Text to accompany Nevada Bureau of Mines and Geology Map 115

GEOLOGY OF THE EUGENE MOUNTAINS, NORTHWESTERN NEVADA

by

Ronald H. Thole and Douglas W. Prihar

INTRODUCTION

The Eugene Mountains, on the Humboldt-Pershing county line about 22 miles southwest of Winnemucca, Nevada, consist of a thick sequence of late Late Triassic sedimentary rocks belonging to an early Mesozoic marine province of the western Great Basin that was a subsiding region during parts of the Triassic and Jurassic (Speed, 1978a,b). Two regional lithic terranes constitute the exposed fill of this subsiding region in the vicinity of the Eugene Mountains: a basinal terrane and a shelf terrane (fig. 1, on plate). The basinal terrane underlies much of northwestern Nevada and occupies an irregular discontinuous belt west of the shelf terrane. Speed (1978a,b) considers the basinal terrane to be allochthonous with respect to the shelf terrane.

The Late Triassic sedimentary rocks in the Eugene Mountains accumulated in a slope to a lower slope/basin setting that is preserved in a complex package of upward-ramping southeast-directed thrust plates (Thole and Prihar, 1982, unpub. report). The oldest sedimentary rocks are progressively exposed in structurally higher thrust plates from south to north. The northernmost thrust plates consist of a package of pelitic metasedimentary rocks, sandstone, and limestone. The ammonite *Metacarnites* (fossil location number Jw-65) was collected possibly by S.W. Muller or his students at Stanford University in 1949 (N.J. Silberling, 1993, written commun.). *Metacarnites* is typical of the *Juvavites magnus* zone which is assigned a late early Norian age. In the next thrust plate to the south a very distinctive ammonite, *Didymites* (U.S. Geological Survey Mesozoic fossil location number M-5015), was collected by W.C. Smith and his associates at the U.S. Geological Survey from 1945 to 1955 (N.J. Silberling, 1993, written commun.). *Didymites* is restricted to the middle Norian. The southern two-thirds of the Eugene Mountains is dominated by the informal stratigraphic units Triassic siliciclastics 1, Triassic carbonate clastics, Triassic siliciclastics 2; and, the Raspberry Formation. The clam *Monotis subcircularis* was found by W.C. Smith and his associates and the authors in all four of these units. In Nevada, these clams are probably restricted to the *Gnomohalorites cordilleranus* ammonite zone which has been assigned an early late Norian age (N.J. Silberling, 1993, written commun.).

Detailed studies of the stratigraphy and structure of the basinal and shelf terranes have been made in the East Range by Elison (1987) and Elison and Speed (1988, 1989), and in the southern Humboldt Range by Oldow and others (1986, 1990), Heck (1987), and Heck and Speed (1987). The stratigraphy and structural development of the basinal terrane rocks in the East range as described by Elison (1987) and Elison and Speed (1988, 1989) are similar to those we found in the Eugene Mountains. The interpretations and conclusions by Elison and Speed support our attempt to correlate the transitional slope facies to slope/basin facies of the northernmost thrust plates in the Eugene Mountains with the shelf facies (Grass Valley, Dun Glen, and Winnemucca Formations) in the East Range.

Middle and Upper Triassic shelf-basin transition rocks in the southern Humboldt Range have been described by Oldow and others (1986, 1990), Heck (1987), and Heck and Speed (1987). However, Heck (1987, 1991) and Heck and Speed (1987) differ greatly from Oldow and others (1986, 1990, 1991) in their interpretations of stratigraphic correlations, mode of deposition, and structural relations. A general description of stratigraphy in the southern Humboldt Range is similar to that found in the northernmost thrust plates in the Eugene Mountains. The Hollywood and Antelope Springs Formations of Oldow and others (1990) were assigned an upper lower Norian age on the basis of ammonites characteristic of the *Juvavites magnus* zone. Thus, penecontemporaneity or age equivalency between the sedimentary rocks in the northernmost thrust plate in the Eugene Mountains and these formations is established. In addition, the middle Norian ammonite *Didymites* in the adjacent thrust plate to the south in the northern Eugene Mountains is approximately age equivalent with the lower Lori Formation of Oldow and others (1990). We suggest that the sedimentary rocks exposed in the northernmost thrust plates in the Eugene Mountains represent possible slope or slope/basin facies of coeval shelf sedimentary rocks (Grass Valley, Dun Glen, and Winnemucca Formations) during the early to middle Norian, although direct correlation between rocks of the shelf and slope/basin is made difficult by the inadequate age control within the shelf sequence and the limited stratigraphic range of the sections as noted by Oldow and others (1990), and structural complexity.

Similarities between the description of the composition, stratigraphy, and sedimentology of the very thick section of early late Norian sedimentary rocks in the southern two-thirds of the Eugene Mountains are found with the slightly older (late early to middle Norian) Hollywood, Antelope Springs, and Lori Formations (Pershing Ridge Group) of Oldow and others (1990) in the southern Humboldt Range, and the middle Norian Fencemaker allochthon of Elison (1987) and Elison and Speed (1988, 1989) in the East Range. These units in the Eugene Mountains are somewhat enigmatic temporally and either their cumulative thickness implies extraordinarily active rates of sedimentation during the early late Norian or that *Monotis subcircularis* in Nevada is possibly more widely distributed over time than previously described and may not be a reliable index fossil for this area. The former is probable because it is unlikely that the stratigraphic range of *Monotis subcirculatis* is substantially greater than that generally attributed to it where it is widely known from the eastern Pacific Rim (N.J. Silberling, 1995, written commun.). Nevertheless, the repetition of sedimentary cycles occurred over a relatively short time interval during the early late Norian if the assignment of this age to *Monotis subcircularis* is accurate.

Structurally, the Eugene Mountains form the overturned limb of a southeast-verging, miles-wide anticline; the complimentary syncline is projected beneath the alluvial covered valley bottom to the east. Most significantly, regional structure is characterized by north-northeast-trending, southeast-verging folds of early development and southeast-directed thrust faulting. Similar structures were described for the slightly older proposed basin-to-shelf transition in the East Range by Speed (1978b) and Elison and Speed (1988, 1989) where the leading western edge of the shelf terrane acted as a buttress along which basin strata were folded and almost everywhere ramped eastward over shelf terrane along the Fencemaker thrust system. Limited displacement is indicated locally in the southern Humboldt Range where Heck (1987), Heck and Speed (1987), and Oldow and others (1986, 1990) described correlative proximal basin-to-shelf transitional relationships.

QUATERNARY DEPOSITS

Recent alluvial deposits (Qal, Qed, Qp)

Qal: Undifferentiated, unconsolidated, sorted to unsorted alluvial fan deposits and fluvial gravels, sands, and boulders. **Qed:** Eolian sheet and dune sands. **Qp:** Playa deposits; silt and clay.

Lahontan lakebeds (Qls)

Exposed near-shore deposits of the late Pleistocene pluvial Lake Lahontan include sand, silt, clay, and terrace and beach gravel deposits.

Older alluvium (Qoal)

Fifty feet or more of silt, sand, and gravel deposited by sheet wash and early Pleistocene streams.

TERTIARY AND CRETACEOUS ROCKS

Silicic pyroclastics (Tsv)

Light-gray, cream, and white crystal-vitric to local crystal-lithic ash-flow tuff with quartz (3–7%), plagioclase feldspar (0–10%), sanidine (0–3%), rare biotite, and angular fragments of rhyolite and/or pumice, 5 to 50 mm in diameter. Locally, basal portion of ash-flow tuff consists of nonwelded to poorly welded ash overlain by thin (5-foot) layers of black or gray vitrophyre. One or more cooling units may be present. The interior portions of the cooling units are moderately to densely welded with columnar joints developed locally. Silicic ash-flow tuff in the Eugene Mountains is interbedded with basalt (Tb).

