still poorly understood, and several deposit types do not have grade and tonnage models based on worldwide occurrences of similar deposits. The lack of grade and tonnage models precludes estimation of the number of undiscovered deposits for any of these deposit types using the three part methodology of Singer and Cox (1988).

There are difficulties in the application of some existing grade and tonnage models to deposits in the Reno quadrangle, notably to adularia-sericite gold-silver deposits, which are the most important type of metallic mineral deposit therein. Because of more than 100 years of exploration, changing economics, and improved exploration and extraction techniques, most recently discovered epithermal gold-silver deposits are disseminated, bulk minable deposits rather than classic vein deposits mined by underground techniques. Present U.S. Geological Survey grade and tonnage models assign all bulk minable, volcanic-hosted gold-silver deposits to a hot-springs type (Berger and Singer, 1990), because many individual deposits do not fit the data sets of other types of epithermal gold-silver deposits that were mostly mined by underground techniques (D.A. Singer, oral commun., 1990). Thus, the hot-springs model includes both quartz-alunite gold (for example, Paradise Peak and Borealis) and adularia-sericite gold-silver (for example, Round Mountain, Sleeper, and Rawhide) deposits, and the Comstock Lode and the recently discovered Rawhide deposit are considered different deposit types in these grade and tonnage models, although there are few geologic and genetic differences between them. In contrast, the Rawhide and Paradise Peak deposits are considered similar deposit types, although there are many genetic differences between them (Black and others, 1991; John and others, 1991). Moreover, historical (early 20th century) production at Rawhide is considered an adularia-sericite (Comstock) type deposit, whereas recently discovered bulk-minable ore at Rawhide is considered a hot-spring type deposit in the grade and tonnage models, although both deposits are part of the same mineralizing system. Consequently, we were uneasy using the existing grade and tonnage models to characterize some types of undiscovered deposits.

The approach used to estimate the numbers of undiscovered deposits in this and most other CUSMAP and AMRAP studies is to use experts who use "expert judgement or subjective probability" to evaluate undiscovered mineral deposits (Menzie and Singer, 1990). Menzie and Singer (1990) described two end-member approaches used by experts to estimate numbers of undiscovered deposits: (1) comparison to well-explored regions geologically and metallogenically similar to the one being evaluated, and (2) identifying potential exploration targets for the type of deposit being evaluated. Parts of the Reno, Tonopah, and Walker Lake, Nevada, quadrangles with areas of exposed bedrock that have been well explored might be used for comparative purposes for some deposit types, but exploration of exposed bedrock in these quadrangles for many deposit types, including bulk-minable gold-silver deposits, has not been thorough. We also lack the detailed geologic, geochemical, and subsurface knowledge necessary to identify and evaluate potential exploration targets. In particular, the poor quality of the regional stream-sediment geochemistry and the lack of detailed geochemical studies of hydrothermally altered rocks in many tracts delineated as favorable for undiscovered mineral deposits hinders our evaluation of the tracts. Thus, we were not comfortable using this methodology and have not made quantitative estimates of numbers of undiscovered deposits in the Reno quadrangle.

Definitions

In this assessment we used the definitions put forth by Cox and Singer (1986, p. 1) for the terms "ore deposit," "mineral deposit," and "mineral occurrence." Specifically, a "mineral occurrence" is "a concentration of a mineral ... that is considered valuable by someone somewhere, or that is of scientific or technical interest." A "mineral deposit" is "a mineral occurrence of sufficient size and grade that it might, under the most favorable of circumstances, be considered to have economic potential." An "ore deposit" is "a mineral deposit that has been tested and is known to be of sufficient size, grade, and accessibility to be producible to yield a profit." An undiscovered ore deposit is defined as an ore deposit that does not have published grade and tonnage data (D.A. Singer, oral commun., 1990). In the Reno quadrangle, recent exploration has resulted in discovery of several gold-silver deposits that are "undiscovered" because grade and tonnage data have not been released (for example, deposits in the Ramsey and Talapoosa Mining Districts).

Mineral occurrences, mineral deposits, and ore deposits are divided into deposit types that are based on descriptive mineral-deposit models contained in Cox and Singer (1986) or other references cited in this report. The mineral-deposit models are based on groups of mineral deposits that share a wide variety and large number of geologic attributes. Deposit types identified in the Reno quadrangle and references to descriptive models for these deposit types are listed in table 1.

Grade and tonnage models contain data on average grades and tonnages for groups of mineral deposits. They are useful in quantitative resource assessments for providing information about the potential value of undiscovered deposits within an assessment area and are used in economic analyses of these resources (Singer, in press). Typically, grade and tonnage models are based on average grades of each metal or mineral commodity and the associated tonnage based on the total of past production, reserves, and resources at the lowest possible cutoff grade (Singer, in press). Grade and tonnage models are usually developed simultaneously with mineral-deposit models, where there are sufficient grade and tonnage data available to build a model, and the grade and tonnage data can help refine descriptive mineral-deposit models (for example, Singer, 1990, in press). Singer (in press) discussed some of the problems associated with the formulation and use of grade and tonnage models. Two major shortcomings of present grade and tonnage models applied to deposits in the Reno quadrangle involve classification of bulk-minable, volcanic-hosted gold-silver deposits and the small size (tonnage) of most mineral occurrences or deposits.

Permissive Terranes and Favorable Tracts for Undiscovered Metalliferous Mineral Resources

For each type of metalliferous mineral deposit identified in the Reno quadrangle, we discuss the characteristics of the deposit type and, for many deposit types, we delineate permissive terranes. Notable characteristics of known deposits in the quadrangle are described. Criteria for delineating areas that may contain undiscovered deposits are described, and the geologic characteristics of these areas are also briefly described. Both permissive terranes and favorable tracts, either of which may contain undiscovered mineral deposits, were delineated for many deposit types. Permissive terranes are areas that conceivably might contain a certain deposit type. We define permissive terranes as areas remaining after we exclude terranes where it is unreasonable to expect a deposit of the type in question to be present based on our present understanding of the characteristics of this deposit type and the geology of the Reno quadrangle. In other words, unless there are negative reasons for making an area permissive, all parts of the quadrangle are considered permissive (for example, sediment-hosted gold deposits are not permissive in areas that are entirely granitic rock of the Sierra Nevada batholith). Lack of data is not used as a reason to exclude an area from being permissive. Permissive terranes are necessarily very broadly defined, and for most deposit types, it is unlikely that the type of deposit being discussed is present within most of the terranes considered permissive for that deposit type.

Favorable tracts are areas that contain some sort of positive indication that an undiscovered mineral deposit is present or that mineralizing processes have occurred. For example, the presence of known deposits and occurrences, hydrothermal alteration known to be related to a certain deposit type, and plutons that are associated with known mineral deposits are all reasons to consider an area favorable. Criteria used to delineate favorable tracts are listed in tables 2, 4, 5, and 6 and discussed in the following sections for each type of deposit. Because positive indications that ore-forming processes have occurred are required to include an area as favorable for a certain deposit type, favorable tracts are much smaller areas than permissive terranes and are more likely to contain undiscovered mineral resources. By definition, permissive terranes include all favorable tracts.

We used a 500-m depth limit in delineating areas that are permissive or favorable for undiscovered mineral resources (figs. 2 and 3). This depth limit is somewhat arbitrary (for comparison, the Nevada State assessment used a 1-km depth limit; Blakely and Jachens, 1990), but we believe that at the scale of our assessment (1:250,000) there are too many uncertainties associated with projection of bedrock terranes to large areas under Carson Sink and elsewhere that are shown on Jachens's map to contain bedrock at depths between 500 and 1,000 m. Also, under present economic conditions, it is highly unlikely that blind exploration for mineral deposits would exceed a 500-m depth, although exploration may well continue to greater depths in areas of known mineralization or altered rock.

For deposits hosted by Mesozoic rocks, a map showing contours of depth to Mesozoic bedrock was constructed using procedures described by Jachens and Moring (1990) and data they generated for the Nevada State assessment. This map was then modified by D.A. John (fig. 2) to reflect the more detailed geologic map used for this project (Jachens and Moring (1990) used the 1:500,000-scale state geologic map of Nevada (Stewart and Carlson, 1978)) and a more recent set of gravity observations (Donald Plouff, unpub. data, 1990). As described by Jachens and Moring (1990), there are several uncertainties associated with the depth to Mesozoic bedrock contours, and the 500-m contour probably is less precise than the 1-km contour used in the Nevada State assessment (R.C. Jachens, oral commun., 1990). Thus, the extent of permissive terranes and favorable tracts buried beneath Cenozoic deposits shown on figure 2 and plates 1 and 2 should be viewed with caution.

Thickness of nonmagnetic upper Cenozoic basin fill was semiquantitatively estimated using aeromagnetic data collected during the NURE Program and other data. The NURE data were collected along east-west flightlines flown approximately 5 km apart and 120 m above the ground. These data were analyzed using both qualitative and quantitative techniques by R.J. Blakely as part of the Nevada State assessment (Blakely and Jachens, 1990) to produce a map showing areas of shallow magnetic sources, ≤1-km depth to magnetic source, in the Reno quadrangle. This map was modified slightly by D.A. John to reflect the more detailed geologic map used in this project. The map showing shallow magnetic sources (fig. 3), when combined with the geologic map, the depth to Mesozoic basement rocks map, and the well-log map, allows separation of areas of thick (≥1 km), nonmagnetic Cenozoic deposits, or basin-fill sediments, from areas of shallow basin fill. Areas of shallow basin fill are considered permissive for various types of mineral deposits on the basis of subsurface extensions of permissive terranes in exposed bedrock.

Mineral deposits of the Reno quadrangle can be separated into two groups. These are deposits that formed during the Mesozoic and deposits that formed during the Cenozoic. Many deposit types may have formed during both the Mesozoic and Cenozoic (for example, copper skarn and porphyry copper deposits). These deposit types are discussed twice, because the characteristics of known deposits of different ages and the distribution of permissive terranes and favorable tracts for these deposits are different.

MINERAL DEPOSITS OF MESOZOIC AGE

Porphyry Copper Deposits

Known Occurrences

Two porphyry copper systems are present in the Yerington Mining District along the southern edge of the Reno quadrangle (pl. 1). These are the Bear and Lagamarsino Prospects and MacArthur deposit. The Bear and Lagamarsino Prospects are fault blocks of a single porphyry copper system that collectively contain greater than 500 million tons of resources averaging 0.4 percent Cu (Einaudi, 1982). Both prospects are covered by alluvium and were discovered in the early 1970's by the Anaconda Company. The MacArthur deposit crops out at the north end of the Yerington Mining District and is a small oxidized deposit containing about 13 million tons of resources averaging 0.43 percent Cu (Heatwole, 1978; Einaudi, 1982). Two other porphyry copper deposits, the Yerington and Ann Mason deposits, are present just south of the Reno quadrangle in the Yerington Mining District.

Porphyry copper deposits in the Yerington Mining District are genetically related to the Middle Jurassic (168 Ma) Yerington batholith and are associated with swarms of quartz monzonite porphyry dikes that cut the central part of the batholith (Proffett and Dilles, 1984; Dilles and Wright, 1988; Dilles, 1984, 1987). Porphyry copper deposits in the Yerington Mining District are atypical of other porphyry copper deposits and are distinguished by the presence of large areas of sodic-calcic alteration in their deeper levels (Carten, 1986; Dilles, 1984) and low concentrations of other metals generally associated with such deposits (Mo, Au, Ag, Pb, and Zn are not enriched in the Yerington deposits; Wilson, 1963; Hudson, 1983, p. 135). Moreover, distal polymetallic (Ag-Pb-Zn) replacement and vein deposits are not associated with the Yerington deposits. Other mineral deposits genetically related to the Yerington batholith include several copper skarn deposits in the Walker Lake quadrangle (Knopf, 1918; Einaudi, 1977, 1982; Harris and Einaudi, 1982) and several iron skarn deposits including the Minnesota Iron Mine in the Buckskin Range (Reeves and others, 1958; Hudson and Oriel, 1979; Dilles and Wright, 1988).

A second area of possible porphyry copper-type alteration and mineralization is present at Fireball Ridge in the north-central part of the Reno quadrangle (pl. 1; table 4). Harlan (1984) described fracture-controlled copper mineralization in the outer parts and wallrocks of a composite Jurassic(?) pluton on Fireball Ridge that he believes is part of a porphyry copper system. Most hydrothermal alteration in the pluton is propylitic although zones of quartz-sericite-pyrite and tourmaline alteration are locally present. Polymetallic veins and weak iron (pyrite+magnetite) skarn alteration also are present along the margins of this pluton.

Permissive Terranes

We believe terranes permissive for Mesozoic porphyry copper deposits are limited to areas underlain by Jurassic granitic rocks (fig. 7; pl. 1). The inferred maximum extent of Jurassic granitic rocks (outlined on pl. 1) was determined using outcrops of known or probable Jurassic granitic rocks (fig. 7), geophysical data, areas where depth to Mesozoic bedrock was ≤500 m (fig. 2), and location of large, continuous exposures of Cretaceous granitoids of the Sierra Nevada batholith (fig. 7). Cretaceous granitoids of the Sierra Nevada batholith are not considered permissive for porphyry copper mineralization, because there are no known porphyry copper deposits associated with Cretaceous parts of the batholith, large continuous exposures of the batholith in the western part of the Reno quadrangle lack porphyry phases and hydrothermal alteration characteristic of porphyry copper systems, and present exposures of these rocks probably crystallized at depths too deep to allow formation of porphyry copper deposits. Areas underlain by the Jurassic Humboldt complex in the northeastern part of the quadrangle also are excluded, because the complex lacks granitic rocks.

Favorable Tracts

Characteristics of four tracts delineated as favorable for porphyry copper deposits are summarized in table 4. Tracts 4 and 6 cover the south-central parts of the quadrangle; include the northern parts of Wassuk, Singatse, and Buckskin Ranges, the Pine Nut Mountains, and the Calico Hills; and are near the two known porphyry copper systems in the northern Yerington Mining District. These tracts contain large exposures of Jurassic granitic rocks including large areas of hydrothermally altered granitic rocks in the northern Pine Nut Mountains, several areas of endoskarn (notably in the Pine Nut Mountains), and numerous prospects for copper and iron. The area immediately around the MacArthur deposit is excluded from tract 4 because of extensive previous exploration.

Tract 1 is located at the extreme north edge of the quadrangle in Copper Valley along the southwestern side of the Trinity Range (pl. 1). This tract includes small exposures of an altered granodiorite pluton (Copper Valley pluton), which is inferred to be Jurassic in age on the basis of its trace-element geochemistry, and several small copper skarn deposits (Hard-to-Find and Copper Queen Mines) in carbonate wallrocks of the pluton.

Tract 2 encompasses Fireball Ridge and includes weak fracture-controlled copper mineralization in the margins and wallrocks of the composite Jurassic(?) Fireball Ridge pluton and several polymetallic vein occurrences.

Copper Skarn Deposits

Known Occurrences

Only two copper skarn deposits of Mesozoic age are known in the Reno quadrangle. Both are present in Copper Valley along the north edge of the quadrangle on the northwestern side of the Trinity Range (pl. 1). The Hard-to-Find and Copper Queen Mines both contain small amounts of chalcopyrite, scheelite, and secondary copper minerals in garnet-pyroxene skarn (Willden and Speed, 1974; Stager and Tingley, 1988). Pods of massive bull quartz are common on dumps. Skarn is present in marble along the margins of the propylitically altered Copper Valley pluton. The pluton is undated but is inferred to be Jurassic in age on the basis of its trace-element geochemistry (fig. 8*B*).

Copper skarn deposits also are present in the Yerington Mining District just south of the Reno quadrangle. These deposits are related genetically to the Yerington batholith and porphyry copper deposits, although they formed in Triassic carbonate rocks as much as several kilometers away from contacts with the Yerington batholith and 3 to 4 km distant from the outermost edge of significant porphyry copper mineralization in the granitic rocks (Knopf, 1918; Einaudi, 1977, 1982; Harris and Einaudi, 1982). Skarn mineralization is present as intergrowths of chalcopyrite and pyrite with little or no magnetite. Gangue minerals are dominantly andraditic garnet in skarns developed in hornfels and skarnoids near the Yerington batholith and coarse-grained, bladed salite and andraditic garnet in more distal skarns formed in dolomitized limestone (Einaudi, 1977, 1982).

Permissive Terranes

Terranes permissive for copper skarn deposits are the same as terranes permissive for Mesozoic porphyry copper deposits. These terranes include the inferred extent of Jurassic granitic rocks and are limited to areas where carbonate rocks form a substantial part of the pre-Middle Jurassic stratigraphic section. Thus, permissive terranes are limited to part of the Pine Nut, Sand Springs, and Jungo terranes where Jurassic granitic rocks are exposed or may be present at shallow depths (pl. 1).

Favorable Tracts

We delineated three tracts as favorable for copper skarn deposits (tracts 1, 5, and 6, pl. 1). Tracts 1 and 6 are identical to the tracts favorable for porphyry copper mineralization. Tract 5 is a subset of tract 4, which is favorable for porphyry copper deposits, but excludes large continuous exposures of Jurassic granitic rocks. Characteristics of these tracts are summarized in table 4. Copper skarn deposits are not known to be present in tract 5, although granitic rocks in and near this tract are part of the Yerington batholith, and several copper skarn deposits genetically related to the Yerington batholith are present just south of the Reno quadrangle in the Yerington Mining District. Tract 6 contains several iron-copper skarn prospects in the Calico Hills. Tract 1 contains small copper-tungsten skarn deposits at the Copper Queen and Hard-to-Find Mines.

Iron Skarn (Magnesium Magnetite Skarn) Deposits

Known Occurrences

Iron skarn deposits, consisting of magnetite replacement of carbonate rocks, are present in the south-central part of the quadrangle associated with Jurassic granitic rocks (pl. 1). We classify these deposits as the magnesium magnetite skarn deposit type of Einaudi and others (1981), although with the exception of the Minnesota Iron Mine, published descriptions of the deposits are insufficient to distinguish them from calcic magnetite skarns. The largest deposit in the Reno quadrangle is the Minnesota Iron Mine in the northern Buckskin Range. It consists of massive magnetite replacement of dolomitized Triassic limestone along the margin of the Yerington batholith (Reeves and others, 1958). The other major occurrence is the Dayton iron deposit, which consists of replacement of limestone by magnetite, pyrite, and minor(?) calc-silicate minerals formed from hydrothermal fluids apparently related to an unaltered Jurassic(?) granodiorite pluton (Reeves and others, 1958; Roylance, 1966). Other iron skarn occurrences include several prospects in the Calico Hills and the Iron Blossom Prospect near the Dayton iron deposit (Reeves and others, 1958; Roylance, 1966; Lawrence and Redmond, 1967; Satkoski and others, 1985; John and Sherlock, 1991).

Permissive Terranes

Terranes permissive for iron skarn deposits are the same as terranes permissive for Mesozoic copper skarn and porphyry copper deposits (pl. 1). These permissive terranes contain all known and probable Jurassic granitic rocks, all known magnesium magnetite skarn deposits and all pre-Tertiary tectonostratigraphic terranes with locally thick sequences of carbonate rocks. We excluded areas that only contain Cretaceous plutons, because we believe it is unlikely that these plutons developed hydrothermal fluids that might have formed magnetite skarn deposits. Mesozoic terranes that do not contain carbonate horizons and the Humboldt complex have also been excluded from terranes that we judge are permissive for magnesium magnetite skarn deposits.

