U.S. GEOLOGICAL SURVEY CIRCULAR 927

The Conterminous United States Mineral Appraisal Program: Background Information to Accompany Folio of Geologic, Geochemical, Geophysical, and Mineral Resources Maps of the Walker Lake 1° x 2° Quadrangle, California and Nevada

Prepared in cooperation with the Nevada Bureau of Mines and Geology

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ABSTRACT

The Walker Lake 1° by 2° quadrangle in eastern California and western Nevada was studied by an interdisciplinary research team to appraise its mineral resources. The appraisal is based on geological, geochemical, and geophysical field and laboratory investigations, the results of which are published as a folio of maps, 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 selected references to the geology, geochemistry, geophysics, and mineral deposits of the Walker Lake 1° by 2° quadrangle.

INTRODUCTION

This circular, as well as a separately published folio of maps, is part of a series of U.S. Geological Survey reports that give information about the mineral-resource potential of the conterminous United States. Both this circular and the folio maps were compiled under the Conterminous United States Mineral Appraisal Program (CUSMAP). CUSMAP is intended to provide regional mineral appraisal information both 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 are also intended to increase geological, geochemical, and geophysical knowledge of the conterminous United States. Thus, the program provides a regional geologic and mineral resource framework for mineral exploration and for specific studies such as the mineral appraisal of wilderness areas.

Location and Geography

The Walker Lake 1° by 2° quadrangle, the subject of this study, covers approximately 19,000 km² in eastern California and western Nevada between lat 38° and 39° and long 118° and 120° (fig. 1). The western third of the quadrangle, where maximum elevations are about 3,800 m, lies in the high mountains of the Sierra Nevada. A system of mountains and valleys, part of the Basin and Range physiographic province, occurs east of the Sierra Nevada in the eastern two-thirds of the quadrangle, where elevations range from about 1,250 m in valleys to 3,400 m in the higher mountains.

Major rivers in the quadrangle include the West and East Walker Rivers, which head in the Sierra Nevada and empty into Walker Lake in the eastern part of the quadrangle, and the Carson River, which flows across the northwestern part of the quadrangle. Rivers draining westward from the Sierra Nevada include the Stanislaus and Mokelumne. Part of Lake Tahoe lies in the northwestern corner of the quadrangle, and Mono Lake lies along the southern boundary.

The Walker Lake quadrangle is crossed by several major highways including those across major passes in the Sierra Nevada (Carson, Ebbetts, and Sonora Passes). U.S. Highway 395 runs generally south-southeastward across the western part of the quadrangle east of the Sierra Nevada, and U.S. Highway 95 runs southeastward through the eastern part of the quadrangle. Major towns are Bridgeport, Gardnerville, Minden, Yerington, and Hawthorne.

Previous Work

Prior to the 1900's, only brief references were made about the geology in the area of the Walker Lake 1° by 2° quadrangle. The first reports in the 1900's to describe the geology and ore deposits in parts of the quadrangle are by Spurr (1903) and Hill (1915). Early studies of mining districts include those of Knopf (1918) in the Yerington district, Clark (1922) in the Santa Fe district, and Knopf (1922) in the Candelaria district.

The first detailed geologic studies of a large area within the quadrangle were by H. G. Ferguson, S. H. Cathcart, and S. W. Muller; these led to the publication of comprehensive descriptions of the geology of much of the quadrangle's eastern half (Muller and Ferguson, 1939; Ferguson and Muller, 1949; Ferguson and others, 1954).

During the 1950's, studies at the University of California led to the mapping of a large region of the Sierra Nevada in the Walker Lake quadrangle (Wilshire, 1956, 1957; Curtis, 1951, 1954; Halsey, 1953; Slemmons, 1953; Parker, 1961; Gilbert, 1959). Also during the 1950's, Axelrod (1956) published a detailed