Basalt flows (Tb)

Black, dense, vesicular to amygdaloidal olivine-bearing basalt. Columnar joints are found locally. Microphenocrysts of olivine and clinopyroxene in a hyalopilitic groundmass. Microlites of plagioclase feldspar display pilotaxitic texture. Amygdules are composed of chalcedony. Basalt flows in the Eugene Mountains are interbedded with silicic ash-flow tuffs (Tsv). The tops of basalt flows underlying Tsv are brick red and hematitic.

Older alluvial deposits (Tal)

Tertiary stream boulder, cobble, and gravel deposits occur in isolated exposures across the Eugene Mountains. These deposits grade laterally into a red regolith. The boulder-, cobble-, and pebble-size material is made up of well-rounded and polished milky quartz, quartzite, chert, and hornfels. Several of the deposits have been worked for placer gold. Some of these conglomeratic deposits are located in the higher elevations and others are on the northeast and southeast flanks of the Eugene Mountains. They have been displaced by Tertiary basin-and-range faulting and the location of these deposits indicates that the western half of the Eugene Mountains was uplifted with concomitant easterly tilting of the range, the amount of which has not been determined.

Quartz porphyry (TKiqp)

Dikes and small plugs of rhyolite to rhyodacite containing small (1–2 mm) and sparse (5%) phenocrysts of quartz in a pale-gray aphanitic matrix. A good example is located at the head of Bonita Canyon.

Diabase and gabbro plugs and dikes (TKid)

These are equigranular, fine to medium grained and exhibit ophitic intergrowth of albite, augite, and hypersthene.

Porphyritic hornblende andesite stocks, dikes, sills, and autobreccia (TKia)

A cluster of three large volcanic pipes of porphyritic andesite occurs in the southwest of the Eugene Mountains in Bonita Canyon. The plugs are porphyritic andesite with large crystals (2 cm in diameter) of oscillatory zoned plagioclase feldspar as well as hornblende and garnet (G). Iron-oxide-stained breccia with tourmaline and gold mineralization is found in association

with the central pipe. Chlorite-bearing andesite breccia with hornfels fragments occurs along the outer edge of all three pipes. There is a possibility that the andesite pipes were the vent for the somewhat thick sequence of volcanics of dominantly andesitic basalt composition that occur immediately to the south.

Equigranular granodiorite (TKgd)

Southwest Springer stock, K-Ar dated at 68.4±2.5 Ma (Tingley, 1975; all ages recalculated using decay constants of Steiger and Jager, 1977).

Granodiorite, porphyritic andesite, and aplite (Kia, Kgd, Kap)

Kia: Porphyritic andesite and andesite porphyry sometimes occurs as a chill-border facies on the margins of the granodiorite stocks; andesite dikes and sills are concentrated at and cut across the granodiorite and pelitic rock contact. **Kgd:** Granodiorite; fairly fresh holocrystalline, of medium grain size and indistinctly porphyritic, showing phenocrysts of milky feldspar and large biotite books in a dark, medium- to fine-grained groundmass; K-Ar dates of four granodiorite stocks range between 76.1±2.8 Ma and 89.3±3.2 Ma (Tingley, 1975; recalculated 1998). **Kap:** Aplite, leucogranite, and pegmatite occur in the hood zone of differentiated granodiorite stocks and in places as dikes and plugs in hornfels and in granodiorite; in the Springer stock, adularia in a quartz vein was K-Ar dated at 78.2±2.7 Ma (Tingley, 1975; recalculated 1998). The main granodiorite stocks are composed of quartz, orthoclase, andesine, albite, hornblende, and biotite with accessory magnetite, sphene, apatite, pyrite, zircon, and epidote. The associated dikes are variable in composition and texture. Some contain only trace amounts of dark minerals and some are composed entirely of quartz, albite, and minor potassium feldspar. Near the center of the Eugene Mountains elongate cusps of granodiorite and leucogranite are exposed and are interpreted to be the very top portions of granodiorite stocks. These cupolas are argillic and quartz-sericite altered granodiorite that in places grade into leucogranite and aplite. The intrusions contain about 0.3% pyrite; however, where calcareous beds are present, the beds are replaced by skarn and contain scheelite, molybdenite, and pyrite. Adularia in quartz veins from skarn beds adjacent to the Springer stock was K-Ar dated at 74.1±2.6 Ma (Tingley, 1975; recalculated 1998). Numerous granodiorite dikes and sill-like intrusions occur in the northwest part of the range. The sills are largely conformable with the local structural grain and probably were emplaced at relatively high structural level along preexisting fracture zones formed during an early period of thrust deformation.

TRIASSIC ROCKS

Raspberry Formation (Ŧr, Ŧrls, Ŧrss)

Ŧr: Up to 7,000 feet of gray-green, lavender, and black pelitic strata intercalated with thin (about 3 feet to 50 feet thick) lenses of gray to black, somewhat carbonaceous micritic limestone. Limestone beds (1 to 20 feet thick) host scheelite-bearing contact metasomatic deposits at the Nevada-Massachusetts Company Mines. The pelecypod *Monotis subcircularis* is common in the pelitic strata of the Raspberry Formation and establishes an early late Norian age. At least 12 major limestone units (Ŧrls) have been mapped in the district. Nine beds or groups of beds of particular economic interest listed stratigraphically from oldest to youngest are the West beds, Seel bed, Ribbon beds, Yellow-scheelite bed, Stank bed, Sutton beds, West Mill beds, East Mill beds, and Forge beds. The limestone beds, especially the Sutton beds on the east margin of the Springer stock, serve as marker horizons in this otherwise undistinctive sequence of strata. The pelitic strata that are in proximity to the limestone units contain 1-inch- to 20-foot-thick siliceous beds of gray, yellow, or green calc-silicate rock that is metamorphosed marl. The limestone and marl units comprise about 25% of the pelitic section. To the south-southwest, near the base of the Raspberry Formation, the micritic limestones grade into calcarenites and in places these are interbedded with or grade into calcareous feldspathic sandstone (Ŧrss). These clastic sedimentary rocks exhibit both symmetric and asymmetric ripple marks, interference ripples, crossbedding, load casts, and flute casts.

Triassic siliciclastics 2 (Ŧs$_2$, Ŧs$_2$ls, Ŧs$_2$ss)

Ŧs$_2$: Up to 2,000 feet of black, dark-lavender, and green-gray argillite and silty argillite with 2- to 30-foot-thick lenses of limestone (Ŧs$_2$ls), and calcareous feldspathic sandstone and pale laminated fine-grained sandstone (Ŧs$_2$ss). The base of Ŧs$_2$ is drawn at the first laterally continuous limestone, Ŧc. The upper contact is gradational and is tentatively drawn at the appearance of somewhat continuous micritic limestone and marl lenses in a dominantly pelitic sequence. Ŧs$_2$ is composed of about 4% limestone, 8% sandstone, and 88% argillite. Argillite, phyllite, and shale with scarce, about 4-foot-thick quartzite beds (Ŧs$_2$ss) comprise Ŧs$_2$ west of the Nevada-Massachusetts Company Mines and over much of its occurrence. Feldspathic sandstone lenses (Ŧs$_2$ss) are more abundant in higher parts of the formation near the Keystone Mine to the northeast and in section 4, T33N,R34E to the southwest. Some of the limestone lenses are calcarenites and may be interbedded with sandstone, and in some places grade laterally into sandstone. Sedimentary structures associated with these clastic sedimentary rocks include load casts, flute and groove casts, crossbedding, and asymmetric ripple marks. These sedimentary structures consistently indicate that the strata on the east slope of the Eugene Mountains face east. Likewise, southwest of the Nevada-Massachusetts Company Mines, ripple marks indicate that the beds dipping to the east are right side up. The pelecypod *Monotis subcircularis* is common and establishes an early late Norian age.