Favorable Tracts

We delineated four tracts as favorable for iron skarn deposits (tracts 3, 5, and 6, pl. 1). Characteristics of these tracts are summarized in table 4. Tract 5 contains exposures of Jurassic granitic rocks, contains large areas of hydrothermal alteration both within the plutons and in surrounding wallrocks, and contains the Minnesota Iron Mine. This tract is also favorable for porphyry copper and copper skarn deposits. Tract 6 contains iron-copper skarns at the Calico Hills and Afterthought Prospects. Tract 3 contains the Dayton iron deposit and the Iron Blossom Prospect. This tract is north of the main exposures of Jurassic granitic rocks, although a small, metamorphosed fine-grained diorite lithologically similar to Jurassic diorites in the northern Pine Nut Mountain is exposed at the Dayton iron deposit, and a granodiorite pluton exposed at the Iron Blossom Prospect and underlying the Dayton iron deposit has major- and trace-element compositions that suggest that it is Jurassic in age (John, 1992). Both Reeves and others (1958) and Roylance (1966) suggest that the granodiorite pluton was the source of mineralizing fluids for these iron skarns. Tract 1 was delineated because it contains local skarn alteration of carbonate wallrocks.

Iron Endoskarn (Calcic Magnetite Skarn) Deposits

Known Occurrences

Iron endoskarn or stockwork magnetite deposits, which may be analogous to calcic magnetite skarn deposits of Einaudi and others (1981), are associated with the Humboldt complex in the northeastern corner of the Reno quadrangle and the southeastern part of the adjacent Lovelock 1° by 2° quadrangle. These deposits consist of massive and vein replacement of Jurassic gabbro and basalt by magnetite commonly associated with scapolite and albite alteration (Reeves and Kral, 1955; Willden and Speed, 1974; Speed, 1976). The Buena Vista Mine is the largest iron endoskarn deposit in the Reno quadrangle (Reeves and Kral, 1955; Willden and Speed, 1974).

Small iron and iron-copper skarns also are present in Mesozoic dioritic intrusions on Peavine Peak north of Reno (Hudson, 1977). These skarns are present as irregular veins as much as 25 cm wide and 10 m long and consist of magnetite and hematite as well as localized pyrite and chalcopyrite. Wallrocks of the veins are altered to scapolite, chlorite, quartz, actinolite, epidote, and albite (Hudson, 1977). Because of their small size, these occurrences probably do not represent iron endoskarns.

Permissive Terranes

Terranes permissive for the occurrence of iron endoskarn deposits are limited to the Humboldt complex in the northeastern part of the quadrangle (pl. 1). We did not delineate a tract favorable for undiscovered iron endoskarn deposits within this terrane, however, because large undiscovered deposits are unlikely to be present at shallow depths owing to extensive exploration undertaken in the 1950's (Reeves and Kral, 1955) and the strong magnetic anomalies associated with these deposits that make shallow deposits readily detected by magnetic surveys.

Sediment-Hosted (Carlin-type) Gold Deposits

Known Occurrences

The Fondaway Canyon gold deposit, in the northern Stillwater Range near the northeastern corner of the quadrangle (pl. 2), is the only deposit in the quadrangle that can be classified as a sediment-hosted gold deposit (Sidder, 1987). Host rocks are Upper Triassic to Lower Jurassic carbonaceous, locally calcareous shale and siltstone of the Jungo terrane. Gold is disseminated in carbonaceous shale and is also contained in vuggy quartz+pyrite+gold veins. Mineralized rock is localized in a steeply dipping fault zone that strikes about N. 70° E. (Sidder, 1987; R. Fisk, oral commun., 1986; K. Cluer, oral commun., 1990). Mineralized zones are locally as wide as 15 m. Most gold-bearing veins are unoxidized and surrounding wallrocks contain abundant fine-grained sulfide minerals and carbonaceous material. Arsenic content of the ore is locally high (thousands of ppm) and is present as disseminated arsenopyrite in unoxidized rocks. Pods and veins of stibnite are common. Silver content of the ore is extremely low. Tennaco Minerals is currently (1991) mining the more oxidized parts of the deposit and attempting to delineate areas of unoxidized rock with gold grades high enough to be mined economically by underground methods (K. Cluer, oral commun., 1990). A muscovite selvage on a gold-bearing quartz+stibnite+pyrite vein yielded a K-Ar age of 94.0±2.7 Ma (Russell and others, 1989), which is thought to approximate the age of gold mineralization (P.G. Vikre, oral commun., 1990). However, no igneous rocks of Late Cretaceous age crop out near the Fondaway Canyon deposit and the origin and classification of the Fondaway Canyon deposit is unclear.

Permissive Terranes

We delineated all areas of overthickened crust that contain Mesozoic sedimentary and metasedimentary rocks and that have not undergone metamorphism greater than greenschist facies as permissive for sediment-hosed gold deposits (pl. 2). Berger and Henley (1989) emphasized the role that overthickened crust plays in the genesis of sediment-hosted gold deposits and suggested that overthickening of the crust may allow entrapment of saline, connate fluids in sedimentary sequences, a fluid composition important in the genesis of these deposits. Overthickened crust is defined as areas where the crust has been thickened by movement along Mesozoic thrust faults. These areas include the Jungo, Paradise, and Pine Nut terranes and the Marble Butte rocks. The presence of thrust faults in the Pine Nut terrane is controversial, and we consider the presence of sediment-hosted gold deposits is less likely in this terrane than in other terranes. The Sand Springs terrane, which is metamorphosed to amphibolite facies (Satterfield and Oldow, 1989), probably lost connate fluids during metamorphism that apparently are necessary for formation of sediment-hosted gold deposits (Berger and Henley, 1989; W.C. Bagby, oral commun., 1990) and, therefore, is not permissive for these deposits. Neither are metavolcanic terranes, which lack suitable host and source rocks, and the Humboldt complex, which also lacks suitable host and source rocks.

Favorable Tracts

We did not delineate favorable tracts for sediment-hosted gold deposits, because we lack the detailed data necessary to delineate favorable tracts except for the area immediately around the Fondaway Canyon deposit.

Tungsten Skarn Deposits

Known Occurrences

Numerous tungsten skarn deposits associated with granitic plutons of Cretaceous or probable Cretaceous age are scattered throughout much of the Reno quadrangle (pl. 2). They constitute the second most important type of deposit in the quadrangle in terms of historic production (Sidder, 1986). The largest deposits are present in the Regent (Nevada Scheelite Mine), Toy (St. Anthony Mine), and Nightingale (Crosby and Jay Bird Mines) Mining Districts. The Nevada Scheelite Mine produced an estimated 310,000 units WO_3 from 1935–1982, the St. Anthony Mine produced about 23,000 units WO_3 from 1915–1956, and combined production from the Jaybird and Crosby Mines was about 760 units WO_3 from 1942–1957 (Stager and Tingley, 1988). Skarn consists of irregular replacement of marble by garnet, pyroxene, epidote, quartz, and other calc-silicate minerals along contacts with granitic intrusions. Pods of bull quartz are common. Scheelite is the primary ore mineral. Granitic plutons spatially associated with tungsten skarns are mostly biotite granite and biotite-hornblende granodiorite that range in composition from 63 to 76 weight percent SiO_2 (table 5). The plutons are metaluminous to weakly peraluminous, lack magmatic muscovite, and generally are sphene bearing. They have notably lower K_2O contents than Jurassic plutons have at the same SiO_2 content (fig. 8*A*). Generally, there is little hydrothermal alteration present in the granitic rocks.

Permissive Terranes

Terranes permissive for tungsten skarn deposits encompass all Mesozoic terranes containing carbonate units that could serve as host rocks for tungsten skarns. Permissive terranes exclude metavolcanic terranes such as the Carson Range and areas north and west of Reno. Although these areas contain large exposures of the Sierra Nevada batholith and might have formed tungsten skarn deposits similar to deposits in other parts of the batholith (for example, Pine Creek, Calif., Mining District), they lack widespread outcrops of carbonate units to serve as host rocks for skarn mineralization. Several small tungsten skarn occurrences are described by Stager and Tingley (1988) in the metavolcanic terranes, but owing to the lack of significant amounts of carbonate wallrocks, these terranes are not permissive for tungsten skarn deposits. The Humboldt complex is also excluded from terranes permissive for tungsten skarn, because its composition is inappropriate for the formation of tungsten skarn and its contacts with carbonate rocks are faults (Page, 1965; Speed, 1976).

Favorable Tracts

We delineated five tracts that are favorable for tungsten skarn deposits (tracts 7-11, pl. 2). Criteria for delineating tracts and characteristics of these tracts are summarized in table 5. All tracts contain tungsten skarn deposits that have been mined in the past, although most of the deposits are small (Stager and Tingley, 1988). Aeromagnetic data were used to estimate the subsurface extent of plutonic rocks buried beneath shallow Cenozoic cover and extend the favorable tracts. Tract 11, which encompasses the Sand Springs Range and the south end of Fairview Peak, contains the most known deposits. Within this tract, tungsten skarn deposits are associated with at least three plutons, and the tract includes the Nevada Scheelite deposit and many smaller deposits in the Regent, Sand Springs, and Fairview Mining Districts.

Low-Fluorine (Quartz Monzonite-Type) Porphyry Molybdenum Deposits

Known Occurrences

There are no known occurrences of low-fluorine porphyry molybdenum mineralization in the Reno quadrangle. However, low-fluorine porphyry molybdenum deposits of Late Cretaceous age are present elsewhere in western Nevada (Westra and Keith, 1981), and two areas of hydrothermal alteration in Late Cretaceous plutons in the eastern part of the Reno quadrangle are similar to hydrothermal alteration associated with low-fluorine porphyry molybdenum systems.

The La Plata Canyon pluton in the southern Stillwater Range was explored and drilled for porphyry molybdenum mineralization in the late 1970's by Phelps Dodge Corporation (Quade and Tingley, 1987). No minable ore was found during exploration (Quade and Tingley, 1987, p. 60). Exploration was primarily centered on an area of brecciated greisen (muscovite-altered granite) and skarn that locally contains anomalous amounts of molybdenum, copper, and tungsten (Phelps Dodge drill site, pl. 2; Quade and Tingley, 1987). Elsewhere, quartz veins containing copper and silver sulfide minerals and traces of molybdenite cut the La Plata Canyon pluton, and fluorite veins are locally present in carbonate wallrocks along the margins of the pluton and along aplite dikes (Quade and Tingley, 1987). Muscovite associated with fluorite veins yielded a K-Ar age of about 84 Ma (Garside and others, 1981).

A second area of hydrothermal alteration that might be related to a porphyry molybdenum system is present in the central Sand Springs Range about 3 km north of GZ Canyon (tract 12, pl. 2). Here, a large area characterized by sericitic and pyritic alteration and locally containing stockwork quartz+pyrite+sericite veins is present in the granite phase of the Sand Springs pluton and crosscutting rhyolite porphyry dikes. Samples of altered rock contain small amounts of molybdenum (as much as 70 ppm), although no molybdenite was noted (Quade and Tingley, 1987; D.A. John, unpub. data, 1990). This hydrothermally altered area was also detected by remote-sensing techniques (fig. 13).

Permissive Terranes

Terranes permissive for low-fluorine porphyry molybdenum deposits include all parts of the Reno quadrangle except for major exposures of the Sierra Nevada batholith, which underlies the Carson Range and the area north of Reno, and the Humboldt complex in the northeastern part of the quadrangle (fig. 7, pl. 2). We believe that these exposures of the main part of the Sierra Nevada batholith represent parts of the batholith that crystallized at depths too great for low-fluorine porphyry molybdenum systems to have formed. Porphyry textures and hydrothermal alteration assemblages characteristic of this deposit type are uncommon or absent in this part of the batholith, and no porphyry molybdenum deposits are known to be present elsewhere in the Sierra Nevada batholith. The mafic composition of the Humboldt complex precludes porphyry molybdenum mineralization.

Favorable Tracts

We delineated one tract in the Sand Springs Range as favorable for a low-fluorine porphyry molybdenum deposit (tract 12, pl. 2). Little is known about this tract other than it contains localized stockwork quartz+pyrite+sericite veins with anomalous molybdenum content that cut Late Cretaceous granite phase of the Sand Springs pluton (table 5). However, the composition of the Sand Springs pluton is unlike compositions of granitic plutons associated with low-fluorine porphyry molybdenum deposits elsewhere (fig. 8*C*). We did not delineate the La Plata Canyon pluton as favorable for a low-fluorine porphyry molybdenum deposit, because previous exploration did not reveal any exploitable molybdenum mineralization and much of the molybdenum is present in skarn rather than in porphyry-style alteration. Jurassic granitic plutons in the Reno quadrangle are unlikely to have porphyry molybdenum deposits associated with them, because their compositions are notably different from compositions of plutons associated with porphyry molybdenum systems elsewhere (fig. 8*C*; Mutschler and others, 1981; Westra and Keith, 1981), hydrothermal alteration in exposed Jurassic plutons is notably different from hydrothermal alteration found in porphyry molybdenum systems, and porphyry copper systems in the Yerington Mining District have notably low molybdenum contents (for example, Hudson, 1983, p. 135). Present exposures of most Cretaceous granitic plutons apparently crystallized at depths greater than depths at which most porphyry molybdenum deposits form (most exposures have paleodepths ≥5 km(?), whereas most porphyry molybdenum systems form at depths <3 km, Westra and Keith, 1981). Moreover, large areas of hydrothermal alteration and quartz veining are not exposed in Cretaceous granitic rocks, with exception of the central Sand Springs Range. Also, Cretaceous plutons in the Reno quadrangle are metaluminous or weakly peraluminous, whereas plutons associated with porphyry molybdenum deposits generally are strongly peraluminous (fig. 8*C*; Westra and Keith, 1981; Mutschler and others, 1981).

Gold-bearing Skarn Deposits

No gold-bearing skarn deposits as defined by Theodore and others (1991) are known to be present in the Reno quadrangle. No gold was detected in samples collected from Mesozoic skarn occurrences as part of this study (0.05 ppm lower detection limit for gold).

Permissive Terranes

Permissive terranes for gold-bearing skarn deposits (pl. 2) include all areas that are permissive for other types of skarn deposits. We did not delineate separate permissive terranes for gold-bearing skarns, because analysis of worldwide gold-bearing skarns by Theodore and others (1991) indicates that there are no unique characteristics that allow distinction of gold-bearing skarns from other types of skarns except for gold content. Detailed studies of the Fortitude and McCoy gold-bearing skarn deposits, Nevada, however, suggest that gold-bearing skarns may be genetically related to reduced granitic rocks (for example, granitic rocks with low ferric/ferrous iron ratios; Myers and Meinert, 1990; Brooks and Meinert, 1990). In the Reno quadrangle, chemical analyses of about 30 Mesozoic plutons indicate widely varying ferric/ferrous iron ratios (weight ratios vary from 0.24 to 5.22) with large variations within single plutons or closely spaced plutons (for example, 9 analyses of the Sunrise Pass pluton have Fe^{3+}/Fe^{+2} ratios ranging from 0.78 to 5.22; John, 1992). Also, in the Reno quadrangle there are not consistent differences in ferric/ferrous iron ratios between plutons that have different types of mineralization associated with them. Thus, the use of ferric/ferrous iron ratios of granitic rocks to separate types of skarn deposits does not appear to be useful in the Reno quadrangle. Consequently, all areas that are permissive for the occurrence of tungsten, copper, iron, and lead-zinc skarns are considered permissive for gold-bearing skarns. These areas include all terranes containing calcareous units and consist of the Pine Nut, Sand Springs, Paradise, and Jungo terranes and Marble Butte rocks.

Favorable Tracts

No favorable tracts for gold-bearing skarn deposits were delineated because of the lack of known gold-bearing skarn occurrences in the Reno quadrangle and the lack of adequate criteria to distinguish favorable areas.

Polymetallic Vein Deposits

Known Occurrences

Polymetallic veins hosted by Mesozoic rocks are present in many mining districts scattered across the Reno quadrangle including the Mountain Well, Holy Cross, Desert, Jessup, Delaware, Galena, and Fairview Mining Districts (John and Sherlock, 1991). These veins generally are associated with felsic granitic rocks (veins hosted by diorite in the Desert Mining District are an exception) and are found near several other types of deposits associated with felsic plutons. The age of mineralization of most of these deposits is unknown. Most are small prospects that probably produced only a few tons or tens of tons of ore; the Commonwealth (Union) Mine in the Galena Mining District is an exception in that it produced more than 14,000 tons of Pb-Zn-Ag-Cu ore valued at approximately $232,000 during the period 1943-45 (Geehan, 1950). Polymetallic vein deposits primarily consist of narrow quartz or quartz-calcite veins in Mesozoic plutonic rocks (for example, veins at Desert Queen Mine, Desert Mining District; Bimetal Mine, Holy Cross Mining District; Bidwell Mine, Delaware Mining District). Vein quartz commonly contains several percent base-metal sulfide minerals (generally Cu, Pb, and Zn sulfides) or their oxidized equivalents and trace to significant amounts of gold and silver. Several other occurrences, such as those at the Commonwealth Mine (Galena Mining District), are hosted by metavolcanic rocks in which quartz veins filled fault zones (Geehan, 1950; Thompson and White, 1964).

Permissive Terranes

We did not delineate separate terranes permissive for Mesozoic polymetallic vein deposits, because they could be present nearly anywhere proximal to felsic granitic rocks and the age of most occurrences is unknown or poorly understood.

Polymetallic Replacement and Zinc-Lead Skarn Deposits

No polymetallic replacement or zinc-lead skarn deposits of Mesozoic age are known to be present in the Reno quadrangle. Polymetallic replacement deposits are present in the Chalk Mountain Mining District, but these deposits are Tertiary in age. There are no known zinc-lead skarn deposits in the Reno quadrangle, although skarns related to the IXL pluton in the IXL Mining District and the Copperaid deposit in the White Cloud Mining District are transitional between copper and zinc-lead skarn types. However, both deposits are Tertiary in age.

Permissive Terranes

Terranes permissive for polymetallic replacement and zinc-lead skarn deposits include all terranes containing carbonate units—these are the Pine Nut, Sand Springs, Paradise, and Jungo terranes and the Marble Butte rocks (fig. 6, pl. 2).

Favorable Areas

No areas were delineated as favorable for Mesozoic polymetallic replacement or zinc-lead skarn deposits, because no deposits of Mesozoic age are known to be present in the Reno quadrangle. Jurassic plutons in the southern part of the quadrangle appear to have little lead or zinc associated with them, and exposures of most Cretaceous plutons probably were emplaced at depths greater than those at which these deposits generally form.

Deposits Related to the Humboldt Complex

The Humboldt complex contains iron endoskarn deposits associated with scapolite and albite alteration as described in the section on "Iron Endoskarn (Calcic Magnetite Skarn) Deposits." Several other types of mineral occurrences are also present in the complex including small occurrences of copper, nickel, and cobalt (Willden and Speed, 1974; John and Sherlock, 1991). The environment in which the Humboldt complex formed is not clearly understood, and evaluation of mineral resources associated with the complex hinges on interpretation of its origin. Speed (1976) considered these rocks—which he termed the Humboldt lopolith—to be a lopolithic-shaped, layered mafic intrusion emplaced into the Jungo terrane near the beginning of a compressional tectonic event. In contrast, Dilek and others (1988) suggested that the Humboldt complex is the ophiolitic basement of the lower Mesozoic strata of the Jungo terrane. Other possible origins include intrusion of the Humboldt complex during an episode of Middle Jurassic rifting (D.P. Cox, oral commun.,

1990) or that the complex is a synorogenic subduction-related (volcanic arc) intrusion (M.L. Zientek, oral commun., 1989). The tectonic setting of the Humboldt complex could be determined from chemical analysis of relatively immobile elements in the volcanic rocks (for example, Pearce, 1982; Pearce and Cann, 1973). However, to our knowledge no trace-element chemical data are available for rocks of the Humboldt complex. Thus, we can only indicate types of deposits that might be present in each tectonic setting and present some evidence supporting various possible origins.