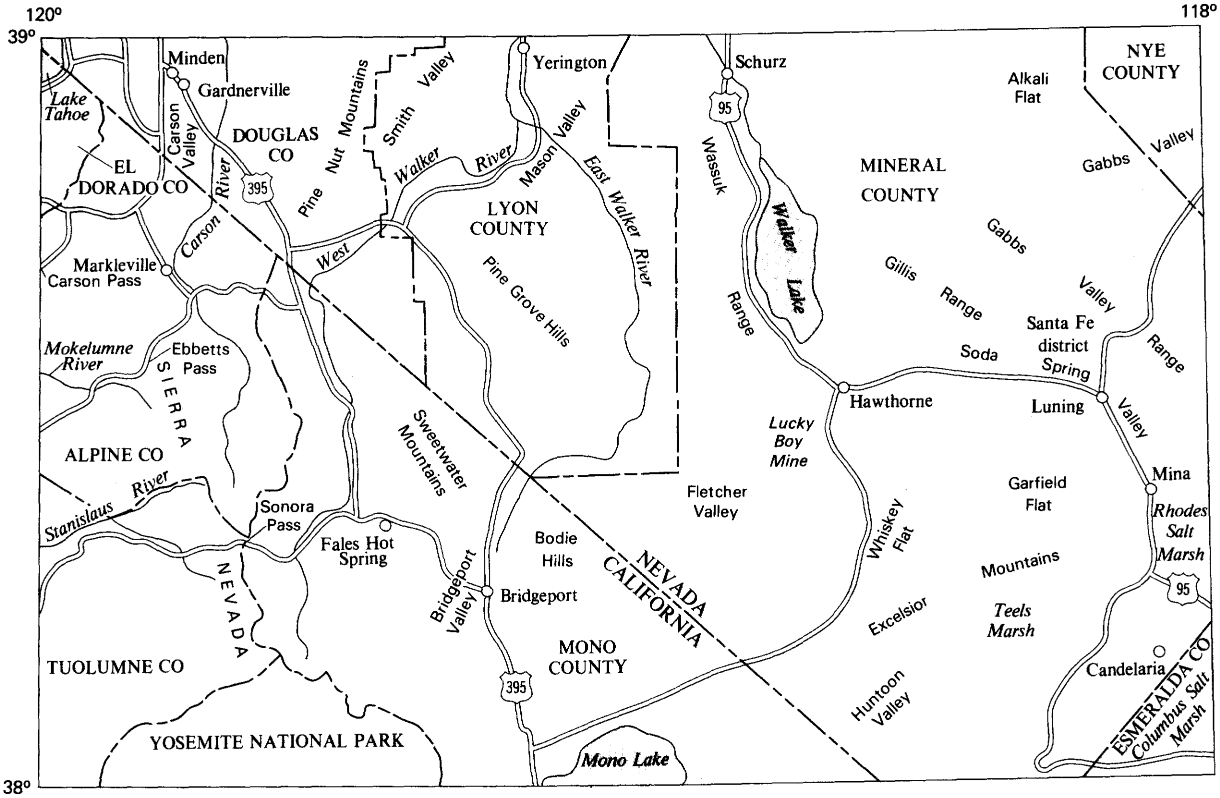

FIGURE 1.--Walker Lake 1° by 2° quadrangle.

account of the stratigraphy and flora of Tertiary sedimentary rocks, and Page (1959) described the Candelaria district in detail.

Regional maps and reports published during the 1960's include a description of the geology and mineral deposits of Mineral County, Nev. (Ross, 1961), a geologic map of the California part of the Walker Lake 1° by 2° sheet (Koenig, 1963), and a report on the geology and mineral deposits of Lyon and Douglas Counties, Nev. (Moore, 1969). Among the other important reports in the 1960's are descriptions of geophysical and geologic investigations of Mono Lake basin (Pakiser and others, 1960; Pakiser, 1968; Gilbert and others, 1968; Christensen and others, 1969), of Mesozoic geology of the southern Pine Nut Mountains (Noble, 1962), of Cenozoic volcanism in the Sierra Nevada (Slemmons, 1966), and of Pleistocene glaciation in the Sierra Nevada (Clark, 1968).

Since the 1960's, a large number of maps and reports have been published describing areas within the Walker Lake 1° by 2° quadrangle. Most of these are listed in the selected bibliography at the end of this report. Reports of particular importance include descriptions of plutonic rocks in the eastern Sierra Nevada (Schweickert, 1972, 1976), of the Cenozoic structural geology and stratigraphy of the Yerington district (Proffett, 1972, 1977; Proffett and Proffett, 1976), of the character and chronology of Tertiary basin development (Gilbert and Reynolds, 1973), of the aeromagnetic, gravity, and geologic character of the Bodie Hills region (Kleinhampl and others, 1975), of the Paleozoic and Mesozoic stratigraphy and tectonics of the Mina region (Speed, 1977a, b, 1978; Speed and others, 1977; Speed and Kistler, 1980), of the Tertiary volcanic stratigraphy of the Candelaria area (Speed and Cogbill, 1979a, b, c, d, e), and the Gabbs Valley and Gillis Ranges (Ekren and others, 1980; Hardyman, 1980).

References of particular importance to the study of ore deposits in the quadrangle include the county reports by Ross (1961) and Moore (1969) and regional reports by Lincoln (1923), Vanderburg (1937), Couch and Carpenter (1943), Archbold (1966), and Clark (1977). Fairly complete descriptions of individual mines are given in Knopf (1918), Clark (1922), Page (1959), Kerr (1936), Bailey and Phoenix (1944), Johnson (1951), Matson and Trengrove (1957), Reeves and others (1958), Lawrence and Redmond (1967), Archbold and Raul (1970), Hunter (1976), and Einaudi (1977).

Present Study

The maps and interpretations included in the CUSMAP folio of the Walker Lake 1° by 2° quadrangle are the product of numerous multidisciplinary studies, most of them conducted between 1976-1981. The program of field mapping and office compilation of a 1:250,000-scale map of the Walker Lake 1^{o} by 2^{o} quadrangle started in 1976 as a cooperative project of the U.S. Geological Survey and the Nevada Bureau of Mines and Geology. In 1977, the program was assigned to CUSMAP and enlarged to include geophysical and geochemical studies as well as to increase emphasis on geologic mapping and assessment of ore deposits. Associated work included studies of granitic rocks, surficial deposits, late Cenozoic faults, isotopic dating, early Mesozoic megafossils, linear features, and rock alteration.

The program was integrated with studies of wilderness areas in the Sierra Nevada (Brem and others, 1984; John and Federspiel, 1984; John and Scott, 1984; John and Stebbins, 1984; Keith and Miller, 1984; Kennedy and Lambeth, 1984; McKee and Federspiel, 1984; Seitz and Federspiel, 1984; Tooker and Zilka, 1984) and with the National Uranium Resource Evaluation program (Durham and Felmlee, 1982).

Geologic mapping and geophysical work in Nevada was supported in part by the Nevada Bureau of Mines and Geology.

The results of the Walker Lake 1^{o} by 2^{o} quadrangle CUSMAP program are presented in a series of Geological Survey Miscellaneous Field Studies Maps (table 1). Other maps and reports related to the program are indicated by an asterisk in the bibliography at the end of this report. Mineral-resource data have been entered into a computer file in the U.S. Geological Survey's Computerized Resource Information Bank (CRIB); information about CRIB may be obtained from the U.S. Geological Survey, 920 National Center, Reston, VA 22092.

