U.S. GEOLOGICAL SURVEY CIRCULAR 1078

The Conterminous United States Mineral Assessment Program: Information to Accompany Folio of Geologic, Geochemical, Geophysical, and Mineral Resources Maps of the Reno 1° by 2° Quadrangle, Nevada and California

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The Conterminous United States Mineral Assessment Program: Information to Accompany Folio of Geologic, Geochemical, Geophysical, and Mineral Resources Maps of the Reno 1° by 2° Quadrangle, Nevada and California

By DAVID A. JOHN, JOHN H. STEWART,
JOHN D. HENDRICKS, LARRY C. ROWAN, and
DONALD PLOUFF

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By David A. John, John H. Stewart, John D. Hendricks, Larry C. Rowan, *and* Donald Plouff

Abstract

The Reno 1° by 2° quadrangle in west-central Nevada was studied by an interdisciplinary research team to appraise its mineral resources. The assessment is based on geological, geochemical, and geophysical field and laboratory investigations, the results of which are published as a folio of maps, reports, figures, and tables, with accompanying discussions. This circular provides background information on the investigations and integrates the information presented in the folio. The selected bibliography lists references to the geology, geochemistry, geophysics, and mineral deposits of the Reno 1° by 2° quadrangle.

INTRODUCTION

This circular, as well as separately published maps and reports, is part of a series of U.S. Geological Survey reports that present information about the mineral resource potential of the conterminous United States. These reports were compiled under the Conterminous United States Mineral Assessment Program (CUSMAP). CUSMAP is intended to provide mineral resource assessment information to assist in the formulation of a long-range national minerals policy and to assist Federal, State, and local governments in their land-use planning. The products of CUSMAP also are intended to increase geological, geochemical, and geophysical knowledge of the conterminous United States. Consequently, CUSMAP provides a regional geologic, geochemical, geophysical, and mineral resource framework for mineral exploration and for more specific studies such as resource appraisals of U.S. Forest Service and U.S. Bureau of Land Management Wilderness Study Areas.

Manuscript approved for publication, December 30, 1991.

Location and Geography

The Reno 1° by 2° quadrangle encompasses about 19,000 km^2 between latitudes 39° and 40° north and longitudes 118° and 120° west 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 northwestern edge of the quadrangle lying in eastern California. Most of the quadrangle is located in the Basin and Range physiographic province, an area of alternating north-northeast- to north-northwest-trending mountain ranges and valleys formed by late Cenozoic faulting; the west edge of the quadrangle lies in the Sierra Nevada physiographic province, an area of high mountainous terrain. Carson Sink and Carson Lake, remnants of Pleistocene Lake Lahontan, form much of the east half of the quadrangle. Elevations range from 10,776 ft at the summit of Mt. Rose to about 3,360 ft on the floor of Dixie Valley.

The Reno quadrangle includes parts of 10 counties: Churchill, which forms more than 50 percent of the quadrangle; Carson City, Douglas, Lyon, Mineral, Nye, Storey, and Washoe Counties in Nevada; and Lassen and Sierra Counties in California. Reno, Sparks, Carson City, and Fallon are the major cities in the quadrangle and contain most of the population. Smaller population centers include Dayton, Fernley, Genoa, Hazen, Incline Village, Nixon, Silver Springs, Verdi, Virginia City, Wabuska, and Wadsworth. Most of the rest of the quadrangle is very sparsely populated.

Major highways in the Reno quadrangle are: Interstate 80, which runs east-west across the central and northern parts of the quadrangle; U.S. Highway 50, which runs east-west across the central and southern parts of the quadrangle; and U.S. Highways 395, 95, and Alternate 95, which run north-south through the western and central parts of the quadrangle (fig. 1). Numerous state and county roads (both paved and improved gravel)