Triassic carbonate clastics (Ŧc)

From 50 to 1,500 feet of black to gray calcarenite with beds of calcilutite, micrite, and calcirudite. It is composed mainly of both lithoclastic detrital dolomite and calcite of sand size, and locally contains pebbles and reworked calcarenite. The calcarenite shows well-developed graded bedding and crossbedding. Fragments of reddish-brown sandstone occur near

the base of TRc. A few scattered grains of detrital quartz and albite are usually present and some of the calcarenite is sufficiently impure to weather reddish brown. In places the calcarenite grades into micrite or calcilutite and is interbedded with gray and black argillite. The formation is a distinctive marker and forms cliffs and north-northeast-trending cuesta-like ridges for 10 miles along strike in the Eugene Mountains. Where TRc is thin, about 100 feet thick, it is composed mainly of dense gray bedded micritic limestone. The thicker sections are composed of intraclastic limestone, dolomite breccia, sandy limestone, and calcareous sandstone. The breccias consist of sand- to pebble-size angular and sub-rounded fragments that are crudely stratified by maximum grain-size and are so closely packed as to be nearly devoid of matrix. These clastics show a sharp basal contact and are crudely graded upwards in individual bands; however, as a unit, the banding may be repeated, and coarse fragments are as common near the top as they are near the base. TRc is displaced by both transverse and strike faults. The formation is folded in proximity to these faults and secondary calcite veinlets fill fractures that have formed both parallel and transverse to the bedding of the folded strata. Elsewhere, TRc is intensely folded at its north-northeast and south-southwest extremities at the inferred banks of this large paleochannel deposit, where its thickness decreases from about 1,000 feet to 50 feet. Sedimentary structures and overall texture in TRc are generally well preserved but they are locally obliterated by intense marmorization. A primary sedimentary control to some of the folds is indicated by their concentration at the facies change between the thick sequence of interbedded coarse and fine carbonate clastics and the relatively thin calcilutite and/or micrite unit. The pelecypod *Monotis subcircularis* is found locally and establishes an early late Norian age.

Triassic siliciclastics 1 (TRs_1, TRs_1ls, TRs_1ss)

TRs_1: Up to 8,000 feet of dark-gray, almost black chlorite-bearing argillite, slate, and phyllite interlaminated in part with micaceous siltstone or very fine-grained sandstone (TRs_1ss), some of which weathers to olive black and olive gray to gray. Subordinate interbedded units of well-sorted sandstone from 1 to 300 feet in thickness form dark craggy outcrops on the otherwise smooth rounded slopes underlain by these rocks. The upper contact of TRs_1 is at the base of the lowest laterally persistent limestone. TRs_1 is composed of about 2% limestone, 12% clean sandstone, 20% impure sandstone, and 66% argillite. Although largely noncalcareous, TRs_1 contains some laterally discontinuous limestone beds and limestone channel deposits (TRs_1ls). The limestone beds are 2 to 10 feet thick. The limestone channels are 20 to 100 feet thick and have an apparent width of 1,000 feet along strike. The limestone beds are dark-gray and have a silty texture, probably being calcilutites. The channel deposits are medium gray and are calcarenite to calcirudite in texture. They are composed of both angular and partly rounded fragments of limestone, fossil fragments, and sandstone. Clean quartz sandstone (TRs_1ss) comprises both lenses and channel deposits that are commonly 10 to 50 feet thick but may be up to about 300 feet thick where sandstone channels are stacked vertically. Laterally continuous sandstone lenses are in places interstratified with argillaceous sandstone beds. These sandstone lenses are commonly dark, thin-bedded, very fine-grained sandstone that occur in laterally discontinuous units throughout the section. Linguoid ripple marks on the upper surface of the argillaceous sandstone beds and load casts and flute and groove casts on the lower surfaces of these beds indicate east-to-west transport. The laterally continuous sandstone units and channel deposits are made up of nearly white to medium-light-gray and light-brownish-gray, massive, clean, well-sorted, medium-grained sandstone. Some of the sandstone contains up to 10% calcareous cement; most is cemented by abundant interlocking overgrowths of quartz. Quartz grains are the most abundant and in the coarser size fractions are moderately well rounded. The grains contain as much as 10% albite but usually not more than 1 to 2%. No magnetite was detected in either the clean or the impure sandstones. Sedimentary structures are absent in the channel sandstones; however, the basal contact is often marked by a mud-pebble conglomerate with either a mudstone or sandstone matrix. Fossil wood fragments were found in one of these channel deposits about 1,000 feet below the base of TRc. The pelecypod *Monotis subcircularis* is common and establishes an early late Norian age.

Pelitic metasedimentary rocks, sandstone, and limestone (TRms, TRss, TRls)

Up to 3,000 feet of dark-gray to black argillite, slate, and phyllite, commonly with 0.5% disseminated pyrite, interlaminated in part with micaceous siltstone and fine- to medium-grained green-gray to light-brown sandstone and quartzite (TRss), whose thickness is commonly several inches to 50 feet. Some laterally discontinuous limestone beds and limestone channel deposits (TRls) occur intercalated in this unit and are from 2 to 200 feet thick. The limestone beds and channel deposits are medium gray to black and are micrite to calcarenite and calcirudite in texture. The limestone channel deposits are composed of both angular and partly rounded fragments of limestone, fossil fragments, and sandstone. Fossil fragments include pieces of crinoids, brachiopods, bryozoans, and corals. The unit is composed of about 2% limestone, 10% clean sandstone, 18% impure sandstone, and 70% argillite. Ammonites assigned to the *Juvavites magnus* zone (late early Norian) are found in the northwesternmost thrust plates and the middle Norian ammonite, *Didymites*, is found in the next plate to the south.

SEDIMENTATION

The Triassic rocks exposed in the north Eugene Mountains occur in allochthonous thrust slices emplaced from the northwest. The sequences consist mostly of black and gray phyllite and argillite and subsidiary siltstone, sandstone, and fossiliferous calcirudite channel deposits. Fossils identified in the calcirudite channels are shallow water marine invertebrates including echinoderms, corals, pelecypods, and brachiopods. The channels are typically interbedded and cross-stratified calcarenite and calcirudite.

These sediments probably were deposited on a prograding delta within a relatively high-energy shallow-water shelf environment. In addition, ammonites assigned to the *Juvavites magnus* zone (late early Norian) are found in the northernmost thrust plates and the middle Norian ammonite *Didymites* is found in the next thrust plate to the south.