GEOLOGIC MAP (MF-1382-A)

The geologic map of the Walker Lake 1^{o} by 2^{o} quadrangle is based almost entirely on new information collected after the previous 1:250,000-scale maps (Ross, 1961; Moore, 1969; Koenig, 1963) were published. Much of the information shown in the 1:250,000 scale compilation is published as detailed maps at 1:24,000, 1:48,000, or 1:62,500 scale (see "Selected Bibliography").

The geology of the Walker Lake 1^{o} by 2^{o} quadrangle is complex and varied. Uppermost Precambrian and lower Paleozoic rocks crop out in the southeastern part of the quadrangle; these consist of uppermost Precambrian and Lower Cambrian shallow-water strata considered to have been deposited near the edge of the North American continental shelf. Offshelf deep-water Ordovician and Devonian strata also occur in the southeastern part of the quadrangle. The uppermost Precambrian and lower Paleozoic rocks were folded and faulted during the middle Paleozoic Antler orogeny and were overlapped by Mississippian carbonate rocks and Permian conglomeratic strata of the Diablo Formation.

Paleozoic rocks also occur in two other areas in the quadrangle: (1) volcanic and volcanogenic sedimentary rocks in the Huntoon Valley-Mina region in the southeastern part of the quadrangle, and (2) Paleozoic nonvolcanic metamorphosed sedimentary rocks in roof pendants along the east side of the Sierra Nevada. The Paleozoic rocks in the Huntoon Valley-Mina region are of Pennsylvanian and Permian age; they consist mainly of andesitic rocks, with associated sedimentary rocks considered to have formed near an island arc and emplaced onto the North America continent during the Mesozoic. The Paleozoic rocks on the east side of the Sierra Nevada include rocks dated as Ordovician, Mississippian, and Pennsylvanian. The strata, which are locally thick, include argillite, conglomerate, and carbonate, but no volcanic rocks. The paleogeographic setting of these rocks in relation to other Paleozoic rocks in the quadrangle is not clearly understood.

The Mesozoic rocks in the quadrangle consist of widely exposed units of sedimentary and volcanic rocks and of granitic to gabbroic intrusive rocks. The sedimentary and volcanic rocks range in age from Early Triassic to Cretaceous, but most are Late Triassic and Early Jurassic. They are carbonate, shale, sandstone, and conglomerate, with, primarily in the central and western parts of the quadrangle, interlayered volcanic rocks. The Mesozoic sedimentary and volcanic rocks were folded and imbricately thrust faulted during the Mesozoic. The Mesozoic igneous rocks range in age from Late Triassic to Late Cretaceous and occur over most of the Sierra Nevada region within the quadrangle in California and large areas within some mountain ranges in the Nevada part of the quadrangle.

No dated Tertiary rocks older than about 30 m.y. are known in the quadrangle. The oldest sequence of Tertiary rocks consists primarily of silicic ash-flow tuffs that range in age from about 30 to 22 m.y. They occur primarily in the eastern and north-central parts of the quadrangle. Andesitic volcanic rocks, commonly laharic breccias, are widespread in the quadrangle; most of them range in age from 22 to 9 m.y. Andesite, rhyolite, basalt, basaltic andesite, and tuffs less than 9 m.y. have a spotty distribution throughout the quadrangle. Tertiary tuffaceous sedimentary rocks ranging in age from about 12 to 5 m.y. are widely exposed east of the Sierra Nevada. Quaternary sedimentary deposits consist primarily of alluvial fan, basin fill, and playa deposits that underlie the present-day valleys of the quadrangle east of the Sierra Nevada.

During the late Cenozoic the Sierra Nevada was uplifted and the Basin and Range blocks that characterize the quadrangle east of the Sierra Nevada were developed. Right-lateral strike-slip movement on a system of northwest-trending faults in the Gabbs Valley and Gillis Ranges also occurred in part, or perhaps entirely, during the late Cenozoic. This belt of right-lateral offset is commonly referred to as the Walker Lane (Locke and others, 1940).

GRANITIC-ROCK MAP (MF-1382-B)

The granitic-rock map of the Walker Lake 1^{o} by 2^{o} quadrangle shows the distribution of individually mapped plutons and tabulates all available age, modal, and textural data for each pluton. Much of the information that was used in the compilation of this map is published in more detailed maps elsewhere (see

Table 1.—Contents of Walker Lake 1° by 2° CUSMAP folio, U.S. Geological Survey Miscellaneous Field Studies Maps MF-1382-A to V