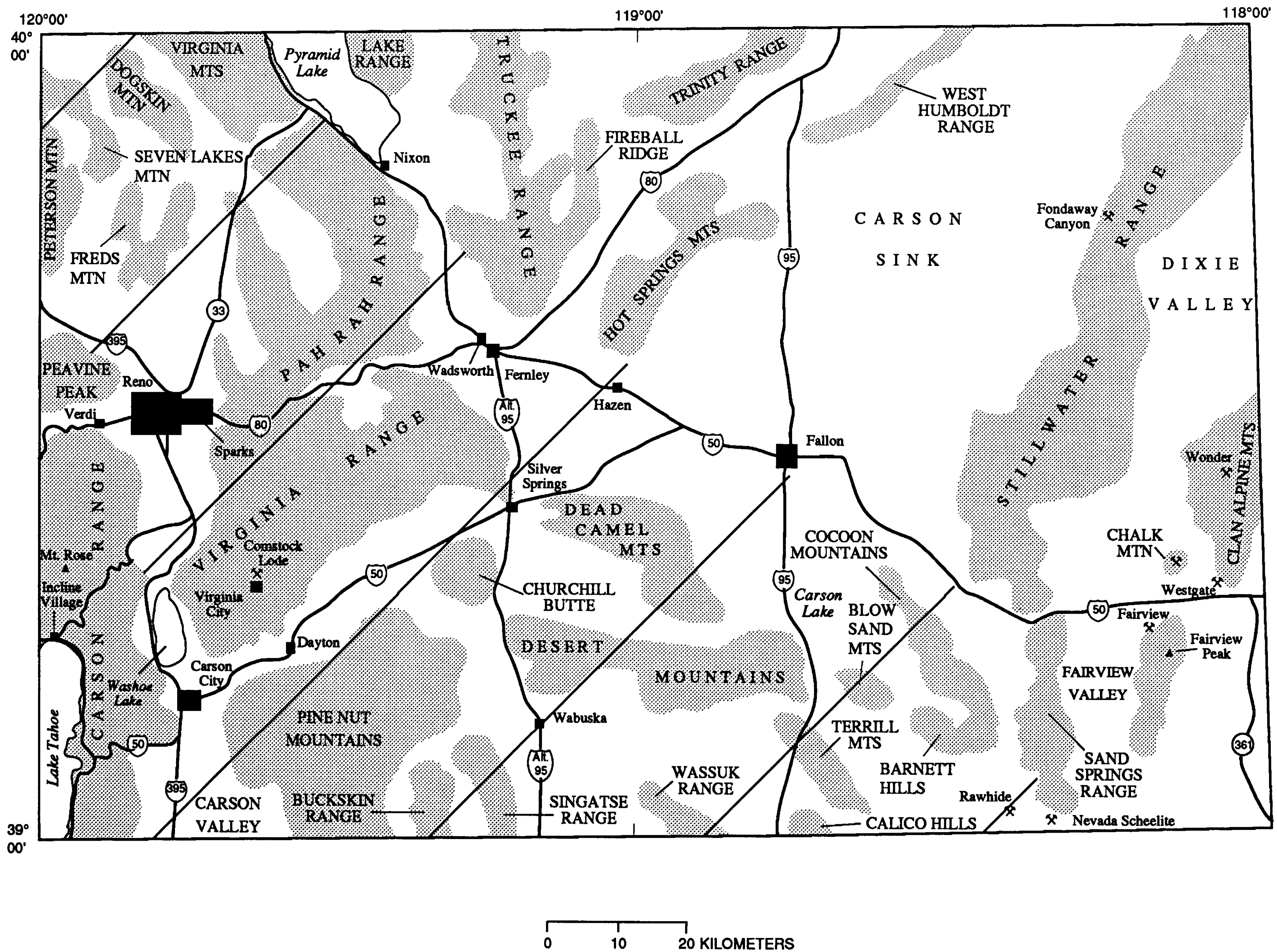

Figure 1. Index map showing major geographic and physiographic features in the Reno 1° by 2° quadrangle and locations of roads and major mines (mine symbols). Diagonal lines show Walker Lane belt as depicted by Stewart (1988).

are present in the western half of the quadrangle, but relatively few roads are present throughout much of the eastern third of the quadrangle.

Internal drainage characterizes the Reno quadrangle. Major rivers are the Truckee River, which flows out of Lake Tahoe, through Reno, and into Pyramid Lake; the Carson River, which flows from the southwest edge of the quadrangle into Carson Sink; and the Walker River, which flows through the south-central part of the quadrangle into Walker Lake south of the Reno quadrangle. Most other streams are ephemeral. Major lakes include Pyramid Lake, Lake Tahoe, Washoe Lake, and Lahontan Reservoir.

Much of the area of the Reno quadrangle is public land that is administered by numerous Federal and State agencies. Lands near the west edge of the quadrangle are part of Toiyabe National Forest, which includes the Mt. Rose Wilderness Area, established by 1989 Nevada Wilderness Act. The Bureau of Land Management (BLM) administers much of the rest of the quadrangle, and parts of three BLM Wilderness Study Areas are located in the eastern part of the quadrangle (Clan Alpine Mountains, Job Peak, Stillwater Range). The northern part of the Walker River Indian Reservation and the southern end of the Pyramid Lake Indian Reservation are located in the south-central and north-central parts of the quadrangle, respectively. The Fallon and Stillwater National Wildlife Refuges are located on the north and south sides of Carson Sink, respectively. Several U.S. Navy bombing ranges are located in the eastern half of the quadrangle. Nevada state parks include lands around Lake Tahoe, Washoe Lake, and Lahontan Reservoir.

Previous Work

Geologic studies in the Reno quadrangle date from the discovery of the Comstock Lode in 1859 and the 40th Parallel Survey in the 1860s (Richtofen, 1866; King, 1870, 1878). The "Selected References" list many of the earlier studies.

Most early studies of the geology of the Reno quadrangle focused on mineral deposits, primarily the Comstock Lode. Early studies of the Comstock Lode include Richtofen (1866), King (1870), Becker (1882a, b), Reid (1905), Bastin (1922), Lincoln (1923), Gianella (1936), Coats (1940), Calkins (1944), and Calkins and Thayer (1945). Detailed studies of the regional geology around the Comstock Lode were conducted by the U.S. Geological Survey in the 1950s and 1960s, and the results of these studies include Thompson (1956), Cornwall and others (1967), and Whitebread (1976). Recent detailed studies of the Comstock Lode include Vikre (1989), Vikre and McKee (1987), Vikre and others (1988), Criss and others (1989), Hudson (1986), and Hudson and Smith (1991).