Speed (1976) and Willden and Speed (1974) presented field and geophysical data suggesting that the Humboldt rocks constitute a lopolithic-shaped mafic intrusion that was emplaced during a regional compressional event. Types of deposits that might have formed in this tectonic environment in addition to iron endoskarn deposits are not known (D.P. Cox, oral commun., 1990).

Localized evaporitic rocks in the Lovelock Formation of Speed (1974) and in the western part of the Boyer Ranch Formation, which were deposited in restricted basins and are of the same general age as the Humboldt rocks (Speed, 1974, 1976; Speed and Jones, 1969), suggest a possible rift-related origin of the complex. However, Speed (1974) interpreted these rocks to have been deposited in small closed basins formed by compressional tectonic activity rather than rifting. Moreover, the Humboldt complex apparently lacks flood basalts typical of continental rifts, and most intrusive rocks in the complex lack cumulate textures and layering that are also characteristic of rift-related intrusive complexes (M.L. Zientek, oral commun., 1989). If the Humboldt complex formed during a Middle Jurassic rifting event, it may contain Noril'sk-type copper-nickel-platinum group elements deposits (Page, 1986) in the gabbroic rocks, basaltic copper deposits (Cox, 1986f) in the volcanic and overlying sedimentary rocks, and sediment-hosted copper deposits (Gustafson and Williams, 1981; Cox, 1986e) in the overlying sedimentary rocks. The Boyer Copper Mine in the Millet quadrangle just east of the Reno quadrangle, which consists of copper sulfide minerals filling narrow fractures and amygdules in the basalts (Willden and Speed, 1974), may be a basaltic copper deposit. No other mineral occurrences associated with the Humboldt complex appear to fit these models, and chemical analyses of samples of the complex and its altered wallrocks are not enriched in PGEs (M.L. Zientek and G.B. Sidder, unpub. data, 1990).

Dilek and others (1988) interpreted the Humboldt complex to represent the upper parts of an arc-marginal basin ophiolitic sequence on the basis of reinterpretation of field relations between the volcanic and intrusive parts of the complex and comparison of the complex with the informal Smartville complex in the northern Sierra Nevada. Dilek and others (1988) also described sheeted dikes that locally lie between the intrusive and volcanic rocks. However, published descriptions of the Humboldt rocks suggest that many of the unit's volcanic rocks are subaerial or shallow water in origin and pillow basalts and deep water (pelagic) sedimentary rocks have not been reported (Speed, 1976). Also, unlike most ophiolites, ultramafic lithologies are sparse in the Humboldt rocks (Speed, 1976). If the Humboldt complex is an ophiolitic sequence, it may contain podiform chromite deposits in the ultramafic parts of the complex (Albers, 1986), Cyprus-type massive sulfide deposits (Singer, 1986a), and lateritic nickel deposits (Singer, 1986b). No known mineral occurrences associated with the Humboldt complex appear to fit these deposit types.

Other Deposits

Several other types of mineral occurrences and small deposits are present in Mesozoic rocks and may be of Mesozoic age. Known deposit types include pegmatitic uranium, quartz-copper (bornite)-gold-tourmaline veins, and simple antimony. Other types of deposits that might be present in the Reno quadrangle include volcanogenic massive sulfide deposits (Kuroko-type) and low-sulfide gold-quartz veins. These deposit types are briefly described in the following sections, but no attempt was made to outline permissive terranes and favorable tracts for these deposits.

Simple Antimony Deposits

Small antimony deposits, which we classify as simple antimony deposits (Bliss and Orris, 1986), are present in the Lake and Nightingale Mining Districts and in unnamed mining districts in the Pah Rah Range and at Fireball Ridge (pl. 2; Lawrence, 1963). The antimony deposits are present as narrow quartz± calcite veins that cut Triassic marble (Lake Mining District) or cut Mesozoic granitic rocks (occurrences outside of Lake Mining District) (Lawrence, 1963). Stibnite and (or) secondary antimony minerals, pyrite, and minor amounts of other base-metal sulfide minerals are present in the veins. Antimony production from these deposits has been small or nonexistent (Lawrence, 1963).

Pegmatitic Uranium Deposits

Garside (1973) and Bonham (1969) described several pegmatite dikes in Cretaceous(?) granitic plutons or Mesozoic wallrocks that contain anomalous radioactivity and uranium and (or) thorium (pl. 4). These occurrences have only low uranium contents and appear to be quite small (Garside, 1973).

Quartz-Copper-Gold-Tourmaline Vein Deposits

Quartz-tourmaline veins containing copper sulfide minerals (primarily bornite), native gold, and silver are present in metavolcanic rocks on the north and west sides of Peavine Peak and in Mesozoic (Cretaceous?) granitic rocks near Granite Peak (Bonham, 1969; Hudson, 1977). The veins consist of white quartz containing pods of tourmaline or bornite, chalcocite, and gold (Hudson, 1977). Several generations of crosscutting veins are evident, and individual veins range from a few centimeters to 5 m in width and extend for as much as 300 m along strike (Hudson, 1977). Hydrothermal alteration is not evident in the metavolcanic rocks, although local epidote alteration is present in granodiorite wallrocks (Hudson, 1977). The veins probably formed during the Mesozoic because they are limited to Mesozoic rocks and appear to be spatially unrelated to Tertiary rocks (Hudson, 1977).

Low-Sulfide Gold-Quartz Vein Deposits

Low-sulfide gold-quartz (mesothermal) veins are a type of deposit that might be present in the Reno quadrangle, although there are no known occurrences. Low-sulfide gold-quartz veins form in low to medium grade (greenschist and amphibolite grade) regionally metamorphosed volcanic and volcaniclastic rocks along regional high-angle faults and joint sets (Berger, 1986d; Kerrich and Wyman, 1990; Bliss, 1992). They characteristically are associated with regional structures that suture allochthonous terranes to continental margins or arcs and form in a recurring sequence of transpressive deformation, uplift, late kinematic gold mineralization, and alkalic (shoshonitic) magmatism (Kerrich and Wyman, 1990). Kerrich and Wyman (1990) suggested that thermal reequilibration of underplated, subducted oceanic crust in a transpressive tectonic regime is a necessary prerequisite to gold mineralization.

Little is known about regional metamorphism and possible subduction of Mesozoic volcanic rocks in the Reno quadrangle. The only terrane that is known to have been regionally metamorphosed is the Sand Springs terrane, which was metamorphosed to lower amphibolite grade under ductile conditions during a Jurassic deformational event (Satterfield and Oldow, 1989). However, it is not known whether metamorphism of the Sand Springs terrane is related to subduction. Other Mesozoic terranes in the Reno quadrangle are metamorphosed to varying degrees, although much of this metamorphism is thermal metamorphism related to emplacement of Jurassic and Cretaceous plutons or may be simple burial metamorphism; there is no evidence for ductile deformation accompanying metamorphism or for subduction. Regional high-angle structures are not known to be present in Mesozoic rocks in the Reno quadrangle, with the possible exception of the hypothesized Pine Nut Fault (fig. 6), which is covered for its entire length by Cenozoic deposits, and the southwestern margin of the Jungo terrane. Alkalic (shoshonitic) magmatism in Mesozoic rocks has not been identified in the Reno quadrangle. Because of the lack of large-scale, throughgoing high-angle structures (with the possible exception of the Pine Nut Fault), the lack of evidence for subduction of oceanic crust, and the lack of known occurrences of low-sulfide gold-quartz veins, we did not delineate any areas as permissive for low-sulfide gold-quartz vein deposits.

Kuroko-Type Volcanogenic Massive Sulfide Deposits

Sherlock (1989) suggested that five mines and prospects in Triassic and Jurassic metavolcanic rocks in the western part of the Reno quadrangle might be Kuroko-type volcanogenic massive sulfide occurrences. Her work was based entirely on published descriptions of these occurrences, and subsequent fieldwork indicates that these occurrences are not volcanogenic massive sulfides, but rather that they are polymetallic veins (for example, Freds Mountain Prospect, Peavine Mining District) or volcanic-hosted copper skarns (for example, Red Metals Mine, Peavine Mining District).

We do not believe that the Triassic and Jurassic metavolcanic rocks in the western part of the Reno quadrangle (Pine Nut terrane and undifferentiated metavolcanic rocks) are permissive for Kuroko-type volcanogenic massive sulfide deposits, because the volcanic rocks were erupted in the wrong environment for the formation of these deposits. Kuroko deposits in Japan formed in submarine volcanic rocks that were erupted at depths of approximately 3.5 km (Ohmoto and Skinner, 1983). In contrast, Triassic and Jurassic metavolcanic rocks in the western part of the Reno quadrangle are subaerial and shallow marine in origin and interbedded sedimentary rocks commonly are continental and shallow marine although some may have been deposited in moderately deep water (Proffett and Dilles, 1984; Dilles and Wright, 1988; Bell and Garside, 1987; Doebrich and others, 1991).

MINERAL DEPOSITS OF TERTIARY AGE

Volcanic-Hosted Epithermal Gold-Silver Deposits

Volcanic-hosted epithermal gold-silver deposits are the most productive type of metalliferous mineral deposit in the Reno quadrangle, both in terms of past and current production. Several types of epithermal deposits are present in the Reno quadrangle, and the most abundant type is adularia-sericite or Comstock vein deposits. Numerous classification schemes for epithermal gold-silver deposits have emerged during the past ten years based on many criteria including volcanic-tectonic setting, wallrock alteration, ore mineralogy, nature of basement rocks, and fluid chemistry (for example, Buchanan, 1981; Berger and Eimon, 1983; Sillitoe and Bonham, 1984; Hayba and others, 1985; Nelson and Giles, 1985; Mosier and others, 1986; Heald and others, 1987; Berger and Henley, 1989, and White and Hedenquist, 1990). These recent classifications build on earlier classifications proposed by Nolan (1933) and Lindgren (1933), who recognized important characteristics of epithermal deposits and proposed somewhat similar divisions of deposit types.

Currently, most authors divide volcanic-hosted epithermal gold-silver deposits into two major types: adularia-sericite (also called quartz-adularia, Comstock epithermal vein, or low sulfidation) and quartz-alunite (also known as acid-sulfate, alunite-kaolinite±pyrophyllite, or high sulfidation) (for example, Heald and others, 1987; Berger and Henley, 1989). Hot-spring gold deposits are a third type of epithermal gold-silver deposit commonly described in the literature (for example, Berger and Eimon, 1983; Nelson and Giles, 1985; Berger, 1986b; Nelson, 1988). However, most detailed studies of so-called hot-spring deposits show that they are a subtype (shallow-level end member) of the other two types. For example, Paradise Peak, Nevada (John and others, 1991) and Sleeper, Nevada (Nash and others, 1991) are examples of shallow-level quartz-alunite and adularia-sericite deposits, respectively, that previously have been called hot-spring deposits and are included in the hot-spring gold-silver grade and tonnage model (Berger and Singer, 1991).

We discuss adularia-sericite and quartz-alunite deposits separately, although our current knowledge does not allow us to distinguish separate areas that are permissive for these two deposit types at the scale of this assessment because alteration assemblages characteristic of both deposit types are found near each other in several mining districts (for example, the Comstock, Ramsey, and Como Mining Districts). However, available K-Ar ages do suggest small age differences (1–3 m.y.) between adularia and "hypogene" alunite alteration within mining districts (table 2). We also discuss known occurrences of hot-spring systems (active and fossil) and mineralization formed in hot-spring environments, although mineralization related to hot-spring systems probably represents the surficial expressions of adularia-sericite or quartz-alunite systems (White, 1981).

Adularia-Sericite (Comstock) Gold-Silver Veins

Known Occurrences

Adularia-sericite gold-silver vein deposits in Tertiary volcanic rocks are the most productive type of metalliferous mineral deposit in the Reno quadrangle. The world-class Comstock Lode deposit produced more than 192 million troy oz of silver and 8.25 million troy oz of gold from about 19 million tons of ore from 1859 to 1957 (Bonham, 1969). Most mining was from underground stopes. In comparison, the Rawhide deposit, which recently (1989) went into production as an open-pit mine, has estimated ore reserves of 59.3 million tons containing about 17.5 million troy oz of silver and 1.62 million troy oz of gold (Black and others, 1991).

Adularia-sericite vein deposits are present in at least 14 mining districts spread throughout the Reno quadrangle except along the west border and possibly the northeastern corner (the Dixie-Comstock Mine in the northeastern corner of the quadrangle may be an adularia-sericite deposit). Characteristics of mining districts containing adularia-sericite vein deposits in the Reno quadrangle are summarized in table 2. Adularia-sericite deposits are hosted by Oligocene and Miocene volcanic rocks. Deposits dated by K-Ar methods on hydrothermal minerals range from about 23 Ma at Wonder to 7(?) Ma at Como (table 2). Deposits older than about 15 Ma only are present in the southern and southeastern parts of the quadrangle, although this distribution may be an artifact of the lack of exposure of older volcanic rocks throughout much of the northern and western parts of the quadrangle. Most deposits are present within several kilometers of igneous centers defined either by subvolcanic intrusions and (or) dike swarms or unusually thick accumulations of volcanic rocks (figs. 9 and 10, table 2). However, the role of the igneous centers beyond supplying heat to drive hydrothermal systems is unclear (for example, Vikre, 1989). Adularia-sericite deposits apparently are present in all three volcanic assemblages, although the largest deposits are associated with the western andesite assemblage (including the Comstock Lode and Rawhide deposits), and an unusually large proportion are associated with the Kate Peak Formation (table 2). Most of the deposits are structurally controlled by high-angle faults with veins filling fault zones or cross fractures; to date, Rawhide is the only deposit that contains significant tonnage of "disseminated" ore that is bulk minable by open-pit methods (recent exploration in the Talapoosa and Ramsey Mining Districts have defined bulk-minable ore bodies, although grade and tonnages have not been released; Nieuwenhuyse, 1991; Larry MacMaster, oral commun., 1990). Two dominant vein orientations of north-south (±30°) and east-west (±30°) are evident (table 2). Veins typically consist of vuggy, often rhythmically banded, quartz+sulfide minerals±chalcedony±calcite±adularia. Mineralized zones containing numerous veins may be continuous for more than 5 km along strike and more than 1 km down dip (Vikre, 1989). Widths of individual mineralized zones may be as wide as 30 m as at the Comstock Lode (Vikre, 1989), but generally they are much narrower (≤10 m). Bulk-minable ore at Rawhide consists of zones of narrow stockwork quartz+adularia veins (Black and others, 1991). Wallrock alteration around veins typically consists of narrow alteration zones containing of various combinations of adularia, sericite, and clay minerals (mostly montmorillinite) superimposed(?) on broader areas of propylitic alteration (for example, Vikre, 1989; Black and others, 1991). Advanced argillic alteration and alunitic alteration temporally related to precious-metal mineralization are absent or uncommon. Ore minerals typically consist of electrum and a variety of silver sulfide and sulfosalt minerals. Base-metal content usually is low, although bonanza parts of veins in the Comstock Lode contained up to 30 weight percent base-metal sulfide minerals, mostly sphalerite, galena, and chalcopyrite (Vikre, 1989). Most deposits were oxidized and most ore mined from mining districts other than Comstock was oxide ore (for example, ores in the Wonder Mining District were oxidized to depths greater than 650 m; Willden and Speed, 1974).

Permissive Terranes

Terranes permissive for undiscovered adularia-sericite vein deposits include all areas of Tertiary volcanic rocks except isolated exposures of Pliocene to Holocene basalts in Carson Sink (pl. 3). We did not exclude any other areas of Tertiary volcanic rocks from being permissive for undiscovered deposits, because known deposits are present throughout most of the quadrangle in all three volcanic assemblages, although most deposits are associated with the western andesite or interior andesite-rhyolite assemblages (table 2).

Favorable Tracts

We delineated 21 tracts as favorable for undiscovered adularia-sericite vein deposits (tracts 15-35, pl. 3, table 2). These tracts include most known deposits and occurrences. Favorable tracts are defined by the presence of known deposits, presence of hydrothermal alteration detected either during field studies or by remote-sensing techniques, proximity to igneous centers, and by favorable geochemical signatures in regional stream-sediment and rock geochemistry. Several tracts (notably tracts 27 and 30) contain few known prospects, although they contain large areas of hydrothermal alteration. Tract 27, located between the southeastern shore of Lahontan Reservoir and Camp Gregory and centered on Red Mountain, includes large areas of silicified and adularized, interbedded fine-grained sedimentary rocks and basalts of middle to late Miocene age. The southeastern part of this tract was explored during the early 1980's by Noranda Exploration Inc. and was described by Quade and Tingley (1987). Here, silicified rocks are cut by large numbers of hydrothermal breccias that locally contain anomalous amounts of Ag, As, Hg, Pb, and Tl. Tract 30 in the southern Stillwater Range consists of large areas of hydrothermally altered, locally pyritic, intracaldera ash-flow tuff and rhyolite and andesite intrusions (John, in press). Most of the alteration is propylitic, although several large zones of bleaching, localized silicification, and localized narrow stockwork quartz ±pyrite veins and wider quartz+calcite±pyrite±chalcopyrite veins are present. Silicified, hematitic fault breccias also are present at several locations. The bleached and silicified rocks commonly contain anomalous amounts of As, Hg, Mo, Pb, and Tl, and anomalous amounts Ag, Au, Bi, Sb, and Sn are present locally.

Quartz-Alunite (Acid-Sulfate) Gold Deposits

Known Occurrences

Quartz-alunite (acid-sulfate, alunite+kaolinite±pyrophyllite) gold deposits are the second principal type of epithermal gold-silver deposit present in the Reno quadrangle. Small deposits and areas of hydrothermal alteration that may represent this type of hydrothermal system are present in nine areas in the western part of the quadrangle (table 2). Hydrothermal alteration and precious- and base-metal mineralization are present in upper Oligocene and Miocene volcanic rocks, and with the exception of the Pyramid Mining District, all are associated with the western andesite assemblage. Alunite and sericite K-Ar ages range from about 22 to 6 Ma (table 2). All known occurrences lie within the Walker Lane Belt (see fig. 1).

Small gold-silver deposits in the Wedekind and Peavine Mining Districts (tract 16, pl. 3) are associated with advanced argillic and alunitic alteration, have high base-metal contents, and are mostly contained within numerous hydrothermal breccia zones that are present in a broad east-west-trending band through the two mining districts (Bonham, 1969; Hudson, 1977). Similar types of hydrothermal alteration and hydrothermal breccias are present at the north end of the Carson Range (tract 17, pl. 3), although no precious- or base-metal mineralization is known to be present in this area (Hudson, 1983). Silicified zones of quartz+alunite+kaolinite±pyrophyllite alteration with scattered precious-metal contents are present on the east side of the Como Mining District (tract 22, pl. 3) (Russell, 1981; P.G. Vikre, oral commun., 1990). Large areas of quartz+alunite±pyrophyllite alteration are present in the northern Virginia Range from near Virginia City east to the Ramsey Mining District (tracts 18, 20, 21, and 24, pl. 3) (Whitebread, 1976; Ashley and others, 1979; Vikre and others, 1988). Alunitic alteration in the Virginia City area predates, postdates, and apparently is unrelated to formation of the Comstock Lode (Vikre and others, 1988; Vikre, 1989). Base-metal rich vein deposits in the Pyramid Mining District (tract 15, pl. 3) lack alunitic alteration but contain inner alteration zones containing pyrophyllite vein selvages (Wallace, 1975). Hydrothermal alteration in all areas except the north Carson Range is proximal to inferred igneous centers and shallow intrusive rocks (table 2 and fig. 10).