1382-A	Geologic map, by John H. Stewart, J. E. Carlson, and D. C. Johannesen
1382-B	Distribution, ages, and petrographic characteristics of Mesozoic plutonic rocks, by D. A. John
1382-C	Surficial geology map, by J. C. Dohrenwend
1382-D	Late Cenozoic fault map, by J. C. Dohrenwend
1382-E	Bouguer gravity and isostatic residual gravity map, by Donald Plouff
1382-F	Aeromagnetic map, by Donald Plouff
1382-G	Distributions of copper, lead, zinc, cadmium, and silver in samples of minus-0.25-mm stream sediment and nonmagnetic heavy-mineral concentrate, by M. A. Chaffee, R. H. Hill, and S. J. Sutley
1382-H	Distributions of molybdenum, tin, boron, tungsten, and gold in samples of minus-0.25-mm stream sediment and (or) nonmagnetic heavy-mineral concentrate, by M. A. Chaffee, R. H. Hill, and S. J. Sutley
1382-I	Distributions of iron, cobalt, barium, strontium, arsenic, antimony, and bismuth in samples of minus-0.25-mm stream sediment and (or) nonmagnetic heavy-mineral concentrate, by M. A. Chaffee, R. H. Hill, and S. J. Sutley
1382-J	Distributions of 12 selected elements (Cu, Pb, Zn, Cd, Ag, Au, Mo, Sn, W, As, Sb, and Bi) in samples of rock, by M. A. Chaffee, R. H. Hill, and S. J. Sutley
1382-K	Distributions of anomalies based on the use of R-mode factor analysis for selected groupings of elements in samples of minus-0.25-mm stream sediment or nonmagnetic heavy-mineral concentrate, by M. A. Chaffee
1382-L	Distributions of anomalies based on the use of SCORESUM plots for selected groupings of elements in samples of minus-0.25-mm stream sediment, by M. A Chaffee
1382-M	Distributions of anomalies based on the use of SCORESUM plots for selected groupings of elements in samples of nonmagnetic heavy-mineral concentrate, by M. A. Chaffee
1382-N	Isotopic dating, by A. C. Robinson and R. W. Kistler
1382-O	Localities and correlation of age-diagnostic early Mesozoic megafossils, by N. J. Silberling
1382-P	Linear features map, by L. C. Rowan and T. L. Purdy
1382-Q	Alteration map, by L. C. Rowan and T. L. Purdy
1382-R	Mineral-resources map, by F. J. Kleinhampl, J. B. Fiebelkorn, D. A. John, and W. J. Moore.
1382-S	Mineral-resource assessment of gold and silver resources, by W. D. Menzie, F. J. Kleinhampl, R. P. Ashley, R. T. Golia, G. M. Jones, and K. R. Long
1382-T	Mineral-resource assessment of copper and iron resources, by W. D. Menzie, F. J. Kleinhampl, W. J. Moore, D. P. Cox, G. M. Jones, and D. A. John
1382-U	Mineral-resource assessment of molybdenum and tungsten, by W. D. Menzie, F. J. Kleinhampl, T. G. Theodore, W. J. Moore, and G. M. Jones
1382-V	Mineral-resource assessment of miscellaneous commodities, by W. D. Menzie, F. J. Kleinhampl, and G. M. Jones

references for MF-1382-A); age data are taken from the isotopic dating map (MF-1382-N).

Granitic rocks are exposed over approximately 25 percent of the area of the Walker Lake 1° by 2° quadrangle. The granitic rocks have been divided into 156 plutons and 3 additional units of gabbro, diorite, and aplite. About half of these plutons are part of the Sierra Nevada batholith, which extends diagonally across the western third of the quadrangle. Other areas with major exposures of granitic rocks include the Sweetwater Mountains, the Pine Nut Mountains, the Wassuk Range, the Gabbs Valley Range, and the Excelsior Mountains.

Modal data indicate that most of the plutons have granodioritic compositions; however, the plutonic rocks range in composition from leucogranite to gabbro. Isotopic dating of various granitic rocks suggests a wide range of ages spanning the latest Triassic to the latest Cretaceous (approximately 215 m.y. to 75 m.y.). Several northwest-southeast-elongate belts of plutons are identified. These include a Middle to Late Jurassic belt that extends from the Pine Nut Mountains to the Wassuk Range and a Late Cretaceous belt in the Sierra Nevada. The latter consists of an extremely widespread intrusive sequence centered on Sonora Pass.

SURFICIAL-GEOLOGY MAP (MF-1382-C)

The surficial-geology map of the Walker Lake 1° by 2° quadrangle shows the distribution and structure of late Cenozoic surficial deposits as classified into 30 different map units. The compilation is the first systematic classification and mapping of surficial deposits in the quadrangle. Previous work on surficial deposits in the quadrangle (Bonham and Burnett, 1976; Bingler, 1978; Clark, 1968; Chesterman, 1975; Chesterman and Gray, 1975; Hardyman, 1980; Sharp, 1972) have been limited to detailed maps of relatively small areas, most of these along the east flank of the Sierra Nevada.

Surficial deposits cover nearly 40 percent of the area of the Walker Lake quadrangle. These extensive deposits are the products of several subaerial depositional processes. The Sierra Nevada contains extensive deposits of glacial drift. East of the Sierra Nevada, uplands of the Basin and Range province are bounded by piedmonts of varying width composed of both bajadas and pediments. Within these uplands, particularly those closest to the Sierra Nevada, large landslides are numerous and widely distributed. In some intervening basins, lacustrine clay and silt deposits of late Pleistocene pluvial lakes are extensive. In other, smaller basins, playa deposits of silt and clay are dominant. Extensive eolian deposits, primarily low sand dunes and sand sheets, veneer large areas leeward of the more extensive lacustrine and playa deposits.

LATE CENOZOIC FAULT MAP (MF-1382-D)

Six distinct regions of late Cenozoic and historical faults in the Walker Lake 1° by 2° quadrangle can be recognized on the basis of contrasting orientations, densities, and styles of faulting: (1) The Sierra Nevada region contains few Quaternary faults except for several basin-range faults that extend into the region along its northeast flank. (2) A region in the northwestern and north-central parts of the quadrangle contains five major north- to north-northwest-trending range-front fault systems that dominate the topography and the late Cenozoic structure. The lengths of these fault systems range from 35 to 110 km, and their vertical offsets measure 2,300 m or more. (3) The Walker Lane region in the northeast and east-central parts of the quadrangle contains five major late Cenozoic strike-slip fault systems. (4) A region northeast of Walker Lane region has faults with a north-northeast orientation. All the late Cenozoic faults in this region display evidence of Quaternary movement; that evidence includes surface ruptures associated with the Cedar Mountain earthquake of 1932 and the Dixie Valley-Fairview Peak earthquakes of 1954 (Gianella and Callaghan, 1934; Ekren and Byers, 1978b; Slemmons, 1957). (5) A region composed of the Pine Grove Hills and Bodie Hills is characterized by relatively short dip-slip faults of variable trend. (6) The Mono Lake basin-Excelsior Mountains region contains a broad zone of northeast- to east-trending late Cenozoic faults, some with left-slip displacement (Speed and Cogbill, 1979c). This region exhibits small surface ruptures produced in the 1934 Excelsior Mountains earthquake (Callaghan and Gianella, 1935).