County reports published by the Nevada Bureau of Mines and Geology 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) provide much of the geologic and mineral-deposit framework for the present study. Geologic maps in these reports were used to compile a preliminary geologic map and to evaluate the need for new geologic mapping.

In addition to the county reports, previous regional geologic and mineral deposit studies in the Reno quadrangle include Russell (1885), Hill (1911), Vanderburg (1940), Bailey and Phoenix (1944), Schrader (1947), Lawrence (1963), Morrison (1964), Southern Pacific Company (1964), Silberman and others (1976), Hurley and others (1982), Bell (1984), Oldow (1984), Deino (1985), Sidder (1986, 1987), Quade and Tingley (1987), Stewart (1988), Stager and Tingley (1988), Cox and others (1991), Seedorff (1991), Schweickert and others (in press), and Doebrich and others (1991, in press). Regional geophysical studies include Thompson and Sandberg (1958), Thompson (1959), Erwin (1970), Stanley and others (1976), Nevada Bureau of Mines (1977), Erwin and Berg (1977), Schaefer (1983), Tabor and others (1983), Kucks and Hildenbrand (1987), Hildenbrand and Kucks (1988), and Blakely and Jachens (1991). Bennett (1980) presents a regional stream-sediment geochemistry survey. Mineral occurrences on the Walker River and Pyramid Indian Reservations are described by Satkoski and others (1985) and Satkoski and Berg (1982), respectively.

Numerous geologic and geophysical studies of the structure and extensional history of Dixie Valley have been published subsequent to the 1954 earthquakes. These studies include Byerly (1956), Slemmons (1956, 1957), Thompson and others (1967), Thompson and Burke (1973, 1974), Anderson and others (1983), Okaya and Thompson (1985), Bell and Katzer (1987, 1990), and Schaefer (1988).

There have been numerous studies of mining districts and mineral deposits in the Reno quadrangle in addition to studies of the Comstock Lode. The Yerington district is the most well described district. Studies of the Yerington district include Knopf (1918), Wilson (1963), Proffett (1977), Proffett and Proffett (1976), Proffett and Dilles (1984), Heatwole (1978), Dilles (1984, 1987), Dilles and others (in press), Carten (1986), Harris and Einaudi (1982), Einaudi (1977, 1982), Battles (1991), and Doebrich and others (in press). Reeves and Kral (1955) describe iron deposits in the Buena Vista Hills, and Reeves and others (1958), Roylance (1966), Lawrence and Redmond (1967), and Doebrich and others (in press) describe other iron deposits in the quadrangle. The Rawhide deposit is described by Black and others (1991). The Talapoosa deposit is described by Nieuwenhuyse (1991). Geason (1980) describes the Olinghouse district. Wallace (1975, 1979) describes the Pyramid district. Hudson (1977) describes mineral deposits in the Peavine and Wedekind districts. Harlan (1984) describes mineralization on Fireball Ridge. Russell (1981) describes the Como district. Bryan (1972) describes mineral deposits in the Chalk Mountain and Westgate districts.

Studies of uranium resources include Garside (1973), Hutton (1978), Benhem (1982), and Hurley and others (1982). Geothermal resources are described by Garside and Schilling (1979) and Hess and Garside (1990). Oil and gas exploration in Carson Sink is described by Hastings (1979). Industrial minerals are described by Archbold (1969), Papke (1969), and Castor (1989, 1990).

Present Study

The maps and interpretations included in the CUSMAP folio of the Reno 1° by 2° quadrangle are the product of several multidisciplinary studies, mostly conducted during 1986–1990. Work undertaken as part of the Reno CUSMAP 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 (Plouff, in press) and aeromagnetic (Hendricks, in press) maps, compilation of well log data showing depth to bedrock (G.B. Sidder, unpub. data, 1987), construction of interpretative gravity and aeromagnetic maps that show depth to pre-Tertiary basement, depth to magnetic sources, and edges of magnetic bodies (Blakely and Jachens, 1990, 1991; D.A. Ponce, unpub. data, 1991), compilation of remote sensing maps showing distribution of hydrothermal alteration and lineaments (Rowan and others, in press), characterization of mines and prospects (John and Sherlock, 1991), K-Ar and Rb-Sr geochronology (John and McKee, 1991; John, Stewart, and others, in press; E.H. McKee, unpub. data, 1991), geochemical sampling of mines, prospects, and hydrothermally altered areas (D.A. John and J.E. Kilburn, unpub. data, 1990), geochemical analyses of regional stream-sediment samples collected by the National Uranium Resource Evaluation (NURE) program in the late 1970s (Kilburn and others, 1990), geochemical studies of granitic rocks (John, Schweickert, and Robinson, in press), and paleomagnetic studies (Hudson and Geissman, 1991; M.R. Hudson and D.A. John, unpub. data, 1990). Summaries of the geology and mineral resources in the Reno quadrangle are given in John, Stewart, and others (in press). Several of the studies were done as part of or in conjunction with the Nevada State Mineral Assessment undertaken by the U.S. Geological Survey and the Nevada Bureau of Mines and Geology (Cox and others, 1990, 1991) and the U.S. Geological Survey Reno Field Office Centerpiece Project (Schweickert and others, in press; Doebrich and others, in press).

