Trip 3:

Great Basin Porphyry Cu-Mo Deposits: Yerington, Robinson, Hall, Bingham Canyon

October, 1994

Bootprints Along the Cordillera

Porphyry Copper Deposits from Alaska to Chile

Dear Field Trip Participants:

On behalf of the **Arizona Geological Society, Society for Mining, Metallurgy and Exploration Inc., and the U. S. Geological Survey**, we bid you welcome to the Bootprints Along the Cordillera field trip program. We have assembled a collection of field trips that portray the geologic and mineralogic diversity that exists along the cordillera of North and South America.

We wish to thank all of the field trip leaders who volunteered their time, effort, and expertise to organize their individual trips. We also want to thank collectively, all of the mining companies and staff who graciously allowed us to visit their properties. Without their cooperation, this program would not have occurred. A special thanks goes to Kathie Harrigan of Asarco for her help in the compilation of the field trip guides. We also want to thank Tucson Blueprint who underwrote the complete reproduction cost of the guides.

Mark Miller and Jim Briscoe
Field Trip Co-Chairmen
October 2, 1994

ROADSIDE GEOLOGY AND PRECIOUS-METAL MINERALIZATION ALONG THE I-80 CORRIDOR, RENO TO BATTLE MOUNTAIN, NEVADA

R. Cuffney, R. Atkinson and R. Buffa
Revised 1990, by O. Adams and A. Coyner
Revised 1994, by M. Dennis

modified from
Tingley and Bonham (1986)

The 216-mile-long stretch of Interstate 80 from Reno to Battle Mountain traverses several major mineral belts which contain numerous producing precious metal mines, former producers, resources and prospects. Roberts (1960, 1966) defined several broad northwest-trending mineral belts transverse to the generally north-south ranges of central and northeastern Nevada (Fig. 1). These belts, or their extensions, contain the vast majority of precious metal deposits found in Nevada to date. Our trip begins in the Walker Lane mineral belt which contains the rich Comstock, Tonopah and Goldfield bonanza-vein districts as well as the gold-silver deposits at Paradise Peak and Rawhide. Before leaving the Walker Lane structural zone along the I-80 corridor, we will pass near the volcanic-hosted vein deposits of the Ramsey, Talapoosa and Olinghouse districts and the Gooseberry mine. Northeast of Lovelock we pass through Roberts' Lovelock-Austin belt which contains the Rochester and Nevada Packard bulk-tonnage silver deposits hosted in Triassic volcanic rocks; the Relief Canyon, Willard, Standard and Florida Canyon gold deposits hosted in Triassic sedimentary rocks; and the Trinity Silver deposit hosted in Tertiary rhyolitic rocks. East of Golconda we enter the Getchell trend which Roberts interpreted to be a split of the Battle Mountain-Eureka mineral belt. The Preble, Pinson, Getchell, Rabbit Creek and Chimney mines will be seen in the distance. These deposits are hosted in rocks of Cambrian through Pennsylvanian age and exhibit both strong lithologic and structural control. Further east, as we cross the main Battle Mountain-Eureka trend, we will pass the Lone Tree/Stonehouse deposit, and the Marigold and Surprise mines near Battle Mountain.

NOTE: Mileage is based on the Interstate mileposts on the right-hand side of the road.

14.5 Leave Reno. Road log begins at the junction of US 395 and Interstate 80.

15.0 The large bleached area visible at 2:00 just after turning onto I-80 is WASHINGTON HILL. Argillic to advanced argillic alteration affects andesitic flows and breccias of the Miocene Kate Peak Formation. Cinnabar occurs disseminated within opalite replacement bodies and quartz-alunite ledges, and a few flasks of quicksilver were produced from the prospect (Whitebread, 1976). A Pliocene(?) extrusive dome of devitrified rhyolite glass and perlite forms the summit of Washington Hill east of the altered zone.

Scattered low-grade gold values occur in the area and gold exploration was previously conducted by Superior Oil Co. Westley Mines and joint-venture partner Santa Fe Pacific Minerals Company have recently explored the property.

15.5 At 9:00, one can see the quartz-alunite ledges present in the hills north of Sparks in the WEDEKIND mining district. The Wedekind ores consisted of silver haloids, free gold, cerussite, galena, sphalerite, and pyrite. The numerous workings in the district consist of shallow shafts, pits, trenches, and a few adits. The main period of production in the district was during 1901-1903.

19.5 EXIT 21 VISTA. Ahead is the upper end of the canyon that the Truckee River has cut through the Virginia and Pah Rah Ranges. The Pah Rah Range is north of the river and the Virginia

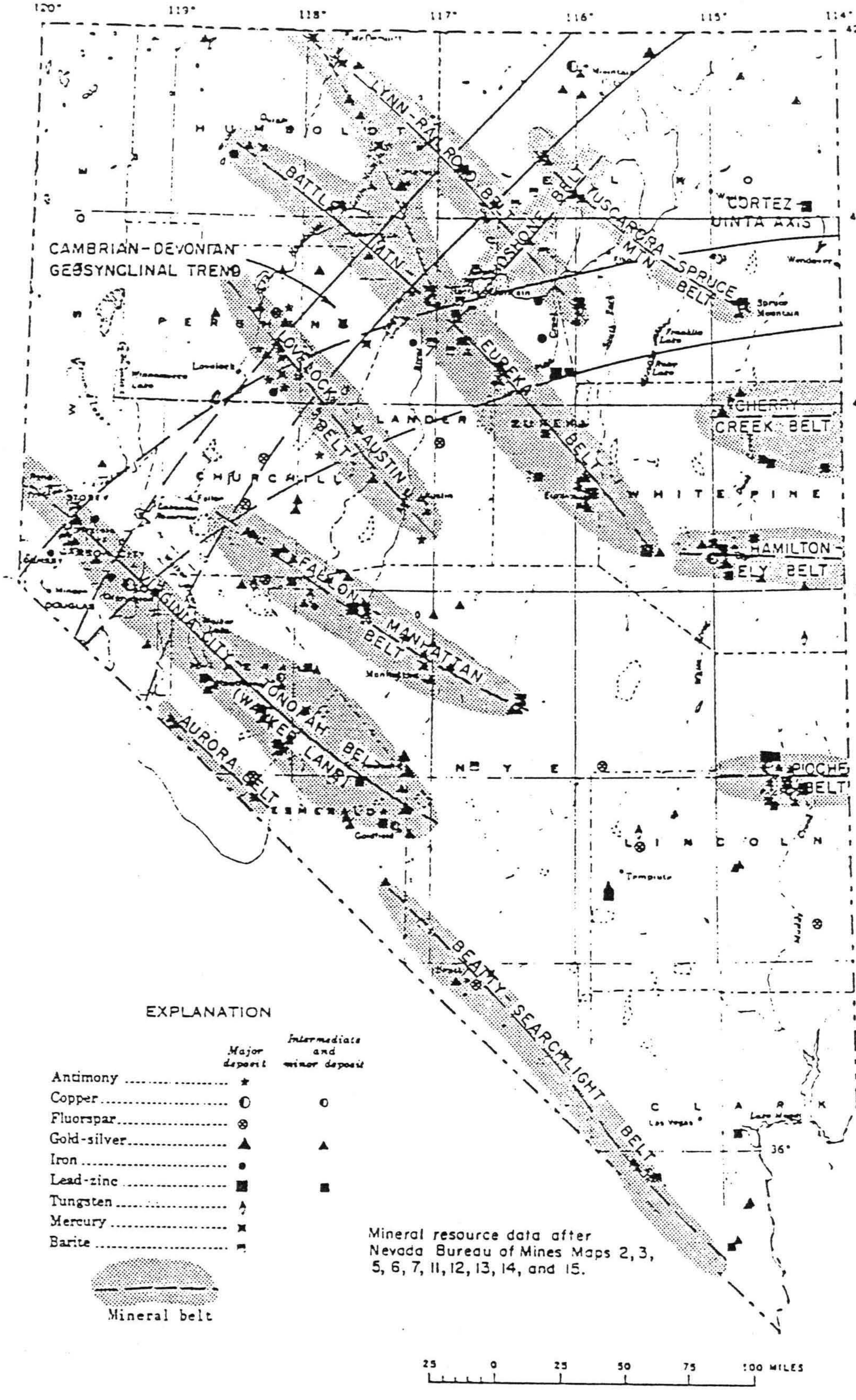


FIGURE 1. Mineral belts and principal ore deposits in Nevada.

(after Roberts, 1966)

Range is south of the river. In a very general way, this range is a large syncline. At both ends of the canyon, metamorphosed volcanic and sedimentary rocks of the Triassic and/or Jurassic Peavine Sequence are exposed. Progressively younger volcanic rocks are found towards the central portions of the Virginia Range. The volcanic rocks range in composition from basalt to rhyolite and their origin varies from intrusive plugs to ash-flow tuffs and extensive lava flows. The age of the volcanic rocks ranges from Oligocene to Pleistocene.

The Truckee River existed before warping and faulting uplifted the Virginia Range. As uplifting took place, the river apparently downcut at about the same rate, and no deep lake was formed in the Truckee Meadows area. The Truckee River drains Lake Tahoe and flows into Pyramid Lake. This river is about 100 miles in length.

21.3 River gaging station on right. Triassic(?) andesite metavolcanic rocks are exposed along the Truckee River for the next 3 miles. Farther east in the canyon, Miocene tuffaceous and diatomaceous sedimentary rocks and interbedded rhyodacitic to basaltic flows are the main rock types. Locally these rocks are covered by Pleistocene lava flows and lake beds.

22.9 EXIT 22 LOCKWOOD. For the next 8 miles, Miocene tuffaceous and diatomaceous sediments of the Truckee Formation and intertonguing dacitic and rhyodacitic flows of the Kate Peak Formation are the main rock types, with Pleistocene flows of the McClellan Peak Olivine Basalt capping this sequence.

23.5 At 3:00, a quarry on the far side of the river produces crushed rock for road building from the Pleistocene Mustang Andesite.

23.9 EXIT 23 MUSTANG. On the right are eroded flows of Pleistocene Mustang Andesite lying on an eroded Miocene composite volcano. The Quaternary flows display initial dips to the west, away from their source vent near the summit of Clark Mountain.

26.4 At 3:00 is a gravel pit in Holocene Truckee River gravel. The white beds visible on the right are Miocene rhyolitic air-fall tuffs, interbedded with Miocene basaltic andesite flows.

28.3 EXIT 28 PATRICK. At about 11:30, there is a prominent left lateral strike-slip fault zone, trending east-northeast, with Holocene to historic (latest 1869) movement. This fault zone merges to the east with the Walker Lane fault zone.

28.8 Pleistocene Lake Lahontan sediments on right in road cut. At its highest level in Pleistocene time, Lake Lahontan extended up the Truckee Canyon to approximately this point. From this point eastward, flat-lying, varved Lahontan lake sediments are exposed in road and railroad cuts and canyon sides. We will be traveling along the bottom of ancient Lake Lahontan from here to Golconda.

Lake Lahontan was an extensive middle to late Quaternary (Pleistocene and early Holocene) pluvial lake, or series of lakes that covered the intermontane basins in portions of what are now Washoe, Storey, Pershing, Lyon, Mineral, Humboldt, and Churchill Counties. At its maximum, Lake Lahontan was the second largest pluvial lake in the Western Hemisphere, about 8,500 square miles in area, or nearly the size of Lake Erie. It had a maximum depth of about 920 ft at Pyramid Lake, 525 ft at Walker Lake, and 490 ft at the Carson Sink.

During the middle and late Pleistocene (approximately one million years ago), four major deep-lake episodes occurred, each lasting on the order of 104 to 105 years. Each deep-lake episode had several oscillations in lake level. Long intervals occurred between the main deep-lake episodes, which also lasted on the order of 104 to 105 years, when the lakes in some of the terminal basins were dry or at low levels.

30.8 On the south side of the freeway is the oil and gas fueled Tracy Power station. This plant contains three units which produce 55, 85 and 114 megawatts, respectively.

The high voltage power line crossing the road is Sierra Pacific Power Company's 345,000 volt intertie to the North Valmy coal-fired generating station near Battle Mountain.

31.8 EXIT 32 CLARK STATION

32.9 At 3:00, the diatomite plant of Eagle-Picher Industries can be seen. The open-pit mines are about 7 miles to the east and will be visible later. Diatomite (diatomaceous earth) is the white skeletal remains of microscopic organisms. It is used extensively in many consumer products as an absorbent filter material, insulation, and filler. The crushing, drying, calcining, and air-classification sections of this plant produce mostly absorbents ("floor-dry" materials) and fillers for domestic and foreign consumption.

For the next 8 miles, Miocene basaltic to rhyodacitic flows and interbedded tuffaceous to diatomaceous sediments of the Chloropagus and Kate Peak Formations are the predominant rock types.

33.0 The GOOSEBERRY mine is located about 9 miles to the south of this point. Production at the mine is from an east-west trending, high-angle, quartz-calcite vein which cuts late Miocene flows of intermediate composition (Kate Peak Formation). Adularia from the vein has been dated at about 10 Ma by K-Ar methods.

Ore minerals include native gold, acanthite, electrum and native silver. Sparse pyrite, chalcopyrite, sphalerite, and galena are also present. The vein averages 7 ft in width. Original reserves totaling 607,000 tons averaging 0.23 opt gold and 9.71 opt silver (Asamera Company report). Operations at the mine were suspended in 1985, but Asamera began operations again in January, 1988.

35.0 EXIT 36 THISBE-DERBY DAM. Derby Dam is on the right, about .7 mile west of the exit. This small concrete and earthen structure is used to divert water from the Truckee River southeastwardly to Lahontan Reservoir on the Carson River.

38.8 EXIT 38 ORCHARD. High up at 3:00 are waste dumps at the Celatom mine, which supplies the diatomite processed in the Eagle-Picher plant at Clark Station. The white band in the canyon walls is volcanic tuff and ash, not the diatomite bed.

40.0 EXIT 40 PAINTED ROCK. Silicic ash-flow tuffs, 28-22 Ma old, exposed on left.

43.8 EXIT 43 WADSWORTH-PYRAMID LAKE. At 9:00 are foundations of a mill of the OLINGHOUSE gold mining district which is located 6 miles to the northwest. The gold ore bodies in the district occur as small, discontinuous, high-grade shoots in quartz and calcite veins emplaced along fault zones in or adjacent to granodiorite porphyry dikes and intrusive masses which cut rocks of the Tertiary Chloropagus Formation (which consists predominantly of andesitic and basaltic rocks). Native gold, pyrite, chalcopyrite, and minor bornite occur in veinlets in the dikes; petzite and coloradoite are reported from one mine.

44.6 Truckee River Bridge. For the pioneers on the California Trail, the Truckee River at this point marked the end of the terrible Forty Mile Desert. From this point the Truckee River flows about 20 miles to the northwest where it empties into Pyramid Lake.

We are now crossing the northwest-southeast trending Walker Lane fault zone; from here northward the fault zone follows the Truckee River valley to Pyramid Lake.

46.1 EXIT 46 FERNLEY. To the left of the freeway lies a cement plant owned by Nevada Cement Company. The limestone for the plant is mined in the hills south of Fernley and is visible on the right side of the freeway. The limestone is a Tertiary fresh-water deposit.

48.3 East Fernley exit, exit here. Turn right at the intersection.

NOTE: Mileage on the Fernley to Yerington portion of the field trip starts at the Helms gravel pit in Sparks, just east of the intersection of McCarran Blvd. and I-80. This portion of the road log is modified from:

Carr, T., and Beck, L., (1987);
Johnson, J. (1987);
Garside and Bonham, (1984)

34.3 Railroad bridge. Follow Alternate 50/95 to right into Fernley (elevation 4,200 feet). Ahead is the Canyon Resources diatomite plant. The main quarries are to the northeast and southeast of town.

35.8 Junction Alternate 95 to Yerington. Turn left.

36.0 Cross the diversion canal which carries water from Derby Dam on the Truckee River, east of Reno, to Lahontan Reservoir. To the right, the white material is waste material from the Canyon Resources diatomite plant.

39.6 On the left is the limestone quarry for the Nevada Cement plant. The limestone is a Tertiary lacustrine unit. Rocks for the next 10 miles are mainly Miocene flows and interbedded sedimentary rocks similar to those exposed in the Truckee Canyon.

47.7 Three miles to the right in the Virginia Range is the TALAPOOSA mining district. The district produced a few thousand tons of high-grade gold ore in the late 1930s to early 1940s. The district is underlain by intermediate composition flows, plugs, tuffs and sedimentary rocks of the middle Miocene Kate Peak Formation). Post-mineral units Pleistocene Lousetown Formation. Important structures include east-west-, northwest-, and northeast-trending high-angle faults. Mineralization is structurally controlled and forms a tabular zone within a sequence of andesite tuffs and flows adjacent to a late-stage dacite plug. Gold-silver mineralization occurs in chalcedonic quartz stockwork veins and local sulfidic silicified breccias associated with widespread phyllic and propylitic alteration. The sulfide mineral assemblage is dominated by pyrite but includes minor amounts of marcasite, sphalerite, galena, chalcopyrite, stibnite, cinnabar, arsenopyrite, argentite, and acanthite; and the sulfosalt minerals polybasite, pyrargyrite, and freibergite. Gold occurs as fine, free electrum in quartz and adularia veins, within, and on the surface of pyrite, argentite and sulfosalt mineral grains. Grain size of the electrum ranges from 5 to 200 microns and averages 75 microns. Age dating of the alteration and the andesitic host rocks brackets the timing of the dacite porphyry intrusion between 10 and 12 Ma. Field studies demonstrate that the porphyry intrusions are the latest event associated with Kate Peak volcanism and that alteration and mineralization is closely associated with porphyry emplacement (Van Nieuwenhuyse, 1991). The Talapoosa district is controlled by Miramar. Athena previously announced geological reserves of 17.9 mt at 0.054 opt Au and 0.65 opt Ag.

49.8 Community of Silver Springs (elevation 4,190 feet). Intersection of US 50 and Alt. 95; continue straight ahead on Alt. 95.

55.5 At right, Churchill Butte (the large mountain, not the smaller, more butte-like hill). Mesozoic metamorphic rocks are exposed over much of the Butte; locally Mesozoic quartz monzonite intrudes, and Tertiary basalt flows cap the metamorphic rocks.

Lahontan Reservoir is to the left. The reservoir was created in 1915 by construction of a dam on the Carson River. The reservoir stores waters of both the Carson and Truckee Rivers. Truckee River water is delivered from the vicinity of Pyramid Lake to the reservoir by a diversion canal. The water in the reservoir is used for both irrigation and recreation.

57.9 Side road to the right; 1 mile to ruins of historic Fort Churchill, established in 1860 to protect Virginia City and the surrounding area from Indian raids. Later, during the Civil War, troops were stationed here to discourage active support of the South by Confederate sympathizers. The fort was abandoned in 1868. Fort Churchill was designated a State Park in 1935, some buildings have been preserved in "arrested" decay. There is a visitor center, picnic area, and campgrounds on the river nearby.

58.2 Cross Southern Pacific Railroad's Mina branch line at Weeks. Historic crossing of the Carson River used by the Pony Express and early freight and stage lines. Formerly known as Bucklands, the large, old building on the left (built in 1870) was a hotel, bar, dance hall and stage station.

59.4 Highway begins grade to the pass through the west end of the Desert Mountains, which consist predominantly of late Miocene andesite, basaltic andesite flows, and lahars with intercalated tuffaceous sedimentary rocks.

68.8 To the left are Wabuska Hot Springs. The hot springs range in temperature from 138°F to 162°F and occur over an area of several square miles. The springs occur along an east-west line that coincides with the course of a recent fault, which is plainly shown by an irregular scarp which is 20 feet high in some places. Using evaporating ponds, the American Sodium Co. refined and shipped sodium sulfate from here in the late 1930's.

In 1959 Magma Power drilled three steam wells in the Wabuska area. Two of the wells were shallow (less than 600 feet) and the third was drilled to 2,233 feet with a maximum reported temperture of 227°F. Samples of water from the wells yielded estimated reservoir temperatures of 293°F and 206°F based on the silica and Na-K-Ca geothermometers (Garside and Schilling, 1979). In 1972, Agri-Technology Corp. began building greenhouses near the site of the steam wells. The company planned to grow vegetables hydroponically, especially tomatoes, using the steam and hot water from the wells to heat the greenhouses. More recently, Tad's Enterprises used the geothermal heat to produced alcohol from grain for use in gasahol. Presently, the spring waters are being used to grow algae, which is sold in health-food stores as a dietary supplement.

To the right, on the point of hills, can be seen the foundations of the Thompson smelter, built in 1910-1912, and operated intermittently to 1928, which smelted ores from copper mines in the Singatse Range south and west of Yerington. The Nevada Copper Belt Railroad ran from the Ludwig Mine, on the west side of the Singatse Range, around the south end, then north through the town of Mason to Thompson.

70.1 Wabuska, Railroad Station on the Southern Pacific Railroad Mina Branch (and formerly a station on the Nevada Copper Belt Railroad).

71.1 Road to the left leads to Sierra Pacific Power Co. Fort Churchill electric generating station (oil fired).

76.3 In the mountains to the right is the MACARTHUR deposit owned by Timberline Minerals. It is a porphyry copper deposit with oxide reserves of 16 million tons of 0.4% Cu (co. report) with sulfide copper at depth. Gold mineralization occurs in the porphyry and above a low-angle fault to the west.

80.0 Turn right. Road leads to Weed Heights, former Anaconda Mining Company town. Tailings pond and waste pits ahead and to the right are for the former Anaconda Yerington copper mine.

81.9 Remains of Yerington copper mine plant and facilities to the north and east. Company housing to west and an overview of the pit south across the road. The YERINGTON mining district (Einaudi, 1982) is recognized as a major porphyry copper district with a future reserve of greater than 1 billion tons of 0.4% Cu. Anaconda's Yerington mine, which closed in June, 1978, produced about 162 million tons of 0.55% Cu.

Copper deposits are associated with the Yerington batholith, a Jurassic age intrusive which occupies much of the northern end of the Singatse Range. Strongly folded and faulted lower Mesozoic volcanic and sedimentary rocks form an east-west-trending system 5 miles long and up to 2 miles wide between the Yerington batholith and the batholith to the south. Limestone beds within the sedimentary section constitute the host rock for numerous small copper-bearing skarn deposits located on the outer fringe of the hornfels-skarnoid aureole which extends 2000 to 6000 feet from the Yerington batholith. The Yerington batholith consists of granodiorite intruded by quartz monzonite and later, by quartz monzonite porphyry dike swarms. Known porphyry copper mineralization is restricted to the core of the batholith and is associated with the porphyry dike swarms. The small skarn copper ore bodies were mined mainly between 1912 and 1930. The porphyry deposit was mined between 1953 and 1978. Copper reserves remain around the old mine, and in drilled but undeveloped deposits in the range to the west of Yerington.