In the southern Eugene Mountains, the uniform current direction recording east-to-west sediment transport, lateral discontinuity, and other features of the impure and pure sandstone units within the pelitic facies agree with the interpretation of these units as channel deposits representative of the channel distributary system that is characteristic of turbidites deposited in a prograding submarine fan. The facies model implies deposition of the entire assemblage of fine-grained sedimentary rocks (of which the Triassic siliciclastics unit is a part) along a prograding shoreline. It also implies major river drainage into northwestern Nevada as a source of the sediments. The calcarenite channels may have been locally derived from the east from correlative carbonate platform deposits. To the west, these sediments were deposited in a prograding delta in a shallow shelf environment; however, further west, near the Eugene Mountains, the depositional slope steepened and the deltaic sediments were redeposited in turbidite fans and channels basinward of the zone of maximum instability. A transitional facies between the basinal and shelf facies is implied by stratigraphic trends. The sediment thickness in the Eugene Mountains is about 3 times that recorded for equivalent sequences of the shelf terrane and the average sandstone-to-mudstone ratio is 1:2.1 versus 1:2.28, respectively, for Triassic siliciclastics 1 unit ($\bar{T}Rs_1$) in the Eugene Mountains versus the Grass Valley Formation of the prodelta shelf facies (Silberling and Wallace, 1969). The Triassic siliciclastics 1 unit exhibits five siliciclastic facies: dominantly mudstone in all regions with sandy channel-margin deposits in the northeast; channel fill, channel-margin deposits and sandy turbidites in the central Eugene Mountains, and mudstone dominant with sandy channel-margin deposits decreasing in abundance to the southwest. The northeast and central regions contain graded, tabular sandstones that contain Bouma sequences and grade to mudstone. The Eugene Mountains record an early period of progradation and submarine fan development in the Triassic siliciclastics 1 unit, and to a less extent during deposition of the Triassic siliciclastics 2 unit. Periods of fan abandonment are indicated by changes from siliciclastic to dominantly hemipelagic carbonate deposition associated with greatly reduced channeling. The facies model implies major river drainage feeding into this area from subaerially exposed regions to the east as a source of the siliciclastic sediment (Silberling and Wallace, 1969; Burke and Silberling, 1973; Lupe and Silberling, 1985; Elison and Speed, 1988).

The Triassic carbonate clastics unit is a composite of turbidite channel fan deposits and debris flows and represents carbonate slope facies sedimentation. The style of sedimentation and geometry of this unit suggest deposition as a base of slope carbonate apron. The slope facies is transitional between the rapid and active production of calcium carbonate on the shallow water shelf to the east and the gentle rain of pelagic sediments to the west. The platform-to-basin transition in places may have been abrupt, in the form of a steep cliff; although it may have been a gently inclined slope decreasing in grade with depth and merging with the basinal deposits. A thick continuous carbonate reef probably formed as the influx of siliciclastic sedimentation nearly ceased at the end of the Triassic siliciclastics 1 unit deposition. It is likely that the reef was brecciated, eroded, and redistributed by wave action. Streams may have further eroded the carbonate reef and carried the debris basinward. Gravity-induced catastrophic sedimentation triggered by an unstable build up of chemical sediments and clastics at the platform-slope transition or by earthquakes may have caused large quantities of material to be transported and deposited in turbidite channels and fans.

The Triassic siliciclastics 2 unit was deposited under oscillating conditions of sedimentation which followed the period in which carbonate deposition was dominant. Facies changes from marine shales to areas with clastic carbonate and sandstone lenses imply deposition on a stable, shallow-water shelf in proximity to estuaries or their associated delta deposits.

The Raspberry Formation probably represents quiescent, very fine clastic, below-wave-base water deposition on a stable shelf. It is probable that storms may have stirred up the wide, shallow, mud-floored areas of the shelf and the carbonate ooze may have been carried across the shelf margin to settle in deep water. There is some difference in interpretation about the inferred life habit of *Monotis subcircularis* which is so abundant in the Raspberry Formation, but all agree that it is nearly restricted to below-wave-base deposits. Most specialists seem to believe it was planktonic in the sense of being attached to something (Sargasso-like) floating near the surface of the sea (some *Monotis* clearly show a paleolatitudinal distribution); others argue for a seafloor attached habit in a deep low-energy, possibly low-oxygen environment (N.J. Silberling, 1995, written commun.).

STRUCTURE

The deformational history of the Eugene Mountains is complex and the chronology of deformation is difficult to decipher because of discontinuous outcrops, faulting, lack of marker horizons, and intrusion of igneous stocks. However, the continuity of the Sutton beds and other limestone beds in the Raspberry Formation for many miles along a north-northeast structural grain testifies that these beds have not been repeated to any large extent by folding. Likewise, the Triassic carbonate clastics unit was traced as a single stratigraphic unit trending north-northeast for at least 9 miles. It is, however, folded back on itself at least once, resulting in up to 1,500 feet of local stratigraphic repetition along a macroscopic isoclinal fold whose axial plane is almost concordant to the structural grain of the range. This fold has a 4,500-foot amplitude and an 800-foot wavelength. Sedimentary structures located throughout the range support the conclusion of a somewhat continuous stratigraphic sequence facing east, from the Triassic siliciclastics 1 unit in the west through the Raspberry Formation in the east.

The structural grain of the Eugene Mountains is mainly N10°–30°E and dips steeply both to the east and to the west.

Table 1. Chemical and selected minor element analyses of plutonic, volcanic, sedimentary, and metasomatic rocks from the Eugene Mountains[1]