GRAVITY MAP (MF-1382-E)

The gravity map includes data from 3,447 stations. The data from a total of 1,470 of the stations were extracted from previous compilations gathered by the U.S. Geological Survey for large parts of the Walker Lake 1° by 2° quadrangle in California (Robbins and Oliver, 1976) and Nevada (Healey and others, 1980). These data have been supplemented by data from 63 gravity stations near South Lake Tahoe (Blum, 1979), data from 243 stations reported on in an unpublished water resources survey of Carson Valley by the U.S. Geological Survey (D. K. Maurer, written commun., 1981), a recalculation of values for 45 stations collected by the Nevada Bureau of Mines and Geology (Erwin, 1970; J. W. Erwin, written commun., 1978), and 383 gravity values reduced from a gravity survey in Nevada by C. M. Gilbert and M. W. Reynolds (written commun., 1978) from a gravity survey in Nevada that they conducted while they were at the University of California at Berkeley. A total of 1,243 gravity stations were established during and for the present study. Our methods of establishing a base station network, tying various surveys to a common datum, and calculating anomalies are discussed by Plouff (1982b). The results of the gravity surveys are shown on two maps, a Bouguer gravity anomaly map and an isostatic residual gravity map, in MF-1382-E.

The Bouguer gravity anomaly map shows a steep north-northwest-trending gravity gradient along the west edge of the Walker Lake 1° by 2° quadrangle that reflects major crustal changes and associated density contrasts in the transition zone between the Sierra Nevada batholith and the Basin and Range province. Relatively small anomalies within the Sierra Nevada may be due to a small but significant density contrast between plutonic rocks and denser metamorphic wallrocks (Oliver, 1977).

The diverse gravity patterns in the Basin and Range province are due primarily to the contrast between thick deposits of low-density late Cenozoic sedimentary rocks in presumed structural depressions and Paleozoic, Mesozoic, and Tertiary rocks of higher density in adjacent mountain ranges. Elongate gravity lows with amplitudes ranging from 10 to 20 mGal are associated with the principal structural basins of the quadrangle, including Carson Valley, Brideport Valley, Smith Valley, Mason Valley, Walker Lake, Gabbs Valley, Alkali Flat, Soda Spring Valley, Mono Lake, Fletcher Valley, Whisky Flat, Teels March, Garfield Flat, Rhodes Salt Marsh, and Columbus Salt Marsh. A prominent gravity low (A. A. Oliver, 3d, unpub. data, 1974) is centered on the Little Walker caldera (Noble and others, 1974), about 20 km northwest of Bridgeport, Calif. Gravity values increase to the northeast in an irregular but conspicuous zone that extends southeastward across a large segment of the central part of the quadrangle. This feature may be due to a northeastward thinning of the crust.

The isostatic residual-gravity map is a modification of the Bouguer gravity anomaly map in which a correlation is made at each station to compensate for assumed thicker crust beneath areas of higher elevation (Jachens and Roberts, 1981). The isostatic residual gravity map permits better recognition of local gravity anomalies in areas of large Bouguer gravity gradients, such as in the Sierra Nevada.

AEROMAGNETIC MAP (MF-1382-F)

The aeromagnetic map of the Walker Lake 1° by 2° quadrangle was compiled at 20- and 100-nT contour intervals from six previously published aeromagnetic surveys. The earliest survey, which covered almost all of the Nevada part of the quadrangle, was flown along east-west flight lines at a 1.6-km (1 mi) spacing and at constant barometric elevation of 2,740 and 3,350 m (9,000 and 11,000 ft) above sea level (U.S. Geological Survey, 1971). The Earth's normal field was subtracted from the original map by using values from Fabiano and Peddie (1969). The second survey, which fills a small gap left by the first survey at the south edge of the quadrangle, was flown along east-west flight lines at a 1.6-km (1 mi) spacing, at a constant barometric elevation of 4,110 m (13,500 ft) above sea level (U.S. Geological Survey, 1974). The aeromagnetic map of this second survey is corrected for the effect of the Earth's normal field. The remaining four surveys were flown at an altitude of 300 m (1,000 ft) above the average terrain ("drape-flown") at flight line spacings of 0.8 km (0.5 mi) and 1.6 km (1 mi), and the Earth's normal field was then subtracted (U.S. Geological Survey, 1979a, b, 1981, 1982). In all these surveys, arbitrary magnetic datums were subtracted from the original values of total magnetic intensity to minimize the datum shifts between survey borders. A shipborne magnetic survey of Lake Tahoe (Henyey and Palmer, 1974) was not included in the compilation.

Supplemental maps in MF-1382-F show the altitude of the aeromagnetic surveys above the ground and the location of rock samples for which remanent magnetization and magnetic susceptibilities were measured. The measurements of magnetization and susceptibilities of 83 samples indicate a wide variation in total magnetization. Metamorphic rocks generally have the lowest values, plutonic rocks have moderate values, and volcanic rocks have the highest values of magnetization.

The aeromagnetic map shows a complex pattern of local magnetic highs and lows as well as of broader features. Many anomalies are correlated with rocks of either significantly high or low magnetization mapped in the surface; the subsurface extent of these rocks can be inferred from the aeromagnetic map. Other anomalies appear to be related to magnetic bodies that do not crop out. Such anomalies are particularly important because they may indicate hidden intrusive rocks potentially of interest in mineral-resource studies.