Results of the Reno 1° by 2° quadrangle CUSMAP project are presented in a series of U.S. Geological Survey Miscellaneous Field Studies Maps and a Bulletin listed in table 1. Other maps and reports related to the project are indicated by asterisks in the "Selected References" at the end of this report.

GEOLOGIC MAP (MF–2154–A)

The geologic map of the Reno 1° by 2° quadrangle is a compilation of existing maps supplemented with new information from geologic mapping conducted during the course of the project. New mapping was concentrated in the southern part of the Reno quadrangle, compiled at 1:62,500- and 1:24,000-scale, and generalized for the compilation at 1:250,000. Sources of data for the geologic map of the Reno quadrangle are shown on the published 1:250,000-scale map (Greene and others, 1991).

Rocks in the Reno quadrangle consist of Triassic and Jurassic (perhaps locally Paleozoic) metasedimentary, metavolcanic, and gabbroic rocks; Jurassic and Cretaceous granitic rocks; and Cenozoic volcanic, granitic, and sedimentary rocks. Triassic and Jurassic metasedimentary, metavolcanic, and gabbroic rocks are widely distributed in the quadrangle, but in most areas are present in relatively small outcrops. These rocks are assigned to several major allochthons or tectonostratigraphic terranes previously established in western Nevada (Oldow, 1984; Silberling and others, 1987; Silberling, 1991). Distinction between these terranes is based on different lithic sequences and (or) tectonic characteristics. The boundaries between these terranes are considered to be major tectonic zones, along which major tectonic transport has occurred or is likely to have occurred. The Jungo terrane is the most widespread terrane and underlies much of the northeast part of the Reno quadrangle (Silberling, 1991). 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. Structurally overlying the marine sedimentary sequence are Middle Jurassic mafic igneous rocks and gabbroic complexes that form a large part of the Jungo terrane. Local quartzite and subordinate limestone and conglomerate occur conformably or structurally above other sedimentary rocks of the Jungo terrane or are intruded by the gabbroic complexes of the terrane. The Paradise terrane is exposed only in the southeastern part of the Reno quadrangle, where it consists of Upper Triassic to Lower Jurassic platform carbonate rocks and shallow-water fine-

Table 1. Contents of the Reno 1° by 2° CUSMAP folio

MF–2154–A	Geologic map, by Robert C. Greene, John H. Stewart, David A. John, Richard F. Hardyman, Norman J. Silberling, and Martin L. Sorensen.
MF–2154–B	Mines and prospects map, by David A. John and Maureen G. Sherlock.
MF–2154–C	Aeromagnetic map, by John D. Hendricks.
MF–2154–D	Hydrothermal alteration map, by Larry C. Rowan, Barbara A. Eiswerth, David B. Smith, William J. Ehmann, and Timothy L. Bowers.
MF–2154–E	Gravity maps, by Donald Plouff.
USGS Bulletin 2019	Geology and mineral resource assessment, by David A. John, John H. Stewart, James E. Kilburn, Norman J. Silberling, and Larry C. Rowan.

grained clastic rocks in strong contrast to the basinal clastic rocks of the Jungo terrane. The Sand Springs terrane crops out in the southeastern part of the Reno quadrangle and is characterized by ubiquitous volcanoclastic rocks and a complex, partly metamorphic, history. The sparse fossils in the Sand Springs terrane are of Late Triassic and Early Jurassic age. The Pine Nut terrane, predominantly a magmatic arc terrane, crops out in the southwestern part of the Reno quadrangle and consists of four major units (1) Middle and (or) Upper Triassic volcanic rocks, (2) Upper Triassic limestone and interstratified volcanogenic rocks, (3) uppermost Triassic and Lower Jurassic siltstone, tuffaceous sandstone, thin-bedded limestone, and argillite, and (4) Middle Jurassic and possibly younger volcanic rocks. Orthoquartzite, locally associated with gypsum, is present in places between unit 3 and unit 4. Other metasedimentary and metavolcanic rocks in the quadrangle are not easily assigned to any named terrane. The most important of these may be the complexly deformed marbles in the northwest part of the quadrangle (near Marble Butte) that cannot be correlated with any other lower Mesozoic succession and could be late Paleozoic in age. Mesozoic rocks of the Reno quadrangle have undergone several phases of folding and thrusting. An important, but unexposed transpressional Mesozoic fault—the Pine Nut fault—was proposed by Oldow (1984) to extend through the Reno quadrangle and to bound the Pine Nut terrane on the east.

Mesozoic granitoids are widespread in the Reno quadrangle and can be divided into two groups, Middle Jurassic and Cretaceous, on the basis of age and composition. Middle Jurassic granitoids crop out along the southern edge of the quadrangle, and small plutons of possible Jurassic age are present elsewhere in the quadrangle. The Middle Jurassic granitoids and comagmatic volcanic rocks in the southern part of the quadrangle represent the northern part of a Jurassic (ca. 172–165 Ma) magmatic arc that is extensively exposed and well described farther south in the adjacent Walker Lake quadrangle (Dilles, 1987; Dilles and Wright, 1988; Proffett and Dilles, 1984). The granitoid rocks range in composition from diorite to granite, although the largest exposures are primarily granodiorite and granite. The Jurassic igneous rocks form a high-potassium calc-alkaline series typical of island arcs.