Permissive Terranes

Terranes permissive for undiscovered quartz-alunite gold deposits include all areas of Tertiary volcanic rocks except young (Pliocene to Quaternary) basalts in Carson

Sink (unit QTv, pl. 3). We cannot exclude any other areas of Tertiary volcanic rocks from being permissive, because at the scale of this assessment, there are not adequate criteria to distinguish separate permissive terranes for adularia-sericite and quartz-alunite deposits and both adularia-sericite and quartz-alunite alteration are present in several mining districts. Regionally, quartz-alunite deposits appear to be restricted to the Walker Lane Belt, and with exception of the Pyramid Mining District, they only are associated with the western andesite assemblage (Cox and others, 1990; Ludington and others, 1990).

Favorable Tracts

We delineated eight tracts as favorable for quartz-alunite gold deposits (tracts 15, 16, 17, 18, 20, 21, 22, 24, pl. 3). Characteristics of the tracts are summarized in table 2. The tracts were defined by the presence of known deposits, areas of hydrothermal alteration containing advanced argillic and (or) hypogene alunitic alteration, and proximity to igneous centers (table 2). The tracts are equivalent to some of the tracts favorable for adularia-sericite deposits.

Hot-Springs Deposits (Gold and Mercury)

Known Occurrences

Active and fossil hot-springs systems are present at several localities in the Reno quadrangle. The Steamboat Springs system (tract 19, pl. 3) is the most well studied active hot-spring system in the quadrangle (for example, White and others, 1964; Thompson and White, 1964; White, 1968, 1981; Silberman and others, 1979). Other active hot-springs systems in the Reno quadrangle include Brady's, Lee, Walley's, Wabuska, and Patua (also known as Hazen) hot springs (Garside and Schilling, 1979). Small amounts of mercury are associated with several of these hot springs, although there has been little or no production from any of them (Bailey and others, in press).

Hot-springs activity at Steamboat Springs is related to several rhyolite domes that White (1968) suggests represent the upper part of a large magma chamber (minimum volume of 100 km^3). The rhyolitic igneous activity is part of the bimodal basalt-rhyolite volcanic assemblage. The geothermal system at Steamboat Springs has been active for about 3 m.y. (Silberman and others, 1979). Sinter at Steamboat Springs generally contains detectable amounts of gold and silver, and chemically precipitated muds in active spring vents contain highly anomalous concentrations of gold, silver, mercury, and antimony (White, 1981). Although a total of less than 400 flasks of cinnabar have been recovered from Steamboat Springs (Silica Pit) Mine (Bailey and others, in press), White (1981) considers the Steamboat Springs system to represent a modern-day analog of fossil geothermal systems that formed epithermal gold-silver deposits throughout the Western United States.

Fossil hot-springs systems locally containing mercury and (or) gold are present in the Castle Peak, Ramsey, Holy Cross, Leete, Lake, and Desert Mining Districts, and on the southeastern shore of Lahontan Reservoir between the reservoir and Camp Gregory (John and Sherlock, 1991). The fossil systems are present in rocks of both the western andesite and bimodal basalt-rhyolite assemblages, although most known systems (both active and fossil) are associated with the bimodal basalt-rhyolite assemblage. The apparent absence of hot-spring activity in the older interior andesite-rhyolite assemblage may reflect (1) the lack of igneous centers of the interior andesite-rhyolite assemblage throughout most of the quadrangle (fig. 9), and (2) deep erosional levels of these older volcanic rocks, which may have removed any surficial features that were present. Mercury mineralization is present in the Castle Peak, Holy Cross, and Leete Mining Districts and is described by Bailey and Phoenix (1944), Bailey and others (in press), Bonham (1969), Willden and Speed (1974), and Quade and Tingley (1987). The Castle Peak Mine in the Castle Peak Mining District in the only property that had significant mercury production (Bonham, 1969).

Camp Gregory and the area immediately to the north (Red Mountain), as described in the section "Adularia-Sericite (Comstock) Gold-Silver Veins" section, includes large areas of silicification and adularia alteration within a sequence of interbedded fine-grained sedimentary rocks and basalts of middle Miocene age. Both rock types are cut by numerous structurally controlled zones of hydrothermal breccia. Several rhyolite domes are present near Camp Gregory, and siliceous sinters are locally present. The area of hydrothermal alteration extends about 10 km farther northwest than shown by Quade and Tingley (1987, fig. 31) to the southeastern shore of Lahontan Reservoir (tract 27, pl. 3). Geochemical analyses reported by Quade and Tingley (1987) and analyses of samples collected during this study indicate that this area locally contains anomalous amounts of Ag, As, Hg, Pb, and Tl, and many silicified zones within it contain as much as 60 weight percent adularia.

In the Ramsey and Talapoosa Mining Districts (tract 24, pl. 3), numerous ledges of siliceous sinter deposits and silicified ledges of hydrothermal breccia containing sinter fragments are present in the middle and upper parts of the Kate Peak Formation. The sinters locally contain detectable gold (Larry MacMaster, oral commun., 1989), and the hydrothermal breccia matrix contains adularia and anomalous amounts of As, Hg, Sb, and Tl.

In the Desert Mining District (tract 26, pl. 3), hematite-rich hydrothermal breccias cut and overlie silicified and argillized rhyolite and andesite on the south and east sides of Cinnabar Hill. Samples of hydrothermal breccia contain anomalous amounts of As, Hg, and Sb.

Permissive Terranes

As discussed above, we believe that precious-metal-bearing hot-spring systems are shallow level end members of adularia-sericite and quartz-alunite type hydrothermal systems, and thus, we did not delineate separate areas as permissive for hot-spring deposits.

Porphyry Copper Deposits

Known Occurrences

No porphyry copper deposits of Tertiary age are known to be present in the Reno quadrangle. One locality, the Guanomi Mine on the southwestern edge of Pyramid Lake, was described as a possible porphyry copper-molybdenum system (Bonham, 1969; Prochnau, 1973; Wallace, 1975; Satkoski and Berg, 1982). Wallace (1975, 1979) and Hudson (1977, 1983) have suggested that several areas of advanced argillic alteration in Tertiary volcanic rocks may represent the upper parts of porphyry copper systems.

At the Guanomi Mine, hydrothermal alteration and low-grade copper-molybdenum mineralization are associated with a quartz monzonite porphyry stock that intruded and hydrothermally altered upper Oligocene ash-flow tuff. Most surface alteration is quartz+pyrite+sericite, although Prochnau (1973) reported potassium feldspar alteration in drill holes. Mineralized rock at the Guanomi Mine is limited to stockwork quartz veins containing abundant pyrite and minor amounts of molybdenite. Elsewhere, copper and molybdenum are widely disseminated, particularly along sericitized margins of the stock. A 100-m by 300-m breccia zone containing abundant oxidized pyrite is present along the southern margin of the stock (Bonham, 1969). Nine holes drilled by American Selco, Inc., in 1971–72 confirmed the presence of large areas of low-grade copper-molybdenum mineralization (0.05 percent Cu and 0.003 percent Mo) (Prochnau, 1973). Wallace (1975) reported a muscovite alteration age of about 24 Ma from a sample collected at the Guanomi Mine.

Wallace (1975, 1979) and Hudson (1977, 1983) suggested that three areas of advanced argillic alteration in Tertiary volcanic rocks may represent the upper parts of unexposed porphyry copper systems. These areas are the Pyramid and Peavine-Wedekind Mining Districts and the northern end of the Carson Range just west of Reno (tracts 15, 16, and 17, pl. 3). All three areas are characterized by structurally controlled zones of relatively high temperature (≥250°C) advanced argillic (pyrophyllite and diaspore) alteration and local hypogene alunitic alteration. Hydrothermal alteration is present both in the interior andesite-rhyolite and western andesite assemblages and ranges in age from 22 to 11 Ma (table 2; Wallace, 1975; Hudson, 1983; E.H. McKee, unpub. data, 1990).

Mineralized areas in the Pyramid Mining District (tract 15, pl. 3) consist of precious-metal bearing quartz veins that also contain abundant base-metal sulfide and sulfosalt minerals (Wallace, 1975, 1979). Vein assemblages are concentrically zoned from the center of the district outwards from an inner high-sulfidation-state enargite+pyrite±luzonite assemblage through a medial sphalerite+galena+tetrahedrite+pyrite+chalcopyrite+bornite assemblage to an outer lower sulfidation-state galena+pyrite assemblage. Metal zoning is also present in vein assemblages—the inner veins are Cu-rich and Pb-poor, whereas more distal veins are Pb-rich and Cu-poor. Hydrothermal alteration is also zoned—the innermost quartz veins contain inner pyrophyllite±diaspore and outer sericite alteration envelopes, whereas more distal veins only contain sericite vein envelopes. Wallace (1975, 1979) noted that zoning patterns of hydrothermal alteration, sulfidation state of vein assemblages, and metals in the Pyramid Mining District are similar to zoning patterns in these features present in the upper levels of porphyry copper deposits elsewhere, and he suggested that a porphyry copper system may underlie the center of the Pyramid Mining District.

The Peavine and Wedekind Mining Districts (tract 16, pl. 3) contain numerous east-west trending hydrothermal breccia zones commonly developed in intrusions of the Kate Peak Formation (Bonham, 1969; Hudson, 1977). Hydrothermal alteration is concentrically zoned around the hydrothermal breccias and grades from inner quartz+alunite+diaspore+pyrite assemblages through quartz+pyrophyllite+diaspore+dickite+pyrite and quartz+sericite+pyrite assemblages to outer propylitic assemblages (Hudson, 1977). Ore consists of disseminated sulfide minerals, brecciated quartz veins, and hydrothermal breccia matrix and is present in intrusions related to the Kate Peak Formation, Tertiary diorite stocks, and surrounding Mesozoic wallrocks. Pyrite is the dominant sulfide mineral with less abundant chalcopyrite, enargite, tetrahedrite, galena, and sphalerite. Argentite also is present in the Peavine Mining District (Bonham, 1969). Past production has been mostly silver and gold from oxidized zones (Bonham, 1969), but Hudson (1977) noted the similarity between deposits in the Peavine and Wedekind Mining Districts and the El Salvador, Chile, porphyry copper deposit (Gustafson and Hunt, 1975), and Wallace (1979) suggested that the Peavine and Wedekind Mining Districts may represent the upper parts of a porphyry copper system.

An area in the northern Carson Range (tract 17, pl. 3) contains hydrothermal breccia zones in the Kate Peak Formation (Hudson, 1983). Hydrothermal alteration is concentrically zoned around the breccias from inner alunitic alteration to advanced argillic (pyrophyllite), illitic, and argillic alteration to outer propylitic alteration. No base- or precious-metal enrichment is associated with surface expressions of this alteration (Hudson, 1983), although the Wheeler Ranch mercury prospect is nearby.

Permissive Terranes

We limited terranes permissive for Tertiary porphyry copper deposits to known areas of high-temperature, advanced argillic alteration and the area around the Guanomi stock. Four of these areas (Guanomi Mine, Pyramid Mining District, Peavine and Wedekind Mining Districts, and northern Carson Range, tracts 15, 16, 17, 36, pl. 3) are described in the preceding section. A fifth area is present on the east side of the Como Mining District (tract 22, pl. 3) where silicified ledges containing alunite, pyrophyllite, diaspore, and kaolinite and scattered precious metals are present (P.G. Vikre, oral commun., 1990; Russell, 1981). Three areas between the Comstock and Ramsey Mining Districts in the northern Virginia Range (tracts 18, 20, and 24, pl. 3) containing numerous ledges and areas of alunite+pyrite±pyrophyllite±diaspore±kaolinite alteration are developed in intermediate composition lavas of the Alta and Kate Peak Formations (Thompson, 1956; Rose, 1969; Whitebread, 1976; Ashley and others, 1979; Vikre and others, 1988; Vikre, 1989) are also considered permissive for porphyry copper deposits.

Deeply buried Tertiary porphyry copper deposits could be present nearly anywhere in the quadrangle where Tertiary volcanic rocks of the western andesite or interior andesite-rhyolite assemblages are exposed or are inferred to underlie rocks of the bimodal basalt-rhyolite assemblage. However, because disseminated copper ore is present hundreds to thousands of meters beneath areas of advanced argillic and alunitic alteration in known porphyry copper deposits (for example, Gustafson and Hunt, 1975; Corn, 1975), the absence of these types of hydrothermal-alteration assemblages in surface exposures of Tertiary volcanic rocks elsewhere in the quadrangle precludes the possibility of currently exploitable copper resources being present within 500 m of the surface, the depth limit used in this assessment. Thus, terranes permissive for Tertiary porphyry copper deposits were limited to areas of known advanced argillic and (or) alunitic alteration (tracts 15, 16, 17, 18, 20, 22, and 24, pl. 3) and the Guanomi stock (tract 36, pl. 3).

Favorable Tracts

We did not delineate any areas as favorable for the presence of Tertiary porphyry copper deposits, because of the uncertainty that any of the areas of advanced argillic and alunitic alteration in the western part of the Reno quadrangle are actually related to a large porphyry-type hydrothermal system. Also, if disseminated copper is present within any of the permissive terranes, it is likely to be present at depths greater than 500 m. The area around the Guanomi stock is not considered favorable because the area has been extensively but unsuccessfully explored.

Zinc-Lead and Copper Skarn Deposits

Known Occurrences

Two skarn deposits are associated with Oligocene plutons in the IXL and White Cloud Mining Districts in the Stillwater Range. Published descriptions (Vanderburg, 1940; Schrader, 1947; Willden and Speed, 1974) and geochemical analyses of samples collected in this study suggest that these deposits are transitional between copper and zinc-lead skarns (Einaudi and others, 1981; Cox, 1986g). The Copperaid Mine in the White Cloud Mining District reportedly was a copper skarn prospect, although the description of underground workings by Vanderburg (1940) suggests that significant amounts of Zn, Pb, and Ag were present in addition to a body of specular hematite+chalcopyrite. Both types of mineralization are present in skarn zones that replace Triassic marble along the margins of a granite porphyry stock. The Mottini Mine and other prospects in the IXL Mining District consist of magnetite+garnet+pyroxene skarn formed in Triassic marble along the margins of a granodiorite pluton. The skarns contain a variety of base metals including Fe, Pb, Zn, Cu, W, and locally high amounts of Ag (D.A. John and G.B. Sidder, unpub. data, 1987). Schrader (1947) also reported very high gold grades, but the presence of gold could not be confirmed (see "Gold-bearing Skarn Deposits" section).

Permissive Terranes

Terranes permissive for zinc-lead and copper skarn deposits include all terranes containing Mesozoic carbonate rocks (Jungo, Paradise, Sand Springs, and Pine Nut terranes and Marble Butte rocks) and are the same as those permissive for polymetallic replacement deposits (pl. 2). Zinc-lead skarn deposits generally are present distal to shallowly emplaced felsic plutons, although exposures of intrusive rocks may be very small or absent (Einaudi and others, 1981). Copper skarns generally form proximal to shallowly emplaced, felsic to mafic granitic intrusions, although copper skarns in the Yerington Mining District formed several kilometers distant from the margins of the Yerington batholith (Einaudi, 1982). Thus, the absence of exposed or inferred Tertiary intrusive rocks in large parts of the permissive terranes does not preclude them from being permissive for zinc-lead or copper skarn deposits.

Favorable Tracts

Two tracts are favorable for undiscovered zinc-lead and copper skarn deposits (tracts 13 and 14, pl. 2 and table 6).

Both areas contain Triassic carbonate rocks locally intruded by Tertiary granite and granodiorite plutons. Polymetallic replacement deposits are present in the Chalk Mountain and Westgate Mining Districts (tract 14, pl. 2) and may be present in the White Cloud Mining District (Vanderburg, 1940) and copper and (or) zinc-lead skarn deposits are present in the IXL and White Cloud Mining Districts (tract 13, pl. 2).

Polymetallic Replacement Deposits

Known Occurrences

Polymetallic (silver, lead, and zinc) replacement deposits are present in the Chalk Mountain and Westgate Mining Districts near the east edge of the Reno quadrangle (Vanderburg, 1940; Schrader, 1947; Bryan, 1972; Willden and Speed, 1974). The deposits are present in Triassic carbonate rocks several hundred meters distant from the margins of a composite Oligocene granite-granodiorite pluton. Mineralized rock consists of gossaneous quartz, calcite, and iron oxides occurring as veins and irregular replacement of limestone and dolomite (Bryan, 1972). Calc-silicate minerals are absent in mineralized zones. Ore minerals consist of secondary lead, zinc, and silver minerals and argentiferous galena (Vanderburg, 1940; Bryan, 1972). Sulfide minerals have been oxidized to the bottom of the deepest workings (Bryan, 1972). Narrow magnetite-rich skarn zones are present along the margin of the pluton, and epidote-rich endoskarn is developed locally within the pluton. Small polymetallic vein and (or) replacement deposits generally similar to occurrences at Chalk Mountain also are present in the Westgate Mining District about 3 km east of Chalk Mountain (Bryan, 1972).

Polymetallic replacement deposits also may be present in the White Cloud Mining District. Description of underground workings in the White Cloud Mining District by Vanderburg (1940) suggests that polymetallic replacement and (or) zinc-lead skarn deposits are present around the margin of a Oligocene granite porphyry stock (White Cloud Canyon pluton) in addition to specular hematite+chalcopyrite skarn.

Permissive Terranes

Terranes permissive for the occurrence of polymetallic replacement deposits include all terranes containing Mesozoic carbonate rocks and consist of the Jungo, Paradise, Sand Springs, and Pine Nut terranes and Marble Butte rocks. The permissive terranes are the same as terranes permissive for zinc-lead and copper skarn deposits (pl. 2).

Favorable Tracts

Two tracts are favorable for undiscovered polymetallic replacement deposits (tracts 13 and 14, pl. 2 and table 6). Both areas contain Triassic carbonate rocks that are locally intruded by Tertiary granite and granodiorite plutons. Polymetallic replacement and vein deposits are present in the Chalk Mountain and Westgate Mining Districts (tract 14, pl. 2) and may be present in the White Cloud Mining District (Vanderburg, 1940) (tract 13, pl. 2). Polymetallic veins are present in the IXL pluton (tract 30, pl. 3) and copper and (or) zinc-lead skarn deposits are present in the White Cloud and IXL Mining Districts (tract 13, pl. 2).

Gold-Bearing Skarn Deposits

No gold-bearing skarn deposits as defined by Theodore and others (1991) are known to be present in the Reno quadrangle. One skarn occurrence mentioned by Theodore and others (1991), the Mottini Mine in the IXL Mining District, reportedly contained very high gold grades (average gold grade >600 ppm based on production figures given in Schrader (1947)). However, analyses reported by Vanderburg (1940) and analyses of about 20 samples collected from old workings as part of this project did not contain the high gold grades reported by Schrader (1947); in fact, most samples contain less than 0.05 ppm gold and the maximum gold content is only 0.70 ppm (Vanderburg, 1940; D.A. John and G.B. Sidder, unpub. data, 1987). Chemical analyses of samples from the IXL Mining District suggest that the Mottini Mine and other mineral occurrences in the district should not be considered gold-bearing skarns, but rather copper and (or) zinc-lead skarn and polymetallic replacement deposits. The absence of recent workings in IXL Mining District also suggests that production figures quoted in Schrader (1947) are erroneous.