NOTE: Return to the Interstate 80 via Fernley and resume I-80 roadlog

46.5 To the left of the freeway lies the Truckee Range. The visible part of the range is composed of basalt from two to three large shield volcanoes which are 5 to 7 m.y. old.

47.0 To the right of the freeway is a diatomite plant owned by Cyprus Mines. The diatomite is mined about 20 miles north of Fernley.

51.0 To the left, windblown sand partially covers Miocene to Pliocene basalt and andesite flows. Tufa encrustations can be seen part way up the hill.

52.0 Ahead lies the famous Forty Mile Desert. For forty miles there is no potable water. To the right of the freeway, the hills across the Alkali Flat are the southern part of the Hot Springs Mountains. These hills are composed of Tertiary basaltic rocks and some interbedded lacustrine sediments. Note the well developed shorelines which represent various stages of Lake Lahontan. Hazen Hot Springs is located near the south end of this range.

52.5 On the left, late Miocene to Pliocene basalt and andesite form the hills of the Truckee Range. Lake Lahontan strand lines are visible on the hillside and Lahontan sediments outcrop at the base of the hill.

59.5 To the right of the freeway lie the old vats of the Eagle Marsh Salt Works. The Eagle Marsh Salt Works probably produced over 500,000 tons of salt for use in treating ores from Virginia City and Humboldt County between 1870 and 1915. It is reported that on a good day one acre of vats could produce ten tons of salt. The brine came from springs located across the valley. These springs have essentially the same chemistry as water from the Desert Peak geothermal wells.

61.0 Churchill County line.

65.0 EXIT 65 HOT SPRINGS-NIGHTINGALE. The buildings on the right are the Geothermal Food Processors plant. Water at approximately 270°F is passed through a heat exchanger to produce the warm air used to dry onions.

68.0 Numerous shallow pits expose diatomite in the Truckee Formation on both sides of the road for the next 4 miles.

69.0 The newly constructed warehouse and silos on the right are Phase I of Moltan's diatomite plant. Diatomaceous earth beds within the Pliocene Truckee Formation will be mined, dried, crushed and screened to produce kitty litter, to be marketed primarily as the "Sani-cat" brand.

74.0 On either side of the road, tufa mounds are visible for the next 2.5 miles.

78.7 EXIT 78 JESSUP. Drill roads to the left (north) are within the JESSUP mining district. Jessup is a precious-metal district discovered in 1908 and operated until 1909. Recorded production from the district has been only about $15,000 from one claim, the Gold King. Most of the workings are located in rhyolite intrusive bodies or near the contact between the rhyolite and older metavolcanic rocks (Willden and Speed, 1974).

80.0 The large valley to the right of the freeway contains the Carson Sink. This is the largest valley in northern Nevada. The Carson and Humboldt Rivers drain into this area from the crest of the Sierra Nevada and from northeastern Nevada, respectively. Tufa mounds deposited in and around Pleistocene Lake Lahontan are visible in this area on both sides of the freeway.

85.0 The West Humboldt Range is located to the right of the freeway. This small but steep range consists predominantly of calcareous siltstone, shale, and argillite of the Auld Lang Syne Group of Upper Triassic and Lower Jurassic age. The hills at the southwest end of the range are called the Mopung Hills (Mopung is an Indian word for mosquito). The mosquitoes must have been fierce here before the water was diverted for irrigation upstream. The brightly colored rocks in the Mopung Hills are rhyolitic ash-flow tuffs which are equivalent to those overlying the Desert Peak geothermal reservoir and those exposed at Painted Rocks in the Truckee River canyon. The Mopung Hills also contain exposures of gabbroic rocks from the very large Jurassic Humboldt Lopolith.

88.0 The TOY (St. Anthony) mining district is about 2 miles to the left of the highway. Tungsten was discovered here in 1908 in contact deposits related to the St. Anthony stock. This was the first scheelite-bearing contact metamorphic ("tactite") deposit to be discovered and mined in the United States. At the St. Anthony deposit, scheelite occurs in metamorphosed calcareous and argillaceous rocks of the Auld Lang Syne Group near their contact with a Cretaceous granodiorite intrusive body. The deposit was worked mainly before and during World War I.

88.7 Pershing County line.

92.0 The ragged spire on the skyline to the left of the highway is Ragged Top Mountain in the Trinity Range. The rocks are rhyolitic welded tuffs which occupy the center of the Ragged Top caldera, a Miocene eruptive center.

93.5 TOULON. The large buildings to the right are the Toulon mill, erected prior to World War I to treat tungsten ores from the Nightingale district. Tungsten ores from many nearby districts including, Ragged Top, Mill City, and Oreana, were hauled here for treatment. During World War I, the plant was used to produce white arsenic, and the large arsenic roasting furnaces can still be seen in the large (south end) part of the building. In subsequent years, the mill was modified to treat antimony and gold ores.

94.5 Tufa mounds that formed along the shores of Lake Lahontan are visible in the middle distance on the left for the next 1.5 miles.

95.0 The high ridge on the left is Toulon Peak, composed of interlayered Tertiary rhyolite tuff and flow rocks.

106.1 EXIT 106 LOVELOCK. County seat of Pershing County.

108.0 At 2:00, recent drill roads can be seen on the west slope of Gypsum Mountain. Gypsum Mountain is underlain by metasedimentary rocks of the Triassic-Jurassic Auld Lang Syne Group. Gypsum was mined here between 1891 and 1913 from bedded deposits associated with limestone units. Approximately 5 miles south of Gypsum Mountain at the MUTTLEBURY mine, Ag, Pb, Sb ore was mined from a flat vein associated with a thrust fault.

110.0 The RELIEF CANYON mine is approximately 14 miles to the east, on the west margin of the southern end of the Humboldt Range.

At Relief Canyon, shale, siltstone, and quartzite of the Late Triassic Grass Valley formation have been thrust over dolomitic limestones of the Late Triassic Natchez Pass Formation (Figs. 2,3,4). Gold mineralization occurs in a jasperoid breccia that occupies the thrust fault contact. Gold is associated with argillic alteration and silicification and with anomalous Ag, As, Sb, Mg and Fl. (Parratt et al, 1987).

112.0 EXIT 112 COAL CANYON. To the left of the highway is the northern part of the Trinity Range, which consists mainly of granitic intrusive rocks, metasedimentary rocks of the Auld Lang Syne Group, and Tertiary-Quaternary volcanic rocks. On the left side of the highway is the Eagle-Picher diatomite plant. The diatomite is mined from deposits about 20 miles west of Lovelock in the Trinity Range.

The West Humboldt Range to the right of the highway consists mainly of Mesozoic limestone, shale, and quartzite, Tertiary-Quaternary volcanic rocks, and Cretaceous granitic intrusive bodies. The rocks in this area were subjected to large-scale folding and thrust faulting during the Jurassic. Several of the thrust faults are well exposed in this range.

The area of drill roads on the hill ahead and to the right is in the WILLARD mining district, a gold district active from about 1905 to the early 1950's. Antimony has been mined from deposits to the north of Willard. The prospect is hosted by rocks of the Triassic Auld Lang Syne Group. Grade ranges from 0.04 to greater than 0.06 opt gold with narrow higher grade intercepts.

119.5 EXIT 119 OREANA/ROCHESTER. The ROCHESTER silver district is about 10 miles east of here. At Rochester, rhyolitic volcanics of the Permian-Triassic Koipato Group host two stages of high-grade silver-gold mineralization in veins associated with high angle faults (Fig. 5,6). At Nenzel Hill, bulk-mineable, low-grade silver-gold mineralization occurs in thin, randomly oriented, closely spaced fractures associated with major veins. Mineralization occurs within an area of regional quartz-sericite-pyrite alteration of the rhyolites. The mineralization is thought to be related to the Late Cretaceous intrusive event (Vikre, 1981).

Approximately $7 million in silver and gold was produced from veins between 1912 and 1928. Coeur-Rochester commenced an open pit heap-leach mine operation at Nenzel Hill in 1986 (and by 1988 it was the largest primary silver mine in the United States.

123.0 Due west of here, on the west side of the Trinity Range, the TRINITY deposit is hosted in Tertiary rhyolite along a northeast-trending structure. Silver occurs as freibergite with lesser amounts of pyrargyrite, argentite and native silver occurring along fractures and as disseminations within the

Figure 2
After Parrat, Wittkopp and Bruce, (1987)

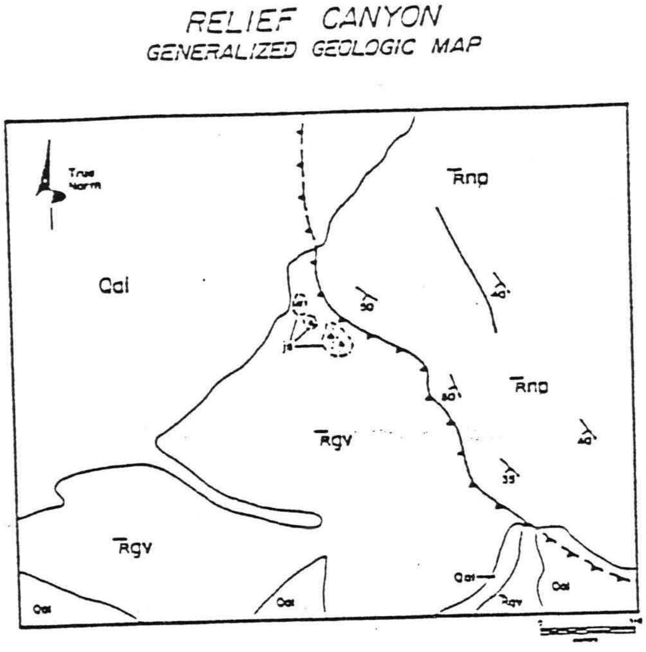


Figure 3

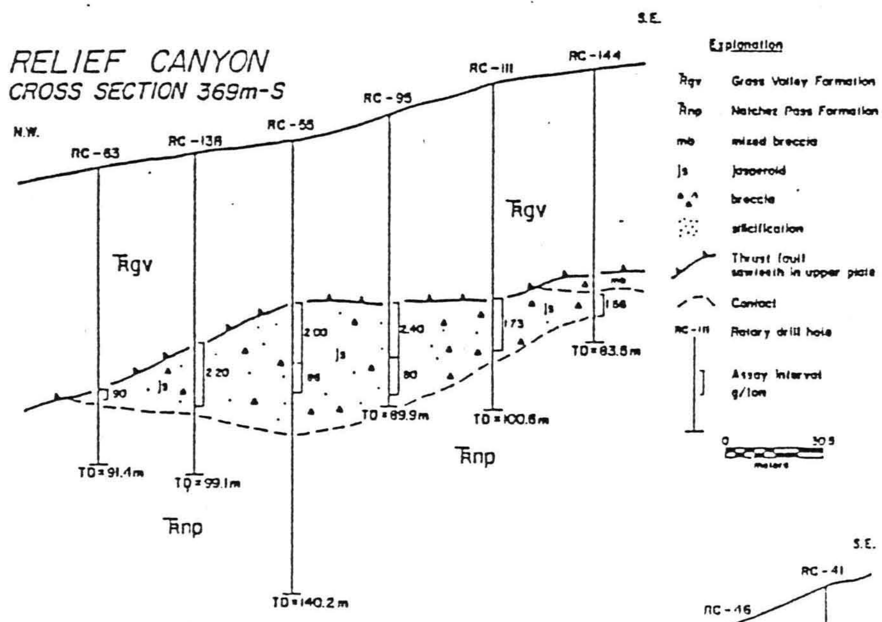


Figure 4

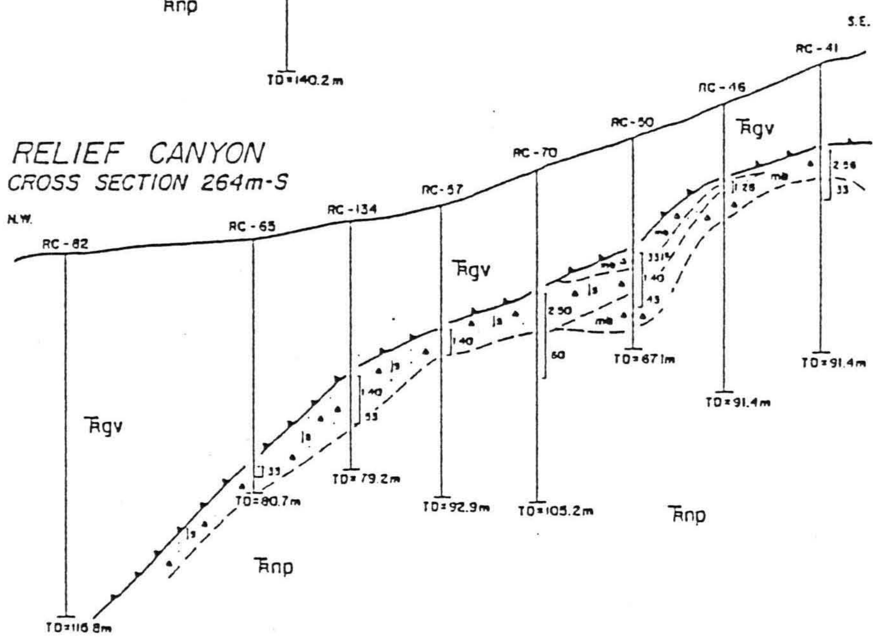
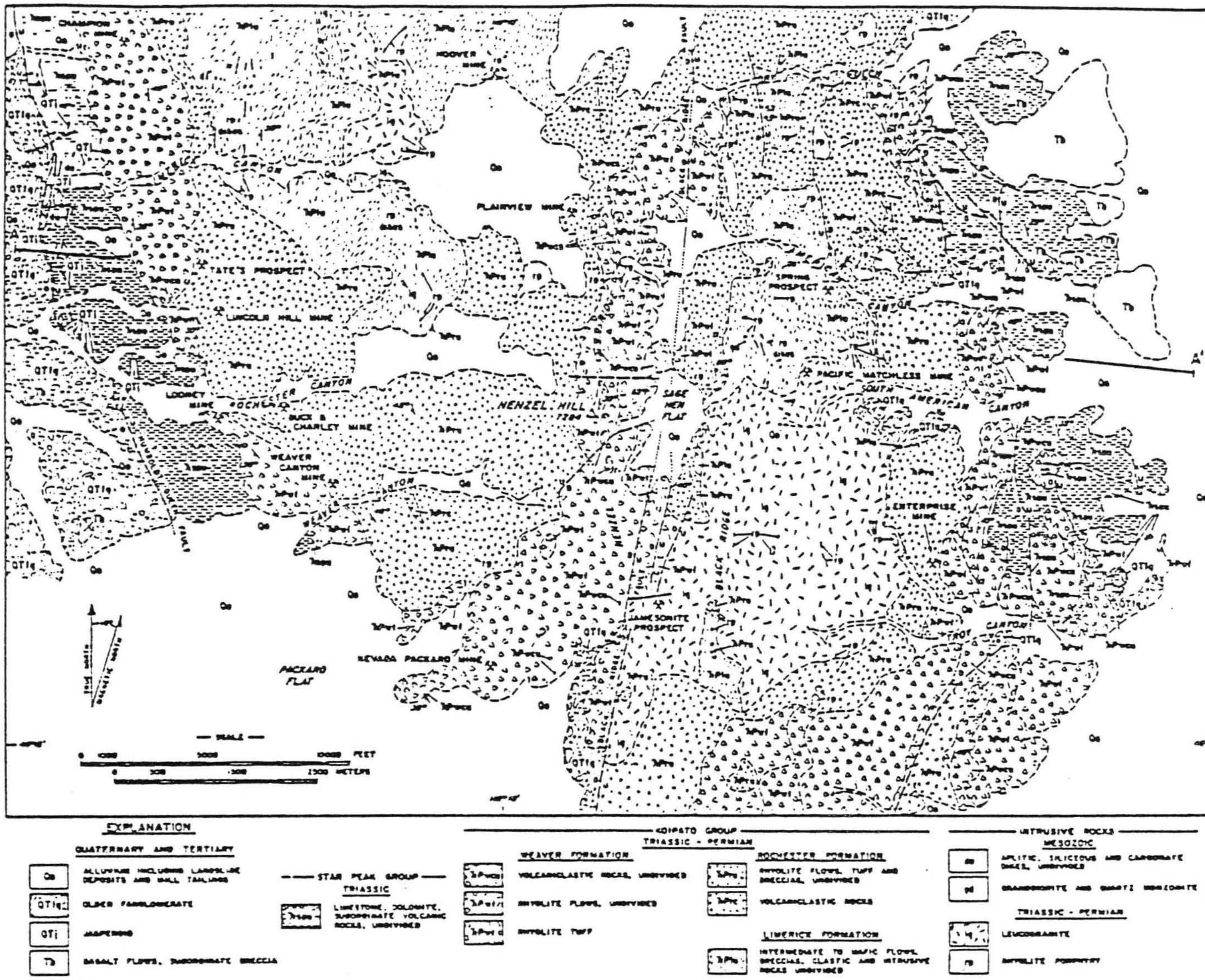
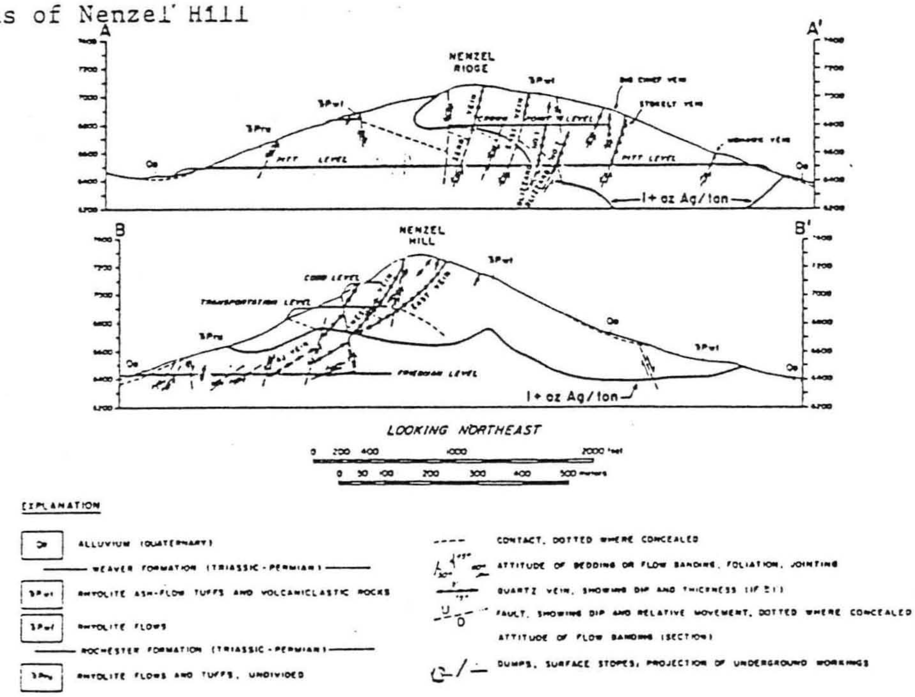


Figure 5 After Vikre, 1981



Geologic map of the Rochester district.

Figure 6
Cross sections of Nenzel Hill



rhyolite. Production began in late 1987 and the deposit was mined out in August, 1988. The mine was an open pit that produced 1.85 million tons of heap leach ore at 6.32 opt silver with some minor gold (Dick Jenson, personal communication, 1990).

123.5 The Oreana pegmatite is located to the right. It contains beryl and was mined for scheelite. Ragged outcrops are the Rocky Canyon stock. The Humboldt River and Rye Patch Reservoir can be seen to the left of the highway.

127.0 At 2:00, the craggy gray outcrops are Cretaceous granodiorite of the Rocky Canyon stock intruding the Triassic Rochester Rhyolite.

128.0 On the left, exposures of Lake Lahontan sediments incised by the Humboldt River.

129.3 EXIT 129 RYE PATCH. Rye Patch Reservoir, on the west, has a capacity of approximately 180,000 acre-feet. The water is used almost exclusively to irrigate about 44,000 acres of land in the Lovelock area. Irrigation waste water and any other Humboldt River-flow below the dam ultimately discharges into the Carson Sink.

131.0 On the left for the next five miles are several good views of Rye Patch Reservoir and Lake Lahontan sediments.

131.5 To the right of the highway at 3:00, dumps and part of the pit of the STANDARD mine can be seen. The Standard is considered the first deposit of "micron" or "disseminated gold" exploited in Nevada. The deposit was discovered in 1932 and was mined prior to World War II. Production amounted to nearly $1 million in gold. Gold is disseminated in a silicified, iron-stained breccia along a thrust contact (Johnson, 1977). Host rocks here are the Triassic Grass Valley and Natchez Pass Formations.

Drill roads are noticeable along the range front for several miles north and south of the Standard mine. A baritic jasperoid with anomalous gold is present along a gravity-slide fault between the Natchez Pass Formation and the overlying Grass Valley Formation and has been the focus of recent exploration.

137.2 To the right is the <u>FLORIDA CANYON</u> mine. Gold mineralization occurs near the south end of a large altered and iron-stained zone localized at the juncture of regionally extensive northeast oriented structures of the Humboldt Structural Trend (Midas Lineament) and north-south trending Basin and Range normal faults. These deep seated structures served as conduits for ascending gold-bearing hot springs solutions. The bulk of economic mineralization is hosted by veins and stockwork quartz-sulfide veinlets developed within a sequence of argillite, siltstone, and shale of the Upper Triassic Grass Valley Formation (Figs.7,8). There is no apparent lithologic control. Pre-ore metamorphism of arenaceous and argillaceous deltaic sediments imparted a brittle nature to wall rocks, promoting subsequent shattering and maintenance of open fissures. Solutions invaded along wide north to northeast-trending fault structures and permeated outward into the fractured wallrock. Alteration products consist of quartz, alunite, kaolinite, adularia, and hematite. Gold is generally associated with quartz, pyrite, and marcasite and occurs in the native state, averaging 3 to 5 microns in size.