Sample	32939	32941	32823	37218	37520	33777	43738	32990	33197	33210	33297	32784A	37473A	33117	33154	33120	33119	375L	37406	32783	6251A&B	33617
Map unit	Tsv	Tb	TKiqp	TKiqp	TKid	TKia	TKia	TKgd	Kap	Kia	Kia	Kgd	Kgd	Ꞧr	Ꞧr	Ꞧls	Ꞧls	Ꞧls	Ꞧls	Ꞧls	Ꞧls	Ꞧs$_1$ss
Site no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Rock type	Dacite welded tuff	Basalt	Quartz porphyry	Quartz porphyry	Diabase	Porphyritic hornblende andesite	Porphyritic hornblende andesite breccia	Equigranular granodiorite	Leucogranite	Andesite porphyry	Sericitized andesite porphyry	#Granodiorite	Porphyritic hornblende granodiorite	Phlogopite actinolite hornfels	Actinolite epidote diopside hornfels	Actinolite epidote skarn	Actinolite diopside skarn	Diopside epidote garnet skarn	Epidote diopside skarn	Diopside garnet skarn	Scheelite-bearing garnet skarn	Silty quartzite
wt. %																						
SiO_2	68.07	49.09	62.10	68.34	49.05	63.07	64.73	69.25	75.88	56.22	65.55	66.18	58.50	61.39	44.14	50.52	69.23	42.92	63.12	23.60	50.20	64.35
TiO_2	0.31	1.06	0.49	0.28	2.27	0.46	0.53	0.45	0.10	0.71	0.92	0.50	0.62	0.82	1.02	0.22	0.67	0.36	0.47	0.25	0.26	0.85
Al_2O_3	16.14	14.38	18.47	17.92	14.42	15.03	12.66	14.56	13.68	17.84	19.69	17.07	17.58	15.13	14.00	8.85	9.85	11.89	8.37	4.94	7.06	18.11
Fe_2O_3	2.26	5.04	2.52	1.39	9.58	10.66	10.93	2.13	0.25	3.46	1.83	2.43	3.90	2.81	3.30	4.54	1.51	7.35	9.85	1.02	6.65	4.80
FeO	0.04	4.18	1.36	0.26	4.93	0.22	0.24	0.44	0.20	2.38	0.09	1.30	2.57	3.78	5.08	1.54	2.31	1.88	0.44	1.08	1.45	0.11
MnO	0.04	0.14	0.04	0.06	0.20	0.01	0.01	0.02	0.01	0.11	0.00	0.05	0.10	0.10	0.13	0.45	0.18	0.67	0.25	0.05	0.31	0.01
MgO	0.31	9.54	0.90	0.41	4.28	0.36	0.50	0.82	0.24	2.29	0.51	1.17	2.55	3.61	7.84	2.63	2.68	3.24	0.25	3.45	1.98	0.40
CaO	3.73	8.18	5.22	1.15	8.54	0.79	0.99	3.24	2.33	6.72	0.89	3.20	5.88	7.23	9.86	22.10	10.00	26.11	14.78	43.46	24.71	1.21
Na_2O	4.07	3.54	5.27	5.23	3.79	1.32	2.25	2.54	4.87	4.55	2.24	3.91	4.19	1.77	2.74	0.41	1.83	0.10	0.43	0.14	0.29	1.74
K_2O	3.52	2.24	1.96	2.84	1.49	3.26	2.28	5.32	1.63	2.27	2.98	2.53	2.75	2.66	0.48	0.06	0.91	0.02	0.32	0.24	<0.01	3.22
P_2O_5	0.07	0.41	0.16	0.10	0.32	0.11	0.10	0.16	0.03	0.24	0.07	0.20	0.20	0.15	0.31	0.17	0.12	0.19	0.05	0.19	0.27	0.10
S	0.04	<0.01	<0.01	0.04	0.01	0.18	0.26	0.02	0.15	0.42	0.29	<0.01	<0.01	0.15	<0.01	0.05	0.17	-	<0.01	<0.01	-	0.35
CO_2	0.46	0.27	0.37	0.39	0.15	0.31	0.09	0.24	0.21	1.54	0.35	0.21	0.50	0.24	5.96	7.81	0.50	-	0.38	21.98	-	0.06
$H_2O^{\pm}$	1.24	2.21	1.57	1.78	1.96	4.55	5.04	1.04	0.56	2.14	4.86	1.26	1.45	0.66	6.09	1.36	0.66	4.55*	2.05	0	6.00*	5.08
WO_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	0.02	<0.01	1.05	<0.01
Total	100.30	100.28	100.43	100.19	100.99	100.33	100.61	100.23	100.14	100.89	100.27	100.01	100.79	100.50	100.95	100.74	100.62	99.28	100.78	100.40	100.23	100.39
ppm																						
Ag	<0.2	0.4	0.2	0.4	0.3	2.3	15	2.1	0.4	0.3	0.9	1.6	0.3	0.4	0.4	8.0	0.2	1.6	0.4	0.4	0.3	1.3
As	<10	<10	<10	73	10	178	100	27	<10	<10	102	<10	<10	<10	32	<10	<10	3	15	<10	3	465
B	9	<5	<5	30	<5	29	20	27	17	14	126	54	23	6	12	8	11	39	<5	30	30	162
Ba	1330	1210	1280	1250	685	475	250	1320	4200	930	1090	900	1020	685	140	104	425	22	132	87	10	565
Be	<2	2.4	<2	2.2	4.3	<2	<2	<2	2.4	2.5	2.8	7.3	2.6	2.5	2.7	7.8	<2	3	<2	7.3	1	4.4
Bi	<5	<5	7	<5	<5	<5	<5	24	7	<5	<5	22	<5	<5	<5	22	<5	2	46	7	<5	<5
Cd	<1	4	1	2	4	7	6	2	<1	1	1	1	3	2	2	118	<1	2	2	8	1	4
Ce	28	48	3	34	35	8	16	14	12	9	10	15	10	20	27	7	12	-	12	15	-	15
Co	3	31	2	<2	26	4	3	5	<2	9	<2	2	7	12	25	2	5	35	3	2	24	5
Cr	29	53	19	14	33	12	37	45	52	17	22	10	24	81	275	43	36	-	37	10	-	11
Cu	4	79	4	11	118	28	110	76	4	17	7	279	37	23	39	100	29	560	84	6	20	44
In	3	4	<2	3	4	<2	<2	<2	<2	2	<2	8	<2	3	5	3	<2	-	<2	8	-	<2
La	6	17	<2	11	11	3	8	5	6	2	3	6	2	4	9	2	2	-	6	6	-	3
Li	20	35	15	10	30	30	35	25	10	50	50	7	40	25	160	5	<5	-	10	10	-	60
Mo	2	4	2	<1	4	56	7	6	2	1	1	115	3	2	1	16	1	9	10	17	220	4
Nb	3	10	2	<2	25	<2	2	2	<2	2	<2	6	6	<2	5	6	<2	-	4	6	-	4
Ni	13	170	3	3	14	<2	4	5	<2	4	3	6	4	19	70	17	12	20	6	13	12	17
Pb	<2	5	3	9	<2	35	1760	51	8	<2	8	25	<2	5	6	176	28	14	30	<2	12	29
Rb	<2	3	<2	5	26	8	7	6	<2	18	3	24	64	73	<2	4	<2	-	<2	<2	-	5
Sb	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5	<5	<5	<5	<5	<5	-	<5	<5	-	6
Sc	<2	20	<2	<2	35	<2	5	5	<2	10	9	4	12	12	23	<2	7	-	6	<2	-	13
Sn	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	6	<5	6	<5	<5	<5	2	<5
Sr	1480	1090	1190	495	470	330	325	560	430	890	735	700	670	385	825	620	600	-	280	1480	-	520
Th	4	4	<2	2	4	<2	<2	3	4	3	<2	3	4	4	5	6	3	-	5	4	-	4
Tl	6	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	2	<2	<2	-	<2	6	-	<2
V	1030	205	41	16	420	36	100	64	2	118	146	69	130	89	182	975	54	-	162	1030	-	144
W	18	<5	<5	<5	<5	<5	7	67	<5	<5	<5	80	43	<5	<5	215	21	-	158	18	8327	<5
Y	31.2	18.2	6.7	11.6	40.3	2.2	6.2	10.9	8.1	17.1	18.6	10.8	19.7	34.9	25.3	23.6	33.2	-	37.8	31.2	-	29.8
Zn	360	57	38	18	58	43	96	19	5	41	7	60	33	37	31	6450	25	240	18	360	195	59
Zr	80	124	83	148	182	108	128	81	42	114	176	82	106	240	128	69	305	-	136	80	-	192

[1]Analyses by BHP-Utah International Minerals Lab, Sunnyvale, California
#Imlay, Nevada; Springer Mine - granodiorite - average analyses of 251 drill-core samples, each sample represents 10-foot interval from DDH NM-49
-Not assayed
*Assay is equal to loss on ignition (L.O.I.)
±Includes water removed at 105°C and crystalline water