Permissive Terranes

Terranes permissive for gold-bearing skarn deposits (pl. 2) include all terranes that are permissive for other types of Mesozoic and Tertiary skarn deposits. We did not delineate separate permissive terranes for gold-bearing skarns, because we lack adequate criteria to separate terranes that are not permissive for gold-bearing skarns. Detailed studies of the Fortitude and McCoy gold-bearing skarn deposits, Nevada suggest that gold-bearing skarns may be genetically related to reduced granitic rocks (that is, low Fe^{3+}/Fe^{2+} ratios; Myers and Meinert, 1990; Brooks and Meinert, 1990). In the Reno quadrangle, chemical analyses of the White Cloud and IXL plutons and the Davidson Granodiorite suggest that exposed Tertiary granitoids are relatively oxidized (Fe^{3+}/Fe^{2+}=0.80-1.24 by weight; Thompson and White, 1964; Lee, 1984; John, 1992), and the absence of known gold-bearing skarns might be related to this trait. However, analysis of worldwide occurrences of gold-bearing skarns by Theodore and others (1991) indicates that there are no unique characteristics that allow distinction of gold-bearing skarns from other types of skarns. Thus, we consider all areas that are permissive for the occurrence of tungsten, copper, iron, and lead-zinc skarns to be permissive for gold-bearing skarns (pl. 2). In the Reno quadrangle, these areas consist of all terranes containing calcareous horizons (particularly carbonate units) and only metavolcanic terranes and the Humboldt complex are excluded.

Favorable Tracts

No favorable tracts for gold-bearing skarn deposits were delineated, because there are no known gold-bearing skarns in the quadrangle and adequate criteria needed to distinguish favorable areas are not available.

Volcanogenic and Sandstone Uranium Deposits

Numerous uranium occurrences and small deposits are present in Tertiary volcanic and volcaniclastic rocks in Washoe County in the northwestern part of the Reno quadrangle (McJannet, 1957; Bonham, 1969; Garside, 1973; Hutton, 1978; Benham, 1982; Hurley and others, 1982). Hurley and others (1982) evaluated the potential for uranium deposits in the Reno quadrangle as part of the NURE Program and provided maps showing areas favorable for uranium deposits in the Reno quadrangle. Most uranium occurrences fall into one of two types: (1) vein or fracture fillings primarily hosted by rhyolite ash-flow tuff (corresponding to hydroallogenic deposits of Hurley and others, 1982), and (2) "disseminated" deposits commonly present in carbonaceous horizons in volcaniclastic or sedimentary units at or near the base of the Tertiary volcanic section (corresponding to Wyoming roll-type and unconformity-related hydroallogenic deposits of Hurley and others, 1982). These deposit types generally correspond to the volcanogenic uranium and sandstone uranium models described by Bagby (1986) and Turner-Peterson and Hodges (1986), respectively. Total uranium production from all deposits in the Reno quadrangle is estimated at about 6,000 pounds and is primarily from the Buckhorn Mine, located along the California-Nevada border north of Reno (pl. 4; Garside, 1973). Uranium at the Buckhorn Mine is present in northeast-striking, iron-stained, siliceous veinlets in Tertiary ash-flow tuff that is faulted against Cretaceous granitic rocks (Bonham, 1969; Garside, 1973).

Permissive Terranes and Favorable Tracts

Terranes permissive for uranium deposits in Tertiary rocks are shown on plate 4. We slightly modified the map of Hurley and others (1982, pl. 1) that shows areas favorable for uranium deposits. Hurley and others (1982) limited areas favorable for sedimentary uranium deposits (herein equated with sandstone uranium deposits) to Warm Springs, Hungry, and Spanish Springs Valleys, and they limited areas favorable for hydroallogenic deposits (herein equated with volcanogenic uranium deposits) to exposures of Tertiary volcanic rocks on Petersen, Seven Lakes, and Dogskin Mountains, in the Virginia Mountains, in the Pah Rah Mountain area, and in the southern Nightingale Mining District (pl. 4).

We consider all permissive terranes (pl. 4) as favorable for sedimentary or volcanogenic uranium deposits, because of the many small uranium deposits or occurrences present in these areas and geochemical anomalies and other positive indications of the presence of uranium mineralization within these areas as discussed by Hurley and others (1982).

Other Deposits

Several other types of metallic mineral deposits and occurrences of Tertiary age are present in the Reno quadrangle. These include polymetallic vein, epithermal manganese, and placer gold deposits (John and Sherlock, 1991). Deposits or occurrences of these types are generally small, and at the present time, they are of little economic interest. Many occurrences have not been described in detail, which precludes adequate characterization needed to delineate permissive terranes and favorable tracts for undiscovered occurrences. Thus, only brief descriptions of the known occurrences are included herein.

Polymetallic Vein Deposits

The Creore Mine in the IXL Mining District is the only polymetallic vein deposit of demonstrable Tertiary age. Other known polymetallic vein occurrences are present in pre-Tertiary rocks and most appear to be of Mesozoic age. The Creore Mine is a silver-bearing quartz vein that cuts the Oligocene IXL pluton. The vein contains galena, sphalerite, and secondary copper minerals, and it has a small recorded production of Ag, Pb, Cu, and Zn.

Epithermal Manganese Deposits

Two epithermal manganese occurrences are present in the Reno quadrangle (pl. 3) at the Dixon Mine in the northern Pine Nut Mountains (Moore, 1969) and at the Bullion Prospect in the Holy Cross Mining District (Schrader, 1947). Both are manganese-rich shear zones in Tertiary ash-flow tuff. Ore at the Dixon Mine also contains high tungsten content and may be similar to tungsten-manganese-bearing ore mined at the Golconda Mine, Humboldt County, Nevada (Stager and Tingley, 1988). The Bullion Prospect reportedly had small production, approximately 100 tons, in 1918 (Schrader, 1947).

Placer Gold Deposits

Several placer gold deposits and prospects are scattered throughout the Reno quadrangle (John and Sherlock, 1991). None of the placer gold occurrences produced significant amounts of gold.

NONMETALLIC MINERAL RESOURCES

Nonmetallic mineral resources in the Reno quadrangle include industrial minerals (sand and gravel, aggregate, limestone, diatomite, gypsum, salt, clay, borax, and fluorspar) and geothermal energy. Oil and gas resources are not present in the Reno quadrangle. Although these resources were not explicitly studied as part of the Reno CUSMAP project, brief descriptions are included herein of known nonmetallic mineral resources in the quadrangle based on published data. Locations of known occurrences and deposits of nonmetallic mineral resources are shown on plate 4.

Large deposits of sand and gravel, limestone (for cement), diatomite, and gypsum are present in the Reno quadrangle (Castor, 1990). Sand and gravel quarries near Reno including the Patrick Pit about 15 km east of Reno in the Truckee River canyon, diatomite deposits near Fernley, and freshwater Miocene or Pliocene limestone and tufa deposits south of Fernley that are mined for use in making cement are among the most productive nonmetallic deposits in the quadrangle. Other industrial minerals mined in the past few years include small amounts of gypsum near Carson City, salt (for road salt) at the Huck Salt Mine on Carson Lake, lightweight aggregate (pumice) at Washington Hill near Reno, and clay minerals near Wabuska (pl. 4; Castor, 1990). Other types of industrial minerals present in the Reno quadrangle include bentonite, soda, borate minerals, perlite, fluorspar, perlite, cinder, and building stone (pl. 4). Additional descriptions of industrial minerals present in the Reno quadrangle are given by Archbold (1969), Papke (1969), and Willden and Speed (1974).

Six geothermal powerplants were operating in the Reno quadrangle in 1989 (pl. 4): Desert Peak near Brady's Hot Spring, Soda Lake northwest of Fallon, Steamboat and Yankee/Caithness at Steamboat Springs, Stillwater east of Fallon, and Wabuska at Wabuska (Hess and Garside, 1990). In addition, the Fallon Naval Air Station was planning to construct a powerplant and the large Oxbow Geothermal powerplant recently opened in Dixie Valley just north of the Reno quadrangle. Geothermal energy also is used to heat houses in the Reno and Carson City areas and for agricultural purposes at Wabuska and Brady's Hot Springs. Additional data on geothermal resources are given by Garside and Schilling (1979).

No oil and gas resources are known to be present in the Reno quadrangle. Although shallow water wells near Fallon have been known to produce small amounts of oil and natural gas since at least 1911 or 1912 (Gale, 1913; Willden and Speed, 1974), no commercially exploitable quantities of oil and gas have been found to date. Exploration for oil took place in the early 1970's in the Carson Sink—it included drilling of one deep (3,353 m) well (Hastings, 1979). Results were not encouraging, and it was concluded that, although oil seeps are present locally and large volumes of "organic oil-prone source rocks" are present, subsurface temperatures are too low to generate significant amounts of oil (Hastings, 1979).

REFERENCES CITED

Albers, J.P., 1986, Descriptive model of podiform chromite, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 34.

Anderson, R. E., Zoback, M.L., and Thompson, G.A., 1983, Implications of selected subsurface data on the structural form and evolution of some basins in the northern Basin and Range province, Nevada and Utah: Geological Society of America Bulletin, v. 94, p. 1055-1072

Archbold, N.L., 1969, Industrial mineral deposits, in Moore, J.G., 1969, Geology and mineral deposits of Lyon, Douglas, and Ormsby Counties, Nevada: Nevada Bureau of Mines and Geology, Bulletin 75, p. 31-41.

Ashley, R.P., Goetz, A.F.H., Rowan, L.C., and Abrams, M.J., 1979, Detection and mapping of hydrothermally altered rocks in the vicinity of the Comstock Lode, Virginia Range, Nevada, using enhanced Landsat images: U.S. Geological Survey Open-File Report 79-960, 41 p.

Atwater, Tanya, 1970, Implications of plate tectonics for the Cenozoic tectonic evolution of western North America: Geological Society of America Bulletin, v. 81, p. 3513-3535

Axelrod, D. I., 1956, Mio-Pliocene floras from west-central Nevada: University of California Publications in Geological Sciences, v. 32, 321 p.

Bagby, W.C., 1986, Descriptive model of volcanogenic U, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 162.

Bailey, E.H., and Phoenix, D.A., 1944, Quicksilver deposits in Nevada: Nevada University Bulletin, v. 38, no. 5, 206 p.

Bailey, E.H., Rytuba, J.J., Cox, Michael, and Jones, D.B., in press, Mercury deposits in Nevada: Nevada Bureau of Mines and Geology Bulletin.

Battles, D.A., 1991, Metasomatic alteration within a tilted batholith, Yerington mining district, Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., Geology and Ore Deposits of the Great Basin, Symposium Proceedings: Reno, Geological Society of Nevada and U.S. Geological Survey, p. 351-353.

Battles, D.A., and Barton, M.D., 1989, Na-Ca hydrothermal alteration in the western Great Basin [abs]: EOS, v. 70, no. 43, p. 1382.

Bell, J.W., 1984, Quaternary fault map of Nevada, Reno sheet: Nevada Bureau of Mines and Geology Map 79, scale 1:250,000

Bell, J.W., and Bonham, H.F., Jr., 1987, Vista quadrangle, geologic map: Nevada Bureau of Mines and Geology Map 4Hg, scale 1:24,000

Bell, J.W., and Garside, L.J., 1987, Verdi quadrangle, geologic map: Nevada Bureau of Mines and Geology Map No. 4Gg, scale 1:24,000.

Bell, J.W., and Katzer, Terry, 1990, Timing of late Quaternary faulting in the 1954 Dixie Valley earthquake area, central Nevada: Geology, v. 18, p. 622-625.

Benham, J.A., 1982, Geology and uranium content of middle Tertiary ash-flow tuffs in the southern Nightingale Mountains and northern Truckee Range: Reno, University of Nevada, M.S. thesis, 112 p.

Bennett, C.B., 1980, Hydrogeochemical and stream sediment reconnaissance data for the Reno 1° x 2° NTMS area, Nevada: Report GJBX-108 (80).

Berger, B.R., 1986a, Descriptive model of quartz-alunite Au, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 158.

———1986b, Descriptive model of hot-spring Au-Ag, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 143.

———1986c, Descriptive model of carbonate-hosted Au-Ag, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 175.

———1986d, Descriptive model of low sulfide Au-quartz veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 239.

Berger, B.R., and Eimon, P.I., 1983, Conceptual models of epithermal precious-metals deposits, *in* Shanks, W.C., III, ed., Cameron Volume on Unconventional Mineral Deposits, Society of Mining Engineers, p. 191-205.

Berger, B.R., and Henley, R.W., 1989, Advances in the understanding of epithermal gold-silver deposits, with special reference to the western United States, *in* Keays, R.R., Ramsay, W.R.H., and Groves, D.I., eds., The geology of gold deposits: the perspective in 1988: Economic Geology Monograph 6, p. 405-423.

Berger, B.R., and Singer, D.A., 1992, Grade and tonnage model of hot-spring gold-silver, *in* Bliss, J.D., ed., Developments in deposit modeling: U.S. Geological Survey Bulletin 2004, p. 23–25.

Best, M.G., Christiansen, E.H., Deino, A.L., Grommé, C.S., McKee, E.H., and Noble, D.C., 1989, Excursion 3A: Eocene through Miocene volcanism in the Great Basin of the western United States: New Mexico Bureau of Mines and Mineral Resources Memoir 47, p. 91-133

Bingler, E. C., 1978, Abandonment of the name Hartford Hill Rhyolite Tuff and adoption of new formation names for middle Tertiary ash-flow tuffs in the Carson City-Silver City area, Nevada: U.S. Geological Survey Bulletin 1457-D, 19 p.

Black, J.E., Mancuso, T.K., and Gant, J.L., 1991, Geology and mineralization at the Rawhide Au-Ag deposit, Mineral County, Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., Geology and Ore Deposits of the Great Basin, Symposium Proceedings: Reno, Geological Society of Nevada and U.S. Geological Survey, p. 1123-1142.

Blakely, R.J., and Jachens, R.C., 1990, Concealed mineral deposits in Nevada: Insights from three-dimensional analysis of gravity and magnetic anomalies [abs.]: Reno, Geological Society of Nevada, Geology and Ore Deposits of the Great Basin Program with Abstracts, p. 52-53.

———1991, Regional study of mineral resources in Nevada: Insights from three-dimensional analysis of gravity and magnetic anomalies: Geological Society of America Bulletin, v. 103, p. 795-803.

Blakely, R.J., and Simpson, R.W., 1986, Approximating edges of source bodies from magnetic or gravity anomalies: Geophysics, v. 51, p. 1494-1498.

Bliss, J.D., ed., 1992, Developments in deposit modeling: U.S. Geological Survey Bulletin 2004, 168 p.

Bliss, J.D., and Orris, G.J., 1986, Descriptive model of simple Sb deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 183.

Bonham, H.F., Jr., 1969, Geology and mineral deposits of Washoe and Storey Counties, Nevada: Nevada Bureau of Mines and Geology Bulletin 70, 140 p.

Brooks, J.W., and Meinert, L.D., 1990, Petrology and geochemistry of the McCoy Gold-bearing skarn, Lander County, Nevada [abs.]: Geological Society of Nevada, Geology and Ore Deposits of the Great Basin, Program with Abstracts, p. 61-62.

Bryan, D.P., 1972, The geology and mineralization of the Chalk Mountain and Westgate mining districts, Churchill County, Nevada: Reno, University of Nevada, M.S. thesis, 78 p.

Buchanan, L.J., 1981, Precious-metal deposits associated with volcanic environments in the southwest: Arizona Geological Society Digest, v. 14, p. 237-261.

Calkins, F.C., 1944, Outline of the geology of the Comstock Lode mining district, Nevada: U.S. Geological Survey open-file report.

Carten, R.P., 1986, Sodium-calcium metasomatism; chemical, temporal, and spatial relationships at the Yerington, Nevada, porphyry copper deposit: Economic Geology, v. 81, p. 1495-1519.

Castor, S.B., 1972, Geology of the Central Pine Nut and northern Buckskin Ranges, Nevada: A study of Mesozoic intrusive activity: Reno, University of Nevada, Ph.D. dissertation, 270 p.

———1990, Industrial minerals, *in* The Nevada Mineral Industry—1989: Nevada Bureau of Mines and Geology, Special Publication MI-1989, p. 26-29.

Christiansen, R.L., and Lipman, P.W., 1972, Cenozoic volcanism and plate-tectonic evolution of the western United States: 2, Late Cenozoic: Royal Society of London Philosophical Transaction, series A, v. 271, p. 217-248.

Christiansen, R.L., and Yeats, R.S., in press, Post-Laramide geology of the Cordilleran region, *in* Burchfiel, B.C., Lipman, P.W., and Zoback, M.L., eds., Geology of the Cordilleran region: Geological Society of America, Decade of North American Geology.