Pegasus Gold Inc. commenced open-pit mining in September 1986. Initial open-pit mineable reserves were 17.8 million tons but were upgraded in 1989 to 27 million tons grading .025 opt gold at an overall 1.09:1 waste:ore stripping ratio (Rob Wiley, personal communication, 1989).

Steam from a geothermal well can often be seen just past the front edge of the leach pads. To the left of the highway, near the railroad tracks are some low mounds of tufa, sinter and outcrops of silicified rocks associated with an old hot spring system. Sulfur was mined here in the 1860's.

Figure 7 Geologic Map of Florida Canyon. After Hastings, Burkhart & Richardson,

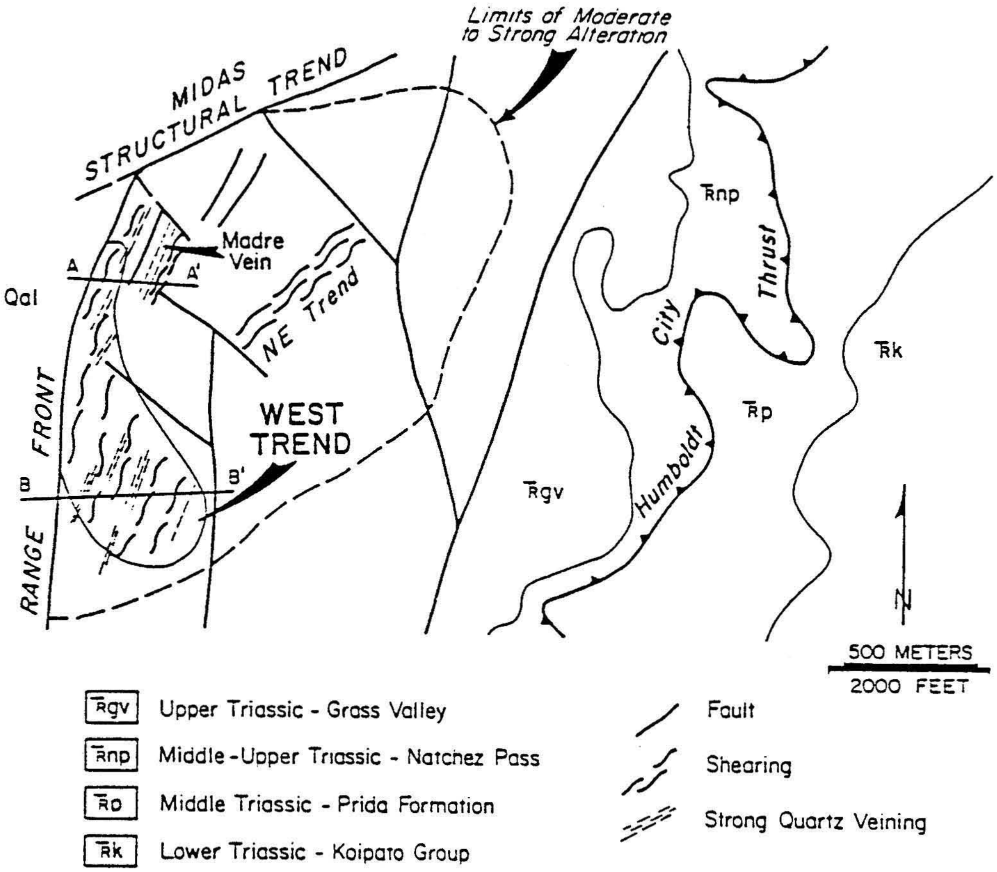
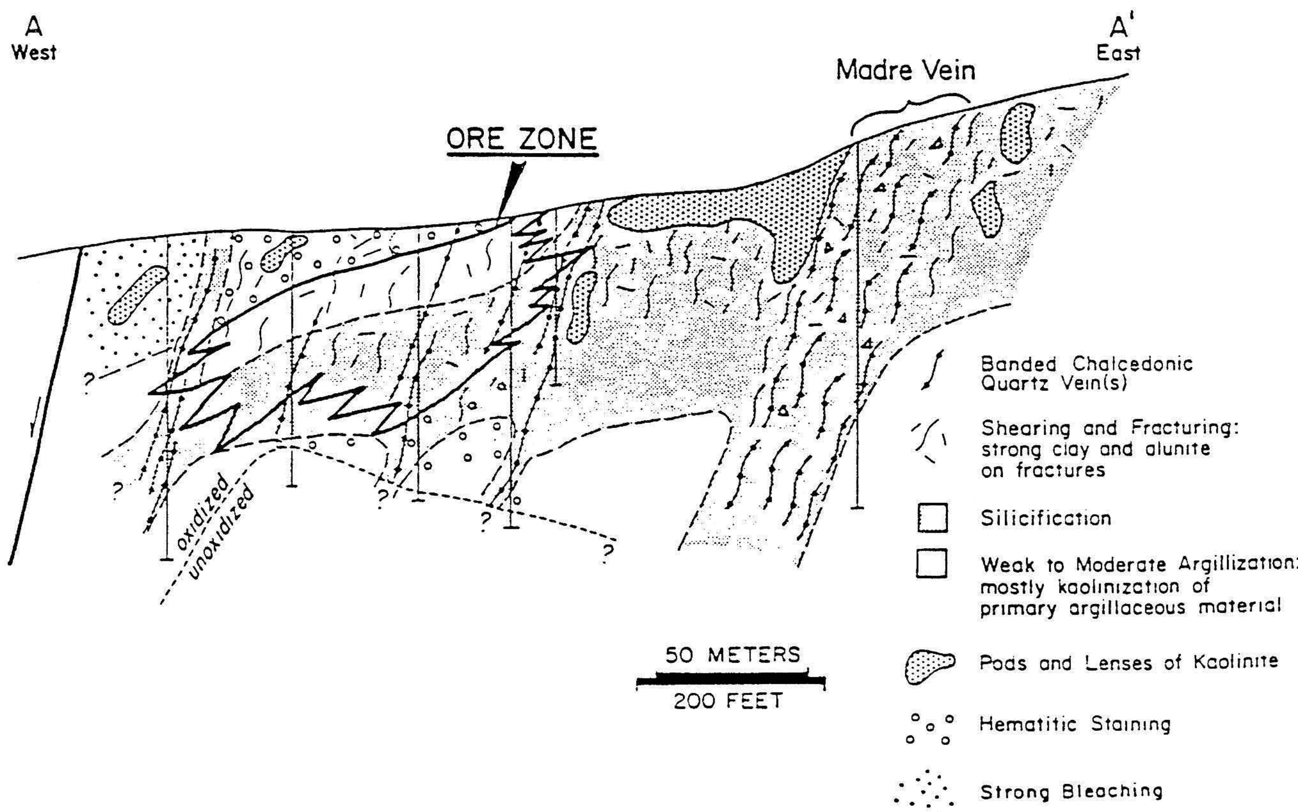


Figure 8 Cross Section, Florida Canyon. After Hastings, Burkhart & Richardson,



138.4 EXIT 138 HUMBOLDT HOUSE. Drill pads to the right mark the sites of recent geothermal test drilling. Phillips Petroleum Co. has one production well, one dry hole, six stratigraphic tests, and many shallow temperature gradient holes at Humboldt House. Union Oil Co. has also drilled in the area and has one deep test. The exploration results show a thermal anomaly of significant size and thermal fluids of good quality, suggesting that a geothermal reservoir of commercial quality exists at depth.

140.0 The prominent craggy hill on the skyline at 9:00 is Majuba Hill, a mid-Tertiary intrusive complex composed of a variety of rhyolite porphyry plugs and dikes and associated intrusive breccias. The MAJUBA mine, on the south side of the hill, produced 23,000 tons of high-grade copper ore (av. 12% Cu) and 23,000 tons of high-grade tin-copper ore (av. 3% Sn and 4% Cu) during the WWI and WWII periods. Low-grade copper and molybdenum stockworks were drilled by Mine Finders in the early 1970's. Mackenzie and Bookstrom (1976) have related the low-grade copper, low-grade molybdenum, and high-grade copper-tin mineralization to three closely spaced but temporally separate intrusive pulses.

145.5 EXIT 145 IMLAY.

146.4 The bizarre structure on the right is "Thunder Mountain of Nevada," a monument to "Man, God, Country and Freedom" founded by George High and Altrum Thunder of the "Rolling Thunder Medicine Chief Society." The artwork features BLM devils throughout and is worth a brief visit.

149.7 EXIT 149 MILL CITY/UNIONVILLE. Stamp mills were built here to treat silver ores from the Humboldt Range camps. The paved road to the left leads north to the Eugene Mountains and the mining camp of Tungsten.

155.0 At 9:00 across the valley and part way up the hill, the head frame at the camp of TUNGSTEN is visible. Tungsten was discovered here in 1916, and the mines were brought into production during the period of high tungsten prices created by World War I. With only a few short periods of inactivity, tungsten was produced here by the Nevada Massachusetts Co. until 1958. The camp produced over 1.8 million units of WO3 during 1917-57, and at the time of closure was the largest tungsten mine in the United States. General Electric Co. is the present owner, and through its subsidiary Utah International, resumed production at the property in 1982. Due to depressed metal prices, the mine closed again after only 6 months of operation and the property is now on standby. The scheelite deposits at Tungsten occur in tactite (skarn) bodies that formed in thin carbonate units of the Middle Triassic Raspberry Formation. The tactite bodies formed as replacements of carbonate rocks near their contact with small Cretaceous granodiorite stocks that intruded the Triassic rocks along the eastern front of the range.

To the right of the highway is the East Range. The rocks consist mainly of Paleozoic and Mesozoic sedimentary and metasedimentary rocks, granitic intrusive rocks and Tertiary-Quaternary volcanics. Gold was the main ore produced from the mining districts in this range.

163.8 Humboldt County line. Blue Mountain can be seen to the far left. To the northwest of Blue Mountain, in the far distance, the Jackson Mountains and Pine Forest Range can sometimes be seen. The Pine Forest Range, on the north margin of the Black Rock Desert, extends north to the Oregon border.

167.0 On the left, windblown sand is deposited against sediments of Triassic-Jurassic Auld Lang Syne Group and overlying Pliocene-Pleistocene basalt.

168.1 EXIT 168 ROSE CREEK. The Krum Hills and Winnemucca Mountain are to the north, across the Humboldt River. To the south, in the north end of the East Range, small dumps of the Rose Creek tungsten mine can be seen.

Recent gold exploration has been conducted at the ROSE CREEK prospect about 6 miles southeast of here, near the north end of the East Range. Anomalous gold values occur in silicified zones along several north-northeast-trending faults cutting shale and siltstone of the Triassic Grass Valley Formation. Alteration and gold mineralization appear to be related to a still active hydrothermal cell, as hot water has been encountered in drill holes.

170.5 At 9:00, north of the Humboldt River, the TEN MILE mining district covers the area of low hills generally between the river and skyline to the north. The district includes numerous small gold prospects and mines developed in quartz veins that cut phyllite. Free gold occurs in a matrix of at the Golden Amethyst property.

174.0 Winnemucca Mountain is at 10:00, just to the left and north of the highway. Gold and silver were discovered in the WINNEMUCCA mining district in 1863. The early productive lodes occurred in quartz veins with small amounts of copper and lead. Gold also occurs in carbonaceous beds associated with seams of quartz and calcite.

178.4 EXIT 178 WINNEMUCCA. The town was named after a local Indian chief. The name was originally interpreted to mean "One Moccasin" but recent research suggests derivation from an ancient Piute word meaning "No sea lions, no caves, no mystery houses" (Cuffney ??).

The Sonoma Range south of Winnemucca consists of structurally complex Paleozoic and Mesozoic marine sedimentary and volcanic rocks and Tertiary welded and non-welded silicic ash-flow tuffs.

183.0 Paradise Valley extends to the north to the Santa Rosa Range and is bounded by the Hot Springs Range on the east. The southern part of the Hot Springs Range consists of Cambrian and Ordovician clastic rocks, predominantly feldspathic sandstone, chert, shale, greenstone, and minor amounts of limestone. The DUTCH FLAT mining district is located on the west side of the range where placer gold was discovered in 1893. Small mercury deposits occur around the south end of the range.

187.0 Button Point. Tertiary welded and non-welded silicic ash-flow tuffs, which locally include thin units of air-fall tuff and sedimentary rocks, are exposed in the roadcut on the right.

187.5 EXIT 187 BUTTON POINT. The southern Osgood Mountains are visible at 10:00. Tertiary basaltic andesite lies on Cambrian Osgood Mountain Quartzite in this part of the range.

192.0 The small hill at 1:00 (south of Golconda) with new drill roads is KRAMER HILL. No historic production is recorded, but the extent of underground workings suggests production of a few thousand ounces of gold. The workings explore quartz veins within a north-trending fault zone cutting quartzite and phyllitic shale of the Cambrian Osgood Mountain Quartzite. A few small, altered granodiorite dikes cut the quartzite. Pinson Mining Company has defined a small reserve of 300,000 tons of 0.05 opt gold in an oxidized zone.

194.7 EXIT 194 GOLCONDA. Steam from active hot springs can sometimes be seen on the north and northeast sides of the town of Golconda. According to Garside and Schilling (1979), the springs range from 109° to 165°F, are anomalously radioactive and are actively depositing travertine. Metals in the spring waters include As (0.02 ppm), Cu (0.05 ppm), Li (0.36 ppm), Mn (0.10 ppm), and Hg (0.0001 ppm). The gravel road to the right (south) leads to the ADELAIDE mining district. The district produced silver and copper ores from replacement ore bodies in silicated and silicified rocks of the Cambrian Preble Formation. The district has been active since 1866, but the main production years were 1897-1910.

197.0 GOLCONDA tungsten/manganese mine on the left. The W/Mn deposits are related to Quaternary hot spring activity and occur in ferruginous and manganiferous clay beds in alluvial gravel that overlies the Cambrian Preble Formation. In part, the deposits are overlain by travertine that forms an irregular, horizontal sheet that strikes north. The deposits occur as blankets and veins adjacent to a fault trending N25øE and dipping gently to the northwest. The deposits vary from a few inches to a few feet in thickness and in places are intermixed with the top of the tufa cap. The veins consist of linear masses of anastamosing groups of veinlets along the northeast trend beneath the tufa caps. Both ferruginous and manganiferous vein fillings contain tungsten with accompanying quartz, barite, and jarosite. Tungsten also occurs as a heterogeneous mixture in psilomelane. Neither wolframite nor scheelite have been found in the ores.

197.5 Pinson Mining Company's PREBLE Mine (9,10) is visible in the middle ground in front of the small pointed hill on the left. Sub-microscopic gold is disseminated within carbonaceous shales and silty limestones of the middle member of the Cambrian Preble Formation. Altered granodiorite dikes and small sills are associated with the gold mineralization. Ore occurs along a broad shear zone parallel to bedding, which strikes northeasterly and dips 30 degrees to the southeast. The shear zone is part of the Getchell Fault System, a series of sub-parallel en echelon faults and broad shear zones that bound the eastern flank of the Osgoods and control gold mineralization at Pinson, Getchell and probably at Chimney Creek.

Gold is strongly associated with replacement quartz. Silicification occurs within the ore horizon and extends out laterally from it. Arsenic and lesser Hg, Ba and Sn are associated with the silicification and gold mineralization. The ore is oxidized to a depth of 200 ft, below which mineralization is highly refractory. (Kretschmer, 1987).

198.5 As the highway begins to climb towards Golconda Summit, the first roadcuts are in the Cambrian Preble Formation (both sides of the highway). When the highway again curves to the southeast, it crosses the general trace of the Iron Point thrust fault; upper-plate rocks (to the east) are chert and shale of the Permian-Pennsylvanian Pumpernickel Formation. Some areas of alteration in the Pumpernickel are related to Cretaceous quartz diorite dikes that cut the older rocks. Scattered copper mineralization is found in some of these altered zones, and considerable prospecting has been done south of the highway between here and the summit.

200.0 GOLCONDA SUMMIT.

201.8 East side of Golconda Summit. Roadcut drops back into the lower plate of the Iron Point thrust (to the east, lower-plate Cambrian Preble Formation).

203.9 EXIT 203 IRON POINT. Colorful alteration on both sides of the highway occurs in shale and chert of the Ordovician Valmy Formation. The Valmy outcrops north of the highway have been explored for vanadium. Black shale here contains Ba, Cu, Ni, Ag, V, and Zn Silver prospects occur north of this zone at the SILVER COIN mine (head frame and old buildings to, deep drilling was done in this area to explore intrusive bodies that underlie the district. A large area here shows anomalous values of As, Sb, and Hg, and there has been exploration . The reclaimed drill pads on the left side of the highway are in hematite stained, thin-bedded limestone of the middle part of the Cambrian Preble Formation.

205.5 EXIT 205 PUMPERNICKEL VALLEY. The Snowstorm Mountains, on the northeast skyline at about 9:00, are just north of the Midas gold district. The mountains are composed of a thick sequence of silicic volcanic flows, ash flows, and plugs associated with a volcanic province that

Figure 9 After Kretschmer, (1987)

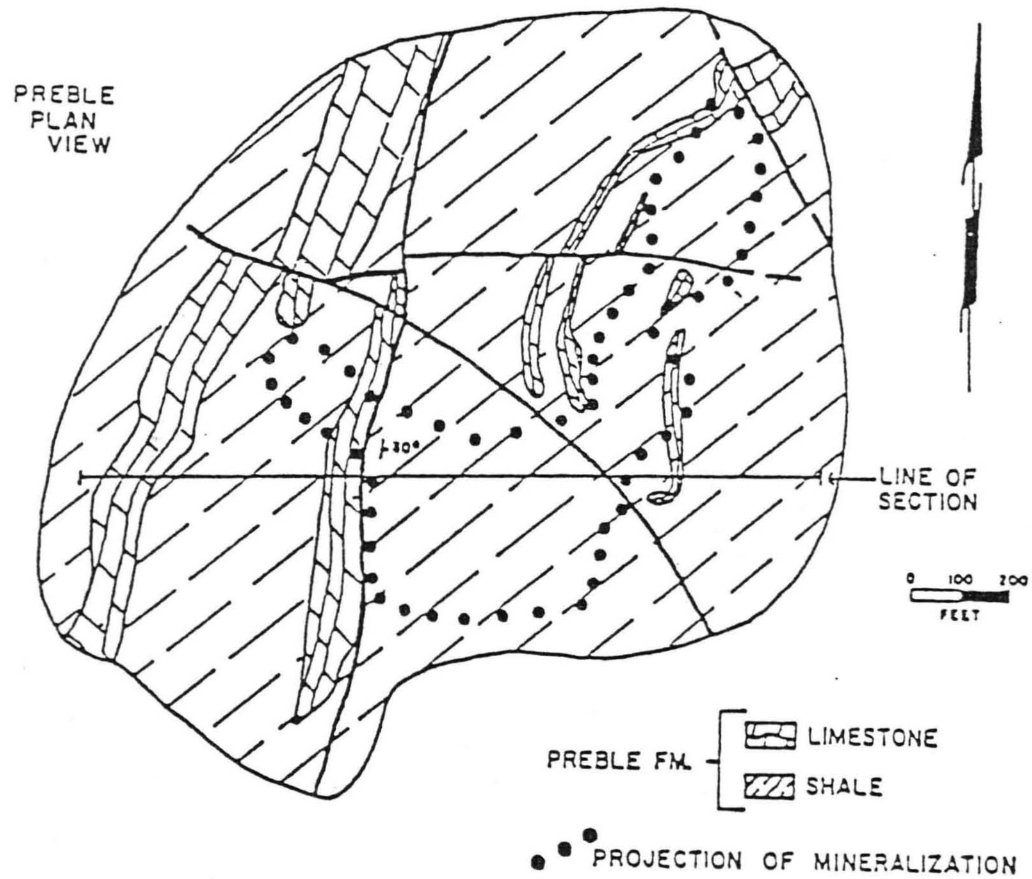
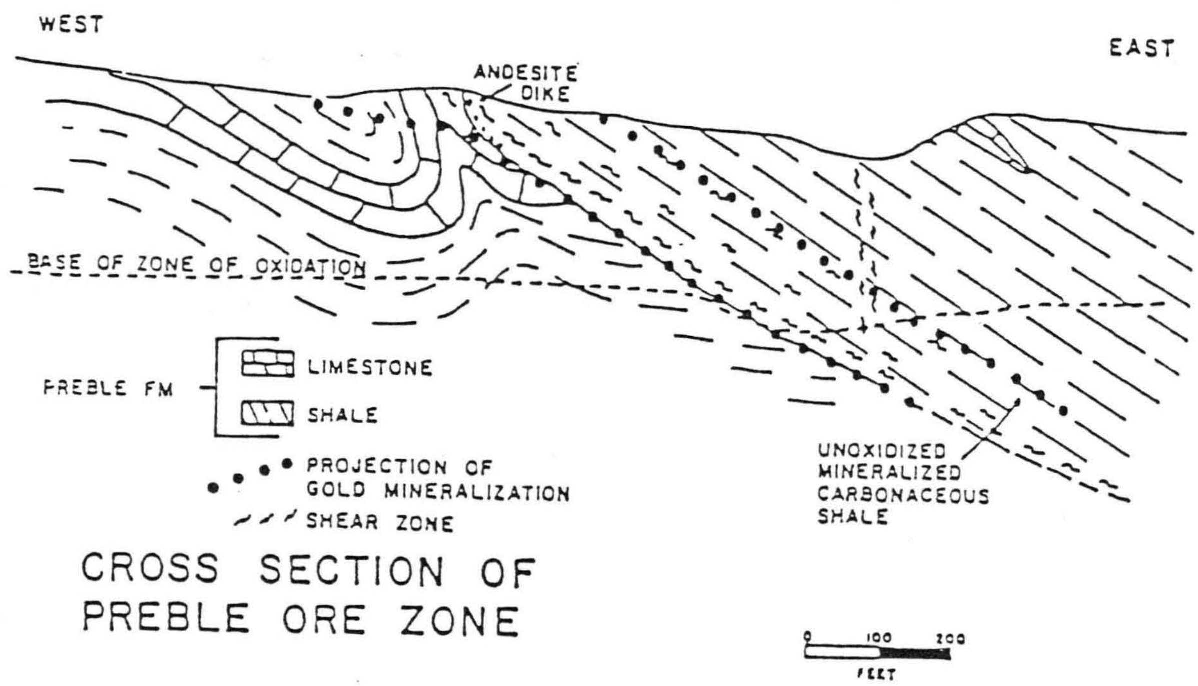


Figure 10. After Kretschmer, (1987)



Cross section of Preble ore zone.

extends north to the Idaho border. Several companies have done extensive exploration for gold in this area.