The attitude of bedding is often difficult to determine because the Eugene Mountains are mainly composed of homogeneous structureless pelitic strata. However, compositional layering is often recognized in hand specimens and, in addition, lenses of limestone, sandstone, and siltstone provide evidence as to the orientation of primary bedding surfaces. On the east side of the Eugene Mountains and to the south, the bedding attitude is generally very steep and to the west; however, farther east, into the pediment, the dip is reversed and quickly changes from steep to almost horizontal in the valley bottom. The disruption of beds is mainly due to irregular displacement and rotation of the strata between a series of range-front Tertiary basin-and-range faults. Movement on these faults is mapped as alternating grabens and horsts, but average displacement is down to the east. Sedimentary structures, including ripple marks, load casts, and scour features, all indicate that the beds dipping east on the eastern side of the range are right side up and that local reversals in facing direction are due to macroscopic asymmetric isoclinal folds. The beds on the north end of the range mainly strike N50°–90°E and dip 30°–70°NW; however, dips of 40°–80°E are common in the extreme northwest. On the west side of the range the beds dip about 40°–60°NW. The symmetry of channel sandstone deposits and scour features in these regions indicate that the beds dipping west and north are mainly overturned. In a few places lithologic banding outlines mesoscopic and macroscopic asymmetric isoclinal folds with vergence to the southeast, and an average fold axis orientation of approximately N50°E, 50°NE and whose axial planes are oriented N60°E, 70°NW. Folds of this orientation are the earliest folds formed in the Eugene Mountains. Intrafolial folds have axial planes sympathetic to the structural grain of the range and are dominantly seen immediately below and above the Triassic carbonate clastics unit (TRc). The mesoscopic and macroscopic isoclinal folds, however, are not restricted to proximity to TRc and have been mapped in a number of locales in TRs_1, TRs_2, and particularly TRms in the extreme northwest corner of the Eugene Mountains. The folds exhibit a form and distribution unlike the folds found near the igneous stocks and near transverse faults. These isoclinal folds formed during an early major deformation of the range and probably resulted from competency contrasts between TRc and the adjacent pelitic rocks. Elsewhere, this deformation was expressed as passive shear within and between pelitic beds during which time the bedding cleavage or structural grain of the range was formed. In the northwest Eugene Mountains, this structural grain conforms to imbricate thrust slices, probably mainly emplaced during the Middle Jurassic (Oldow, 1978: Speed, 1978a,b; Elison and Speed, 1988, 1989). These allochthonous slices involved the southeastward movement of offshelf Triassic pelitic rocks over Triassic shelf rocks. The allochthonous rocks occur in at least five imbricate thrust slices; some are recumbently folded and in turn cut by planar thrusts. Numerous closely spaced sill-like bodies of granodiorite, which strike about northeast and dip 30°–60°NW, occur in the northwest Eugene Mountains mainly within the thrust plates. The presence of these sills indicates the previous existence of structures for their emplacement that may have been the interface between unlike lithologies, but more likely were fault structures. Near the Nevada-Massachusetts Company Mines, pregranodiorite faults are probably minor, and they are largely obliterated by later metamorphism; it is often difficult to distinguish a faulted limestone bed from a lenticular one. Here, the pregranodiorite faults are usually characterized by broad zones of silication and silicification.

Superimposed on the north-northeast structural grain are folds and warps associated with the intrusion of granodiorite stocks. The intrusion of the Springer stock was mainly passive and the beds are clearly truncated without evidence of deformation. However, northeast of the Springer stock the skarn beds outline a large fold structure that conforms to the eastern margin of the Olsen stock and indicates forceful intrusion of this stock. In addition, megascopic intrafolial 'similar-type' folds, formed during plastic and pervasive shear deformation, are outlined by light-colored calc-silicate bands in the otherwise black calc-silicate hornfels (incompetent) and not in the massive siliceous hornfels (competent).

In the region of the Springer stock and particularly the Olsen stock, some faults formed as the result of adjustments to the emplacement of large cylindrically shaped granodiorite bodies. In places, as temperatures increased and volatiles were expelled, the strata became brittle and failed along fault structures. Both transverse and strike faults were formed. The displacement on most of these faults is minor and is in particular associated with offsets across limestone or calc-silicate lenses that are in close proximity to and warped around a granodiorite stock. In most cases it appears that during the initial stages of granodiorite intrusion the calcareous beds were deformed by warping and passive shear folding; however, during the late stages these same beds failed by fracturing.

The Stank fault at the Nevada-Massachusetts Company Mines is a normal fault with about 1,000 feet of vertical displacement. The fault strikes northwest, dips 40°–60°SW and cuts scheelite-bearing skarn beds. The fault also cuts through the Southwest granodiorite stock but offsets it only a few feet. The major displacement apparently took place before intrusion of the granodiorite; however, some displacement is post-granodiorite in age. The Stank fault is part of an anastomosing series of curvilinear normal faults that outline a westerly facing crescent or ring-shaped fault zone, projected to be about 10 miles in diameter located over the central Eugene Mountains. Perhaps this fracture pattern first developed as the result of forces related to emplacement of a centrally located batholithic body; however, doming or faulting of overlying sedimentary rocks was followed by magma devolitization and extrusion of volcanics with concomitant collapse and resultant normal fault offset.

Some of the largest faults recorded in the Eugene Mountains are post-granodiorite in age and probably formed during Tertiary basin-and-range extension faulting and related volcanism. The post-granodiorite faults are commonly recognized by gouge on the fault surface and by lack of associated mineralization. Offsets are generally small, ranging to 100 feet; however, in places displacements greater than 500 feet are recorded. These faults commonly strike north-south and can be traced for considerable distances. They have resulted in minor displacements across the Nevada-Massachusetts Company orebodies and in the granodiorite stocks.

METAMORPHISM

At least two metamorphic events are recognized in the Eugene Mountains. The earliest was a low-grade regional event that affected the entire range. This early low-grade regional event transformed the pelitic rocks to slates and phyllites, and the quartzose siltstones and sandstones to quartzite. The limestones were little affected. The foliation developed in these slates and phyllites formed during a pre-intrusive structural event (i.e., thrusting and folding).

Superimposed on this early regional event is a contact metamorphic (including metasomatism) event that was produced when granodiorite to quartz diorite stocks intruded the sedimentary sequence, about 90 to 60 Ma. Contact aureoles can be recognized around the intrusions. Both the hornblende-hornfels facies and the albite-epidote-hornfels facies of Turner (1968) are present.

The albite-epidote-hornfels facies occurs on the outer margin of the contact aureole and passes inward into rocks of the hornblende-hornfels facies. Because temperature gradients decrease away from the intrusive, recrystallization in the peripheral areas tends to be imperfect. This is reflected in the intensity of the development of albite-epidote-hornfels facies mineral assemblages along the peripheral portions of the contact aureole. In this peripheral area, the regional foliation developed in the slates and phyllites has been preserved. As the intrusive contact is approached, recrystallization becomes complete and the regional foliation has been obliterated. The resultant rock is a dense, massive, very fine-grained to aphanitic rock that crops out as blocky masses. Characteristic granoblastic texture is found in thin sections of these rocks.

Adjacent to the intrusive contact, hornfels and spotted schist are found. The spotted texture is due to the growth of andalusite and/or cordierite and less commonly actinolite porphyroblasts. The foliation in the spotted schists is not the relict regional foliation that was previously described. This schistosity developed during recrystallization as evidenced by the syndeformational texture exhibited between porphyroblast and matrix material in thin section. These spotted schists are contact schists, with schistosity (foliation) having developed in response to local forceful intrusion. Retrograde effects are found locally, especially adjacent to faults.

Because of the fine-grained texture of the recrystallized pelitic metasedimentary rocks, the mineral assemblages characteristic of both contact metamorphic facies are only identifiable in thin section. However, skarn formed in response to contact metasomatism of limestone is generally coarser grained. Mineral assemblages observed in the skarns, representative of those two contact metamorphic facies, are: quartz-grossular garnet-diopside-calcite in the hornblende-hornfels facies; and quartz-epidote- actinolite/tremolite-calcite in the albite-epidote-hornfels facies. Transitional assemblages are found between the two.

MINERAL DEPOSITS

Mineral deposits within the Eugene Mountains include tungsten-bearing skarns, base-metal vein and replacement deposits, and small gold-silver vein deposits (Johnson, and Benson, 1963; Johnson, 1977; Thole, 1981; Thole and Prihar, 1982, 1983).