Cretaceous granitoids (approximately 105 to 80 Ma) crop out extensively in the western part of the Reno quadrangle and constitute the eastern edge of the Sierra Nevada batholith. They also are present in smaller exposures in other parts of the quadrangle. In general, the Cretaceous granitoids are granite and granodiorite and more silica-rich than the Middle Jurassic granitoids. In contrast to Jurassic and Tertiary plutonic rocks in the Reno quadrangle, coeval volcanic rocks are absent in the vicinity of Cretaceous plutonic rocks, suggesting deeper exposure levels for the Cretaceous rocks than either the Jurassic or Tertiary plutonic rocks.

A complex sequence of Cenozoic volcanic, shallow intrusive, and sedimentary rocks rests unconformably on Mesozoic granitoid and metamorphic rocks in the Reno quadrangle. 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 (Christiansen and Yeats, in press; Cox and others, 1990). 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, (2) a western andesite assemblage consisting of andesitic and dacitic lava flows, and (3) a bimodal basalt-rhyolite assemblage and associated sedimentary rocks.

The interior andesite-rhyolite assemblage (31–20 Ma) of widespread silicic ash-flow tuffs and related rocks is exposed in scattered outcrops throughout much of the Reno quadrangle. The assemblage commonly consists of sequences as thick as 800 m composed of several different ash-flow units, each one of which is an outflow sheet from a single eruptive event. Intracaldera accumulations of ash-flow tuff in the eastern part of the Reno quadrangle locally are as thick as 3 km. Small granitic plutons associated with the interior andesite-rhyolite assemblage are scattered across the quadrangle, most notably in the Stillwater and Pah-Rah Ranges.

The western andesite assemblage (20 to 12 Ma) is exposed in a west-northwest-trending belt of outcrops across the southern part of the Reno quadrangle. These rocks consist mainly of andesitic and dacitic lava flows and laharic breccias, locally as thick as 1,500 m, that were erupted from several large and many small volcanic centers. These rocks are a part of an elongate north-south trending belt of magmatic-arc rocks in the western United States and are related to the early development of the Cascade magmatic arc.

The bimodal basalt-rhyolite assemblage and associated sedimentary rocks (16 Ma to present day) are widely distributed in the Reno quadrangle. Much of the assemblage consists of widespread sequences, as thick as 1,000 m, of basalt and andesite. Rhyolitic and dacitic flows and shallow intrusive rocks are in two structural belts and are associated with major volcanic centers. Lacustrine and fluvial sedimentary deposits ranging in age from 16 to 6 Ma are widespread in the quadrangle. They intertongue extensively with volcanic rocks of the basalt-rhyolite assemblage as well as with volcanic rocks of the partly coeval western andesite assemblage. Alluvial valley fill, probably mostly younger than 6 Ma, and lacustrine deposits of Pleistocene Lake Lahontan cover large parts of the Reno quadrangle.

The Cenozoic tectonic history of the Reno quadrangle is dominated by extensional and strike-slip structures. An early phase (19 to 12 Ma) of extension in the southern part of the quadrangle is characterized by closely spaced (1 to 2 km) normal faults that originally were steeply dipping but have subsequently been rotated to a nearly horizontal position during continued extension (Proffett, 1977). The amount of extension during this phase is estimated locally to be more than 100 percent (Proffett, 1977). Possibly overlapping with the time of this early extension, but mainly following it, numerous widespread sedimentary basins developed in the Reno quadrangle. These basins appear to be related to extensional events, but perhaps not of the same deformational style as older events. Starting perhaps at about 6 Ma the deformational style changed again, and the present-day structural pattern consisting of large basin-range blocks developed. This style of deformation continues to the present day (Bell, 1984; Bell and Katzer, 1990).

The western part of the Reno quadrangle lies within the Walker Lane belt, a northwest-trending structural zone about 700 km long and 100–300 km wide that is characterized by northwest-trending right-lateral faults and northeast-trending left-lateral faults (fig. 1; Stewart, 1988). Both right-lateral and left-lateral faults are present in the Reno quadrangle. Strike-slip movement is thought to have occurred at various times throughout the late Cenozoic, and the youngest movement on these structures in the Reno quadrangle is historic (Bell, 1984).

MINES AND PROSPECTS MAP (MF–2154–B)

The mines and prospects map shows locations of approximately 400 mines and prospects in the Reno quadrangle that contain metallic mineral commodities and fluorite. The scale of the map is 1:250,000, although larger scale (1:62,500) inset maps of the Pyramid, Comstock, Wonder, and Fairview districts are included to help identify mines and prospects in these districts. Symbols identifying mineral deposit types are shown on the map for about three-fourths of the numbered localities.

The principal data sources used for the map and accompanying tables are records contained in the U.S. Geological Survey Mineral Resource Data System (MRDS) and in county reports for Churchill (Willden and Speed, 1974), Lyon, Douglas, and Ormsby (Carson City) (Moore, 1969), Mineral (Ross, 1961), Northern Nye (Kleinhampl and Ziony, 1984, 1985), and Washoe and Storey (Bonham, 1969) Counties, and in new data acquired during field studies conducted as part of the Reno CUSMAP. Other commonly used data sources include Reeves and others (1958), Garside (1973), Hurley and others (1982), Quade and Tingley (1987), and Stager and Tingley (1988). Data found in these references were supplemented by field investigations and geochemical sampling of several mines and prospects and many additional references cited in the county reports and MRDS files (see Sidder (1986, 1987) and John, Stewart, and others (in press) for comprehensive bibliographies). About 30 localities were added to the MRDS files and are shown on the map.