206.0 The open-pit mine and mill complex at Santa Fe Gold's TWIN CREEKS mine can be seen low in the distance at about 8:30, along the east edge of the Dry Hills. Announced proven and probable reserves are 8.5 million ounces of gold. The Twin Creek mine is located in a complex tectonic and structural setting that includes both major Paleozoic overthrusting and Tertiary Basin and Range block faulting. Faults that partially control mineralization follow a northeast strike with left lateral displacement. Mineralization in occurs in rocks of Lower Ordovician age, the Pennsylvanian to Permian Etchart Limestone, and in the underlying Lower Mississippian, possibly Goughs Canyon Formation. Structures within the deposit area include a series of northwest-southeast-striking asymmetric anticlines and synclines. Axial planes of several folds are either recumbent or overturned to the east. Small-scale low-angle faults were apparently formed along the axial planes and limbs of folds during compressional deformation. The structure is further complicated by high-angle extensional normal faults which trend primarily north-south or northwest. Alteration includes decalcification, argillization, silicification, carbon remobilization, and supergene oxidation. Most mineralization is hosted within favorable, decalcified shale and limestone horizons and along small-scale low-angle structural zones associated with recumbent anticlines. Gold generally occurs as particles of sub-micron size native gold with a high gold-to-silver ratio. Other minerals include orpiment, realgar, cinnabar, native mercury and stibnite (Parratt et al., 1989).

The dumps of the Pinson and Getchell mines can be seen along the east flank of the Osgood Mountains at about 8:00. At PINSON (Figs. 11,12), gold mineralization occurs as fine disseminations in jasperoid, silicated limestone, and siltstone of the Ordovician Comus Formation in a contact metamorphic aureole adjacent to a Cretaceous granodiorite stock. Altered dikes and sills of intermediate composition are associated with the gold mineralization. A strand of the broad northeast-trending Getchell fault system controls the mineralization, which is generally strongly structurally controlled, forming relatively narrow, steeply dipping ore bodies. Gold is generally submicroscopic, has a gold:silver ratio of 100:1, and occurs with silica and pyrite or with limonite and kaolinite. Antimony, As, and Hg, often with Ba and Fl, are important trace elements (Kretschmer, 1986).

The GETCHELL gold deposit (Fig. 13) lies in a structurally prepared fault zone controlled by N10-15W Basin and Range faults dipping 40 to 750 east. The fault zone runs along the east flank of the Cretaceous granodioritic Osgood Stock, which intruded older, thrust faulted, Paleozoic sedimentary rocks of the Preble, Comus and Valmy Formations. Contact metamorphism along the intrusive contact formed skarns and marble. The Osgood Stock, related dikes, and associated skarns are found in both the footwall and the hanging wall of the Getchell fault system.

The gold at Getchell was deposited by several stages of shallow, middle to late Tertiary hydrothermal activity. The bulk of the deposit contains refractory ore, the gold being associated with several stages of pyrite plus realgar and orpiment. The host rocks, which are another major ore control in the Getchell deposit, were originally carbonaceous shales, thin-bedded limestones and siltstones subjected to deformation and metamorphism prior to mineralization.

Getchell was mined for oxide gold ore by underground and open pit methods from 1936 until 1945, when known oxide ores were mined out. From 1945 until 1967, several attempts were made to mine and roast sulfide ores for gold with varying degrees of success. During this time, about 2 million tons of sulfide ore was mined. Four open pits, the North, Center, South and Hansen Creek Pits, have been developed. Almost half of the historic production from the Getchell was from the North Pit. The ore averaged .321 opt gold and was mined along the main Getchell structure in an ore zone varying from 40 to 100 feet thick in shale and limestone of the Preble Formation (Nanna et al, 1987).

Figure 11. Geology of the Pinson Mine Area. After Kretschmer, (1986)

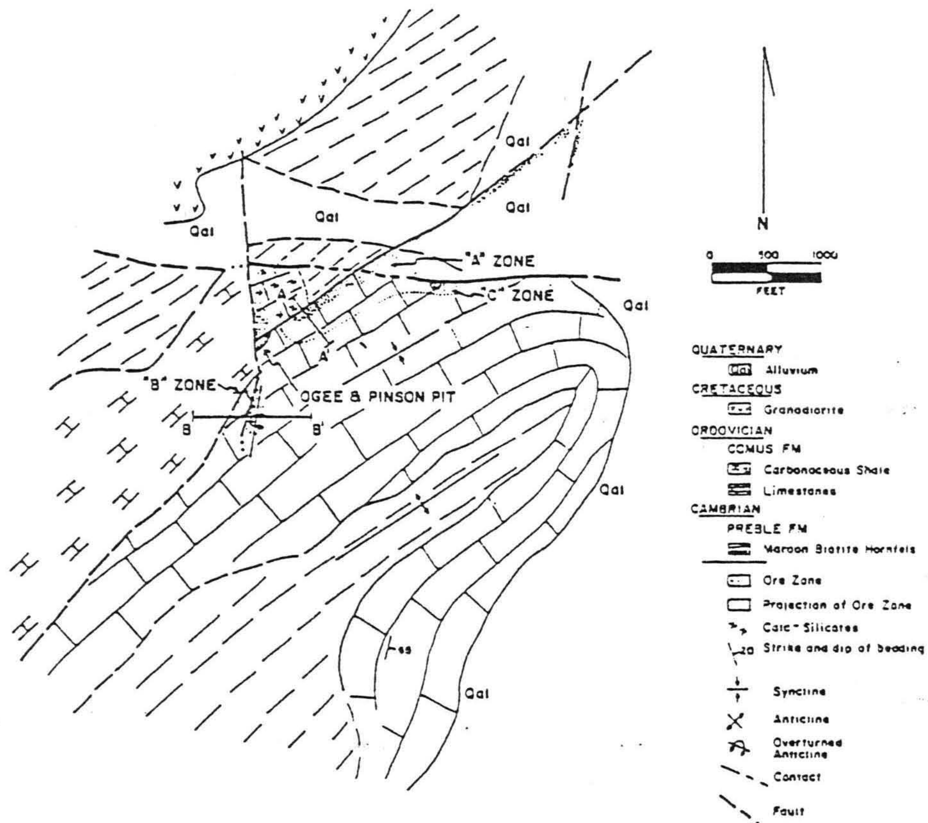


Figure 12. Cross section of the Pinson Ore Zone, "A" ore body. After Kretschmer, (1986)

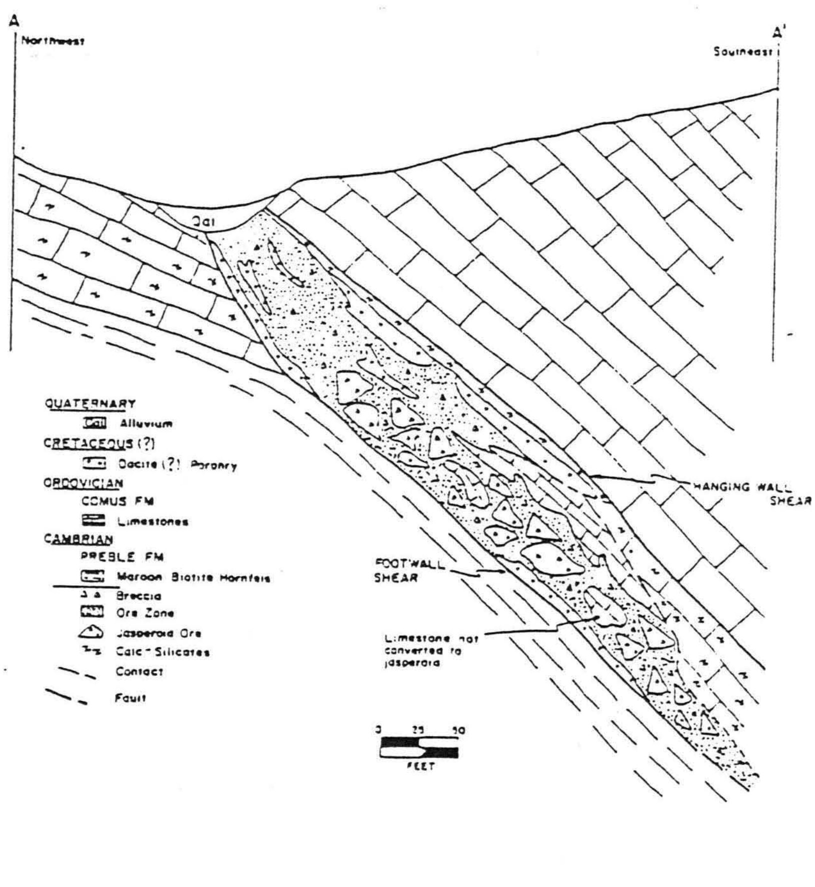
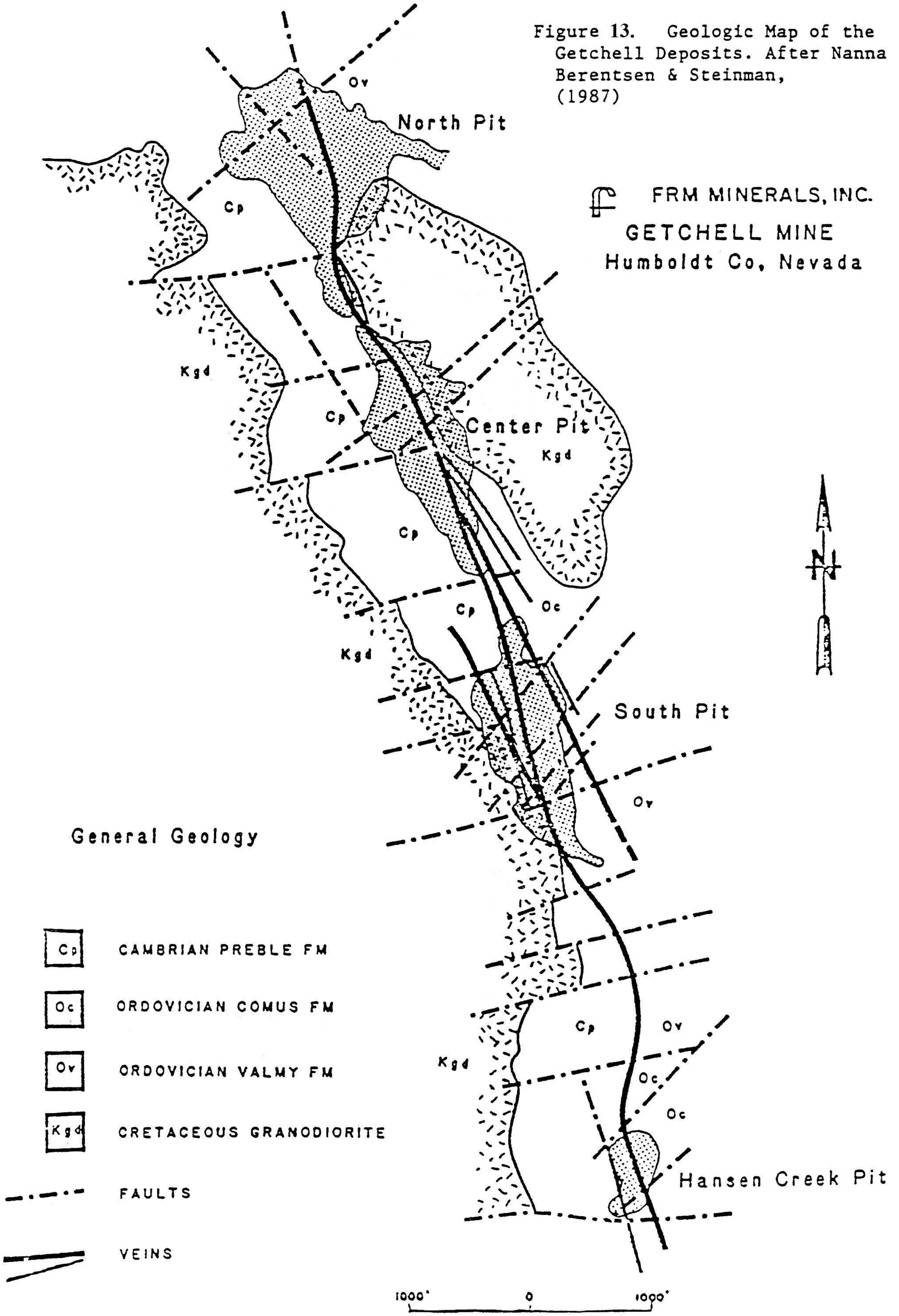


Figure 13. Geologic Map of the Getchell Deposits. After Nanna Berentsen & Steinman, (1987)



FirstMiss Gold announced plans in 1987 to mine refractory open-pit reserves of 7.5 million tons grading .16 opt gold (1.2 million oz) starting in January 1989. Initial proven and probable mineable mill reserves were estimated at 8.1 million tons with an average grade of .154 opt gold. Heap leach reserves were estimated at 1.4 million tons with a grade of .049 opt gold. Geologic reserves were 8.3 million tons with an average grade of .08 opt (FirstMiss Gold Inc. Annual Report, 1990).

210.0 On the right is Santa Fe Gold's LONE TREE deposit, with announced mineable gold reserves of 4 million ounces.

212.2 EXIT 212 STONEHOUSE. Stonehouse foundations to the right. The alteration zone with small adit on flank of the hill is associated with small gold-bearing quartz vein deposits. To the north of the highway, the Valmy power plant can be seen just to the north of Treaty Hill. Treaty Hill, which once marked the boundary of Piute lands (west) and Shoshone lands (east) is composed of Valmy and Battle Formations capped on the north and southeast by Tertiary basalt flows. Southbound power lines from the plant will have to be relocated around the Lone Tree/Stonehouse mine area.

216.9 EXIT 216 VALMY. Workings of the MARIGOLD mine lie along the mountain front at 3:00. The mine produced a few thousand tons of gold ore grading about .20 opt gold between 1937 and 1940 (Willden, 1964). Past production came from the basal conglomerate of the Pennsylvanian-Permian Battle Formation where it is sheared by thrust faulting and north-trending normal faults. The mine lies along the Golconda thrust fault which thrusts upper-plate siliceous clastics and greenstones of the Havallah sequence (Havallah and Pumpernickel Formations) eastward over Valmy Formation quartzites and the overlying Battle Formation.

The Marigold property was acquired in 1986 by the Cordex VI Syndicate and three mineralized zones (Top, East Hill, and Red Rock) of .04 to .06 opt gold were outlined near the old Marigold mine. Further drilling in alluvium covered areas northeast of the mine discovered three additional ore zones (8 South, 8 North, and 5 North).

222.0 EXIT 222 MOTE. To the right, the lower slopes of Battle Mountain extend along the south side of the highway. Small prospects in this area are the ELDER CREEK district, a northern section of the main Battle Mountain mining district. Porphyry copper and molybdenum prospecting was done here in the early 1970's.

About 14 miles southwest, along the west flank of Battle Mountain, is the BUFFALO VALLEY open-pit mine. Gold mineralization occurs within a 50 to 80 ft wide northwest-trending silicified fault zone adjacent to a quartz latite dike. Host rocks are chert, argillite, and limestone of the Havallah Formation (Roberts and Arnold, 1965).

228.0 The COPPER BASIN area is situated in the northeast corner of the Battle Mountain range approximately 6 miles southwest of the town of Battle Mountain. The geologic setting for the area includes interbedded sandstones and shales, which are locally calcareous, and minor limestone of the Cambrian Harmony Formation (Fig. 14). Although locally folded, overall bedding orientation forms a north-striking, easterly dipping homoclinal sequence. Calcareous and formerly calcareous strata of the Harmony Formation located adjacent to mineralized structures are the primary host for secondary enriched copper sulfide replacement deposits, oxidized gold-copper skarn and gold skarn deposits, and gold-bearing silica-pyrite deposits. Unconformably overlying the Harmony Formation are siliceous and calcareous conglomerates, calcareous siltstones, and limestone of the Pennsylvanian Battle Formation and Pennsylvanian-Permian Antler Peak Limestone. Quartz latite, crystal-lithic ignimbrites of the 34 Ma Caetano Tuff unconformably overlie the Antler Peak Limestone in the eastern part of the Copper Basin area.

Intruded into the Paleozoic sediments are Late Cretaceous to middle Oligocene porphyritic stocks, sills, and dikes which range in composition from tonalite to granite. The varying ages of emplacement of these igneous bodies has resulted in widespread, complex zones of contact metamorphism with attendant metasomatism and associated mineralization within the Paleozoic wallrocks (Schmidt et al., 1988).

The north edge of Battle Mountain Gold Co.' s SURPRISE open pit is visible at 3:00 Initial mineable reserves for the Surprise deposit were 1.69 million tons grading .081 opt gold, .82 opt using a .025 opt gold cut-off grade with a strip ratio of 8:1 (Schmidt et al., 1988).

The deposit was discovered in 1984 at the site of the old Surprise mine which produced a small tonnage of copper-gold ore (.161 opt gold, 1.56 opt silver , 1.85% copper) between 1937 and 1954. Production came from oxidized calc-silicated calcareous shale and sandstone of the Harmony Formation (Roberts and Arnold, 1965).

The LABRADOR deposit is located approximately 2000 feet west of Surprise. Mineable reserves are calculated at 1+ million tons grading .046 opt gold and .13 opt silver with a strip ratio of 2.5:1.

The NORTHERN LIGHTS deposit is located approximately 4000 feet south of Surprise and contains 897,000 tons grading .052 opt gold and .23 opt silver with a strip ratio of 2:1.

230 EXIT 229 BATTLE MOUNTAIN. The Battle Mountain-Eureka mineral belt extends southwesterly from the Battle Mountain district to south of Eureka, a distance of over 100 miles. Northwest of Battle Mountain, the belt is less well defined and, as interpreted by Roberts (1966), bifurcates with one fork extending west-northwestward to the Jackson Mountains and the other north-northwesterly to the Opalite district. The mineral belt is defined by the northwesterly alignment of mining districts, associated intrusive rocks and windows of Paleozoic carbonate rocks through the Roberts Mountains thrust fault. Important precious metals deposits within the trend include, from southeast to northwest: Windfall/Ratto Canyon, Gold Bar, Tonkin Springs, Horse Canyon, Cortez, Buckhorn, Gold Acres, Hilltop, Tomboy/Minnie, Fortitude, Buffalo Valley, and possibly (depending on how one draws the forks northwest of Battle Mountain) Preble, Pinson, Getchell, Rabbit Creek, Chimney Creek and Sleeper.

The BATTLE MOUNTAIN mining district lies south and west of town. Mining in the district dates to 1863 when silver was discovered in Galena Canyon. Placer gold was discovered at Copper Canyon in 1912, and small-scale placer mines were intermittently operated in the early 1940's to 1950's. Metal production from the district up to 1961 included 150,000 oz gold, 2.1 million oz silver, 15,000 tons of copper, 5,000 tons of lead and 1,500 tons of zinc (Theodore and Blake, 1975). The first large-scale attempt to mine base and precious metals by open-pit mining methods commenced in 1967 at Duval's Copper Canyon deposits. The copper-rich East and West ore bodies, containing original combined reserves of 17.9 million tons grading .79 percent copper, .47 opt silver and .025 opt gold, were the first deposits mined. Mining later shifted to the relatively gold-rich TOMBOY-MINNIE deposits which contained 3.9 million tons of ore grading .09 opt gold and .28 opt silver

Precious and base-metal deposits in the Copper Canyon area of the Battle Mountain mining district are genetically and spatially related to a middle Tertiary altered granodiorite porphyry that has intruded a sequence of Paleozoic sedimentary and volcanic rocks. The East ore body and Tomboy-Minnie deposits are replacement/disseminated bodies within the basal calcareous conglomerate of the Battle Formation. The West ore body is hosted by andradite-diopside-bearing skarn developed in the Pennsylvanian and Permian Pumpernickel Formation.

Blake et al. (1984) demonstrated a well defined pattern of mineral zonation centered on the Copper Canyon stock. The altered granodiorite contains anomalous but economic Cu, Mo, Au and Ag. Adjacent to the stock and extending outward for up to 1,500 ft is a Cu-Ag-Au zone containing the East and West ore bodies, which is bordered by the outer limit of potassic alteration. Farther outward (1,500 ft to 3,000 ft) from the stock is a high-sulfide Au-Ag zone which contains the Tomboy-Minnie and Fortitude deposits. The outermost zone is a zone of lower overall sulfides characterized by lead-zinc-silver veins.

The FORTITUDE gold-silver deposit is related to a "wallrock" porphyry copper system developed within Middle Pennsylvanian to Permian Antler Sequence rocks adjacent to an altered granodiorite intrusive stock at Copper Canyon. Gold-silver ores of the Fortitude deposit occur as disseminated and massive sulfide replacement mineralization within skarn-like or calc-silicated limey horizons of the Antler Sequence metasediments. A major north-trending, steeply westward dipping normal fault was important as a conduit for hydrothermal fluids responsible for metallization in the Fortitude area. Gold-silver metallization is best developed near a marble front where retrograde chloritization and destruction of prograde calc-silicate mineral phases is most prevalent. Fluid-inclusion studies performed on the Copper Canyon system indicate a wide variation in fluid chemistry during several hydro-silicate stages that ranged in temperature from 250° to 500° C. Surface rock-chip geochemistry and structure did not adequately define the existence of the Fortitude deposit in the highly-mineralized Copper Canyon area. Airborne and ground magnetometer surveys delineated the Fortitude deposit and were instrumental in the discovery process (Wotruba et al., 1988).

Echo Bay Mines' McCOY mine (Figs.14,15) lies about 30 miles to the south of Battle Mountain in the north-central Fish Creek Mountains Gold mineralization occurs in skarn and shear zones which are associated with a Tertiary quartz monzonitic to granodioritic stock. The stock, informally referred to as the Brown Stock, intrudes Triassic carbonate and siliceous sedimentary rocks of the Augusta Mountain sequence. The Brown Stock is elliptical in plan, about 2,200 ft long and 1,400 ft wide. Northeast- and northwest-trending faults with minor displacement are the dominant structural features at McCoy. Metasomatism associated with emplacement of Brown stock formed skarn along limestone-intrusive contacts and stratiform skarn along limestone-pebble conglomerate contacts. Mineralized skarn is present from the surface to depths in excess of 600 ft, and up to 350 ft laterally away from the intrusive. A marble halo up to 600 ft wide surrounds the stock. Mineralization consists of gold with subordinate silver and copper.Typical gold grades in the skarn range from .051 to .100 opt. Gold occurs with disseminated, variously oxidized sulfide minerals associated with skarn. Sulfide mineralogy consists of pyrite with lesser pyrrhotite and occasional chalcocite and sphalerite. The deposit was explored from 1969 to 1984 by Summa Corporation, Houston International Minerals, and Gold Fields Mining Corporation. Tenneco Minerals Company conducted metallurgical, engineering and cost studies during the spring and summer of 1985. Mine and mill construction began during December, 1985, and the first dore was poured in April, 1986 (Kuyper, 1988). In late 1986, Echo Bay Mines purchased the McCoy property from Tenneco.