Production from tungsten-bearing skarns was 2.2 million units of WO_3 from the Nevada-Massachusetts Mines between 1917 and 1958 (Stager and Tingley, 1988, p. 169). At the Nevada-Massachusetts Company Mines, the calc-silicate mineral assemblages have formed by contact metasomatism. Shortly following the emplacement of the Springer stock and concomitant thermal event, hydrothermal fluids were released by differentiating magma at depth and reacted with the sedimentary wall rocks and the stock to form new mineral assemblages. The relationship between zoning and paragenesis of skarn minerals is shown on the plate in figures 2, 3, and 4. Skarn formed by replacement of micritic limestone. The early stage of skarn formation is characterized by high-temperature anhydrous Mg-Al metasomatism. Fine-grained marble is replaced by a very broad inner zone (i.e., proximal to the Springer stock) of grossular-rich pale-pink garnet-quartz-coarse calcite (-diopside-monticellite-powellite-scheelite). This inner zone extends along strike for about 2,000 feet and gives way to a very narrow outer zone of wollastonite-tremolite (-idocrase). The outer zone assemblage is largely replaced by a high-temperature prograde inner zone assemblage, even at the edge of the skarn deposit. This early stage of Mg-Al metasomatism was followed by a main stage of increasing temperatures resulting in prograde, largely anhydrous Fe-metasomatism. It was during this main stage that the bulk of the tungsten was deposited. The evolution of Mg-rich minerals to Fe-rich minerals is best observed in the garnets. Throughout the main stage, the garnets deposited are well zoned with grossular-andradite (red-brown) cores to andradite-rich (brown) rims. Deposition of sulfides commenced during this main stage. Pyrite, chalcopyrite, and molybdenite were deposited in the limestone beds proximal to the Springer stock, and sphalerite was deposited in limestone beds along the outer edges of the skarn deposit and peripheral to the Springer stock. The bulk of the sulfide deposition followed cessation of the main stage skarn growth and was accompanied by widespread hydrous alteration of early skarn minerals. In most cases, a lower-temperature retrograde alteration is intimately associated with quartz-sulfide-scheelite veinlets or crosscutting faults. During retrograde alteration garnet is altered to calcite, quartz-chalcedony, pyrite, epidote, chlorite, and nontronite. Diopside is commonly altered to calcite, quartz, tremolite-actinolite, chlorite, and talc. Wollastonite is altered locally to calcite plus quartz.

Although best developed in the Raspberry Formation, small scheelite occurrences are ubiquitous throughout the Eugene Mountains where granodiorite plugs come in contact with limestone beds. One such occurrence, the Danner Mines, is located in the Triassic siliciclastics unit ($\bar{R}s_1$) at the head of Pole Canyon, about 2.5 miles northwesterly from the Nevada-Massachusetts Company Mines. The old Red Hawk and Ben H. Jackson Mines are within the Danner properties as are

several prospects at the head of Bonita and Woody Canyons. Rocks exposed in the area consist of a sequence of dark lavender to black pelitic strata interbedded with thin lenses of fine-grained channel sandstone and quartzite and with thin, discontinuous lenses of limestone. The metasedimentary rocks are cut by numerous small stocks, plugs, and dikes of granodiorite. In addition, dikes of andesite, aplite, and leucogranite are common in the area. The intrusions often exhibit sericite-clay type alteration. A moderately sized stock, immediately southwest of the Danner Mines, exhibits a fresh granodiorite basal exposure and grades upwards into a quartz-rich, pervasively sericitized leucogranite cupola. Scheelite mineralization occurs in two sets of quartz veins in the granodiorite and in skarn developed in limestone. The quartz veins are commonly 1 inch to 1 foot thick and are spaced about 10 feet apart. The veins are oriented N30°E, 55°SE and N70°E, 60°SE. They consist of white quartz and minor adularia and muscovite, and in places, are stained with copper and iron oxides. The veins commonly contain about 0.01% WO_3. The most significant scheelite mineralization in the Danner area occurs as skarn replacement of limestone. Johnson and Benson (1963) reported that between 1917 and 1950 about 470 tons of ore grading from 11 to 2.5% WO_3 was produced from several of these deposits in the Danner area. Located at the $SE^{1}{}_{4}$, section 17, T34N, R34E, the largest deposit has approximately a 600-foot strike length and 4-foot thickness. The deposit is developed in a limestone bed that has been irregularly replaced by an assemblage of garnet, epidote, quartz, diopside, and 0.3 to 2% scheelite, 0.2 to 2% sphalerite, and traces of molybdenite.

The Imlay View Mine is near the southeast end of the Eugene Mountains, about 3.5 miles southwest from the Nevada-Massachusetts Company Mines and 7 miles northwest of Imlay. The property has a 115-foot inclined shaft from which about 200 tons averaging 0.49% WO_3 or 98 units tungsten was shipped in the 1950s. The ore is developed beneath one of two gossan occurrences in intercalated hornfels, quartzite, and limestone near the contact of a northwest elongate granodiorite stock. The scheelite is sparsely disseminated in part in massive pyrite, in joints in kaolinized aplite sills, in quartzite, and along narrow seams in hornfels. In the adit, in several quartzite ribs, the average grade of the zone is estimated at 0.15% WO_3 across a 6-foot interval.

The Keystone Mines, located on the north side of the mouth of Central Canyon on the east flank of the Eugene Mountains, were first explored for silver in 1872 but no production was reported until 1937. Mine production between 1937 and 1943 was 1,674 tons of sorted ore that averaged 0.04 ounces of gold and 32 ounces of silver per ton, 4.08% lead, 0.14% copper, and an estimated 2.5% zinc (U.S. Bureau of Mines Minerals Yearbooks, 1937 through 1943; Couch and Carpenter, 1943). Mineralization at the Keystone Mines consists chiefly of small silver-lead ore shoots developed at the intersection of flat and steeply dipping shears in a granodiorite plug. The chief ore minerals are argentiferous galena, pyrite, and sphalerite. In 1940 three holes were diamond-drilled to explore a granodiorite dike southwest of the mine and recorded a 22-foot core intercept of silicified granodiorite from 135 feet beneath the surface in one of the holes; a section of this core assayed 2.25% WO_3 and another section contained 0.4% WO_3. The scheelite mineralization is reported to occur in sericite-altered and silicified granodiorite.

Besides the Keystone deposit, a number of other sulfide-vein occurrences lie to the southwest along Triassic carbonate clastics unit (TRc). At most mineralized localities, iron-oxide-stained fracture zones are concentrated in and on the margins of sericite-clay altered granodiorite and leucogranite dikes and small plugs that occur at the contact of the Triassic carbonate clastics unit (TRc) and the pelitic strata. Near the intrusive bodies, TRc is often bleached and calcite veined, and is sometimes brecciated. Pyrite-bearing quartz veins with highly anomalous silver cut across the granodiorite bodies and are found along the TRc contact. These quartz veins are generally less than 1 foot thick; however, zones of silver-bearing sheeted quartz veins up to 10 feet thick are found locally, and can be traced up to 100 feet along strike. Many of these mineralized occurrences have been explored by small pits and adits, evidently testing their precious metal potential.

The 56 Mine is located in the extreme southwestern tip of the Eugene Mountains, about 5 miles northwest of Imlay. The area of mineralization consists of a zone some 50 feet in width and about 300 feet of strike length of roughly parallel quartz veins in granodiorite. The individual veins vary in thickness from 1 to 4 feet and strike approximately north. The granodiorite in this area is fairly fresh, holocrystalline, of medium grain size, and indistinctly porphyritic, showing phenocrysts of milky feldspar and biotite in a dark, medium- to fine-grained groundmass. Irregular plug-like bodies of leucogranite occur in the vicinity of the 56 Mine and possibly represent a highly salic, late stage residuum resulting from the partial crystallization of the magma. The zone of sheeted quartz veins is stained by abundant malachite, chrysocolla, chalcocite, and minor limonite. The veins contain minor pyrite, scheelite, molybdenite, traces of chalcopyrite, and tourmaline. Although the granodiorite stock is relatively unaltered, sericitization and argillization of the feldspar minerals are pervasive along the quartz vein selvages in the immediate vicinity of the sheeted vein system. In places the granodiorite has been altered to greisen and quartz veins exhibit a pegmatitic intergrowth of large muscovite books, adularia crystals, and quartz.