Coney, P.J., 1987, The regional tectonic setting and possible causes of Cenozoic extension in the North American Cordillera, *in* Coward, M. P., Dewey, J. F., and Hancock, P. L., eds., Continental extensional tectonics: Geological Society of London Special Publication 28, p. 177-186

Coney, P.J., and Reynolds, S.J., 1977, Cordilleran Benioff zones: Nature, v. 270, p. 403-406

Cordell, L., and Grauch, V.J.S., 1982, Mapping basement magnetization zones from aeromagnetic data in the San Juan

Basin, New Mexico [abs.]: Society of Exploration Geophysicists, 52 Annual International Meeting, Abstracts and Biographies, p. 246-247.
———1985, Mapping basement magnetization zones from aeromagnetic data in the San Juan Basin, New Mexico, *in* Hinze, W.J., ed., The utility of regional gravity and magnetic anomaly maps: Society of Exploration Geophysicists, p. 181-197.
Corn, R.M., 1975, Alteration-mineralization zoning, Red Mountain, Arizona: Economic Geology, v. 70, p. 1437-1447.
Cox, D.P., 1986a, Descriptive model of Fe skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 84.
———1986b, Descriptive model of porphyry Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 76.
———1986c, Descriptive model of polymetallic vein, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 125.
———1986d, Descriptive model of W skarn, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 55.
———1986e, Descriptive model of basaltic Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 130.
———1986f, Descriptive model of sediment-hosted Cu, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 205.
———1986g, Descriptive model of Pb-Zn skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 90.
Cox, D.P., Ludington, S.D., Sherlock, M.G., Singer, D.A., Berger, B.R., and Tingley, J.V., 1990, Mineralization patterns in time and space in the Great Basin of Nevada [abs.]: Reno, Geological Society of Nevada, Geology and Ore Deposits of the Great Basin Program with Abstracts, p. 53-54.
Cox, D.P., and Singer, D.A., eds., 1986, Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, 379 p.
Cox, D.P., and Theodore, T.G., 1986, Descriptive model of Cu skarn, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 86.
Crock, J.G., Lichte, F.E., and Briggs, P.H., 1983, Determination of elements in NBS geological reference materials SRM 278 obsidian and SRM 688 basalt by ICAP-AES: Geostandards Newsletter, v. 7, p. 335-340.
Dalrymple, G.B, 1979, Critical tables for conversion of K-Ar ages from old to new constants: Geology, v. 7, p. 558-560
Dalrymple, G.B, Cox, Allen, Doell, R.R., and Grommé, C.S., 1967, Pliocene geomagnetic polarity epochs: Earth and Planetary Science Letters, v. 2, p. 163-173
Deino, A.L., 1985, Stratigraphy, chemistry, K-Ar dating, and paleomagnetism of the Nine Hill Tuff, California-Nevada, Pt. 1, Miocene/Oligocene ash-flow tuffs of Seven Lakes Mountain, California-Nevada, Pt. II: Berkeley, University of California, Ph.D. dissertation, 432 p.
Dilek, Y., Moores, E.M., and Erskine, M.C., 1988, Ophiolitic thrust nappes in western Nevada—implications for the Cordilleran orogen: Journal of the Geological Society, London, v. 145, p. 969-975.
Dilles, J.H., 1984, The petrology and geochemistry of the Yerington batholith and the Ann-Mason porphyry copper deposit, western Nevada: Stanford, California, Stanford University, Ph.D. dissertation, 389 p.
———1987, Petrology of the Yerington batholith, Nevada: Evidence for evolution of porphyry copper ore fluids: Economic Geology, v. 82, p. 1750-1789.
Dilles, J.H., and Wright, J.E., 1988, The chronology of early Mesozoic arc magmatism in the Yerington mining district, Nevada, and its regional implications: Geological Society of America Bulletin, v. 100, p. 644-652.
Doebrich, J.L., Garside, L.J., Shawe, D.R., McCarthy, J.H., Jr., Turner, R.L., Hardyman, R.F., Erdman, J.A., Bonham, H.F., and Tingley, J.V., 1991, Triassic-Jurassic magmatic arc of western Nevada and eastern California—Part III: Mineral deposits [abs.], *in* Good, E.E., Slack, J.F., and Kotra, R.K., eds., USGS Research on mineral deposits—1991 program and abstracts: U.S. Geological Survey Circular 1062, p. 20-21.
Ekren, E.B., and Byers, F.M., Jr., 1984, The Gabbs Valley Range —A well exposed segment of the Walker Lane in west-central Nevada, *in* Lintz, Joseph, Jr., ed., Western Geologic Excursions, v. 4, Geological Society of America Annual Meeting, Mackay School of Mines, Reno, Nevada, p. 203-215
———1986, Geologic map of the Murphys Well, Pilot Cone, Copper Mountain, and Poinsettia Spring quadrangles, Mineral County, Nevada: U. S. Geological Survey Miscellaneous Investigations Series Map I-1576, 1:48,000 scale
Einaudi, M.T., 1977, Petrogenesis of the copper-bearing skarn at the Mason Valley Mine, Yerington mining district, Nevada: Economic Geology, v. 72, p. 769-795.
———1982, Description of skarns associated with porphyry copper plutons: southwestern North America, *in* Titley, S. R., ed., Advances in the Geology of Porphyry Copper Deposits, Southwestern North America: Tucson, University of Arizona Press, p. 139-184.
Einaudi, M.T., Meinert, L.D., and Newberry, R.J., 1981, Skarn deposits, *in* Skinner, B.J., ed., Economic Geology Seventy-fifth Anniversary Volume: Economic Geology Publishing Co., p. 317-391.
Erwin, J.W., 1982, Principal facts for a set of regional gravity data for the Reno 1 by 2 degree sheet, Nevada: Nevada Bureau of Mines and Geology Open-file Report 82-2, 31 p.
Fultz, L. A., Bell, E. J., and Trexler, D. T., 1984, Geochemistry, age and strontium isotope composition of late Tertiary and Quaternary basalts and andesites in western Nevada and their relation to geothermal potential: Division of Earth Sciences, Environmental Research Center, University of Nevada, Las Vegas, under contract AC03-82RA50075 to Department of Energy, available through National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia.
Gale, H.S., 1913, The search for potash in the desert basin region: U.S. Geological Survey Bulletin 530, p. 295-312.
Gans, P.B., Mahood, G.A., Schermer, E., 1989, Synextensional magmatism in the Basin and Range Province: a case study from the eastern Great Basin: Geological Society of America Special Paper 233, 53 p.
Garside, L.J., 1973, Radioactive mineral occurrences in Nevada: Nevada Bureau of Mines and Geology Bulletin 81, 121 p.
Garside, L.J., Bonham, H.F., Jr., Ashley, R.P., Silberman, M.L., and McKee, E.H., 1981, Radiometric ages of volcanic and

plutonic rocks and hydrothermal mineralization in Nevada—Determinations run under the USGS-NBMG Cooperative Program: Isochron/West, no. 30, p. 11-19.

Garside, L.J., and Schilling, J.H., 1979, Thermal waters of Nevada: Nevada Bureau of Mines and Geology, Bulletin 91, 163 p.

Geasan, D.L., 1980, The geology of a part of the Olinghouse mining district, Washoe County, Nevada: Reno, University of Nevada, M.S. thesis, 118 p.

Geehan, R.W., 1950, Investigation of the Union zinc-lead mine, Washoe County, Nevada: U.S. Bureau of Mines Report of Investigations 4623, 10 p.

Grimes, D.J., and Marranzino, A.P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p.

Greene, R.C., Stewart, J.H., John, D.A., Hardyman, R.F., Silberling, N.J., and Sorensen, M.L., 1991, Geologic map of the Reno 1° by 2° quadrangle, Nevada and California: U.S. Geological Survey Miscellaneous Field Studies Map MF-2154-A, scale 1:250,000.

Gustafson, L.B., and Hunt, J.P., 1975, The porphyry copper deposit at El Salvador, Chile: Economic Geology, v. 70, p. 857-912.

Gustafson, L.B., and Williams, Neil, 1981, Sediment-hosted stratiform deposits of copper, lead, and zinc, *in* Skinner, B.J., ed., Economic Geology Seventy-fifth Anniversary Volume: Economic Geology Publishing Co., p. 139-178.

Hardyman, R.F., Brooks, W.E., Blaskowski, M.J., Barton, H.N., Ponce, D.A., and Olson, J.E., 1988, Mineral resources of the Clan Alpine Mountains Wilderness Study Area, Churchill County, Nevada: U.S. Geological Survey Bulletin 1727-B, 16 p.

Hardyman, R.F., and Oldow, J.S., 1991, Tertiary tectonic framework and Cenozoic history of the central Walker Lane, Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., Geology and Ore Deposits of the Great Basin, Symposium Proceedings: Reno, Geological Society of Nevada and U.S. Geological Survey, p. 279-302.

Harris, N.B., and Einaudi, M.T., 1982, Skarn deposits in the Yerington mining district, Nevada: Metasomatic skarn evolution near Ludwig: Economic Geology, v. 77, p. 877-898.

Hastings, D.D., 1979, Results of exploratory drilling, northern Fallon basin, western Nevada, *in* Newman, G.W., and Goode, H. D., eds., Basin and Range Symposium and Great Basin Field Conference: Rocky Mountain Association of Geologists and Utah Geological Association, p. 515-522

Harlan, J.B., 1984, Geology and mineralization of Fireball Ridge, Churchill County, Nevada: Fort Collins, Colorado State University, M.S. thesis, 186 p.

Hayba, D.O., Bethke, P.M., Heald, Pamela, and Foley, N.K., 1985, Geologic, mineralogic, and geochemical characteristics of volcanic-hosted epithermal precious-metal deposits, *in* Berger, B.R., and Bethke, P.M., eds., Geology and geochemistry of epithermal systems: Reviews in Economic Geology, v. 2, p. 129-168.

Heatwole, D.A., 1978, Controls of oxide copper mineralization, MacArthur property, Lyon County, Nevada: Arizona Geological Society Digest, v. XI, p. 59-66.

Heald, Pamela, Foley, N.K., and Hayba, D.O., 1987, Comparative anatomy of volcanic-hosted epithermal deposits: Acid-sulfate and adularia-sericite types: Economic Geology, v. 82, p. 1-26.

Heggeness, J.O., 1982, The geology of Ragged Top caldera: Reno, University of Nevada, Reno, M.S. thesis, 107 p.

Hendricks, J.D., 1992, Total intensity magnetic anomaly map of the Reno 1° x 2° quadrangle, Nevada and California: U.S. Geological Survey Miscellaneous Field Studies Map MF-2154-C, scale 1:250,000.

Hess, R.H., and Garside, L.J., 1990, Geothermal energy, *in* The Nevada Mineral Industry—1989: Nevada Bureau of Mines and Geology Special Publication MI-1989, p. 51-55.

Hildenbrand, T.G., and Kucks, R.P., 1988, Filtered magnetic anomaly maps of Nevada: Nevada Bureau of Mines and Geology Map 93B, scale 1:1,000,000 (4 sheets) and 1:2,000,000 (1 sheet).

Hopkins, D.M., 1977, An improved ion-selective electrode method for the rapid determination of fluorine in rocks and soils: U.S. Geological Survey Journal of Research, v. 5, no. 5, p. 583-593.

Hubert, A.E., and Chao, T.T., 1985, Determination of gold, indium, tellurium, and thallium in the same digestion of geologic materials by atomic-absorption spectroscopy and two-step solvent extraction: Talanta, v. 32, p. 383-387.

Hudson, D.M., 1977, Geology and alteration of the Wedekind and part of the Peavine mining districts, Washoe County, Nevada: Reno, University of Nevada, M.S. thesis, 102 p.

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

Hudson, D.M., and Oriel, W.M., 1979, Geologic map of the Buckskin Range, Nevada: Nevada Bureau of Mines and Geology Map 64, scale 1:18,000.

Hudson, M.R., and Geissman, J.W., 1987, Paleomagnetic and structural evidence for middle Tertiary counterclockwise block rotation in the Dixie Valley region, west-central Nevada: Geology, v. 15, p. 638-642

———1991, Paleomagnetic evidence for the age and extent of middle Tertiary counterclockwise rotation, Dixie Valley region, west-central Nevada: Journal of Geophysical Research, v. 96, no. B3, p. 3979-4006.

Hurley, B.W., Johnson, C.L., Cupp, G.M., Mayerson, D.L., Dodd, P.A., and Berg, J.C., 1982, National uranium resource evaluation, Reno quadrangle, Nevada and California: Grand Junction, Colorado, Bendix Field Engineering Corporation, PGJ/F-037(82), 51 p.

Hutton, R.A., 1978, Geology and uranium content of middle Tertiary ash-flow tuffs in the northern part of Dogskin Mountain, Nevada: Reno, University of Nevada, M.S. thesis, 103 p.

Jachens, R.C., and Moring, B.C., 1990, Maps of the thickness of Cenozoic deposits and the isostatic residual gravity over basement for Nevada: U.S. Geological Survey Open-File Report 90-404, 10 p., scale 1:1,000,000.

John, D.A., 1989, Geologic setting, depths of emplacement, and regional distribution of fluid inclusion populations in intrusions of the central Wasatch Mountains, Utah: Economic Geology, v. 84, p. 386-409.

———1992, Chemical analyses of granitic rocks in the Reno 1° by 2° quadrangle and in the northern Pine Nut Mountains, west-central Nevada: U.S. Geological Survey Open-File Report 92-246, 35 p.

———in press, Late Cenozoic volcanotectonic evolution of the southern Stillwater Range, west-central Nevada, *in* Craig, S.D., ed., Structure, tectonics and mineralization of the Walker Lane, a short symposium, April 24, 1992: Reno, Geological Society of Nevada.

John, D.A., and McKee, E.H., 1991, Late Cenozoic volcanotectonic evolution of the southern Stillwater Range, west-central Nevada [abs.]: Geological Society of America Abstracts with Programs, v. 23, no. 2, p. 39.

John, D.A., Nash, J.T., Clark, C.W., and Wulftange, W., 1991, Geology, hydrothermal alteration, and mineralization at the Paradise Peak gold-silver-mercury deposit, Nye County, Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., Geology and ore deposits of the Great Basin, Symposium Proceedings: Reno, Geological Society of Nevada and U.S. Geological Survey, p. 1020-1050.

John, D.A., and Sherlock, M.G., 1991, Map showing mines and prospects in the Reno quadrangle, Nevada and California: U.S. Geological Survey Miscellaneous Field Studies Map MF-2154-B, scale 1:250,000.

John, D.A., and Silberling, N.J., in press, Geologic map of the La Plata Canyon quadrangle, Churchill County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-1710, scale 1:24,000.

John, D.A., Thomason, R.E., and McKee, E.H., 1989, Geology and K-Ar geochronology of the Paradise Peak mine and the relationship of pre-Basin and Range extension to early Miocene precious metal mineralization in west-central Nevada: Economic Geology, v. 84, p. 631-649

Johnson, R.G., and King, B.-S.L., 1987, Energy-dispersive X-ray fluorescence spectrometry, *in* Baedecker, P.A., ed., Methods for geochemical analysis: U.S. Geological Survey Bulletin 1770-F, 5 p.

Kerrich, Robert, and Wyman, Derek, 1990, Geodynamic setting of mesothermal gold deposits: An association with accretionary tectonic regimes: Geology, v. 18, p. 882-885.

Kilburn, J.E., Smith, D.B., and Hopkins, R.T., 1990, Analytical results and sample locality map of stream-sediment samples from the Reno 1° x 2° quadrangle, California and Nevada: U.S. Geological Survey Open-File Report 90-204, 71 p.

King, Clarence, 1870, The Comstock Lode: Report of the geological exploration of the 40th Parallel, v. 3: Washington, D.C., U.S. Government Printing Office, p. 10-91.

———1878, Systematic geology, Report of the geological exploration of the 40th Parallel, v. 1: Washington, D.C., U.S. Government Printing Office.

Kleinhampl, F.J., and Ziony, J.I., 1984, Mineral resources of northern Nye County: Nevada Bureau of Mines and Geology Bulletin 99B, 241 p.

———1985, Geology of northern Nye County, Nevada: Nevada Bureau of Mines and Geology Bulletin 99A, 172 p.

Knopf, Adolph, 1918, Geology and ore deposits of the Yerington mining district, Nevada: U.S. Geological Survey Professional Paper 114, 68 p.

Lawrence, E.F., 1963, Antimony deposits of Nevada: Nevada Bureau of Mines Bulletin 61, 248 p.

Lawrence, E.F., and Redmond, R.L., 1967, Exploration of the Calico area, Walker River Indian Reservation, Mineral County, Nevada: Society of Mining Engineers of AIME, Preprint No. 67-I-311, 10 p.

Lee, D.E., 1984, Analytical data for a suite of granitoid rocks from the Basin and Range province: U.S. Geological Survey Bulletin 1602, 54 p.

Lipman, P.W., Prostka, H.J., and Christiansen, R.L., 1971, Evolving subduction zones in the western United States, as interpreted from igneous rocks: Science, v. 174, p. 821-825

Lindgren, W., 1933, Mineral deposits, 4th ed.: New York, McGraw-Hill Book Co., 930 p.

Ludington, S.D., Cox, D.P., Sherlock, M.G., Singer, D.A., Berger, B.R., and Tingley, J.V., 1990, Spatial and temporal analysis of precious-metal deposit models for a mineral resource assessment of Nevada [abs.]: Toronto, 8th IAGOD Symposium, Program with Abstracts, p. A100-A101.

Margolis, Jacob, 1991, Miocene acid-sulfate epithermal mineralization related to a Mo porphyry system: Washington Hill, Nevada [abs.]: Geological Society of America Abstracts with Programs, v. 23, p. 76.

McJannet, G.S., 1957, Geology of the Pyramid Lake-Red Rock Canyon area, Washoe County, Nevada: University of California, Los Angeles, M.A. thesis

McNerney, J.J., Buseck, P.R., and Hanson, R.C., 1972, Mercury detection by means of thin gold films: Science, v. 178, p. 611-612.

Menzie, W.D., and Jones, G.M., 1986, Grade and tonnage model of W skarn deposits, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 55-57.

Menzie, W.D., and Singer, D.A., 1990, A course on mineral resource assessment [abs.]: Proceedings of international symposium on mineral exploration: the use of artificial intelligence (ISME-AI'90): Tokyo, Mining and Materials Processing Institute of Japan, p. 177-187.

Moore, J.G., 1969, Geology and mineral deposits of Lyon, Douglas, and Ormsby Counties, Nevada: Nevada Bureau of Mines and Geology Bulletin 75, 45 p.

Morris, H.T., 1986, Descriptive model of polymetallic replacement deposits *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 99.

Morton, J.L., Silberman, M.L., Bonham, H.F., Jr., and Garside, L.J., and Noble, D.C., 1977, K-Ar ages of volcanic rocks, plutonic rocks, and ore deposits in Nevada and eastern California—Determinations run under the USGS-NBMG cooperative program: Isochron/West, no. 20, p. 19-29

Morton, J.L., Silberman, M.L., Thompson, G.A., and Brookins, D.G., 1980, New K-Ar ages and strontium isotopic data from late Miocene and younger volcanic rocks of the northern Virginia Range, Nevada: Geological Society of America, Abstracts with Programs, v. 12, no. 3, p. 143

Mosier, D.L., 1986, Descriptive model of epithermal Mn, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 165.

Mosier, D.L., Singer, D.A., Sato, Takeo, and Page, N.J., 1986, Relationship of grade, tonnage, and basement lithology in volcanic-hosted epithermal precious- and base-metal quartz-adularia-type mining districts: Mining Geology, v. 36, p. 245-264.

Motooka, J.M., and Grimes, D.J., 1976, Analytical precision of one-sixth semiquantitative spectrographic analysis: U.S. Geological Survey Circular 738, 25 p.

Mutschler, F.E., Wright, E.G., Ludington, Steve, and Abbott, J.T., 1981, Granite molybdenite systems: Economic Geology, v. 874-897.

Myers, G.L. and Meinert, L.D., 1990, Alteration mineralization and gold distribution in the Fortitude Gold-bearing skarn [abs.]: Reno, Geological Society of Nevada, Geology and Ore Deposits of the Great Basin, Program with Abstracts, p. 61.

Nash, J.T., Utterback, W.C., and Saunders, J.A., 1991, Geology and geochemistry of the Sleeper gold-silver deposit, Humboldt County, Nevada—an interim report, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., Geology and ore deposits of the Great Basin, Symposium Proceedings: Reno, Geological Society of Nevada and U.S. Geological Survey, p. 1063-1084.

National Geophysical Data Center, 1984, DMA gravity file of the U.S.: National Oceanic and Atmospheric Administration, Boulder, Colo., 2 magnetic tapes.

Nelson, C.E., 1988, Gold deposits in the hot spring environment, *in* Schafer, R.W., Cooper, J.J., and Vikre, P.G., eds., Bulk mineable precious metal deposits of the western United States, symposium proceedings: Reno, Geological Society of Nevada, p. 417-431.

Nelson, C.E., and Giles, D.L., 1985, Hydrothermal eruption mechanisms and hot spring gold deposits: Economic Geology, v. 80, p. 1633-1639.

Nelson, S.W., 1975, The petrology of a zoned granitic stock, Stillwater Range, Churchill County, Nevada: Reno, University of Nevada, M.S. thesis, 103 p.

Nevada Bureau of Mines and Geology, 1964, Final report geological, geophysical, chemical, and hydrological investigations of the Sand Springs Range, Fairview Valley, and Fourmile Flat, Churchill County, Nevada, for Shoal Event, Project Shade, Vela Uniform Program: U.S. Atomic Energy Commission.

Newberry, R.J., and Einaudi, M.T., 1981, Tectonic and geochemical setting of tungsten skarn mineralization in the Cordillera, *in* Dickinson, W.D., and Payne, W.D., eds., Relations of Tectonics to ore deposits in the southern Cordillera: Arizona Geological Society Digest, v. XIV, p. 99-112.

Nieuwenhuyse, R.V., 1991, Geology and ore controls of gold-silver mineralization in the Talapoosa mining district, Lyon County, Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., Geology and Ore Deposits of the Great Basin, Symposium Proceedings: Reno, Geological Society of Nevada and U.S. Geological Survey, p. 979-994

Noble, D.C., 1972, Some observations on the Cenozoic volcano-tectonic evolution of the Great Basin, western United States: Earth and Planetary Science Letters, v. 17, p. 142-150

Nolan, T.B., 1933, Epithermal precious metal deposits, *in* Ore deposits of the western states: New York, American Institute of Mining and Metallurgical Engineers, p. 623-640.