Tables accompanying the map contain additional information about each occurrence. Information in the tables includes name, MRDS record number, geographic coordinates, names of 15′ and 7 ½′ quadrangles and mining district where the occurrence is located, principal commodities present, and where possible, deposit type. Deposit types generally follow the deposit models of Cox and Singer (1986) and are assigned to about 300 mines and prospects where data permitted. About 20 deposit types are identified in the Reno quadrangle and are listed in an accompanying table.

Major deposit types include adularia-sericite gold-silver, quartz-alunite gold, porphyry copper, copper, iron, and tungsten skarn, hot-spring mercury, polymetallic vein and replacement, and sediment-hosted gold. Adularia-sericite gold-silver deposits hosted by Tertiary volcanic rocks are present in 14 districts scattered throughout most of the quadrangle and include the Comstock Lode and Rawhide deposits. Quartz-alunite gold deposits are present in the Wedekind district just north of Reno. Porphyry copper and copper and iron skarn deposits are associated with the Middle Jurassic Yerington batholith along the south-central edge of the quadrangle. Iron endoskarn (volcanic-hosted magnetite) deposits are associated with the Humboldt lopolith in the northeast corner of the quadrangle. Tungsten skarn deposits associated with Cretaceous granitoids are scattered throughout much of the quadrangle and include the Nevada Scheelite deposit at the south end of the Sand Springs Range. Hot spring mercury deposits include Steamboat Springs located just south of Reno. Polymetallic replacement deposits are present at Chalk Mountain. Small polymetallic vein occurrences are scattered throughout the quadrangle. The Fondaway Canyon deposit in the northern Stillwater Range is the only known sediment-hosted gold deposit.

AEROMAGNETIC MAP (MF–2154–C)

Data for the aeromagnetic map of the Reno quadrangle were abstracted from a compilation of the State of Nevada by Kucks and Hildenbrand (1987). In this compilation, readings collected at different times, flight line spacings, and elevations were adjusted in order to simulate a "draped" survey, 305 m above ground. The aeromagnetic map of the Reno quadrangle was contoured at an interval of 50 nanoteslas (nT).

Magnetically, the Reno quadrangle is bisected along a northwest-trending line that extends from approximately the southeast corner of the map area to near the northwest corner. The northeast part of the quadrangle is in the Basin and Range physiographic province (fig. 1); here the topographic and dominant structural grain trends north-northeast, reflecting late Tertiary tectonic development. This Tertiary structural grain is superimposed on a subordinate and older (Mesozoic) northwest-trending structural grain. The magnetic fabric in the northeast region reflects both of these trends. In general the ranges contain shallow magnetic sources and are characterized by relatively short-wavelength anomalies whereas the basins display broad, low-amplitude anomalies, reflecting the greater depth to source. Northwest-trending magnetic ridges and troughs reflect Mesozoic lithologies; ridges are located over areas in which the pre-Tertiary basement is composed of granitic to gabbroic intrusive rocks while troughs occur over areas of pre-Tertiary metamorphic basement. A portion of the Humboldt lopolith occupies the extreme northeast corner of the quadrangle; magnetic anomalies here reflect the mafic nature of the igneous complex and related iron skarn deposits. A series of circular negative anomalies in the east-central and southeast parts of the quadrangle may be related to Tertiary calderas, although the source locations in some cases are problematical.

The majority of the southwestern half of the quadrangle occupies part of the Walker Lane belt; only the extreme southwest corner of the quadrangle (Lake Tahoe and Carson Range) is in the Sierra Nevada physiographic province (fig. 1). The magnetic character in the Walker Lane belt reflects the structural orientation; west-northwest-trending magnetic ridges and troughs and alignment of isolated highs typify the region. This magnetic grain results from a combination of structurally controlled topography, emplacement of plutonic rocks, and (or) juxtaposition of rocks of differing magnetizations along transcurrent faults. As in the northeast part of the quadrangle, magnetic highs and ridges in the Walker Lane belt appear to correspond to areas where basement is predominantly granitoid rocks. Magnetic troughs correlate with metamorphic basement. In the west and northwest parts of the quadrangle are a number of isolated magnetic highs flanked on the east and west sides by lows. The magnetic lows are not a result of depolarization in the inclined magnetic field, but appear instead to correspond to north-trending Basin and Range normal faults, suggesting hydrothermal alteration along the faults. Three distinct, circular magnetic lows occur in the central, north-central, and northwestern parts of the quadrangle. These lows do not have an obvious source exposed at the surface and may represent shallow (<1 km) negatively polarized plutons, probably of intermediate composition.

Fifty-five oriented core samples were collected for analysis of magnetic properties during this study. Magnetic susceptibility values ranged from a high of $3{,}014 \times 10^{-6}$ emu (electromagnetic units) on a granite in the southern Virginia Range to a low of 26×10^{-6} emu on a sample of altered diorite in the Desert Mountains. Generally, unaltered granitoids, basalts, and andesites gave the highest susceptibility values; rhyolites, altered diorites, dacites, and metamorphic rocks yielded the lowest values.