GEOCHEMICAL STUDIES MAPS (MF-1382-G, H, I, J, K, L, and M)

Seven sets of geochemical maps are included in the Walker Lake 1° by 2° quadrangle folio. The maps provide information about the distributions and abundances of selected elements determined in 815 samples of rock, 1,116 samples of minus-60-mesh (0.25 mm) stream sediment, and 1,005 samples of nonmagnetic heavy-mineral concentrate. All of the samples were analyzed for 31 elements (Ag, As, Au, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, La, Mg, Mn, Mo, Nb, Ni, Pb, Sb, Sc, Sn, Sr, Th, Ti, V, W, Y, Zn, and Zr) by a six-step semiquantitative emission spectrographic method (Grimes and Marranzino, 1968). The rock and stream-sediment samples were also analyzed for As by colorimetry (Ward and others, 1963) and for Zn, Sb, Cd, and Bi by atomic-absorption spectrometry (Ward and others, 1969; Welsch and Chao, 1975; Viets, 1978). A limited number of the rock and stream-sediment samples were also analyzed for gold by atomic-absorption spectrometry (Meier, 1980).

For the geochemical evaluation, individual element plots for each of the three types of samples were made for many of the elements listed above. In addition, the total element suite in each type was also studied by using R-mode factor analysis (VanTrump and Miesch, 1977) and by using a special technique called Scoresum (Chaffee, 1983).

The geochemical maps in the Walker Lake folio include the following plots showing the distributions and abundance of individual elements:

MF-1382-G. Cu, Pb, Zn, Cd, and Ag in samples of minus-60-mesh (0.25 mm) stream-sediment and nonmagnetic heavy-mineral concentrate.

MF-1382-H. Mo, Sn, B, W, and Au in samples of minus-60-mesh (0.25 mm) stream-sediment and (or) heavy-mineral concentrate.

MF-1382-I. Fe, Co, Ba, Sr, As, Sb, and Bi in samples of minus-60-mesh (0.25 mm) stream-sediment and (or) nonmagnetic heavy-mineral concentrate.

MF-1382-J. 12 selected elements (Cu, Pb, Zn, Cd, Ag, Au, Mo, Sn, W, As, Sb, and Bi) in samples of rock.

One set of maps (MF-1382-K) shows the distributions of anomalies based on R-mode factor analysis of selected groupings of elements in samples of minus-60-mesh (0.25 mm) stream sediment or nonmagnetic heavy-mineral concentrate. The sheets in this map set show the distributions of anomalies related to (1) a precious-metal dominant suite composed of the elements Au, Ag, Bi, Cu, Sb, and As; (2) a silver-dominant precious-metal suite composed of the elements Ag, Sb, As, Au, Zn, Pb, and Cd; (3) a possible porphyry molybdenum deposit suite composed of the elements Ag, Pb, Mo, Cu, W, and Sn; (4) an alteration-mineral-related suite, which also may be related to base and precious metals, including the elements Cu, Pb, Co, Ag, Fe, Sr, and Ba; and (5) a contact-metasomatic tungsten and (or) porphyry molybdenum suite, composed of the elements W, Be, Mo, and B.

Maps showing the distributions of anomalies based on the Scoresum technique for groups of elements in minus-60-mesh (0.25 mm) stream sediment (MF-1382-L) include (1) a map showing all 12 of the selected elements (Ag, As, Au, Bi, Cd, Cu, Mo, Pb, Sb, Sn, W, and Zn) taken as one suite, (2) a map showing a favorable-element suite (Ag, As, Au, Bi, and Sb) for possible use in identifying precious-metal vein deposits, disseminated Carlin-type gold deposits, and silver-associated base-metal deposits, (3) a map showing a favorable-element suite (Ag, As, Au, Bi, Cd, Cu, Pb, Sb, and Zn) for possible use in identifying complex base- and precious-metal deposits and porphyry copper deposits, and (4) a map showing a favorable-element suite (Bi, Mo, and W) for possible use in identifying contact-metasomatic tungsten deposits and (or) deeply buried porphyry molybdenum deposits.

The set of maps showing the distributions of anomalies based on the Scoresum technique for groups of elements in nonmagnetic heavy-mineral concentrate (MF-1382-M) is made up of (1) a map showing all 17 of the selected elements (Ag, As, Au, B, Ba, Bi, Cd, Co, Cu, Fe, Mo, Pb, Sb, Sn, Sr, W, and Zn) taken as one suite; (2) a map showing a favorable-element suite (Fe, Co, Ba, and Sr) for possible use in identifying areas of hydrothermal alteration, (3) a map showing a favorable-element suite (Ag, As, Au, Ba, Bi, Co, Fe, Sb, and Sr) for possible use in identifying altered areas containing precious-metal deposits, (4) a map showing a favorable-element suite (Ag, As, Au, B, Ba, Bi, Cd, Co, Cu, Fe, Pb, Sb, Sr, and Zn) for possible use in identifying complex base- and precious-metal deposits, including deeply buried porphyry copper deposits, and (5) a map showing a favorable-element suite (Bi, Mo, Sn, and W) for possible use in identifying exposed or buried porphyry molybdenum deposits and contact-metasomatic tungsten deposits.

ISOTOPIC DATING MAP (MF-1382-N)

About 375 granitic and volcanic rock specimens from the Walker Lake 1° by 2° quadrangle have been dated by K-Ar methods. In addition, 210 rock specimens have been used for either Rb-Sr whole-rock dating or for study of initial strontium isotopic composition of granitoid plutons. The location of each rock specimen is shown on a map, and a table of analytical data for all samples is included. Most K-Ar dates were previously published. All K-Ar dates published before 1977 were recalculated using the new IUGS decay and abundance constants for potassium (Steiger and Jager, 1977).