Early in 1987, Echo Bay announced the discovery of the COVE deposit about 1 mile northeast of McCoy gold-skarn deposit. The deposit area was identified through stream sediment and soil geochemical sampling. Host rocks for the deposit are the Triassic Favret, Panther Canyon, and Augusta Mountain Formations. The sedimentary sequence is intruded by numerous felsic dikes and sills which have been hydrothermally altered. The deposit is largely covered by alluvium and younger volcanic rock, but gold-anomalous manganiferous jasperoid does outcrop (Emmons and Coyle, 1988).

Initial drill-indicated geological reserves were estimated at 35.5 million tons grading 0.076 opt gold and 3.2 opt silver for a total contained mineral inventory of 2.9 million oz gold and 146.4 million oz silver (Mining Record, June 8, 1988). However, at year end 1989, the proven and probable reserves were reduced by 11% or 603,000 oz Au. The overestimation was a result of

Figure 14. After Kuyper, (in press)

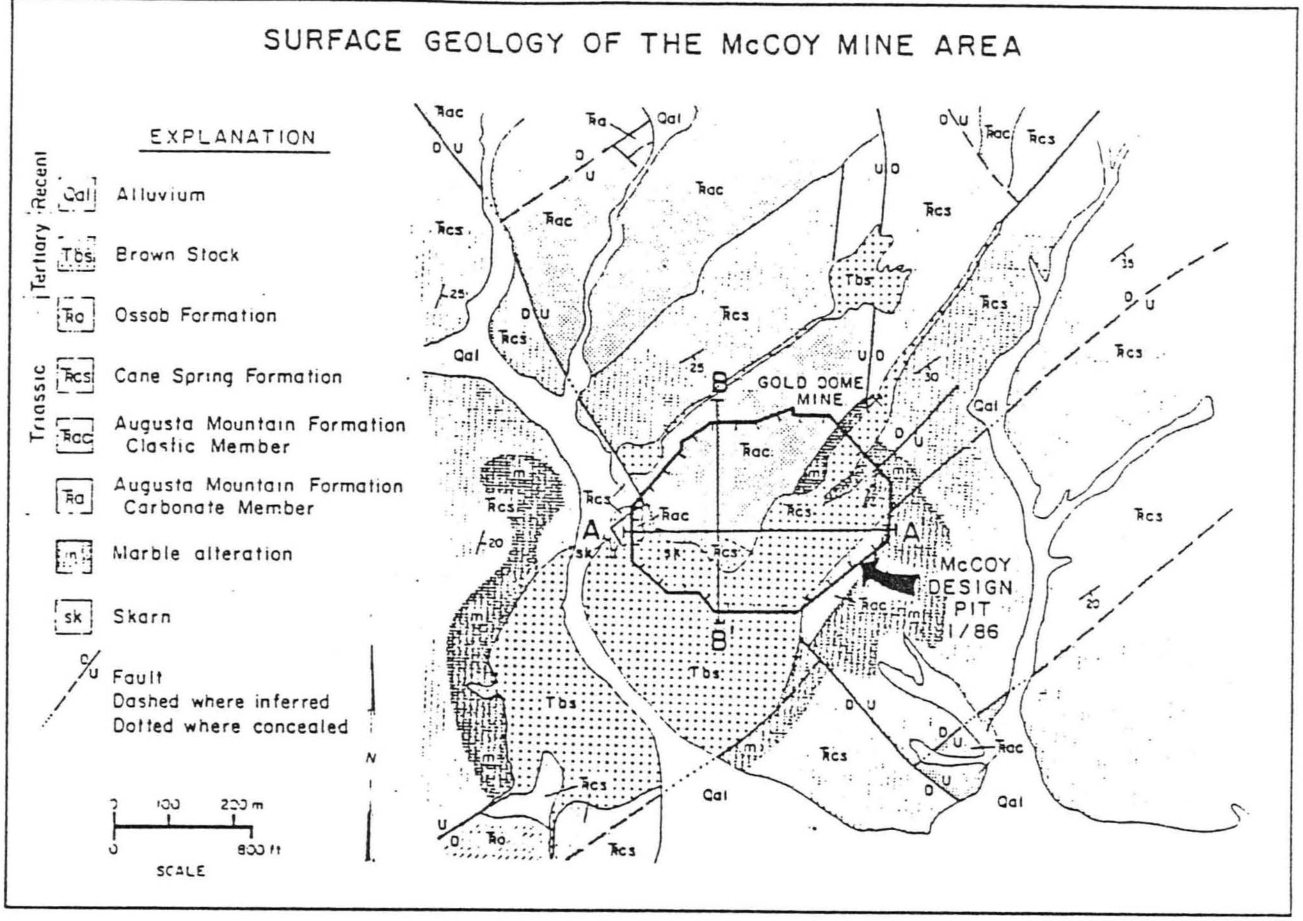
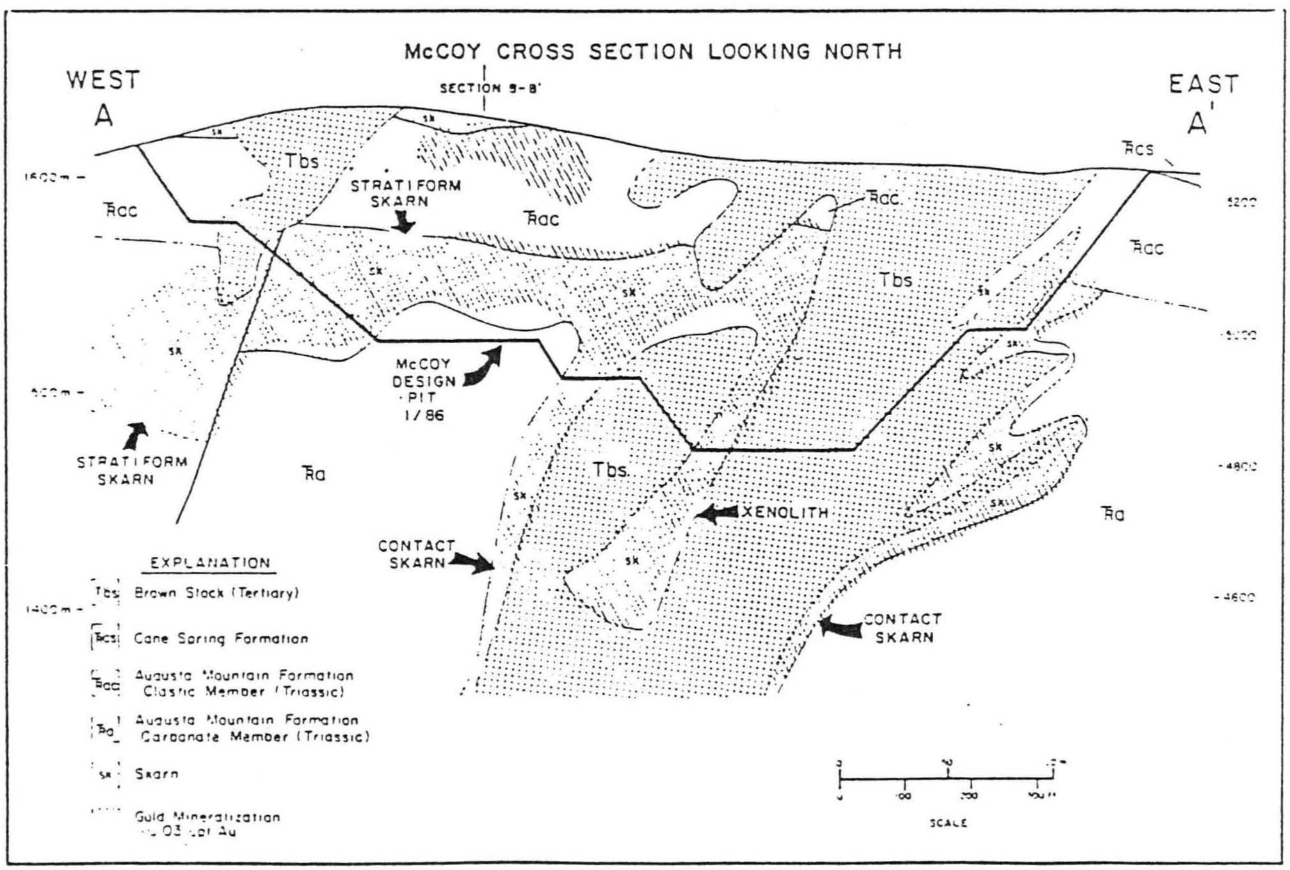


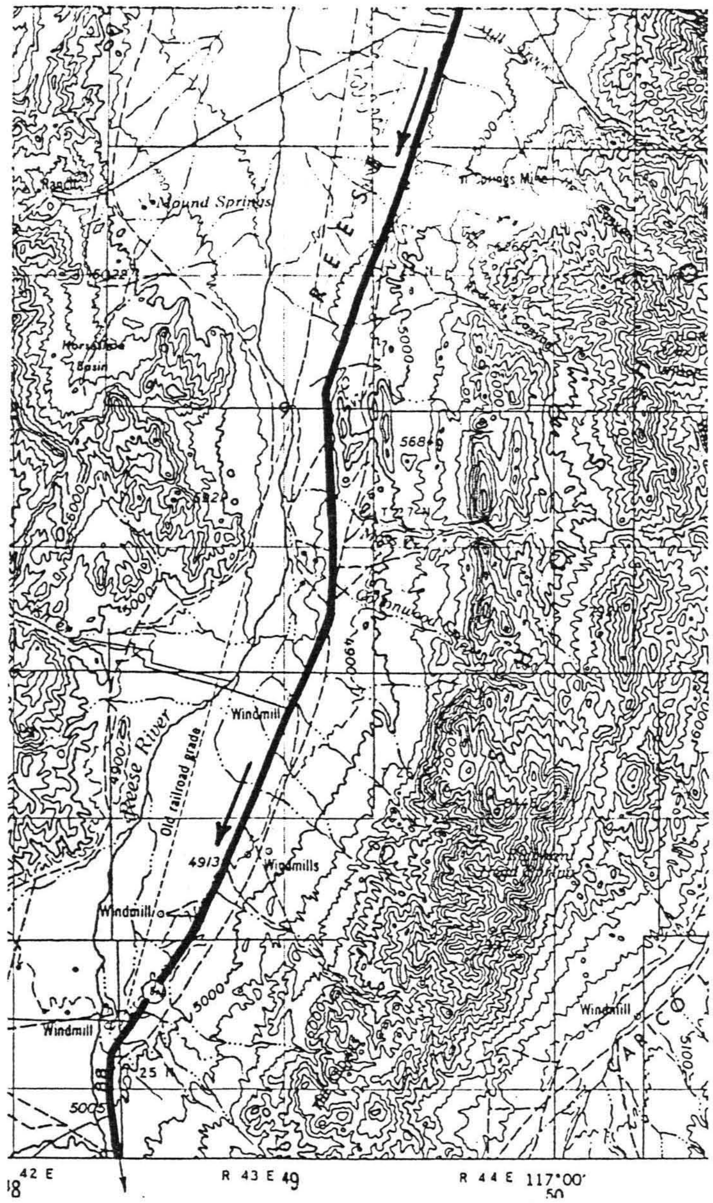
Figure 15. After Kuyper, (in press)



unreliable reverse-circulation drill assay data due to down-hole contamination of samples from below the water table (Echo Bay Mines 1989 Annual Report).

ROAD LOG:
BATTLE MOUNTAIN TO ELY, NV

Road Log modified from:
Shawe, D. R., et al (1978)



0 Leave Battle Mountain south on Nevada Highway 8A.

12 Copper Canyon mine road on right.

15 Tertiary basalt at 3:00 o'clock.

16 Cross Reese River.

17 Mount Lewis (9,688 ft) in northern Shoshone Range at 10:00 o'clock. Mount Lewis is situated in core of cauldron of early Tertiary age (Mount Lewis cauldron of Wrucke and Silberman, 1975) from which most volcanic rocks have been removed by erosion.

18 Mount Tobin (9,777 ft) in Tobin Range, high mountains in distance at 3:00 o'clock.

20 Trout Creek fault to left at Trout Creek Canyon in northern Shoshone Range probably is an arcuate ring fracture on the south side of the Mount Lewis cauldron of early Tertiary age.

21 Barite stockpile at road turnoff to Mill Canyon.

23 Mountain Springs bedded-barite deposit at 11:00 o'clock.

26 IMCO Services property road on left.

26.2 Turn left (east) onto gravel road leading to FMC Corp. Mountain Springs barite deposit.

28 Mountain Springs bedded-barite deposit.

30 Turn left (south) onto Nevada Highway 8A.

31 Hot springs with travertine apron at 9:00 o'clock.

33 Fish Creek Mountains to right consist of middle Tertiary volcanic rocks; the Fish Creek Mountains caldera occupies the main mass of the mountains. To the left, east of the caldera, an east-trending volcano-tectonic depression filled with a great thickness of middle Tertiary ash-flow tuffs extends about 50 miles (80 km) from the Shoshone Range into the Cortez Mountains to the east.

45 Reese River Valley farms. Hills to the left (east) contain upper Paleozoic allochthonous (upper

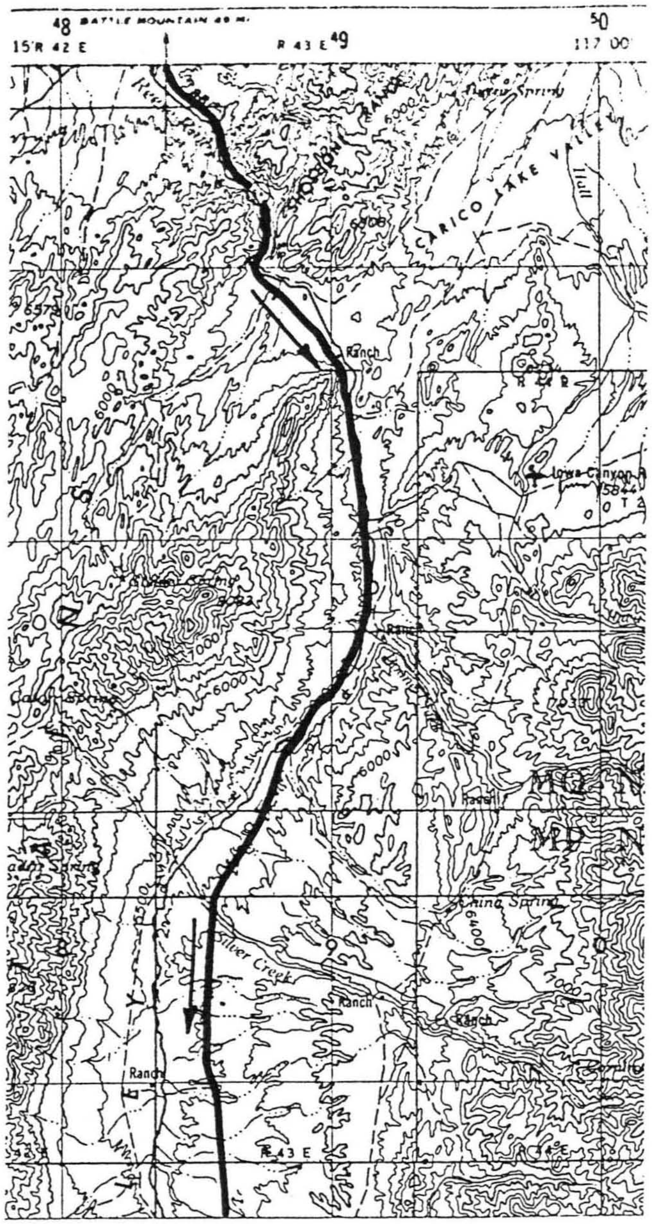


plate) siliceous Havallah and autochthonous (lower plate) Antler sequences, the latter being deposited as an overlap assemblage following the eastward emplacement of the Roberts Mountains allochthon.

56 Tertiary volcanics and Tertiary–Quaternary alluvium. Entering The Narrows cut by Reese River.

64 Mount Callaghan (10,187 ft) in the Toiyabe Range at 11:00 o'clock capped with Cambrian quartzite.

65 Southern Toiyabe Range straight ahead.

67 Tertiary tuffaceous sedimentary rocks along highway. Ravenswood mining district in Shoshone Mountains to west has produced minor silver and gold.

71 Tertiary tuffaceous sedimentary rocks along highway.

72 Tertiary welded ash-flow tuffs on left.

73 Reese River crossing.

77 Small mine in Shoshone Mountains to west.

80 Tertiary tuffaceous sedimentary rocks.

81 Skookum mining district in hills to west has produced minor silver and gold.

94 Intersection with U.S. Highway 50; turn left (east) toward Austin. Stokes castle at 1:30 o'clock at skyline was built by a railroad executive for his family. Austin monument by highway on right commemorates the district's discovery site below the road. Aplite-veined Jurassic granite in road cuts.

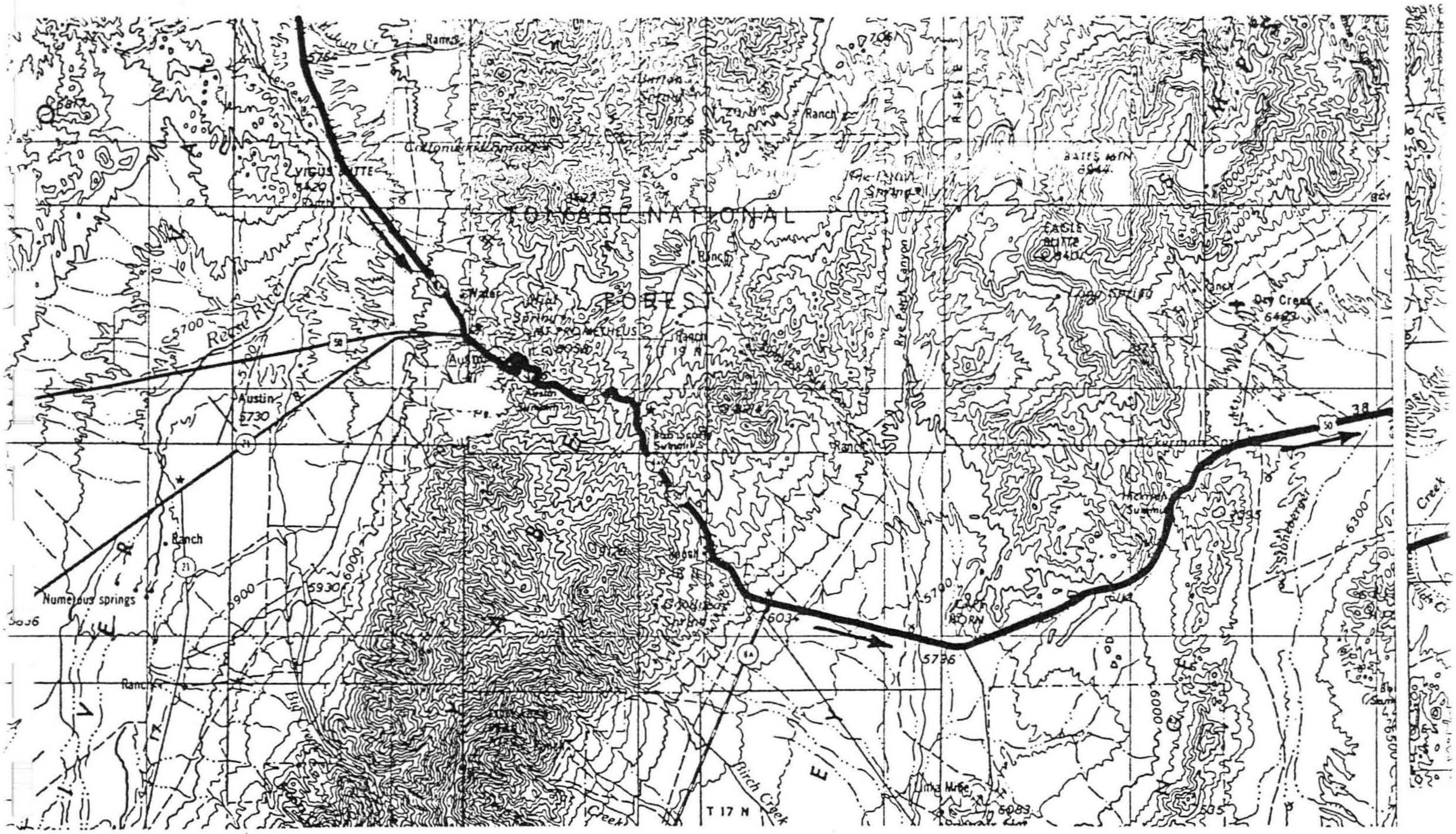
95 Austin, center of the Reese River mining district. Silver was discovered in 1862 at Austin, which quickly became a boom town with a population of nearly 10,000 (now reduced to a few hundred). Rich ores were shortly mined out however, and since 1886 only sporadic operations have taken place. Total production prior to 1886 has been reported variously at $20–65 million, in silver and minor gold. Base metals were not recovered. Since 1886 about $1 million in silver and minor gold, copper, lead, and zinc has been produced. Somewhat less than $1 million of uranium has been produced from the southern part of the district in recent years.

Jurassic quartz monzonite in the district has intruded Cambrian rocks, mostly impure quartzite, and is locally overlain by Tertiary volcanic and sedimentary rocks. Dikes of lamprophyre, aplite, and pegmatite cut the quartz monzonite.

Quartz veins, mostly in quartz monzonite, are widely distributed. The veins contain—in addition to quartz—rhodochrosite, other carbonate minerals, sericite, pyrite, galena, sphalerite chalcopyrite, arsenopyrite, tetrahedrite, stibnite, proustite, molybdenite, argentite, pyrargyrite, stephanite, polybasite, enargite, and xanthoconite. All of these minerals have been considered to be hypogene; chalcocite, covellite, and acanthite are reported as supergene minerals. Alteration of wall rocks adjacent to veins resulted in the formation of sericite, calcite, dolomite, quartz, chlorite, pyrite and other sulfides, tourmaline, and rutile.