Ohmoto, Hiroshi, and Skinner, B.J., 1983, The Kuroko and related volcanogenic massive sulfide deposits: Introduction and summary of new findings, *in* Ohmoto, Hiroshi, and Skinner, B.J., eds., The Kuroko and related volcanogenic massive sulfide deposits: Economic Geology Monograph 5, p. 1-8.

Oldow, J.S., 1984, Evolution of a late Mesozoic back-arc fold and thrust belt, northwestern Great Basin, U.S.A.: Tectonophysics, v. 102, p. 245-274.

O'Leary, R.M., and Viets, J.G., 1986, Determination antimony, arsenic, bismuth, cadmium, copper, lead, molybdenum, silver, and zinc in geologic materials by atomic-absorption spectrometry using a hydrochloric acid-hydrogen peroxide digestion: Atomic Spectroscopy, 7, p. 4-8.

Page, B.M., 1965, Preliminary geologic map of part of the Stillwater Range, Churchill County, Nevada: Nevada Bureau of Mines and Geology Map 28, scale 1:125,000.

Page, N.J., 1986, Descriptive model of Noril'sk Cu-Ni-PGE, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 17.

Papke, K.G., 1969, Industrial rock and mineral deposits, *in* Bonham, H.F., Jr., 1969, Geology and mineral deposits of Washoe and Storey Counties, Nevada: Nevada Bureau of Mines and Geology Bulletin 70, p.108-130.

Pearce, J.A., 1982, Trace element characteristics of lavas from destructive plate boundaries, *in* Thorpe, R.S., ed., Andesites: New York, John Wiley and Sons, p. 525-548.

Pearce, J.A., and Cann, J.R., 1973, Tectonic setting of basic volcanic rocks investigated using trace element analyses: Earth and Planetary Sciences Letters, v. 19, p. 290-300.

Peterson, J.A., Cox, D.P., and Gray, Floyd, 1983, Mineral resource assessment of the Ajo and Lukeville 1° by 2° quadrangles, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF-1834-B, scale 1:250,000.

Plouff, Donald, 1992, Bouguer gravity anomaly and isostatic residual gravity maps of the Reno 1° by 2° quadrangle, Nevada and California: U.S. Geological Survey Miscellaneous Field Studies Map MF-2154-E, scale 1:250,000.

Prochnau, J.F., 1973, Summary report on the 1971-1972 exploration program, Pyramid Lake (Guanomi) property, Pauite Indian Reservation, Washoe County, Nevada: Nevada Bureau of Mines Open-File Report, 12 p.

Proffett, J.M., Jr., 1977, Cenozoic geology of the Yerington mining district, Nevada, and implications for the nature and origin of the Basin and Range faulting: Geological Society of America Bulletin, v. 88, p. 247-266

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

Proffett, J.M., Jr., and Proffett, B.H., 1976, Stratigraphy of the Tertiary ash-flow tuffs in the Yerington mining district, Nevada: Nevada Bureau of Mines and Geology Report 27, 27 p.

Quade, Jack, and Tingley, J.V., 1987, Mineral resource inventory U.S. Navy master land withdrawal area, Churchill County, Nevada: Nevada Bureau of Mines and Geology Open-File Report 87-2, 99 p.

Reeves, R.G., and Kral, V.E., 1955, Iron ore deposits of Nevada. Part A. Geology and iron ore deposits of the Buena Vista Hills, Churchill and Pershing Counties, Nevada: Nevada Bureau of Mines and Geology Bulletin 53, 32 p.

Reeves, R.G., Shawe, F.R., and Kral, V.E., 1958, Iron ore deposits of Nevada. Part B. Iron ore deposits of west-central Nevada: Nevada Bureau of Mines and Geology Bulletin 53, 78 p.

Richter, D.H., Singer, D.A., and Cox, D.P., 1975, Mineral resources map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-655-K, scale 1:250,000.

Richtofen, F., Baron, 1866, The Comstock Lode; its character and probable mode of continuance at depth: San Francisco, Sutro Tunnel Co., Town & Bacon.

Rose, R.L., 1969, Geology of parts of the Wadsworth and Churchill Butte quadrangles, Nevada: Nevada Bureau of Mines, Bulletin 71, 27 p.

Ross, D.C., 1961, Geology and mineral deposits of Mineral County, Nevada: Nevada Bureau of Mines and Geology, Bulletin 58, 98 p.

Rowan, L.C., Eiswerth, B.A., Smith, D.B., Ehmann, W.J., and Bowers, T.L., (in press), Distribution, mineralogy, and geochemistry of hydrothermally altered rocks in the Reno 1° by 2° quadrangle, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-2154-D, scale 1:250,000.

Roylance, J.G., Jr., 1966, The Dayton iron deposits, Lyon and Storey counties, Nevada: Nevada Bureau of Mines Report 13, p. 125-141.

Russell, Kevin, 1981, Geology and ore deposits of the Como mining district, Lyon County, Nevada: Fresno, California State University, M.A. thesis, 85 p.

Russell, P.C., McKee, E.H., and Vikre, P.G., 1989, K-Ar ages from Nevada and eastern California: Isochron/West, no. 52, p. 12-14.

Rytuba, J.J., 1986, Descriptive model of hot-spring Hg, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 178.

Sanders, C.O., and Slemmons, D.B., 1979, Recent crustal movements in the central Sierra Nevada-Walker Lane region of California-Nevada - Part III, The Olinghouse fault zone: Tectonophysics, v. 52, p. 585-597

Satkoski, J.J., and Berg, A.W., 1982, Field inventory of mineral resources Pyramid Lake Indian Reservation, Nevada: U.S. Bureau of Mines Report BIA No. 38-II, 47 p.

Satkoski, J.J., Lambeth, R.H., White, W.W., III, and Dunn, M.D., 1985, Field inventory of mineral resources and compilation of exploration data, Walker River Indian Reservation, Nevada: U.S. Bureau of Mines Report BIA No. 21-11, 271 p.

Satterfield, J.I., and Oldow, J.A., 1989, Early Mesozoic superposition of ductile and brittle structures, Sand Springs Range, west-central Nevada [abs.]: Geological Society of America Abstracts with Programs, v. 21, p. 139-140.

Scholz, C.H., Barazangi, M., and Sbar, M.L., 1971, Late Cenozoic evolution of the Great Basin, western United States, as an ensialic interarc basin: Geological Society of America Bulletin, v. 76, p. 1361-1378

Schrader, F.C., 1947, Carson sink area, Nevada: U.S. Geological Survey Open-file Report, unpaginated.

Seedorff, C.E., 1991, Magmatism, extension, and ore deposits of Eocene to Holocene age in the Great Basin—mutual effects and preliminary proposed genetic relationships, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., Geology and Ore Deposits of the Great Basin, Symposium Proceedings: Reno, Geological Society of Nevada and U.S. Geological Survey, p. 133-178.

Sherlock, M.G., 1989, Metallogenic map of volcanogenic massive-sulfide deposits in pre-Tertiary island-arc and ocean-basin environments in Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-1853-E, scale 1:1,000,000.

Sidder, G.B., 1986, Mineral deposits of the Reno quadrangle, Nevada, with a comprehensive bibliography: U.S. Geological Survey Open-File Report 86-407, 53 p.

———1987, A report on work in progress for the Reno 1° by 2° CUSMAP project, Nevada, with additional bibliography: U.S. Geological Survey Open-File Report 87-656, 21 p.

Silberling, N.J., 1991, Allochthonous terranes of western Nevada—current status, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., Geology and Ore Deposits of the Great Basin, Symposium Proceedings: Reno, Geological Society of Nevada and U.S. Geological Survey, p. 101-102.

Silberling, N.J., and John, D.A., 1989, Geologic map of pre-Tertiary rocks of the Paradise Range and southern Lodi Hills, west-central Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-2062, scale 1:24,000.

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

Silberman, M.L., and McKee, E.H., 1972, A summary of radiometric age determinations of Tertiary volcanic rocks from Nevada and eastern California: Part II, western Nevada: Isochron/West, no. 4, p. 7-28

Silberman, M.L., Stewart, J.H., and McKee, E.H., 1976, Igneous activity, tectonics, and hydrothermal precious-metal mineralization in the Great Basin during Cenozoic time: Society of Mining Engineers of the AIME, Transactions, v. 260, p. 253-263.

Silberman, M.L., White, D.E., Keith, T.E.C., and Dockter, R.D., 1979, Duration of hydrothermal activity at Steamboat Springs, Nevada, from ages of spatially associated volcanic rocks: U. S. Geological Survey Professional Paper 458-D, 14 p.

Sillitoe, R.H., and Bonham, H.F., Jr., 1984, Volcanic landforms and ore deposits: Economic Geology, v. 79, p. 1286-1298.

Singer, D.A. 1975, Mineral resource models and the Alaskan mineral resource assessment program, *in* Vogley, W.A., ed., Mineral materials modeling: A state-of-the-art review: Baltimore, The Johns Hopkins University Press, p. 370-382.

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

———1986b, Descriptive model of lateritic Ni, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 252.

———1990, Development of grade and tonnage models for different deposit types [abs.]: Toronto, 8th IAGOD Symposium, Program with Abstracts, p. A99-A100.

———in press, Development of grade and tonnage models for different deposit types: Geological Association of Canada Special Paper.

Singer, D.A., and Berger, B.R., 1986, Descriptive model of Comstock epithermal veins, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 150.

Singer, D.A., and Cox, D.P., 1988, Applications of mineral deposit models to resource assessments: U.S. Geological Survey Yearbook 1987, p. 55-57.

Singer, D.A., Page, N.J., Smith, J.G., Blakely, R.J., and Johnson, M.G., 1983, Mineral resource assessment maps of the Medford 1° by 2° quadrangle, Oregon-California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1383-C, scale 1:250,000.

Snyder, W.S., Dickinson, W.R., and Silberman, M.L., 1976, Tectonic implications of space-time patterns of Cenozoic magmatism in the western United States: Earth and Planetary Science Letters, v. 32, p. 91-106

Speed, R.C., 1974, Evaporite-carbonate rocks of the Jurassic Lovelock Formation, West Humboldt Range, Nevada: Geological Society of America Bulletin, v. 85, p. 105-118.

———1976, Geologic map of the Humboldt Lopolith and surrounding terrane, Nevada: Geological Society of America, Map and Chart Series, MC-14, scale 1:81,000.

———1978, Basinal terrane of the early Mesozoic marine province of the western Great Basin, *in* Howell, D.G., and McDougall, K.A., eds., Mesozoic paleogeography of the western United States: Society of Economic Paleontologists and Mineralogists, Pacific Section, Pacific Coast Paleogeography Symposium 2, p. 237-252.

———1979, Collided Paleozoic microplate in the western United States: Journal of Geology, v. 87, p. 279-292.

Speed, R.C., and Jones, T.A., 1969, Synorogenic quartz sandstone in the Jurassic mobile belt of western Nevada—Boyer Ranch Formation: Geological Society of America Bulletin, v. 80, p. 2551-2584.

Stager, H.K., and Tingley, J.V., 1988, Tungsten deposits in Nevada: Nevada Bureau of Mines and Geology, Bulletin 105, 256 p.

Stewart, J.H., 1988, Tectonics of the Walker Lane belt, western Great Basin: Mesozoic and Cenozoic deformation in a zone of shear, *in* Ernst, W. G., ed., Metamorphism and crustal evolution of the western United States, Rubey vol. 7: Englewood Cliffs, New Jersey, Prentice-Hall, p. 683-713

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

Streckeisen, A.L., 1976, To each plutonic rock its proper name: Earth Science Reviews, v. 12, p. 1-33.

Taggert, J. E., Lindsay, J. R., Scott, B. A., Vivit, D. V., Bartel, A. J., and Stewart, K.C., 1987, Analysis of geological materials by wavelength-dispersive x-ray fluorescence spectrometry, *in* Baedecker, P.A., ed., Methods for geochemical analysis: U.S. Geological Survey Bulletin 1770-E, 19 p.

Taylor, D.G., Smith, P.L., Laws, R.A., and Guex, Jean, 1983, The stratigraphy and biofacies trends of the lower Mesozoic Gabbs and Sunrise Formations, west-central Nevada: Canadian Journal of Earth Sciences, v. 20, no. 20, p. 1598-1608.

Theodore, T.G., 1986, Descriptive model of porphyry Mo, low F, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 120.

Theodore, T.G., Orris, G.J., Hammarstrom, J.M., and Bliss, J.D., 1991, Gold-bearing skarns: U.S. Geological Survey Bulletin 1930, 61 p.

Thompson, G.A., 1956, Geology of the Virginia City quadrangle, Nevada: U.S. Geological Survey Bulletin 1042-C, p. 45-77.

Thompson, G.A., and White, D.E., 1964, Regional geology of the Steamboat Springs area, Washoe County, Nevada: U.S. Geological Survey Professional Paper 458-A, 52 p.

Turner-Peterson, C.E., and Hodges, C.A., 1986, Descriptive model of sandstone U, *in* Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 209-210.

Vanderburg, W.O., 1940, Reconnaissance of mining districts in Churchill County, Nevada: U.S. Bureau of Mines Information Circular 7093, 57 p.

Vaughn, W.W., and McCarthy, J.H., 1964, An instrumental technique for the determination of submicrogram concentrations of mercury in soils, rocks, and gas, *in* Geological Survey Research 1964: U.S. Geological Survey Professional Paper 501-D, p. D123-D127.

Vikre, P.G., 1989, Fluid-mineral relations in the Comstock Lode: Economic Geology, v. 84, p. 1574-1613.

Vikre, P. G., and McKee, E. H., 1987, New K-Ar ages of hydrothermal minerals and igneous rocks from the western Virginia Range, Washoe and Storey Counties, Nevada: Isochron/West, no. 48, p. 11-15

Vikre, P.G., McKee, E.H., and Silberman, M.L., 1988, Chronology of Miocene hydrothermal and igneous events in the western Virginia Range, Washoe, Storey, and Lyon Counties, Nevada: Economic Geology, v. 83, p. 864-874.

Wahl, R.R., and Peterson, D.L., 1976, Principal facts for gravity stations in the Carson Sink region, Nevada: U.S. Geological Survey Open-File Report, 76-344, 17 p.

Wallace, A.B., 1975, Geology and mineral deposits of the Pyramid mining district, southern Washoe County, Nevada: Reno, University of Nevada, Ph.D. dissertation, 162 p.

———1979, Possible signatures of porphyry-copper deposits in middle to late Tertiary volcanic rocks of western Nevada: Nevada Bureau of Mines and Geology Report 33, p. 69-76.

Welsch, E.P., 1983, Spectrophotometrical determination of tungsten in geological materials by complexing with dithiol: Talanta, v. 30, p. 876-878.

Wernicke, B.P., Christiansen, R.L., England, P.C., and Sonder, L.J., 1987, Tectonomagmatic evolution of Cenozoic extension in the North American Cordillera, *in* Coward, M. P., Dewey, J. F., and Hancock, P. L., eds., Continental Extensional Tectonics, Geological Society of London Special Publication No. 28, p. 203-221

Westra, Gerhard, and Keith, S.B., 1981, Classification and genesis of stockwork molybdenum deposits: Economic Geology, v. 76, p. 844-873.

White, D.E., 1968, Hydrology, activity, and heat flow of the Steamboat Springs thermal system, Washoe County, Nevada: U.S. Geological Survey Professional Paper 458-C, 109 p.

———1981, Active geothermal systems and hydrothermal ore deposits, *in* Skinner, B. J., ed., Economic Geology, Seventy-fifth Anniversary Volume: Economic Geology Publishing Co., p. 392-423.

White, D.E., Thompson, G.A., and Sandberg, C.H., 1964, Rocks, structure, and geologic history of Steamboat Springs thermal area, Washoe County, Nevada: U.S. Geological Survey Professional Paper 458-B, 63 p.

White, N.C., and Hedenquist, J.W., 1990, Epithermal environments and styles of mineralization: variations and their causes, and guidelines for exploration: Journal of Geochemical Exploration, v. 36, p. 445-474.

Whitebread, D.H., 1976, Alteration and geochemistry of Tertiary volcanic rocks in parts of the Virginia City quadrangle, Nevada: U.S. Geological Survey Professional Paper 936, 43 p.

Willden, Ronald, and Speed, R.C., 1974, Geology and mineral deposits of Churchill County, Nevada: Nevada Bureau of Mines and Geology, Bulletin 83, 95 p.

Wilson, J.R., 1963, Geology of the Yerington mine: Mining Congress Journal, v. 49, no. 5, p. 30-34.

Yeend, W.E., 1986, Descriptive model of placer Au-PGE, in Cox, D.P., and Singer, D.A., eds., Mineral Deposit Models: U.S. Geological Survey Bulletin 1693, p. 261.

Zoback, M.L., 1989, State of stress and modern deformation of the northern Basin and Range province: Journal of Geophysical Research, B, v. 94, p. 7105-7128.

TABLES 1–6

Table 1. Types of mineral deposits and occurrences in the Reno 1° by 2° quadrangle, Nevada and California

Deposit type	Reference(s)
Porphyry copper	Gustafson and Hunt (1975); Cox (1986b).
Porphyry copper alteration	Gustafson and Hunt (1975); Wallace (1979).
Low-fluorine porphyry molybdenum	Westra and Keith (1981); Mutschler and others (1981); Theodore (1986).
Copper skarn	Einaudi and others (1981); Cox and Theodore (1986).
Tungsten skarn	Einaudi and others (1981); Cox (1986d).
Iron skarn	Einaudi and others (1981); Cox (1986a).
Iron endoskarn	Einaudi and others (1981).
Polymetallic replacement	Morris (1986).
Polymetallic vein	Cox (1986c).
Adularia-sericite gold-silver	Heald and others (1987); Singer and Berger (1986).
Quartz-alunite gold	Heald and others (1987); Berger (1986a).
Hot-spring gold	Berger and Eimon (1983); Nelson (1988).
Hot-spring mercury	Rytuba (1986).
Epithermal manganese	Mosier (1986).
Simple antimony	Bliss and Orris (1986).
Sediment-hosted gold	Berger (1986c).
Volcanogenic uranium	Bagby (1986).
Sandstone uranium	Turner-Peterson and Hodges (1986).
Pegmatitic uranium	See text.
Scheelite vein	Cox and Bagby (1986).
Placer gold	Yeend (1986).
Basaltic copper	Cox (1986e).
Quartz-copper (bornite)-gold-tourmaline veins	See text.