HYDROTHERMAL ALTERATION MAP (MF–2154–D)

Analyses of satellite and airborne images are used in mineral resource studies to map hydrothermally altered rocks and, in some areas, structural features. The distribution of hydrothermally altered rocks is particularly important, because these rocks form where the original rocks are altered by acid solutions that are formed from sulfide minerals. The visible- and near-infrared-wavelength bands of the Landsat Thematic Mapper (TM) are sensitive to absorption features that are present in reflectance spectra of hydrothermal alteration minerals.

A map showing the distribution of hydrothermally altered rocks in the Reno quadrangle was prepared by (1) delineating areas in digitally processed TM images that exhibit the combination of ferric-iron- and hydroxyl- or carbonate-absorption features and (2) evaluating the rocks in these areas in the field and laboratory to verify the presence of hydrothermally altered rocks. The image processing procedure consisted of selecting the TM bands that are most sensitive to the absorption features, producing ratio images of these bands, and making color composites of the ratio images. Because these absorption features are not unique to hydrothermally altered rocks, field evaluation was necessary.

Analysis of color-ratio composite images of the Reno quadrangle resulted in delineation of 829 areas of potentially hydrothermally altered rocks. Approximately

95 percent of the total area occupied by these areas was evaluated in the field. Samples were collected in most of the evaluated areas and analyzed in the laboratory to identify geochemical anomalies and to describe the alteration mineralogy. Approximately 88 percent of the area encompassed by the 829 mapped areas consists of hydrothermally altered rocks. Geochemical analyses indicate that about 19 percent of the altered areas are geochemically anomalous in at least one of the 17 elements analyzed.

The largest areas consisting of hydrothermally altered rocks, which are located in the western part of the quadrangle, include the Peavine/Wedekind, Olinghouse, and Pyramid mining districts. In the eastern part of the quadrangle, the largest areas are located in the southern Stillwater Range, northern and southern Sand Springs Range, near Fairview Peak, and the Westgate area. Some areas of hydrothermally altered rocks were not delineated in the TM images due to dense vegetation cover that precluded observation of the ground.

Determinations of the alteration mineralogy resulted in identification of 24 minerals. In general, the dominant minerals are hematite, geothite, jarosite, kaolinite, pyrophyllite, alunite, chlorite, and varying proportions of illite/smectite. Most of the geochemically anomalous samples are located in mining areas. However, some anomalies, including anomalously high gold values, occur where no mines or prospects are documented.

Areas mapped in the TM images that proved to be unaltered consist of zeolitic tuffs, sedimentary and metasedimentary rocks containing phyllosilicate and (or) carbonate minerals, glassy volcanic rocks, and dry grass±soil.

GRAVITY MAPS (MF–2154–E)

Interpretation of gravity maps is a standard geophysical technique to estimate the distribution of underlying rocks. A total of 426 gravity stations were established in 1987 and 1988 as part of the present study. After revising locations and elevations to agree with current topographic maps, deleting doubtful and redundant data points, and reconciling datums of observed gravity, a total of 1,771 additional data points were extracted from other gravity data sets. Standard methods were used to reduce gravity values to Bouguer gravity anomalies, with Earth's curvature and terrain corrections carried to a distance of 166.7 km from each data point (Godson and Plouff, 1988). Isostatic corrections also were made by using the method of Jachens and Roberts (1981), to prepare a residual isostatic gravity map (Plouff, in press).

Gravity anomalies reflect lateral density contrasts between adjacent lithologies, with higher values of gravity anomalies occurring over the denser medium. Gravity anomalies clearly reflect basin-range structure, with elongated gravity highs centered near range crests and gravity lows centered over the deepest parts of sedimentary basins. Analysis of the loci of crests of gravity highs and troughs of gravity lows (Plouff, in press, fig. 3) may reveal subtleties of the underlying regional tectonic fabric and associated stress field.

The gravity low over Pyramid Lake and its continuation along the Truckee River valley to the southeast, which primarily reflect thick underlying sedimentary deposits, form the most intense gravity low in the quadrangle. In Carson Sink, large gravity lows reflect locations of depocenters; a small gravity high near Tertiary volcanic rocks at Lone Rock may reflect Tertiary igneous rocks concealed at shallow depth, and a complex gravity high between the Fallon Indian Reservation and the Stillwater National Wildlife Refuge reflects intrabasement density contrasts. Gravity lows are associated with thick Tertiary volcanic rocks in and perhaps extending outward from the Pah Rah Range, the Truckee Range, and the northwest edge of the Spring Mountains. Distinct gravity lows, however, are not associated with extensive outcrops of ash-flow tuff near the east edge of the quadrangle, and gravity lows that might be associated with exposures of ash-flow tuff in the northwest corner of the quadrangle are masked by large regional gravity gradients. Gravity lows possibly reflect Tertiary calderas beneath Carson Sink and elsewhere in the quadrangle.