Most of the productive silver-bearing veins in the district fill distinct fractures that strike north-northwest and dip moderately to the northeast. Locally the veins fill other fracture sets and are reticulate. (Above data on Reese River mining district from Ross, 1953.) Quartz veins in quartz monzonite near the south edge of the Reese River district mineralogically are somewhat similar to the silver-bearing veins, but in addition contain appreciable uranium minerals such as uraninite and secondary oxides, which are not being produced at present.

Several mining districts lie 10–65 miles (15–100 km) south of Austin in the Toiyabe and



Toquima Ranges: The Big Creek district (more than $1 million production of antimony from stibnite-bearing quartz veins in deformed and silicified Paleozoic sedimentary rocks); the Twin Rivers (Millett) district (more than $1 million production of gold, silver, tungsten, and minor lead and zinc); the Northumberland district ($1 million production of gold and minor silver from silicified carbonaceous Paleozoic shale near Jurassic granite stock); the East Northumberland Canyon district (about $10 million production of sedimentary bedded barite that is interlayered with chert and argillite of the Devonian Slaven Chert; similar to Mountain Springs barite deposit); the Round Mountain district ($13 million production of gold; minor silver, tungsten, and mercury also produced; gold and silver were produced from quartz- and iron-mineralized sheeted zones in Tertiary rhyolitic ash-flow tuff, and from associated placers; the deposit in rhyolitic tuff recently has been reactivated); the Manhattan district (more than $10 million production of gold and minor silver, antimony, arsenic, and mercury; production of gold and silver from sheeted zones in Lower Cambrian quartzite and of gold, silver, antimony, arsenic, and mercury from veins and replacement deposits in Cambrian limestone); and the Belmont district ($4 million production of silver and minor gold from quartz veins in Ordovician limestone and shale near a Cretaceous granite stock).

Buses continue through Austin.

98.5 Austin Summit; Jurassic quartz monzonite along highway.

99.5 Tertiary welded ash-flow tuff resting on quartz monzonite.

101 Grass Valley—Cortez road (Nevada Highway 21) on left (north).

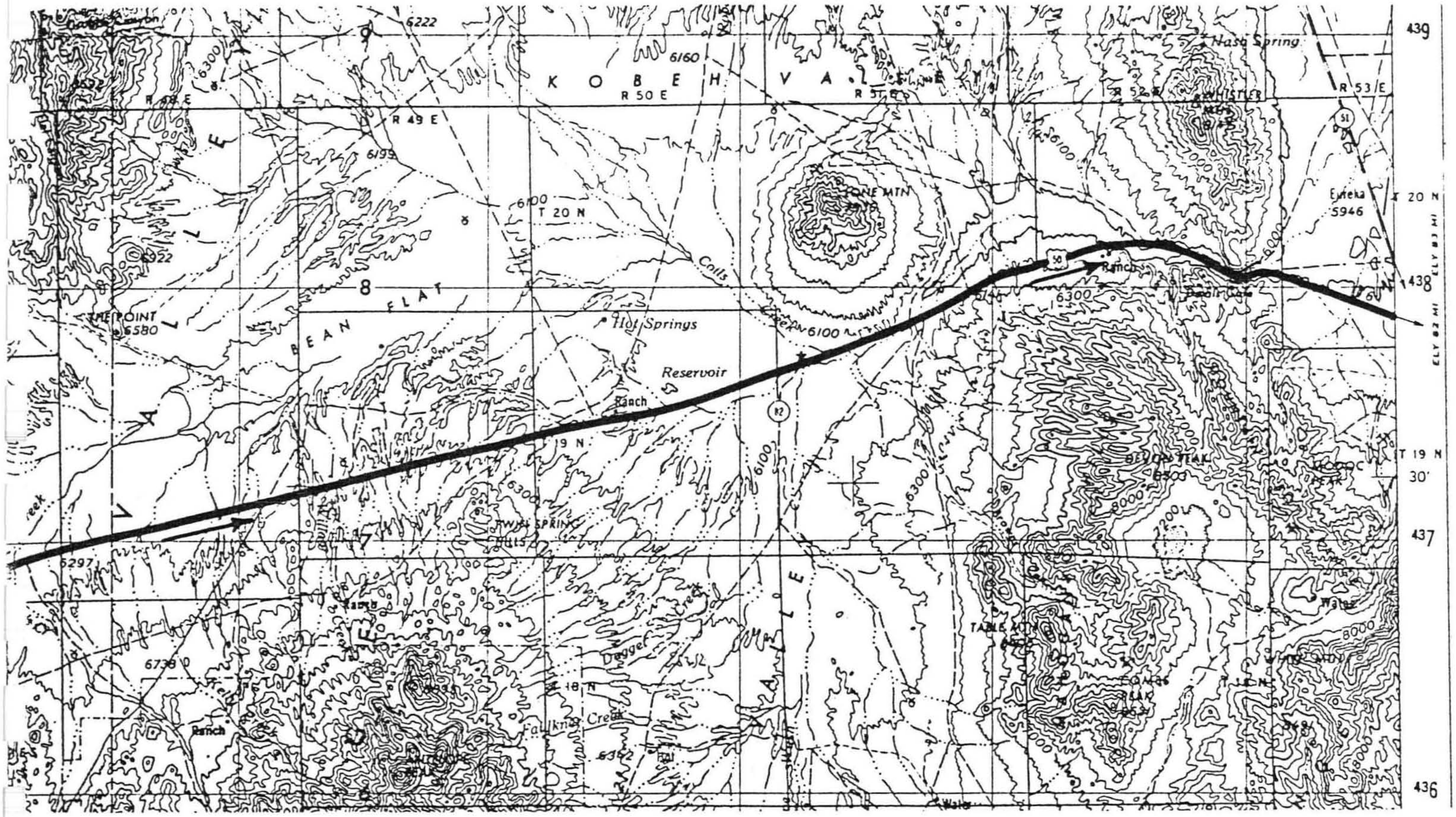
105 Wildcat Peak (10,522 ft) in Toquima Range straight ahead; complexly faulted Paleozoic sedimentary rocks and Tertiary volcanics.

106 Siliceous (western) assemblage Paleozoic rocks along highway.

106.5 Altered igneous dike in road cut on left.

107 Nevada Highway 8A to Round Mountain and Tonopah on right.

109 Mount Jefferson (11,949 ft) at 2:30 o'clock consists of a thick sequence of middle Tertiary



rhyolitic welded ash-flow tuffs, and is probably a resurgently domed caldera.

111 Linka (Spencers Hot Spring) mining district in low hills at 2:00 o'clock has produced more than $1 million in tungsten from a contact-metamorphic deposit.

112 Road to Linka on right.

116 Tertiary volcanic rocks along highway.

120 Hickison Summit. Tertiary ash-fall tuff overlain by Tertiary welded ash-flow tuff; faulted.

121 Simpson Park Mountains to left, trending northeast, consist of siliceous (western) assemblage Ordovician rocks and Tertiary volcanic rocks. Roberts Mountains in distance at 11:00 o'clock consist of complexly faulted Paleozoic rocks where siliceous (western) and transitional- to carbonate- (eastern) assemblage rocks of the same age are juxtaposed by thrusting. Transitional-assemblage Silurian-Devonian Roberts Mountains Formation and earliest Mississippian Roberts Mountains thrust system were originally defined in that area.

122 Diamond Peak (10,614 ft) in Diamond Mountains straight ahead; the mountain range consists of mostly Paleozoic formations, including the Diamond Peak Formation which is Mississippian in age at its type locality and represents a submarine-fan system in the Antler flysch derived from the Antler orogenic highland to the west.

124 Monitor Range (Antelope Peak, 10,220 ft, on left and Summit Mountain, 10,476 ft, on right) at 1:30 o'clock consists of middle Tertiary welded and nonwelded silicic ash-flow tuffs, locally lying on low-angle faults. Tuffs may define a caldera.

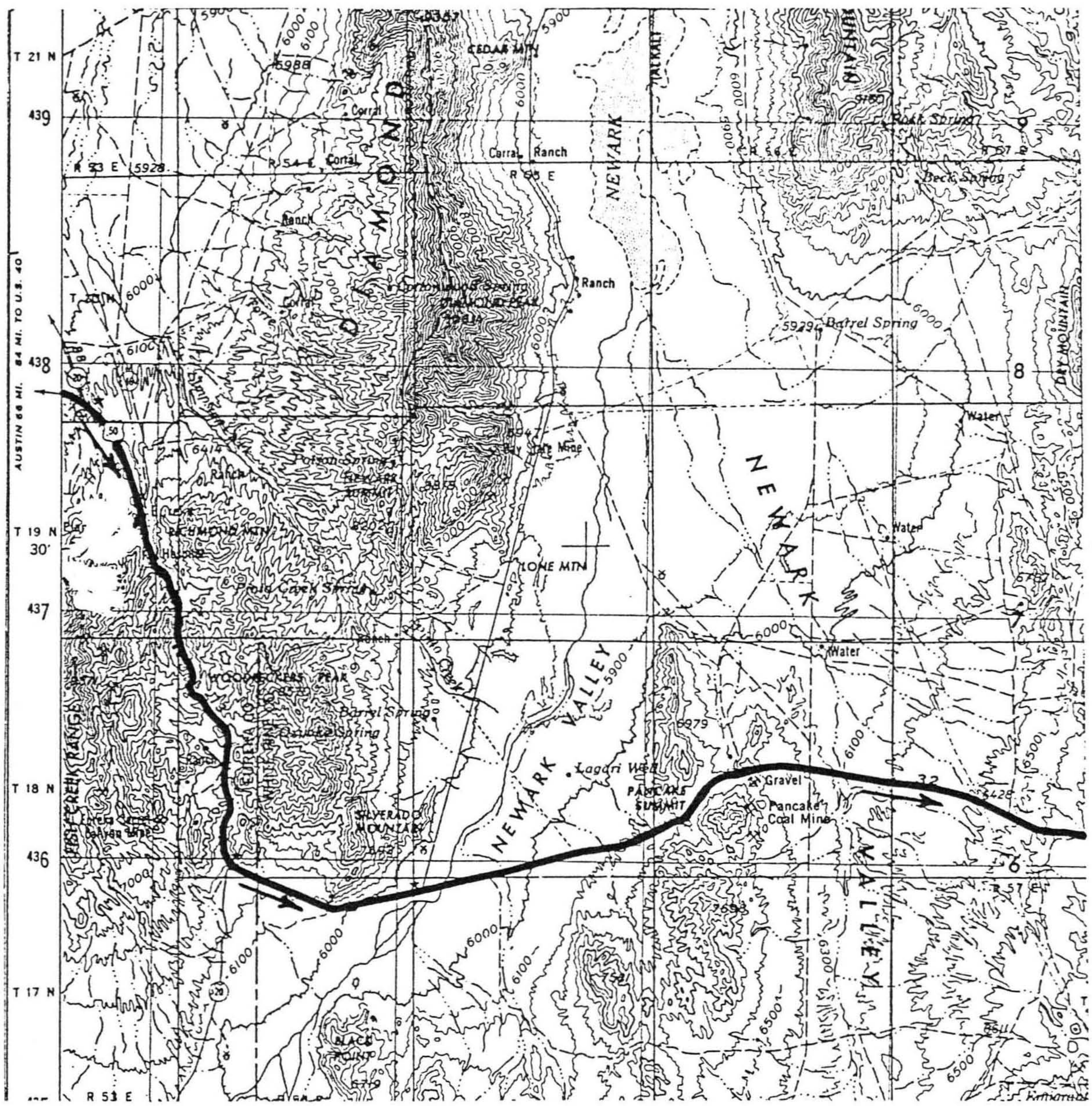
129 Enter Eureka County. About 35 miles (55 km) south, on east side of Toquima Range, is the East Northumberland Canyon bedded-barite district, a major new barite source; just northwest of the barite district is the Northumberland gold mine.

133 Road on right leads to old Belmont silver camp, located 66 miles (105 km) to south. Lincoln crested wheat grass seeding along highway.

141 Antelope Valley. Antelope Peak at 3:00 o'clock near north end of Monitor Range; Fish Creek Range at 1:00 o'clock consists of thrust-faulted Paleozoic rocks; Lone Mountain at 10:30 o'clock consists of Ordovician, Silurian, and Devonian carbonate (eastern) assemblage formations that are in fault contact (possible klippe) with Ordovician siliceous- (western) assemblage rocks; the small Lone Mountain mining district on the north side of the mountain produced a minor amount of high-grade zinc-lead-silver (oxide zinc) ore in the 1950's.

151 Whistler Mountain straight ahead consists of Jurassic granite intruded into Paleozoic sedimentary rocks.

153 Mount Hope at 9:30 o'clock consists of Tertiary rhyolite stock intruded into Ordovician



siliceous-assemblage rocks. The Mount Hope mine has produced minor silver, lead, and zinc; site of a molybdenum porphyry prospect.

157 Allochthonous Ordovician Vinini Formation siliceous-assemblage rocks on right.

158 Devils Gate Pass. Middle and Upper Devonian Devils Gate Limestone (type locality) conformably overlain by Pilot Shale, which is Upper Devonian at this locality. Pilot is unconformably overlain by Lower and Upper Mississippian Chainman Shale (Antler flysch) to left (north).

159 Jurassic alaskite sill near top of ridge to north. This sill is the higher of two sills which intruded the lower part of the Chainman Shale.

160 Diamond Peak at 11:00 o'clock. Phillipsburg mine on west side of Diamond Mountains has produced minor silver, lead, zinc, gold, and copper.

161 Ruby Hill at 1:30 o'clock is site of bonanza ores of the Eureka district.

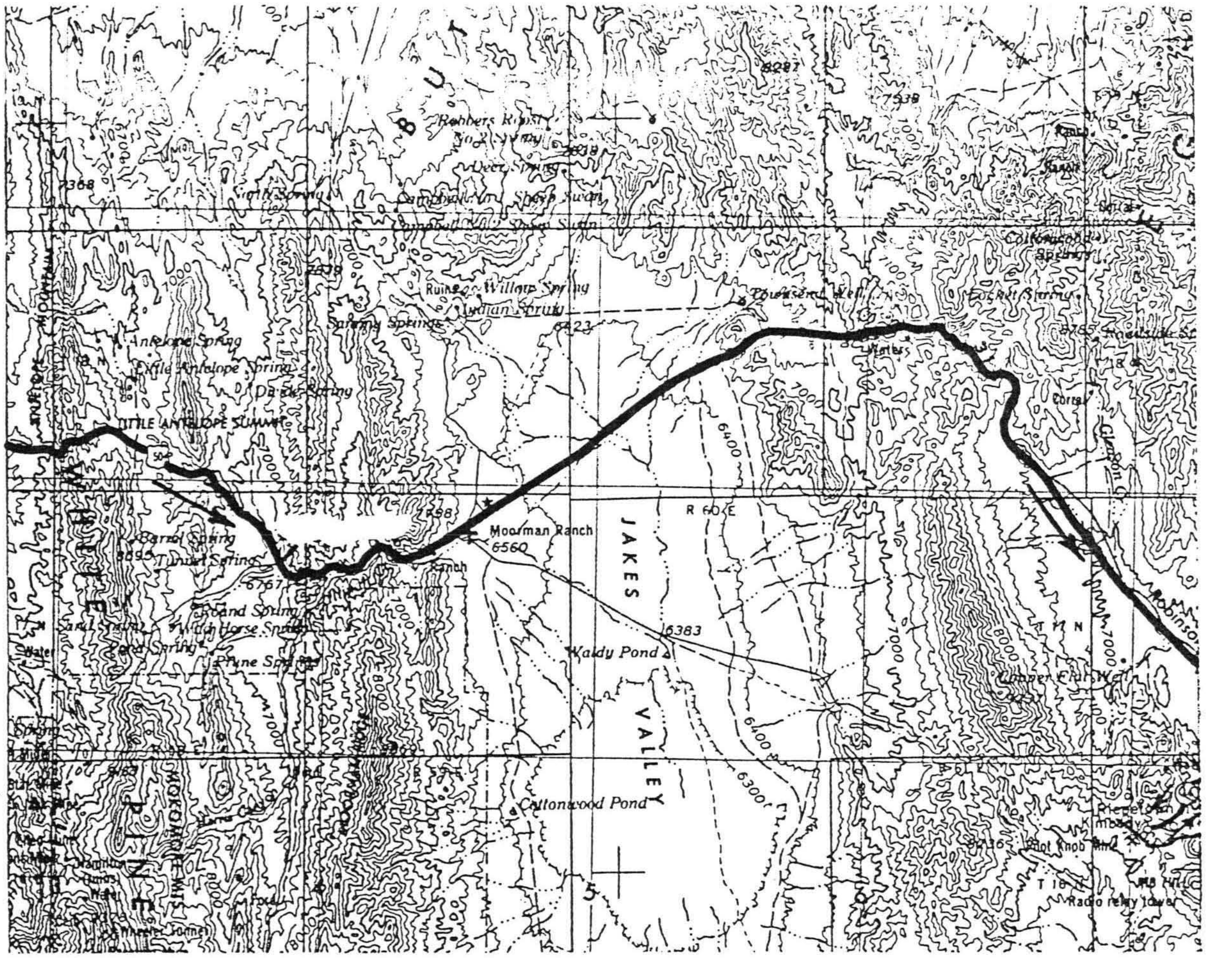
163 Nevada Highway 51 on left leads north to Carlin.

166 Eureka. Discovered in 1864, the district has since produced 1.65 million oz gold, 3.9 million oz silver, and 625 million lbs lead.

166.5 Turn right (west) on street along north side of Eureka County Court House.

167 Tertiary ash-fall tuff along road.

169 Fad Shaft, site of the 1938 discovery of a large lead-zinc-gold-silver replacement ore body in Cambrian Eldorado Dolomite. The shaft was sunk to a depth of 2,250 ft (685 m) in 1941–1946, but severe water problems, despite costly attempts to control the water, have prevented mining of the ore body.



following tour.

173.5 Turn right (south) onto U.S. Highway 50 in Eureka.

178 Pinto Summit. Oligocene Pinto Peak Rhyolite to south.

180 Silurian part of Lone Mountain Dolomite along highway. Hills to northeast are Devonian carbonate strata.

182 Brown ridge at 1:00 o'clock consists of Permian Carbon Ridge Formation.

183 Enter White Pine County.

184 Gibellini and Bisoni sedimentary vanadium claims in allochthonous Devonian siliceous-assemblage rocks about 20 miles (30 km) southwest of highway. Mount Hamilton (Pogonip Mountain) (10,745 ft) straight ahead in White Pine Range beyond Pancake Range in middle distance. White Pine Range is mostly Paleozoic carbonate rocks; Pancake Range is mostly Tertiary volcanic rocks.

187 Small dark knob at 9:00 o'clock is Miocene (20 m.y.) alkalic olivine basalt.

188 The Pinto (Silverado) mining district in saddle at 9:00 o'clock has produced a small amount of silver. Farther north on the east side of the Diamond Mountains, the Newark (Strawberry) mining district has produced more than $1 million in tungsten, silver, and minor lead, copper, zinc, and gold from veins and stockworks in the Devonian Nevada Formation.

189 Diamond Peak at 9:00 o'clock. Newark Valley in foreground.

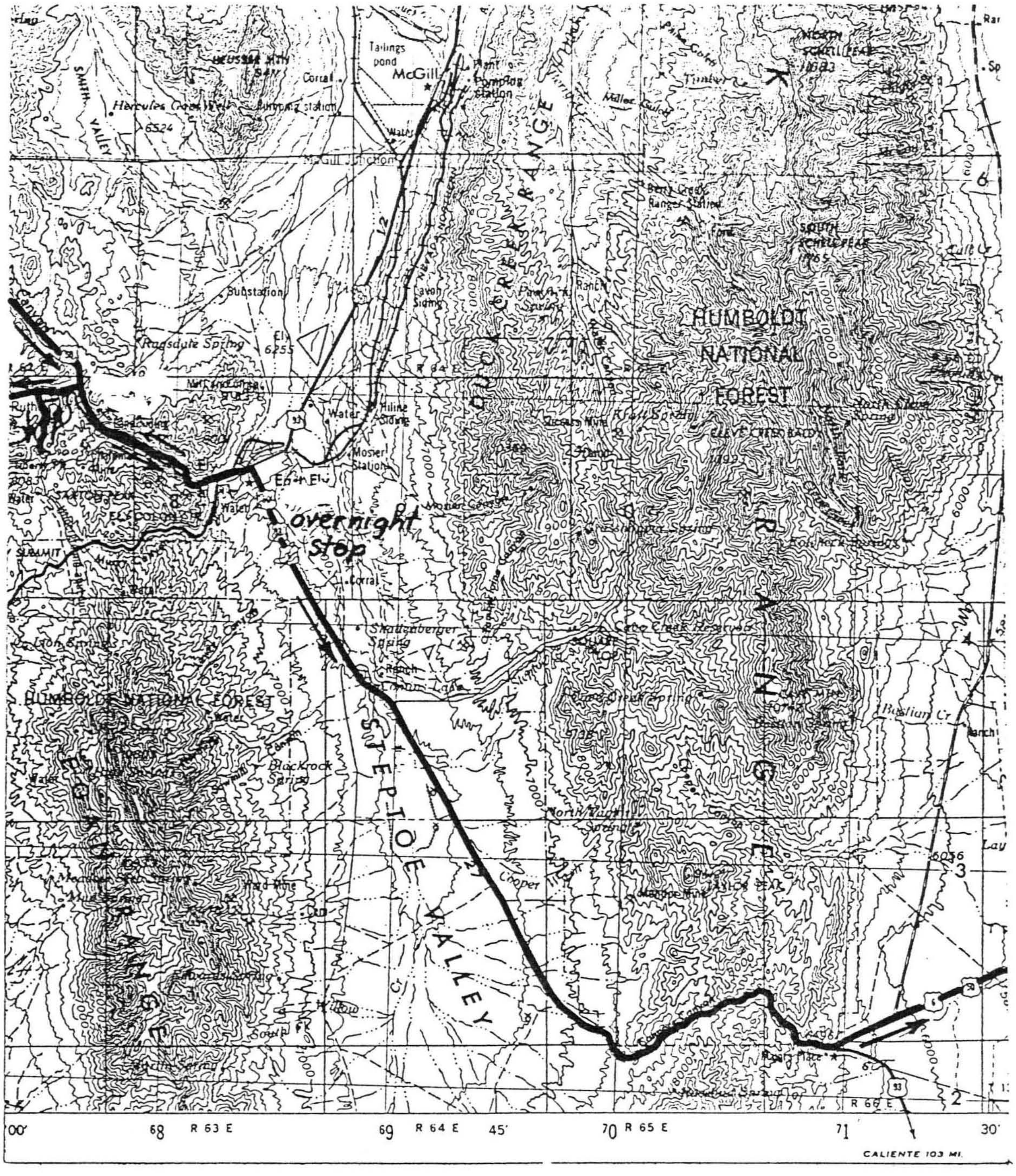
192 Oligocene volcanic rocks at 3:00 o'clock.