The oldest rocks or minerals dated in the quadrangle are volcanic rocks and detrital hornblende in the Black Dyke and Mina Formations of Speed (1977a), respectively, in the southeast part of the quadrangle. On the basis of dating by K-Ar methods these rocks and minerals are about 270 m.y. old (Permian). Ages of Mesozoic volcanic rocks, based on Rb-Sr techniques, form four main groups: about 225 m.y. (Triassic), 185 m.y. (Jurassic), 155 m.y. (Jurassic), and 103 m.y. (Cretaceous). Ages of plutonic rocks, based on K-Ar and Rb-Sr whole-rock dating, range from about 215 to 77 m.y. Most of the plutons in the Sierra Nevada part of the quadrangle are Cretaceous in age (117 to 85 m.y.). Tertiary volcanic rocks in the quadrangle range in age, based on K-Ar techniques, from about 30 m.y. to less than 1 m.y.

The initial strontium isotopic composition of granitoid rocks in the quadrangle was studied because it is a sensitive indicator of the type of crust the plutons intruded. In the western United States, the region where all plutons have initial $^{87}Sr/^{86}Sr$ values greater than 0.7060 is apparently underlain by sialic crust of Precambrian age (Kistler and Peterman, 1973, 1978; Armstrong and others, 1977). Plutons with initial $^{87}Sr/^{86}Sr$ values less than 0.7060 but greater than 0.7040 are intruded into transitional crust, and those with values less than 0.7040 are intruded into oceanic crust.

In the quadrangle, only plutons in the western exposures of the Sierra Nevada composite batholith have initial $^{87}Sr/^{86}Sr$ values greater than 0.7060. In the study of initial strontium isotopic compositions of plutons in the quadrangle, the boundary between plutons with initial $^{87}Sr/^{86}Sr$ greater than 0.7060 and less than 0.7060, which is interpreted to mark the margin of Precambrian sialic crust, has been found to be offset along four distinct northwest-trending zones of right-lateral displacement: one in the central Sierra Nevada with an offset of 100 km, the second in the eastern Sierra Nevada (Kistler and others, 1980) with an offset of 90 km, a third in the central part of the quadrangle on line with the Death Valley-Furnace Creek fault zone with an offset of 60 km, and a fourth along the Walker Lane with an offset of 70 km.

EARLY MESOZOIC MEGAFOSSILS MAP (MF-1382-O)

The location, identification, age, and stratigraphic position of all known, adequately located age-diagnostic invertebrate shelly fossils were determined in the Walker Lake 1° by 2° quadrangle. In all, 26 localities, some including two or more superposed fauna, are known. All are in the Nevada part of the quadrangle. The paleontologic age relations documented so far indicate that despite marked facies changes and tectonic imbrication, several general lithologic units of Late Triassic and Early Jurassic age can be correlated across the region.

LINEAR FEATURES MAP (MF-1382-P)

The distribution of linear or slightly curvilinear features in the Walker Lake quadrangle have been mapped from computer-enhanced Landsat Satellite Multispectral Scanner (MSS) images. These features either represent linear or slightly curvilinear topographic features such as stream valleys, linear ridges, and escarpments or are tonal anomalies associated with linear bedrock exposures or vegetation. Most of these features probably reflect faults or fracture zones that control topography and the distribution of vegetation.

MSS images facilitate the mapping of regional fracture zones and faults because the multispectral synoptic coverage afforded by the satellite allows spatially related linear features to be traced for great distances. The linear features map can be used as a supplement to ground mapping of faults and fractures.

Linear features in the eastern three-fourths of the quadrangle were compiled from black-and-white MSS band-5 and band-7 images that were digitally processed to enhance image contrast. In the western part of the quadrangle, a digitally enhanced color-infrared composite image was used because in this area the distribution of vegetation is important in the detection of linear features.

The linear features were digitized for statistical analysis and plotting. For the purposes of digitizing, curvilinear features were divided into individual linear segments. Cultural features were determined from topographic maps, Skylab photographs, and aerial photographs, and are not shown on the maps.

The purpose of analyzing the linear features was to identify large tectonic features that may have had some influence on mineralization in the region. Because of the complexity of the linear features map, the data were studied statistically. Eleven major lineaments were identified. A lineament is a "simple or composite linear feature of a surface, whose parts are aligned in a rectilinear or slightly curvilinear relationship and which differ distinctly from the patterns of adjacent features and presumably reflect a subsurface phenomenon" (O'Leary and others, 1976, p. 1467).

Many of the individual linear features that make up the lineaments coincide with mapped faults and fractures. In addition, many of the lineaments coincide with belts of altered rocks (see MF-1382-Q), suggesting that hydrothermal activity which caused the alteration was concentrated along the faults and fractures associated with the lineaments.

ALTERATION MAP (MF-1382-Q)

The alteration map of the Walker Lake 1° by 2° quadrangle shows the generalized distribution of hydrothermally altered rocks. This map was produced by combining data from the Landsat Satellite Multispectral Scanner (MSS) and from fieldwork. The first step was to process the MSS data to outline the distribution of limonite (Rowan and others, 1980), a mineral that can be used as an indicator of alteration (Rowan and others, 1974) because it results from oxidation of the pyrite associated with many hydrothermally altered rocks. Limonite is recognizable by means of MSS because it has diagnostic reflectance spectra that can be detected by comparing the reflectance on the four MSS bands. Field data is a necessary supplement to MSS data because though a map prepared from the MSS data alone can show the distribution of limonite at the surface in soils, bedrock, or alluvium, it does not distinguish between limonite in areas of altered rock in contrast to that in alluvium or in an iron-rich unaltered rock. Furthermore, MSS data cannot be used for mapping limonite in areas where vegetation cover exceeds approximately 35 percent.