The Blackbird Mine and Marietta-Railroad Mines area, located 3.5 miles north of the Nevada-Massachusetts Company Mines, is one of a number of small gold-silver districts in the Eugene Mountains with minor production. Mines within the district include the Arnold, Blackbird, Golden Age, Locomotive, Marietta, and Teamster. In all mineral occurrences the mineralization is in quartz veins that are conformable to bedding, about N50°E, 45°–75°NW; some trend about N50°E, 30°–40°SE. The mineralized quartz veins occur in phyllite, less often in quartzite, and rarely along the edges of granodiorite dikes. Ore minerals are free gold, tetrahedrite, and argentiferous galena with arsenopyrite and pyrite. Recorded production from the Blackbird Mine in 1893 was 706 tons of ore that averaged $9.54/ton (Couch and Carpenter, 1943). A variety of samples from the mine assayed 0.11 ounces of gold and 0.72 ounces of

silver per ton, 0.1% copper, 0.21% lead, and 0.14% zinc. At the Golden Age Mine, pockets of rich ore occur in narrow quartz veins. The recorded production in 1875 was 42.5 tons that averaged $400 per ton (Angel, 1881). Minor production from the other mines was recorded prior to 1871.

The central Bonita Canyon area is in $\overline{\text{R}}\text{S}_1$, about 4 miles west of the Nevada-Massachusetts Company Mines. At Bonita Canyon small gold-silver prospects with minor unrecorded production are associated with a Tertiary-Cretaceous quartz porphyry dike and with a volcanic pipe-like body of Tertiary-Cretaceous andesite porphyry.

In the northern Eugene Mountains, mineralized quartz veins and vein networks occur in phyllite and less often in quartzite along the edges of granodiorite dikes, along thrust faults, and in near vertical faults. Mineralization recorded from the veins includes argentite, arsenopyrite, chalcopyrite, galena, native gold, scheelite, sphalerite, and tetrahedrite. This region includes the Dutchman, Golden Eagle, King Midas, and Yellow Jacket Mines of the Central district.

ACKNOWLEDGMENTS

Appreciation is extended to BHP Minerals and General Electric Corp. for permission to publish this map. James F. Park provided invaluable assistance and access to critical data and exposures at the Springer Mine. We acknowledge the contributions of Norman J. Silberling, Antonia E. Allison, Robert Walker, and Mark Nelson. We dedicate this map in honor of the untimely passing of Robert Walker on August 27, 1992 at the age of 43.

REFERENCES

Angel, M., ed., 1881, History of Nevada: Oakland, California, Thompson and West (reprinted in 1958 by Howell-North, Berkeley, California), 680 p.

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

Couch, B.F., and Carpenter, J.A., 1943, Nevada's metal and mineral production (1859–1940): Nevada Bureau of Mines and Geology Bulletin 38, 159 p.

Elison, M.W., 1987, Structural geology and tectonic implications of the East Range, Nevada [Ph.D. thesis]: Northwestern University, Evanston, Illinois, 308 p.

Elison, M.W., and Speed, R.C., 1988, Triassic flysh of the Fencemaker allochthon, East Range, Nevada: Fan facies and provenance: Geological Society of America Bulletin, v. 100, p. 185–199.

Elison, M.W., and Speed, R.C, 1989, Structural development during flysh basin collapse: the Fencemaker allochthon, East Range, Nevada: Journal of Structural Geology, v. 11, no. 5, p. 523–538.

Heck, F.R., 1987, Mesozoic foreland deformation and paleogeography of the western Great Basin, Humboldt Range, Nevada [Ph.D. thesis]: Northwestern University, Evanston, Illinois, 214 p.

Heck, F.R., 1991, Depositional setting and regional relationships of basinal assemblages: Pershing Ridge Group and Fencemaker Canyon sequence in northwestern Nevada: alternative interpretation: Geological Society of America Bulletin, v. 103, p. 842–846.

Heck, F.R., and Speed, R.C., 1987, Triassic olistostrome and shelf-basin transition in the Great Basin: Paleogeographic implications: Geological Society of America Bulletin, v. 99, p. 539–551.

Johnson, A.C., and Benson, W.T., 1963, Tungsten resources of Nevada: U.S. Bureau of Mines Open-File Report, 198 p.

Johnson, M.G., 1977, Geology and mineral deposits of Pershing County, Nevada: Nevada Bureau of Mines and Geology Bulletin 89, 115 p.

Lupe, R., and Silberling, N.J., 1985, Genetic relationship between lower Mesozoic continental strata of the Colorado Plateau and Marine strata of the western Great Basin: Significance for accretionary history of Cordillera lithotectonic terranes, *in* Howell, D.G., ed., Tectonostratigraphic terranes of the Circum-Pacific Council for Energy and Mineral Resources, Earth Sciences Series, no. 1, p. 263–271.

Oldow, J.S., 1978, Structure and kinematics of the Luning allochthon, Pilot Mountains, western Great Basin, U.S.A. [Ph.D. thesis]: Northwestern University, Evanston, Illinois, 206 p.

Oldow, J.S., Bartel, R.L., and Gelber, A.W., 1986, Structure and sedimentology of early Mesozoic basinal rocks of the Fencemaker allochthon, Pershing district, southern Humboldt Range, Nevada: Geological Society of America Abstracts with Programs, v. 18, p. 166–167.

Oldow, J.S., Bartel, R.L., and Gelber, A.W. , 1990, Depositional setting and regional relationships of basinal assemblages: Pershing Ridge Group and Fencemaker Canyon sequence in northwestern Nevada: Geological Society of America Bulletin, v. 102, p. 193–222.

Oldow, J.S., Bartel, R.L., and Gelber, A.W., 1991, Depositional setting and regional relationships of basinal assemblages: Pershing Ridge Group and Fencemaker Canyon sequence in northwestern Nevada: Reply: Geological Society of America Bulletin, v. 103, p. 846–848.

Silberling, N.J., and Wallace, R.E., 1969, Stratigraphy of the Star Peak Group (Triassic) and overlying Mesozoic rocks, Humboldt Range, Nevada: U.S. Geological Survey Professional Paper 592, 50 p.

Speed, R.C., 1978a, 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.

Speed, R.C., 1978b, Paleogeographic and plate tectonic evolution 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. 253–270.

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

Steiger, R.H., and Jager, E., 1977, Subcommission on geochronology: convention on the use of decay constants in geo- and cosmochronology: Earth and Planetary Science Letters, v. 36, p. 359–362

Thole, R.H., 1981, Progress report for September 1, 1980 through December 31, 1981, Springer Base Metal Project, Pershing County, Nevada: unpublished private report for Utah International Inc., Reno, Nevada, 20 p.

Thole, R.H. and Prihar, D.W., 1982, Progress report for September 1, 1980 through March 31, 1982, Eugene Mountains Project, Pershing and Humboldt Counties, Nevada, Vol. I and II: unpublished private report for Utah International Inc., Reno, Nevada, 96 p.

Thole, R.H., and Prihar, D.W., 1983, Tungsten potential - Springer district, Pershing County, Nevada: unpublished private report for Utah International Inc., Reno, Nevada, 51 p.

Tingley, J.V., 1975, K-Ar dates on granodiorites and related scheelite-bearing quartz veins at Tungsten, Pershing County, Nevada: Isochron/West, no. 12, p. 3–4.

Turner, F.J., 1968, Metamorphic petrology: Mineralogic and field aspects: McGraw-Hill, New York.

Willden, R., 1964, Geology and mineral deposits of Humboldt County, Nevada: Nevada Bureau of Mines and Geology Bulletin 59, 154 p.