195 Tertiary volcanic rocks along highway.

196 Pancake Summit (northern Pancake Range). Pennsylvanian part of Ely Limestone is exposed east of summit.

198 Knob at 4:00 o'clock exposes part of Mississippian Diamond Peak Formation (Antler flysch). Farther south bituminous coal has been mined from Upper Mississippian beds just below the Pennsylvanian part of the Ely Limestone.

204 Treasure Hill at 1:30 o'clock in White Pine Range is site of the Hamilton (White Pine) district which produced $30 million in silver, lead, and minor zinc, copper, and gold. Most of the silver was mined from spectacular bonanza bodies of cerargyrite near the top of Treasure Hill in the Middle and Upper Devonian Guilmette Limestone just below the Pilot Shale, which is of Late Devonian age in this area. Most of the lead came from irregular replacement bodies in Paleozoic



dolomitized limestones adjacent to faults concentrated in a belt west of Treasure Hill. Small copper deposits are known in and near Cretaceous stocks west of the lead belt. (Humphrey, 1960.)

206 Road on right (south) leads to the Belmont mill that processed lead ores from the belt west of Treasure Hill.

207 Tertiary volcanics to left (north).

208 Ely Limestone is Pennsylvanian here but has Permian strata farther east.

210 Antelope Summit. Ward Mountain (10,803 ft) in Egan Range visible straight ahead in distance consists of upper Paleozoic marine formations deformed into a large recumbent fold overturned to the east.

212 Mississippian Chainman Shale and Scotty Wash Quartzite on left.

220 Moorman Ranch on right.

221 Road on left leads north to Ruby Marshes east of the Ruby Mountains. Jakes Valley.

228 Lower Triassic sedimentary rocks along highway.

230 Lower Tertiary volcanic rocks.

235 Robinson Summit (7,607 ft). Piñon (*pinus monophylla*)-juniper (*juniperus utahensis*) forest; open areas covered with sage (*artemesia*).

236 Permian Arcturus Formation along highway.

238 Radar Ridge to right consists of marine Pennsylvanian and Permian strata in the west limb of a westward-overturned fold. Mine dumps of Ely district straight ahead. Ward Mountain at 12:30 o'clock. Crested wheat grass seeding along highway on right and extending up to Radar Ridge.

245 Mississippian Chainman Shale along highway.

247 Road on right is turnoff to Kennecott mines near Ruth.

248 Devonian Guilmette Limestone in canyon walls.

249 Ore-train loading area on right. Ore is hauled 25 miles (40 km) by railroad to McGill for milling and smelting.

249.5 Old town of Lane on Copper Flat.

250 Chainman and Joana mines to right located in Mississippian Chainman Shale and Lower Mississippian Joana Limestone.

251 Guilmette Limestone overlain by Pilot Shale (containing mines) and Joana Limestone, on right.

252 Ely. **OVERNIGHT STOP.** Discovered in 1867, the Robinson mining district through 1904 produced $370,000 in gold and silver. Since 1908 it has produced about 2.8 million tons of copper and substantial gold, silver, and molybdenum.

PLATES

Explanation for Plate I Washoe and Storey Counties

Tir

Rhyolite

Intrusive plugs, protrusive domes, and flows (?) of rhyolite glass. Contains phenocrysts of plagioclase, biotite, and alkali feldspar, locally perlitic. Equivalent in part to Washington Hill Rhyolite of Thompson (1956). Rhyolite is contemporaneous with upper part of Tst *in large part, but may include plugs of Hartford Hill age.*

Tab Tst

Basalt and sedimentary rocks

Tab, *Basalt, basaltic andesite and pyroxene andesite flows, pyroclastics and associated intrusive phases. Unit overlies and interfingers with upper portion of* Tst. *Equivalent in part to type Lousetown Basalt (Thayer, 1937).*

Tst, *Pliocene sedimentary rocks. Fluviatile and lacustrine sedimentary rocks including diatomite, arkose, volcanic sandstone, siltstone, mudstone, shale, conglomerate, breccia, silicic vitric tuff, basalt lapilli tuff and locally undifferentiated basaltic flows. Correlative with Truckee Formation of Thompson and White (1964), and Coal Valley Formation of Axelrod (1962).*

Tk Tki

Kate Peak Formation

Tk, *Flows, flow breccia, tuff breccia, mudflow breccia, agglomerate, volcanic conglomerate and associated intrusives ranging in composition from pyroxene andesite to rhyodacite. Includes intercalated sedimentary lenses of diatomite, shale, sandstone,conglomerate and waterlain tuff. Includes Desert Peak Formation of Rose (1969).*

Tki, *Locally differentiated intrusive plugs of hornblende-biotite andesite, dacite or rhyodacite porphyry characterized by conspicuous plagioclase phenocrysts.*

Tgd

Granitic rocks

Stocks, dikes and irregular intrusive masses of quartz monzonite, granodiorite and quartz diorite porphyry. Includes Davidson Granodiorite. These intrusive rocks are usually propylitically altered and locally exhibit argillic and quartz-sericite-pyrite alteration phases.

Tsv

Pyramid Sequence

Basalt, andesite, and dacite flows, flow breccias, mudflow breccias, agglomerates, tuffs and associated intrusives. Lenses of silicic waterlain tuff, diatomite, shale and sandstone intercalated in sequence. Includes Pyramid Formation of MacJannet (1957), Chloropagus Formation, and Old Gregory Formation of Rose (1969) in Truckee Canyon.

Ta

Alta Formation

Pyroxene and hornblende andesite flows, breccias and pyroclastics. Commonly propylitized and locally bleached. The Sutro member in the Virginia City area consists of tuffaceous shale, sandstone, and conglomerate. Chief host rock for the gold-silver deposits of the Comstock Lode district.

Th

Hartford Hill Rhyolite

Predominantly ash-flow tuffs, variably welded, ranging from rhyolite to quartz latite in composition. Includes some beds of ash-fall tuff and lenses of clastic sediments. Ash-flow tuff typically consists of phenocrysts of quartz, plagioclase, alkali feldspar, and biotite in a matrix of devitrified glass shards. Extensive propylitic alteration present in unit.

Tpr

Pah Rah Formation

Propylitized pyroxene andesite mudflow breccia with occasional clasts of Mesozoic granitic and metamorphic rocks. Known outcrops of the formation are confined to the Coal Canyon area of the Pah Rah Range.

Kgd Kgdf

Intrusive rocks

Kgd, *Undifferentiated plutonic rocks ranging from gabbro to granite in composition. Granodiorite and quartz monzonite are most abundant rock types. Typical granodiorite is a medium-grained rock containing 15-25 percent quartz, 40-50 percent plagioclase, 15-20 percent microcline and 10-20 percent hornblende and biotite. Includes pegmatite-aplite dikes.*

Kgdf, *Foliated granodiorite present in the Virginia City quadrangle and in the Fox Range.*

mv mvs ms

Peavine Sequence

Mapped on Peavine and Petersen Mountains, and in small, scattered outcrops in Storey and southern Washoe Counties.

mvs, *Undifferentiated metavolcanic and metasedimentary rocks.*

mv, *Metavolcanic rocks, regionally and thermally metamorphosed volcanic flows, breccias, and pyroclastics ranging from basalt to rhyolite in composition.*

ms *Metasedimentary rocks, slate. phyllite, metatuff, argillite, quartzite, metagraywacke, recrystallized limestone, conglomerate, hornfels, schist, and local skarn and tactite interfingered with metavolcanic rocks.*

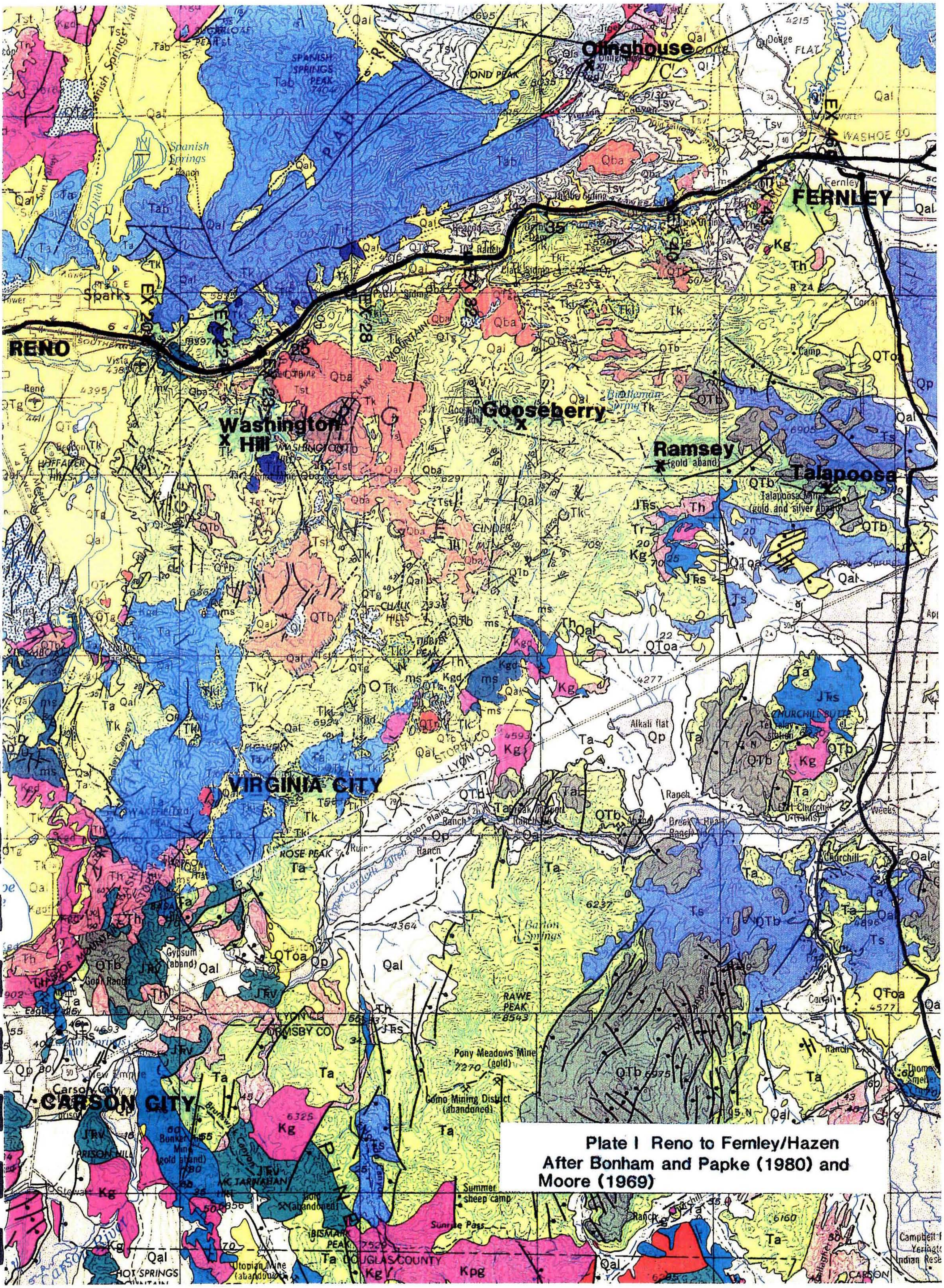


Plate I Reno to Fernley/Hazen
After Bonham and Papke (1980) and Moore (1969)

Explanation for Plates I & II Lyon County

Ta — Andesitic rocks
Flow breccias, lava flows, and agglomerates with interbedded sediments. Locally includes basaltic and rhyolitic rocks. Includes Alta and Kate Peak Formations, and Chloropagus Formation of Axelrod (1956)

Ts — Sedimentary rocks
Lacustrine and fluvatile sediments. Sandstone, mudstone, shale, marl, diatomite, limestone, and calcareous tufa. Interbedded tuffaceous rocks, lava flows, and breccias. Includes Truckee Formation and Aldrich Station, Coal Valley, and Morgan Ranch Formations of Axelrod (1956)

Tr — Rhyolite
Rhyolitic tuffs, flows, and intrusions. Relation to Hartford Hill Rhyolite Tuff is uncertain

Th — Hartford Hill Rhyolite Tuff
Widespread biotite rhyolite pumice tuff-breccia and welded tuff. Welded, black, glassy basal layer is locally present

Kg — Granitic rocks
Kgp, *granite porphyry*
Kpg, *porphyritic quartz monzonite*
Kg, *undivided, nonporphyritic quartz monzonite, granodiorite, and hybrid mafic rocks. In general, porphyritic quartz monzonite is younger than undivided granitic rocks and older than granite porphyry*

JTRs — Metasedimentary rocks
Shale, slate, tuffaceous siltstone, sandstone, and graywacke largely derived from volcanic rocks. Interbeds of conglomerate, limy shale, limestone, dolomite, and gypsum

Explanation for Plate II Churchill County

Tys — Younger sedimentary rocks

Tyb, Ta, Tai — Younger basalt and andesite
Ta, *andesite flows*
Tai, *intrusive bodies*

Td, Tdi — Dacite
Td, *principally flows*
Tdi, *intrusive bodies*

Tr — Rhyolite to rhyodacite
Tr, *extrusive rhyolite units; occurs as flows, tuffs, and welded tuffs*

Jd — Dioritic rocks

Jg — Gabbroic rocks
Locally includes anorthosite and albitite

Jl — Limestone and marble
Largely massive carbonate rocks with intercalated quartz arenite

Jsl — Calcareous siltstone and limestone
Includes minor amount of shale

JTRls — Limestone and marble

JTRph — Hornfels, phyllite, and schist

JTRmv — Metavolcanic rocks

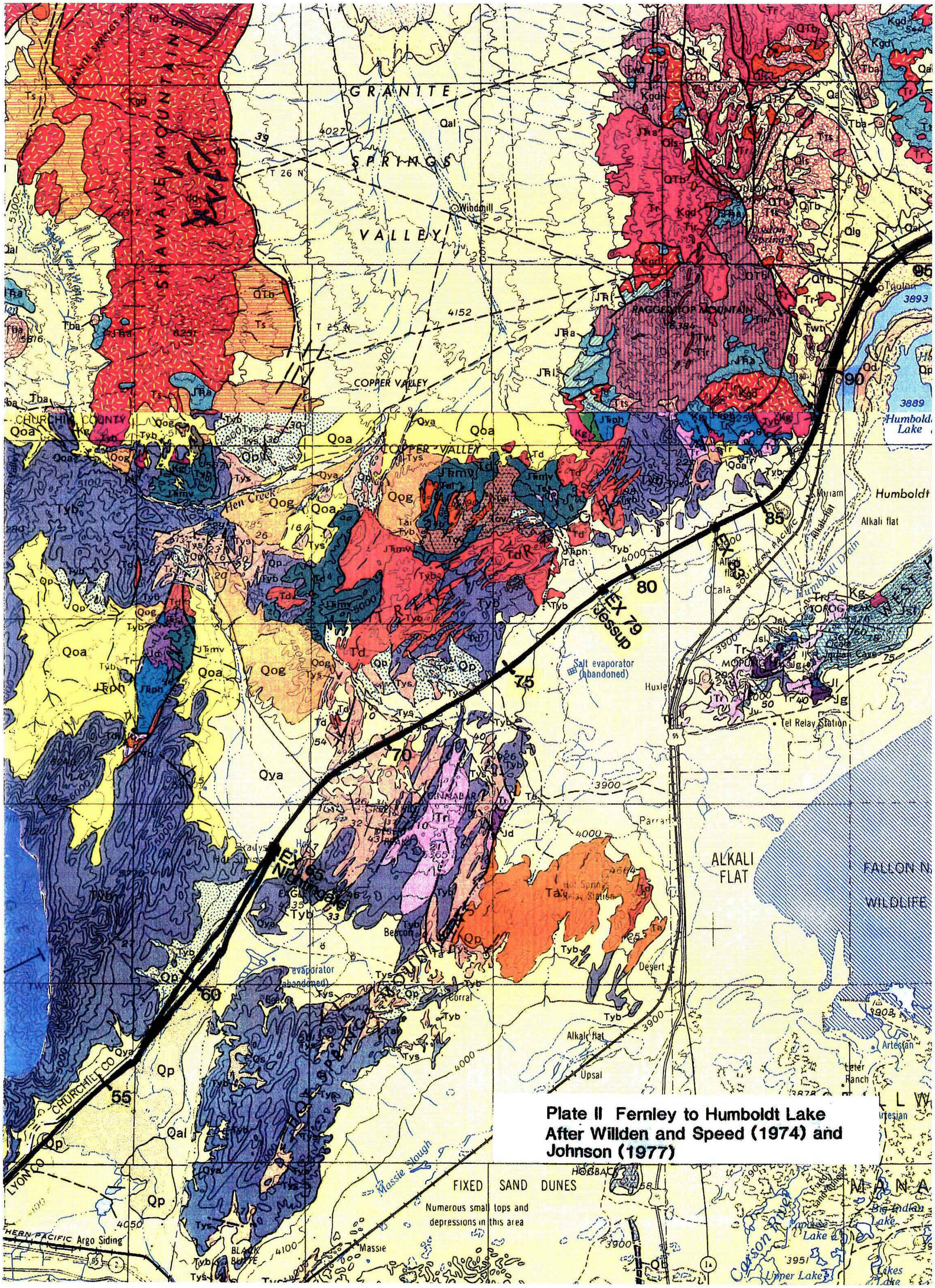


Plate II Fernley to Humboldt Lake After Willden and Speed (1974) and Johnson (1977)

Explanation for Plates II through VI Pershing County

QTb — Basalt

Ts / **Tcg** — Sedimentary rocks
Tcg, conglomerate

Tts — Tuff and sedimentary rocks

Tba — Basalt and andesite

Tr — Rhyolite

Kgrc — Granodiorite of Rocky Canyon

Kgd — Granodiorite

Jgd — Granodiorite

Jgb — Gabbro
Includes extrusive phase

TRra — Raspberry Formation
Phyllitic mudstone, subordinate sandstone and limestone

TRwi — Winnemucca Formation
Feldspathic sandstone and fine-grained clastic rocks interbedded with limestone and dolomite

TRdg — Dun Glen Formation
Thick-bedded limestone and dolomite, minor interbeds of sandstone and argillite

TRgv — Grass Valley Formation
Mudstone and sandstone, variably recrystallized to argillite and quartzite

TRm — Metasedimentary rocks
Includes marble and slate

TRnp / **TRnpv** — Natchez Pass Formation
Massive limestone and dolomite, interfingering with mafic volcanic rock (TRnpv); impure limestone and clastic rocks near top

TRp / **TRpu** / **Ћpml** — Prida Formation
TRpu, *upper member; limestone and dolomite with thin chert beds*
TRpml, *middle and lower members. Middle member; calcareous shale and siltstone, fine-grained fossiliferous limestone. Lower member; sandstone, limestone, and dolomite, calcareous siltstone and sandstone*

TRwe — Weaver Rhyolite
Rhyolite flows and subordinate tuff, tuffaceous siltstone, sandstone, and conglomerate

TRrp — Rhyolite porphyry

TRro — Rochester Rhyolite
Rhyolite welded tuff with minor tuffaceous sedimentary rocks

TRlg — Leucogranite

TRl — Limerick Greenstone
Andesite flows and flow breccias with subordinate tuff and volcaniclastic rocks

TRk — Koipato Group, undivided
Volcanic and sedimentary rocks. Includes China Mountain Formation in eastern part of county

Mi — Inskip Formation
Sandstone, conglomerate, quartzite, siltstone, with minor schist and limestone; locally phyllitic and amphibolitic

Ov — Valmy Formation
Argillite, chert, greenstone, and vitreous quartzite

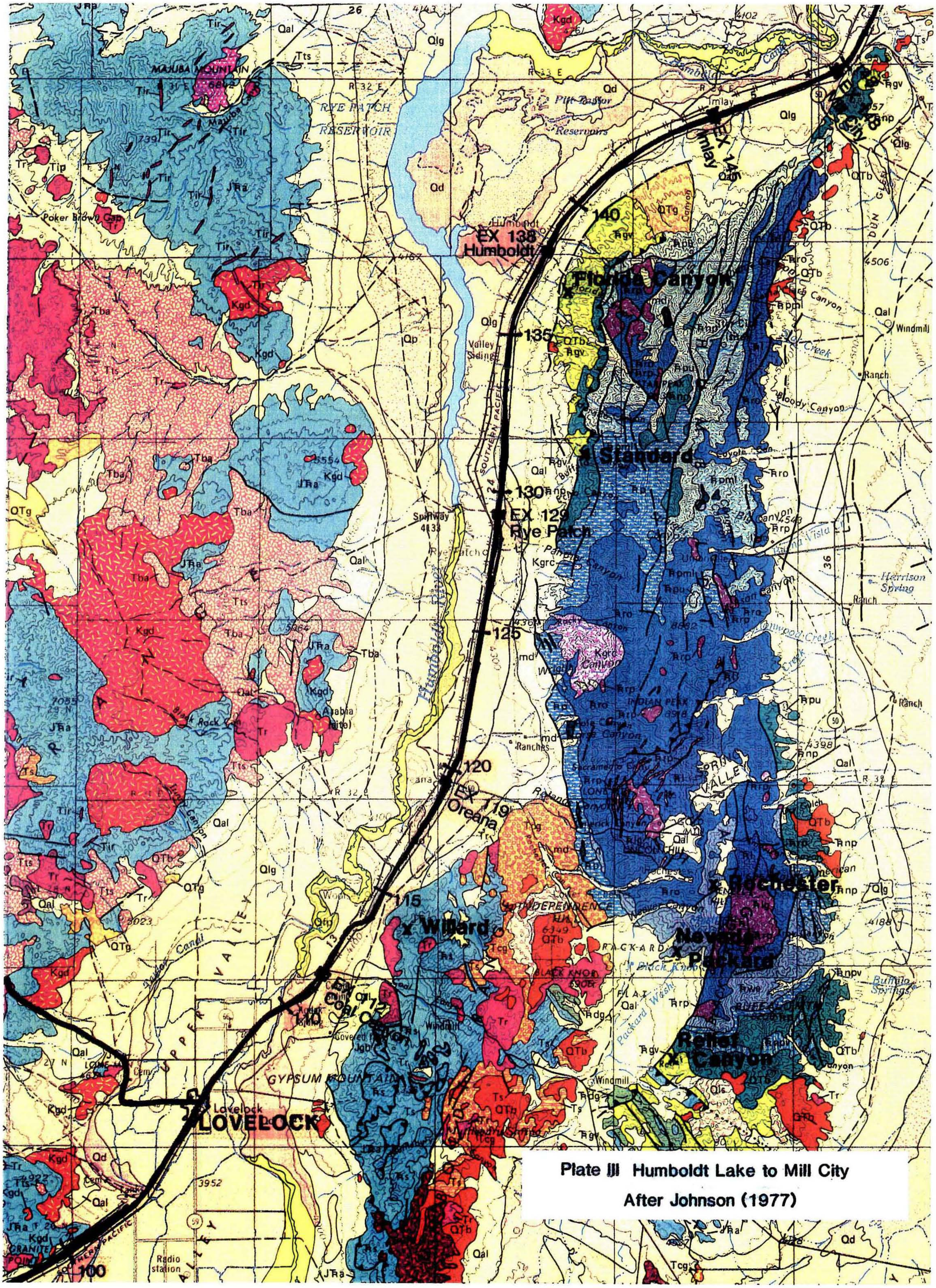


Plate III Humboldt Lake to Mill City

After Johnson (1977)