After a map of the distribution of limonite had been prepared from MSS data, fieldwork was necessary to determine which areas in bedrock contained altered rock rather than unaltered limonite-rich rock. Fieldwork also revealed areas of alteration, also shown on MF-1382-Q, that are not limonite rich and therefore had not been detected using MSS data.

In the field, altered rocks were divided into seven broad categories. (1) Silicified rocks. These rocks have undergone extensive cation leaching, commonly resulting in porous fine-grained masses of silica and minor argillic material. Alunite is common, and kaolinite and pyrophyllite may be locally abundant. Some silicified rocks are deficient in ferric iron and, therefore, cannot be consistently detected in the Landsat images; areas containing these rocks were mapped in the field. (2) Argillized rocks. These rocks have kaolinite and montmorillonite as the dominant minerals. Sericitized rocks are included in this category owing to their limited distribution within the quadrangle. (3) Mixed silicified and argillic rocks with silicic alteration dominant. (4) Mixed silicified and argillic rocks, with argillic alteration dominant. (5) Rocks in calc-silicate zones and altered rock around skarn deposits. (6) Miscellaneous altered rocks. This category includes rocks showing hematitic alteration and assemblages of chlorite-epidote-quartz and andalusite-cordierite-quartz. (7) Rocks in undifferentiated altered areas. This category includes areas where the type of alteration or possible alteration is unknown because the areas were not examined in the field or were only briefly examined.

Six zones or areas of alteration were delineated using the alteration map and a map of the distribution of mines and prospects in the quadrangle. A strong correlation between lineaments and zones of alteration (see map MF-1382-P) was observed in the Basin and Range part of the quadrangle.

MINERAL RESOURCES MAP (MF-1382-R)

The mineral resources map shows the locations of mines and prospects and designates by symbol the kinds of metals and nonmetals known or believed to have been sought or produced in the Walker Lake 1° by 2° quadrangle. An accompanying table lists names of the properties and for most of them lists, in order of decreasing value, the metals yielded or sought.

Metallic mineral deposits are widely and rather evenly distributed throughout the quadrangle, with the exception of alluvial areas and the southwestern part of the quadrangle, particularly Yosemite National Park, where deposits are sparse. The major types of metallic mineral deposits vary in their patterns of distribution, however. The metals occurring in widely distributed deposits include precious metals, mostly of the epithermal gold and silver type, and copper, including skarn and porphyry copper. The copper deposits lie mostly north of lat 38°15' N.; major groups of copper deposits are clustered near Yerington and Luning, Nev. The presence at and around Yerington of copper with no appreciable amounts of other metals is one of the more notable exceptions to the pattern of zoned and (or) paired or associated metals that is discernible elsewhere in the quadrangle. Tungsten and molybdenum deposits are distributed widely, but are less abundant than copper deposits. Commonly, tungsten, molybdenum, and copper deposits are closely related spatially. Lead and zinc deposits are less widely distributed than deposits of gold, silver, copper, and tungsten, and generally have had lower production. Large amounts of lead have been produced from the mines in the Candelaria district, but throughout the rest of the quadrangle, only the Lucky Boy mine has approached the Candelaria district in amount of production. Mercury deposits are restricted geographically and mostly clustered in the area encompassing Fales Hot Spring (southern Sweetwater Mountains) and the Bodie Hills, where the host rocks are hot spring deposits and Tertiary volcanic rocks. In spite of the concentration of mercury deposits in these areas, none of the mines has had significant production. Uranium deposits, widely scattered north of lat 38°15' N. in the quadrangle, are generally not spatially associated with other metallic mineral deposits. The known larger deposits of uranium, which occur in Tertiary sedimentary strata, form two clusters, one in the Sierra Nevada and the other in a large Tertiary basin west of Hawthorne, Nev. Other deposits of uranium are commonly associated with granitic plutons.

MINERAL RESOURCE ASSESSMENT MAPS (MF-1382-S, T, U, and V)

The potential for mineral resources other than oil, gas, and uranium in the Walker Lake 1° by 2° quadrangle is described on four maps. Map MF-1382-S is concerned with the quadrangle's potential for gold and silver resources, MF-1382-T with copper and iron resources, MF-1382-U with molybdenum and tungsten resources, and MF-1382-V with the potential for resources not covered in the other three maps.

These four maps were prepared by the same procedure (Singer, 1975) used to produce many of the Alaska Mineral Resource Assessment Program reports. The basic steps used in the assessments are:

1. The construction of grade/tonnage, or contained metal, models and the description of types of deposits that are known or suspected.
2. The delineation of tracts within which the occurrence of various types of deposits is geologically plausible.
3. The cataloging of known (already discovered) resources by deposit type or type of resource.
4. The estimation of the number of undiscovered deposits of each type that is likely to occur within delineated tracts.

Each report consists of a map together with tables and appendixes that present the following information: (1) Discovered commodities or resources of particular deposit types; (2) locations of the commodities, and related facts including grade/tonnage or amount of contained metal; (3) models for known or suspected deposit types; (4) the boundaries of delineated tracts; (5) the geologic characteristics of the tracts; and (6) probabilistic estimates of the numbers of undiscovered deposits, by type, within the quadrangle. The maps and tables are most useful when used together. The reports are intended for use by planners and resource economists who require quantitative, probabilistic estimates of mineral resource potential to aid in their land-use or policy decisions and by private individuals and corporations who can use regional information on mineral resources to aid in mineral exploration.

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