Table 2. Characteristics of tracts containing or favorable for epithermal gold-silver deposits in the Reno 1° by 2° quadrangle,

[Criteria used for delineating tract boundaries: 1, presence of mines and prospects; 2, presence of igneous centers and (or) intrusions; 3, hydrothermal
6, published descriptions. Volcanic assemblages: IA, interior andesite-rhyolite assemblage; WA, western andesite assemblage; BM, bimodal basalt-

Tract no. (pl. 3)	District and (or) area	Delineating criteria	Age of host rocks and volcancic assemblage	Age of mineralization and(or) alteration and method or material dated
				Tracts containing adularia-sericite
21	Comstock District	1, 2, 3, 6	Miocene; WA (Kate Peak Fm.)	13.7 Ma, K-feldspar
22	Como District	1, 2, 3, 4, 6	Miocene; WA (Kate Peak Fm.)	7(?) Ma, K-feldspar
23	Olinghouse District	1, 3, 6	Miocene; BM? (Chloropagus Fm.)[1]	~13 Ma, regional relations
24	Ramsey District	1, 2, 3, 4, 5, 6	Miocene; WA (Kate Peak Fm.)	10.8 Ma, K-feldspar
24	Talapoosa District	1, 2, 3, 4, 5, 6	Miocene; WA (Kate Peak Fm.)	10.8 Ma, K-feldspar
24	Gooseberry Mine, Ramsey District.	1, 2, 3, 6	Miocene; WA (Kate Peak Fm.)	10.3 Ma, K-feldspar
25	Jessup District	1, 3, 4, 5, 6	Miocene; BM(?)	Miocene?
27	Camp Gregory/Red Mountain area.	1, 2, 3, 4, 5, 6	Miocene; BM	Miocene
28	Holy Cross District (Terrill Mountains area)	1, 3, 4, 6	Oligocene or Miocene; IA(?)	~21 Ma, regional relations
30	Southern Stillwater Range area.	1, 2, 3, 4, 5	Oligocene; IA	28-24 Ma, regional relations
31	Wonder District	1, 2, 3, 6	Oligocene or Miocene; IA	22.2–23.0 Ma, K-feldspar
32	Sand Springs District	1, 6	Oligocene or Miocene; WA(?)	19–19.5 Ma, K-feldspar
33	Fairview District	1, 2, 3, 4, 5, 6	Oligocene or Miocene; IA(?)	Oligocene or Miocene
33	Bell Mountain Mine, southern Fairview District.	1, 6	Oligocene or Miocene; IA	Miocene?
34	Rawhide Mine, Regent District.	1, 2, 3, 4, 6	Miocene; WA	15.7 Ma, K-feldspar
35	Broken Hills District	1, 6	Oligocene or Miocene; IA	Oligocene or Miocene
				Tracts containing quartz–alunite
15	Pyramid District	1, 2, 3, 6	Oligocene to Miocene; IA	21.3 Ma, sericite
16	Wedekind District	1, 2, 3, 6	Oligocene to Miocene; WA (Alta? Fm.)	16.3 Ma, alunite
16	Peavine District	1, 2, 3, 6	Miocene; WA (Alta? Fm.)	14.5–13.1 Ma, alunite
17	Northern Carson Range area.	3, 6	Miocene; WA (Kate Peak Fm.)	11.4–11.2 Ma, alunite
18	Washington Hill area	2, 3, 6	Miocene; WA (Kate Peak Fm.)	12–9 Ma, alunite, sericite
20, 21	Geiger Grade area and Comstock District.	2, 3, 6	Miocene; WA (Alta? Fm.)	17–14 Ma, alunite, sericite
22	Como District	1, 2, 3, 4, 5, 6	Miocene; WA (Kate Peak Fm.)	6 Ma, alunite
24	Ramsey District	1, 2, 3, 4, 5, 6	Miocene; WA (Kate Peak Fm.)	9.3 Ma, alunite
				Tracts containing
18	Washington Hill area	2, 3, 6	Miocene; WA (Kate Peak Fm.)	Miocene
19	Steamboat Springs District.	2, 3, 6	Micoene to Holocene; BM	~3 Ma–present, fresh rocks
20	Castle Peak District	1, 2, 3, 6	Miocene; WA (Kate Peak Fm.)	Miocene
24	Ramsey District	1, 2, 3, 4, 5	Miocene; WA (Kate Peak Fm.)	~10 Ma, regional relations
26	Desert District	1, 4, 5, 6	Miocene(?); BM(?)	Miocene(?)
27	Camp Gregory/ Red Mountain area.	1, 2, 3, 4, 5, 6	Miocene; BM	Miocene
29	Holy Cross District (Cinnabar Hill area).	1, 3, 4, 5, 6	Oligocene or Miocene; IA(?)	Miocene(?)

[1] of Axelrod (1956)

alteration detected by remote sensing studies; 4, hydrothermal alteration detected by field studies; 5, geochemistry of hydrothermally altered rocks; rhyolite assemblage]

Controlling structure(s)	Associated intrusive rocks	References
vein deposits		
NNE-striking Comstock and Occidental Faults; NW-striking Silver City Fault.	Dacite dome	Bonham (1969); Vikre (1989).
Veins trending NE andN-S along faults	Andesite and dacite intrusions	Russell (1981); J.H. Stewart (unpub. data, 1989); this report.
NE-striking faults	Felsic dikes along faults	Geasan (1980).
WNW-striking fault	Rhyolite domes	Rose (1969).
Faults striking E-W and NW	Dacite dome	Rose (1969); Nieuwenhuyse (1991).
WNW-striking fault	Rhyolite dome	Rose (1969).
Margins of rhyolite domes	Rhyolite dome	Willden and Speed (1974).
Faults striking N. 60° E. and hydrothermal breccia zones.	Rhyolite dome	Quade and Tingley (1987); this report.
NNW-trending veins along faults	Intermediate dikes and domes	Satkowski and others (1985); Quade and Tingely (1987); R.F. Hardyman, unpub. data, 1990.
E-W-trending veins along faults; low-angle normal faults.	Granodiorite stock (IXL pluton), andesite dikes, rhyolite domes.	John and Silberling (in press); John (in press).
Fault/shear zone striking N. 25° W.	Rhyolite-dacite dome	Willden and Speed (1974); Quade and Tingley (1987).
WNW-trending veins	Dacite domes	Page (1965); Willden and Speed (1974).
NW-trending veins along faults?	Dacite dome	Willden and Speed (1974); Quade and Tingley (1987).
E-W-trending vein	None known	Schrader (1947); Willden and Speed (1974).
NW-striking fault; N- to NE-trending fractures.	Rhyolite dome	Black and others (1991).
Veins trending N. 30° W. along faults	None known	Schrader (1947).
vein deposits or quartz-alunite alteration		
W- to NW-striking faults	Granodiorite stock (Guanomi stock)	Wallace (1975); Bonham (1969).
E-W and N-S trending hydrothermal breccia zones.	Quartz diorite stocks	Hudson (1977); Bonham (1969).
E-W and N-S trending hydrothermal breccia zones.	Diorite stock	Hudson (1977); Bonham (1969).
N-S and E-W to ENE striking faults	None known	Hudson (1983).
Unknown	Rhyolite dome	Vikre and others (1988); Margolis (1991).
Unknown	Davidson Granodiorite	Whitebread (1976); Vikre and others (1988).
NW-trending veins along faults	Andesite/dacite intrusions	Russell (1981); P.G. Vikre (oral commun., 1990).
Unknown	Rhyolite domes	Vikre and others (1988); Rose (1969).
hot-spring systems		
Faults striking N-S	Rhyolite dome	Bailey and Phoenix (1944); Bonham (1969).
NE-striking faults and domes	Rhyolite domes	White (1981); Silberman and others (1979).
N-S striking faults	None	Bonham, 1969.
Unknown, possibly WNW-striking faults	Dacite and rhyolite intrusions	this report.
Unknown	None known	Bailey and others (1991); this report.
NE- and NNW-striking faults	Rhyolite dome	Quade and Tingley (1987); this report.
NW-striking shear zones	Rhyolite dome	Quade and Tingley (1987).

Table 3. Geochemical anomalies detected in stream-sediment samples in the Reno 1° by 2° quadrangle, Nevada and California

[---, no deposits or commodities known to be present]

Anomaly number (fig. 13)	Location	Deposit types present	Commodities present	Geochemical anomalies
		Anomalies associated with mining districts and (or) prospects		
1	Regent District	W skarn, adularia-sericite Au-Ag.	W, Cu, Ag, Au, Au, Ag, Hg.	Sb, Ag, W, Cu; Te, Bi, La.
2	Regent District	Adularia-sericite Au-Ag	Au, Ag, Hg	Sb, As, Be.
3	Holy Cross District	Adularia-sericite Au-Ag	Au, Ag, Pb, Fe, Zn.	Sb, As, Pb.
4	Como District	Adularia-sericite Au-Ag	Ag, Au, Cu	Au, Ag, Sb.
5	Steamboat Springs and Galena Districts.	Hot-spring Hg, polymetallic vein, W skarn.	Hg, Au, Ag, Sb, Pb, Zn, Ag, Au, Cu, W.	Hg, Ag, Pb.
6	Comstock District	Adularia-sericite Au-Ag	Ag, Au, Cu, Pb, Zn, Fe	Au, Hg, As, Sb; Ag, Mo, W, Pb; Zn, Ba, Te, La.
7	Mountain Wells District	Scheelite vein, polymetallic vein, low-F porphyry Mo.	W, Mo, Ag, Cu, Pb, Bi, Mo, Sb, Mo, Ag, Pb, Bi.	As, Mo, Be, Sb; W, Cd, Zn, Bi; La.
8	IXL District (Mottini Mine).	Cu skarn	Au, Ag, Pb, Cu	As, Ag, W, Be; Cd, Zn, Ba, Ni; Bi, Sn, F, La.
9	Cox Canyon District	---	Au, Ag, Pb, Cu	As.
10	Olinghouse District	Adularia-sericite Au-Ag	Ag, Au, Cu	Au.
11	Unnamed district	Copper prospect	Cu	Co, Cr, Ni.
12	Pyramid District	Volcanogenic U	U	Be.
13	Desert District	Polymetallic vein, hot-springs Hg.	Au, Ag, Cu, Pb, Hg, Au, As.	As, Sb, Te.
14	Shady Run District (White Cloud Canyon).	Cu skarn	Fe, Cu, Au	As, Sb.
15	Peavine District	Quartz-alunite Au, porphyry Cu.	Au, Ag, Cu, Pb, Zn	Te, Pb, Zn.
		Anomalies not associated with mining districts or prospects		
16	East side of Lake Tahoe	---	---	As, Sb, Ag, Mo, W, Pb, Cd, Zn.
17	Red Rock Valley	---	---	Be.
18	West side of Pyramid Lake.	---	---	Co, Cr, Ni.
19	Southwest of Spanish Springs Peak.	---	---	Co, Cr, Ni, Zn.
20	Southeastern side of Hot Springs Mountains.	---	---	Co, Cr, Ni.
21	Dixie Valley north of IXL Canyon.	---	---	As, Ag, Be, Ni.
22	Dixie Valley, Louderback Mountains, Fairview Peak.	---	---	Be.

Table 4. Characteristics of tracts favorable for Mesozoic porphyry copper and copper and iron skarn deposits in the Reno 1° by 2° quadrangle, Nevada and California

[Criteria used to delineate tract boundaries: 1, presence of Jurassic plutons; 2, presence of carbonate rocks; 3, presence of mines and prospects; 4, hydrothermal alteration of granitic rocks; 5, hydrothermal alteration of wallrocks of granitic plutons; 6, presence of high-salinity fluid inclusions in granitic plutons. Modal classification of plutons: gr, granite; grd, granodiorite; qmd, quartz monzodiorite; qd, quartz diorite.]

Tract no. (pl. 1)	Area	Possible deposit types	Host-rock terrane	Mines and prospects	Delineating criteria	Porphyry and skarn-forming plutons	Pluton composition[1]	Pluton age and method dated	References
1	Copper Valley ------	Porphyry copper, copper and iron skarn.	Jungo --------	Copper Queen and Hard-to-Find Mines (Cu skarn).	1,2,3,4,5,6	Copper Valley pluton ------	qd-grd, SiO_2=56.9 (1) (altered).	Jurassic(?) ------	Willden and Speed (1974); Stager and Tingley (1988); John (1992).
2	Fireball Ridge------	Porphyry copper ----	Jungo --------	None ------------------------	1,4,5,6	Composite Fireball Ridge pluton.	qd-grd, SiO_2=55.4-60.4 (2).	Jurassic(?) ------	Harlan (1984); John (1992).
3	Highway 50 east of Dayton.	Iron skarn -----------	Pine Nut -----	Dayton iron deposit and Iron Blossom Prospect (Fe skarn).	1,2,3,4,5,6	Composite Iron Blossom pluton and diorite.	grd, SiO_2=64.5 (1)------	Jurassic(?) ------	Reeves and others (1958); Roylance (1966); John (1992).
4	Northern Pine Nut Mountains, Buckskin, Singatse, and Wassuk Ranges.	Porphyry copper ----	Pine Nut -----	Bear and Lagamarsino Pros-pects and MacArthur deposit (porphyry Cu).	1,3,4,6	Yerington and Shamrock batholiths.	Yerington—qmd-gr, SiO_2=58.5-69.9 (8) Shamrock—grd-gr, SiO_2=59.7-69.7 (7).	Middle Jurassic, 168-165 Ma U-Pb).	Heatwole (1978); Carten (1986); Dilles (1984, 1987); Proffett and Dilles (1984); Dilles and Wright (1988); John (1992).
5	Northern Pine Nut Mountains, Buckskin, Singatse, and Wassuk Ranges.	Copper and iron skarn.	Pine Nut -----	Fe skarn—Minnesota Iron Mine.	1,2,3,4,5,6	Yerington and Shamrock batholiths.	Yerington—qmd-gr, SiO_2=58.5-69.9 (8) Shamrock—grd-gr, SiO_2=59.7-69.7 (7).	Middle Jurassic, 168-165 Ma (U-Pb).	Knopf (1917); Reeves and others (1958); Einaudi (1977, 1982); Harris and Einaudi (1982); Dilles and Wright (1988); Proffett and Dilles (1984); John (1992).
6	Calico Hills---------	Porphyry copper, copper and iron skarn.	Sand Springs	Calico Hills and Afterthought Prospects (Fe-Cu skarn).	1,2,3,4,5,6	Afterthought pluton-------	qd-grd, SiO_2=65.0-67.7 (2).	Jurassic(?) ------	Lawrence and Redmond (1967); Satkoski and others (1985); John (1992).

[1] Modal composition using Streckeisen (1976), SiO_2 content (weight percent), and number of analyses in parentheses.

Table 5. Characteristics of tracts favorable for tungsten skarn and low-fluorine porphyry molybdenum deposits in the Reno 1°by 2°

[Criteria used to delineate tract boundaries: 1, presence of Cretaceous granitic plutons; 2, presence of carbonate rocks; 3, presence of mines and prospects; 7, aeromagnetic data; 8, hydrothermal alteration and stockwork quartz+pyrite+sericite veins. Modal classification of plutons: gr, granite; grd, granodiorite;

Tract no. (pl. 2)	Area	Host-rock terrane(s) or unit	Mines and prospects	Delineating criteria	Skarn-forming plutons
		Tracts favorable for tungsten skarn deposits			
7	Nightingale District	Marble Butte rocks, Jungo.	Crosby and Jay Bird Mines.	1, 2, 3, 4, 5, 6	Coyote Canyon pluton and composite Jay Bird pluton.
8	Toy District ---------	Jungo ----------------	St. Anthony and Granite Mines.	1, 2, 3, 4, 5, 6	St. Anthony pluton ------
9	Churchill Butte -----	Pine Nut -------------	Ruth Mine ----------	1, 2, 3, 4, 5, 6	Churchill Butte pluton --
10	Northern Pine Nut Mountains.	Pine Nut -------------	Valley View and Tactite Thursday Prospects.	1, 2, 3, 4, 6	Prison Hill pluton --------
11	Sand Springs Range–Fairview Peak.	Sand Springs, Paradise.	Nevada Scheelite, Red Ant, Red Top, and Slate Mines.	1, 2, 3, 4, 5, 6, 7	Composite Sand Springs pluton; Scheelite pluton; Slate Mountain pluton.
		Tract favorable for low-fluorine porphyry molybdenum deposit			
12	Sand Springs Range	Sand Springs pluton.	None ----------------	1, 5, 8	Sand Springs pluton -----

[1]Modal composition using Streckeisen (1976), SiO_2 content (weight percent), and number of analyses given in parentheses.

Table 6. Characteristics of tracts favorable for Tertiary polymetallic replacement, zinc-lead skarn, and copper skarn

[Criteria used to delineate tract boundaries: 1, presence of Tertiary plutons; 2, presence of carbonate rocks; 3, presence of mines and prospects; classification of plutons: gr, granite; grd, granodiorite; qmd, quartz monzodiorite. Rb-Sr ages from A.C. Robinson (written commun.,

Tract no. (pl. 2)	Area	Host-rock terrane	Mines and prospects	Delineating criteria	Polymetallic replacement and skarn-forming plutons
13	Stillwater Range -------	Jungo ----------	Copperaid and Mottini Mines.	1, 2, 3, 4, 5	White Cloud Canyon and IXL plutons.
14	Chalk Mountain-Westgate.	Paradise -------	Chalk Mountain and West Side Mines.	1, 2, 3, 4	Composite Chalk Mountain pluton.

[1]Modal composition using Streckeisen (1976), SiO_2 content (weight percent), and number of analyses in parentheses.

quadrangle, Nevada and California

4, presence of skarn alteration in carbonate rocks; 5, rock geochemistry; 6, absence of high-salinity fluid inclusions in granitic plutons; t, tonalite; qd, quartz diorite. Rb-Sr ages from A.C. Robinson (written commun., 1988).]

Pluton composition [1]	Pluton age	References
Tracts favorable for tungsten skarn deposits—Continued		
Coyote Canyon—gr, SiO_2= 71.3 - 71.6 (3); Jay Bird—t-gr, SiO_2=62.6 - 76.2 (3).	Coyote Canyon—approx. 112 Ma (Rb-Sr); Jay Bird—approx. 126 Ma (Rb-Sr).	Stager and Tingley (1988); Bonham (1969); John (1992).
gr, SiO_2=70.0 - 70.1 (2)	approx. 87 Ma (Rb-Sr)	Stager and Tingley (1988); Willden and Speed (1974); John (1992).
grd, SiO_2=64.9 - 67.2 (2)	Cretaceous(?)	Stager and Tingley (1988); Moore (1969); John (1992).
grd, SiO_2=67.2 - 68.7 (2)	Cretaceous(?)	Stager and Tingley (1988); John (1992).
Sand Springs—gr-grd, SiO_2= 65.3 - 73.8 (8) Scheelite—grd, SiO_2= 65.1 - 67.7 (2) Slate Mountain—gr, SiO_2=72.7 - 73.6 (2).	Sand Springs—81.5-78 Ma (K-Ar), 82-81 Ma (Rb-Sr); Scheelite—approx. 98 Ma (Rb-Sr); Slate Mountain—approx. 81 Ma (Rb-Sr).	Stager and Tingley (1988); Willden and Speed (1974); Quade and Tingley (1987); Lee (1984); John (1992).
Tract favorable for low-fluorine porphyry molybdenum deposit—Continued		
gr-grd, SiO_2=65.3 - 73.8 (8)	81.5-78 Ma (K-Ar), 82-81 Ma (Rb-Sr).	Nevada Bureau of Mines and Geology (1964); Willden and Speed (1974); Lee (1984); Quade and Tingley (1987); John (1992).

deposits in the Reno 1° by 2° quadrangle, Nevada and California

4, metasomatic alteration of wallrocks of granitic plutons; 5, presence of high-salinity fluid inclusions in granitic plutons. Modal 1988)]

Pluton composition [1]	Pluton age and dating method	References
White Cloud Canyon—gr, SiO_2 = 74.2 to 77.0 (4); IXL—qmd-grd, SiO_2 = 63.1 to 68.6 (8).	White Cloud Canyon—approx. 30 Ma (Rb-Sr); IXL—29-28 Ma (K-Ar).	Vanderburg (1940); Willden and Speed (1974); Nelson (1975); Lee (1984); John (1992).
gr-grd, SiO_2 = 69.5 to 73.2 (3)-------	26 Ma (K-Ar)----------------	Vanderburg (1940); Bryan (1972); Willden and Speed (1974); S.B. Keith (written commun., 1990); John (1992).