Explanation for Plates IV, V & VI Humboldt County

QTb
Vesicular olivine basalt

Ts
Sedimentary rocks
Includes shale, sandstone, conglomerate, tuff, and diatomaceous shale

Trd
Rhyolitic and dacitic volcanic rocks
Locally includes some more basic rocks and some interbedded sedimentary rocks

Tba
Basaltic and andesitic volcanic rocks
Locally includes more silicic rock types and sedimentary rocks

Tu
Volcanic and sedimentary rocks, undivided

TKg
Granodiorite
Used for all quartz-bearing pre-late Tertiary intrusive rocks Principally granodiorite with local compositional variations to quartz diorite and quartz monzonite; large stock in the Slumbering Hills is mainly quartz monzonite, and the small body in the low hills east of Black Rock Range is quartz monzonite includes dioritic intrusive rocks of the Jackson Mountains

TKpl
Pansy Lee conglomerate

KJi
Intrusive rocks
Includes dioritic intrusive rocks of the Jackson Mountains and Pine Forest Range, gabbro intrusives on Blue Mountain, and diorite intrusives on Winnemucca Mountain

JTRu
Phyllite, slate, and fine-grained quartzite

TRr | **TRm** | **TRa** | **TRs**
Raspberry formation
In the Santa Rosa Range includes the Mullinix, TRm; *Andorno,* TRa; *and Singas,* TRs, *formations of Compton (1960)*

TRqm
Quartzite and mudstone
Thickness 2,000 to 4,000 feet. Correlative unit in the Santa Rosa Range named O'Neill formation by Compton (1960)

PPh
Havallah formation

PPs
Unnamed sandstone, chert, and volcanic rock formation
Present only in the Osgood Mountains

PPu
Antler Peak limestone, Highway limestone, and Battle formation, undivided

PPa
Edna Mountain formation and Antler Peak limestone
Used in Sonoma Range and Edna Mountain. Elsewhere Antler Peak included with underlying Highway limestone and Battle formation

Pp
Pumpernickel formation

Mvr
Unnamed volcanic rocks

Oc
Comus formation

Ov
Valmy formation

Osr
Sonoma Range formation

Ch
Harmony formation

Єc
Unnamed chert

Єp
Preble formation

Єom
Osgood Mountain quartzite

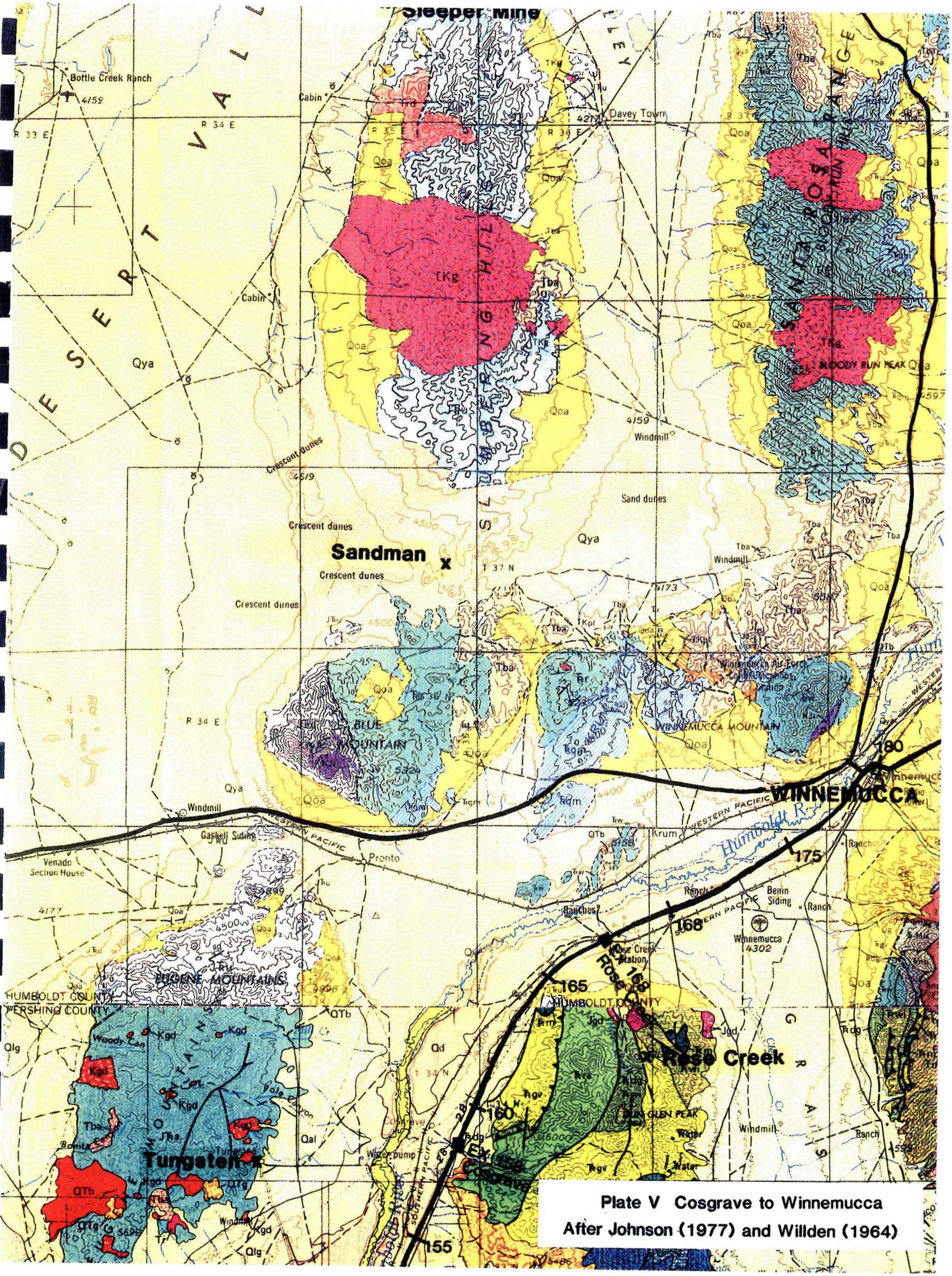


Plate V Cosgrave to Winnemucca
After Johnson (1977) and Willden (1964)

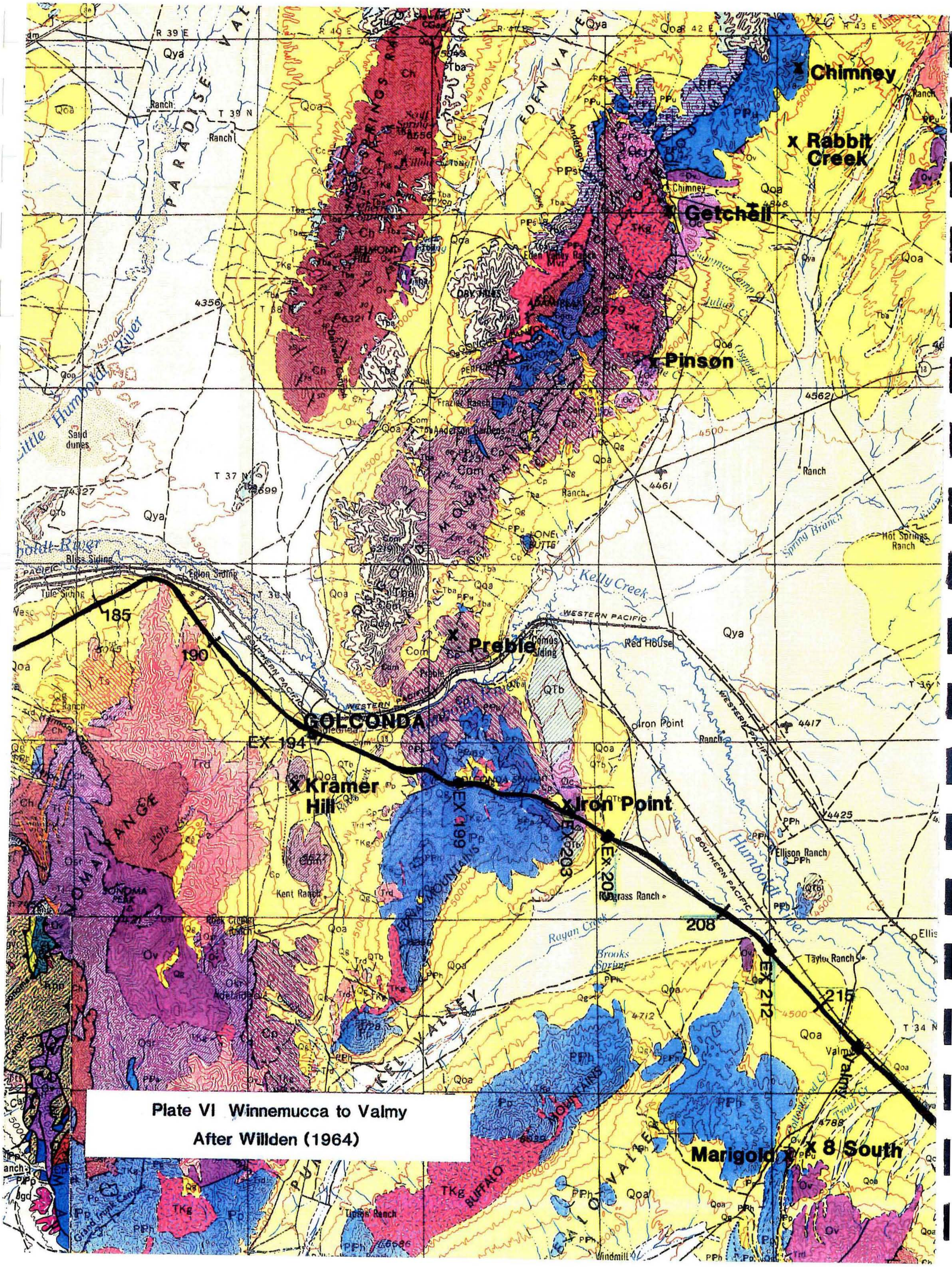


Plate VI Winnemucca to Valmy
After Willden (1964)

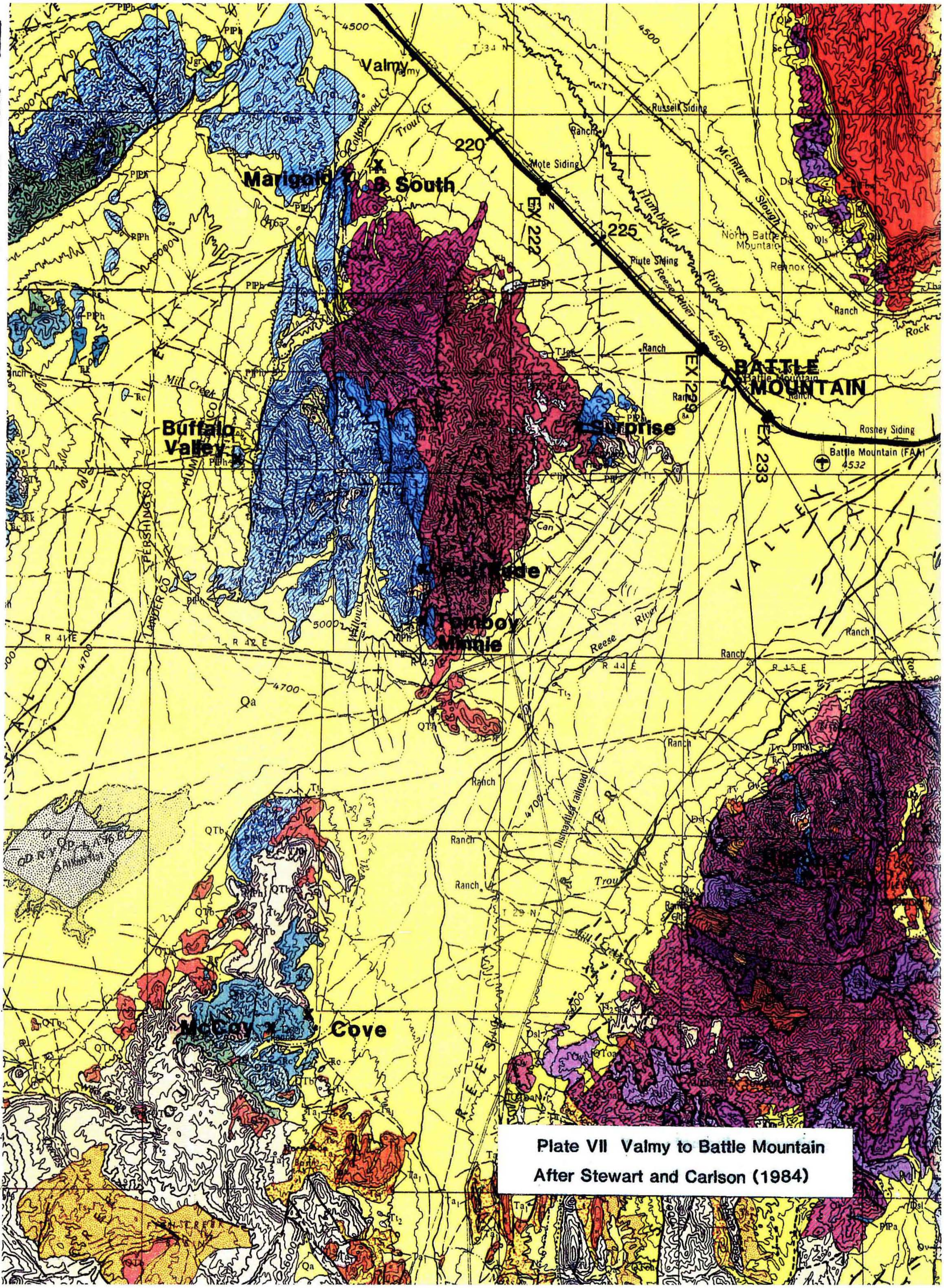


Plate VII Valmy to Battle Mountain
After Stewart and Carlson (1984)

Explanation for Plates VII through X North–Central Nevada

Tv — UNDIVIDED VOLCANIC ROCKS

Tba — ANDESITE AND BASALT FLOWS – Mostly in ∿17 to ∿6 m.y. age range. May include rocks younger than 6 m.y. in places

Ta2 — ANDESITE FLOWS AND BRECCIAS, AND FLOWS OF INTERMEDIATE COMPOSITION

Tt — WELDED AND NONWELDED SILICIC ASH-FLOW TUFFS – Locally includes thin units of air-fall tuff and sedimentary rock

SEDIMENTARY ROCKS

Ks — CONTINENTAL DEPOSITS OF SILTSTONE, SHALE, CONGLOMERATE, AND LIMESTONE – Includes Newark Canyon Formation

PLUTONIC ROCKS

Tgr — GRANITIC ROCKS – Mostly quartz monzonite and granodiorite

Kgr — GRANITIC ROCKS – Mostly quartz monzonite and granodiorite. Includes some undated plutons that could be Jurassic in age

Jgr — GRANITIC ROCKS – Mostly quartz monzonite and granodiorite

JURASSIC AND TRIASSIC ROCKS

Jgb — GABBROIC COMPLEX – Includes gabbro, basalt, and synorogenic quartz sandstone (Boyer Ranch Formation). Churchill and Pershing Counties (Lower and Middle Jurassic)

Jv — VOLCANIC SANDSTONE, FELSIC ASH-FLOW TUFFS, RHYOLITE, AND RHYODACITE FLOWS – Pony Trail Group of Cortez Mountains. Eureka County (Upper? Jurassic)

JRs — SHALE, MUDSTONE, SILTSTONE, SANDSTONE, AND CARBONATE ROCK; SPARSE VOLCANIC ROCKS – Includes Auld Lang Syne Group

Rc — LIMESTONE, MINOR AMOUNTS OF DOLOMITE, SHALE, AND SANDSTONE; LOCALLY THICK CONGLOMERATE UNITS (LOWER, MIDDLE, AND UPPER TRIASSIC) – Includes Tobin, Dixie Valley, Favret, Augusta Mountain, and Cane Spring Formations, the Star Peak Group, and related rocks.

Rk — KOIPATO GROUP AND RELATED ROCKS (LOWER TRIASSIC) – Altered andesitic flows, rhyolitic tuffs and flows, and clastic rocks. Includes Tallman Fanglomerate (Permian?) in Humboldt County

SILICEOUS AND VOLCANIC ASSEMBLAGE (UPPER PALEOZOIC)

Eugeosynclinal rocks originally deposited west of Antler orogenic belt. In most places, allochthonous and thrust eastward as upper plate of Golconda thrust

PPh — HAVALLAH SEQUENCE OF SILBERLING AND ROBERTS (1962) – Chert, argillite, shale, greenstone, and minor amounts of siltstone, sandstone, conglomerate, and limestone. Includes Havallah, Pumpernickel, and Farrel Canyon Formations

Msv — SILICEOUS AND VOLCANIC ROCKS (MISSISSIPPIAN?) – In Humboldt County, consists of altered pillow lavas, coarse volcanic breccias, clastic limestone, and minor sandstone, shale, siliceous shale, and chert of Goughs Canyon Formation. In the East Range, Pershing County, consists of quartzite, conglomerate, slate, limestone, chert, and greenstone of Inskip Formation

CONGLOMERATE, SILTSTONE, AND LIMESTONE SEQUENCES WITHIN ANTLER OROGENIC BELT

Rest unconformably on folded Paleozoic rocks

PPa — ANTLER SEQUENCE OF SILBERLING AND ROBERTS (1962) – Conglomerate, sandy to conglomeratic limestone, limestone, sandstone, and calcareous shale. Thin detrital and carbonate sequence within main part of Antler orogenic belt. Includes such units as Battle Formation, Antler Peak Limestone, and Edna Mountain Formation

CARBONATE-DETRITAL BELT ALONG EASTERN MARGIN OF ANTLER OROGENIC BELT OR CARBONATE DEPOSITED IN WESTERN PART OF FORELAND BASIN

PPcd — SANDY AND SILTY LIMESTONE, CONGLOMERATE, AND SILTSTONE (UPPER PENNSYLVANIAN TO UPPER PERMIAN) – Includes units such as Strathearn Formation of Dott (1955) and Buckskin Mountain, Beacon Flat, and Carlin Canyon Formations of Falls (1960) in Elko County and Carbon Ridge and Garden Valley Formations in Eureka County

MDs — SHALE, SILTSTONE, SANDSTONE, CHERT-PEBBLE CONGLOMERATE, AND LIMESTONE – Includes units such as Pilot Shale, Joana Limestone, Chainman Shale, and Diamond Peak Formation

SILICEOUS (WESTERN) ASSEMBLAGE (LOWER PALEOZOIC)

Eugeosynclinal rocks. Mainly allochthonous rocks in upper plate of Roberts Mountains thrust. Includes Comus Formation that probably is para-autochthonous and in lower plate of Roberts Mountains thrust

Dsl — SLAVEN CHERT – Chert and sparse limy sandstone, siltstone, and limestone. Lander County

Ov — VALMY FORMATION – Chert, shale, quartzite, greenstone, and minor amounts of limestone

Ovi — VININI FORMATION – Shale, chert, and minor amounts of quartzite, greenstone, and limestone

Oco — COMUS FORMATION – Shale, siltstone, dolomite, limestone, and chert

Ch — HARMONY FORMATION (UPPER CAMBRIAN) – Feldspathic and arkosic sandstone and minor amounts of shale, limestone, and chert

Csc — SCOTT CANYON FORMATION (LOWER OR MIDDLE CAMBRIAN) – Chert, shale, greenstone, and sparse limestone and quartzite

TRANSITIONAL ASSEMBLAGE

Para-autochthonous or autochthonous with respect to Roberts Mountains thrust. Marine. In places, interstratified with carbonate assemblage

Dt — ARGILLACEOUS LIMESTONE, CHERT, AND SHALE – Elko and Eureka Counties

DSr — ROBERTS MOUNTAINS FORMATION AND RELATED ROCKS – Platy limestone and limy siltstone. Chert at base in most areas

OCt — PHYLLITE AND LIMESTONE – Includes Broad Canyon sequence of Means (1962)

Ct — SHALE AND THIN-BEDDED OR LAMINATED LIMESTONE – Includes such units as Preble Formation

CARBONATE (EASTERN) ASSEMBLAGE AND RELATED ROCKS

Para-autochthonous or autochthonous with respect to Roberts Mountains thrust. Shallow-marine, intertidal, and supratidal deposits

Dc — DOLOMITE, LIMESTONE, AND MINOR AMOUNTS OF SANDSTONE AND QUARTZITE – Includes such units as Nevada Formation and Devils Gate and Wenban Limestones

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