Gradients near the edges of gravity highs that enclose isolated outcrops of pre-Cenozoic rocks may indicate the lateral extent of pre-Cenozoic rocks where pre-Cenozoic rocks are concealed beneath younger rocks and sedimentary deposits, for example, northeast of Churchill Butte. Pre-Cenozoic rocks may be concealed at shallow depth beneath gravity highs that do not enclose pre-Cenozoic exposures, for example, southwest of the Pyramid Lake-Truckee River gravity low and southwest of the southwest edge of the West Humboldt Range. The most prominent gravity high in the Reno quadrangle encloses Marble Butte southeast of Pyramid Lake; the steepness of enclosing gravity gradients indicates that basement rocks beneath the Pyramid Lake-Truckee River sedimentary deposits are less dense than the basement rocks to the northeast.

GEOLOGY AND MINERAL RESOURCE ASSESSMENT (U.S. GEOLOGICAL SURVEY BULLETIN 2019)

The geology and mineral resources of the Reno quadrangle are summarized in U.S. Geological Survey Bulletin 2019. An introductory section includes a summary of studies undertaken as part of the project. The geologic history of the quadrangle is summarized with an emphasis on igneous and tectonic events that are important in understanding the genesis and distribution of metallic mineral resources. Six page-size maps are presented to illustrate the distribution of pre-Tertiary terranes, plutonic rocks, three major assemblages of Cenozoic rocks, and late Cenozoic structures in the quadrangle. Brief summaries, including page size maps, of the results of geochemical and remote sensing (hydrothermal alteration) studies are presented. Other illustrations include page-size maps showing areas of deep (>0.5 km) pre-Tertiary basement rocks and areas of shallow (<0.5–1.0 km) magnetic sources based on quantitative analyses of gravity and aeromagnetic data. A comprehensive bibliography is included.

The mineral resource assessment is separated into two sections based on age of deposits, with separate discussions of Mesozoic-age deposits and Cenozoic-age deposits. An introductory section describes the methodology used in the assessment and problems and limitations of the assessment. About 20 types of metallic mineral deposits are identified in the Reno quadrangle. The most important deposit types in terms of historic and (or) current production are adularia-sericite gold-silver (including the Comstock Lode, Rawhide, Fairview, and Wonder deposits), porphyry copper (deposits in the Yerington district), tungsten skarn (including the Nevada Scheelite mine), iron skarn, and sediment-hosted gold deposits. Characteristics of 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 (permissive terranes). More specific areas containing evidence for mineralization and thus considered favorable for undiscovered deposits (favorable tracts) 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. Permissive terranes and favorable tracts are limited to 500 m depth as defined by the interpretative gravity and aeromagnetic maps. Characteristics of 36 tracts considered favorable for one or more types of metallic mineral deposits are summarized in a series of tables. Permissive terranes and favorable tracts are delineated on four 1:250,000-scale maps that are overlain on a simplified geologic map which also shows known deposits. Industrial minerals, oil and gas, and geothermal energy resources are described briefly but not evaluated.

Plate 1 shows permissive terranes and favorable tracts for Jurassic age porphyry copper, copper and iron skarn, and iron endoskarn (volcanic-hosted magnetite) deposits. Porphyry copper and copper and iron skarn deposits are associated with the Middle Jurassic Yerington batholith and other Middle Jurassic(?) plutons in the south-central part of the quadrangle. Areas considered permissive for these types of deposits are limited to areas that may contain Middle Jurassic granitoids and include a large area in the south-central part of the quadrangle extending east from Carson Valley to the Calico Hills and north to the southern Virginia Range and a second area in the north-central part of the quadrangle centered on Fireball Ridge. Iron endoskarn or volcanic-hosted magnetite deposits are associated with the Humboldt lopolith near the northeast corner of the quadrangle.

Plate 2 shows permissive terranes and favorable tracts for Cretaceous tungsten skarn, low fluorine porphyry molybdenum, and sediment-hosted gold deposits, Cretaceous and Tertiary gold skarn deposits, and Tertiary polymetallic replacement, zinc-lead skarn, and copper skarn deposits. Tungsten skarn deposits associated with Cretaceous granitoids have had the most past production; most of the quadrangle outside of the Sierra Nevada is considered permissive for additional tungsten deposits of this type and for other types of skarn deposits and polymetallic replacement deposits. Five widely scattered tracts centered on known occurrences of tungsten skarn mineralization are delineated as favorable for undiscovered tungsten skarn deposits, and two tracts in the eastern part of the quadrangle are delineated as being favorable for Tertiary age skarn and polymetallic replacement deposits. One area in the central Sand Springs Range is favorable for a Cretaceous age low fluorine porphyry molybdenum deposit.

Plate 3 shows permissive terranes and favorable tracts for Tertiary epithermal gold-silver and porphyry copper deposits. All parts of the quadrangle where Tertiary volcanic rocks are inferred to lie within 500 m of the surface are considered permissive for epithermal gold-silver deposits. Twenty-one tracts where mineralization and (or) hydrothermal alteration is known are shown as favorable for undiscovered epithermal gold-silver deposits. Terranes permissive for Tertiary porphyry copper deposits are limited to areas of advanced argillic alteration and include the Pyramid, Peavine/Wedekind, and Como districts and several areas in the Virginia and Carson Ranges.

Plate 4 shows favorable tracts for volcanogenic and sandstone uranium deposits based on maps and data in Hurley and others (1982). Plate 4 also shows the locations of industrial mineral occurrences (sand and gravel, limestone, diatomite, gypsum, salt, and so forth) and geothermal energy resources.

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