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The Nevada Bureau of Mines and the Nevada Mining Analytical Laboratory serve the public as State agencies to assist in developing Nevada's mineral resources. They identify, analyze, and evaluate minerals, rocks, and ores found in Nevada. They conduct field studies on Nevada geology and mineral deposits, including metallic and industrial minerals, as well as oil and gas. They pursue laboratory and library research in mineral beneficiation, extractive metallurgy, and economic problems connected with the mineral industry of Nevada.

For information concerning the mineral resources and mineral industry of Nevada, write to: Director, Nevada Bureau of Mines, University of Nevada, Reno, Nevada.

NEVADA BUREAU OF MINES

Vernon E. Scheid, Director

BULLETIN 65

MINERAL AND WATER RESOURCES OF NEVADA

Prepared by the

UNITED STATES GEOLOGICAL SURVEY

and the

NEVADA BUREAU OF MINES

as a

UNITED STATES SENATE DOCUMENT

MACKAY SCHOOL OF MINES

UNIVERSITY OF NEVADA

1964

1864 NEVADA CENTENNIAL 1964

NEVADA BUREAU OF MINES

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MACKAY SCHOOL OF MINES
UNIVERSITY OF NEVADA
Reno, Nevada
1964

STATE OF NEVADA

GRANT SAWYER, *Governor*

UNIVERSITY OF NEVADA

CHARLES J. ARMSTRONG, *President*

NEVADA BUREAU OF MINES

VERNON E. SCHEID, *Director*

For sale by Nevada Bureau of Mines, University of Nevada, Reno, Nevada. Price $1.00.

FOREWORD

Although many reports on Nevada's mineral resources have been issued over the years both by federal agencies and by the Nevada Bureau of Mines, the need for a summary of the State's mineral and water resources has long been recognized. The present report, "Mineral and Water Resources of Nevada," compiled by staff members of the U.S. Geological Survey and of the Nevada Bureau of Mines at the request of Senator Howard W. Cannon of Nevada, fulfills that need.

The report was printed as a United States Senate Document, in which form it has been distributed to many Nevada citizens. When Senator Cannon was informed that the Nevada Bureau of Mines wished to include the report in its mineral industry publication series, so that it would be available for many years, he kindly arranged for the printing of additional copies by the U.S. Government Printing Office. These additional copies have been purchased by the Nevada Bureau of Mines and the report is herewith released as the Bureau's Bulletin 65.

The report will serve as a valued reference to people of Nevada and professional workers in government and industry who are interested in the mineral and water resources of the State. It provides data from which further development of these resources can proceed.

VERNON E. SCHEID, *Director*
Nevada Bureau of Mines

September, 1964
Mackay School of Mines
University of Nevada

Status of geologic mapping in Nevada is shown in figure 5.

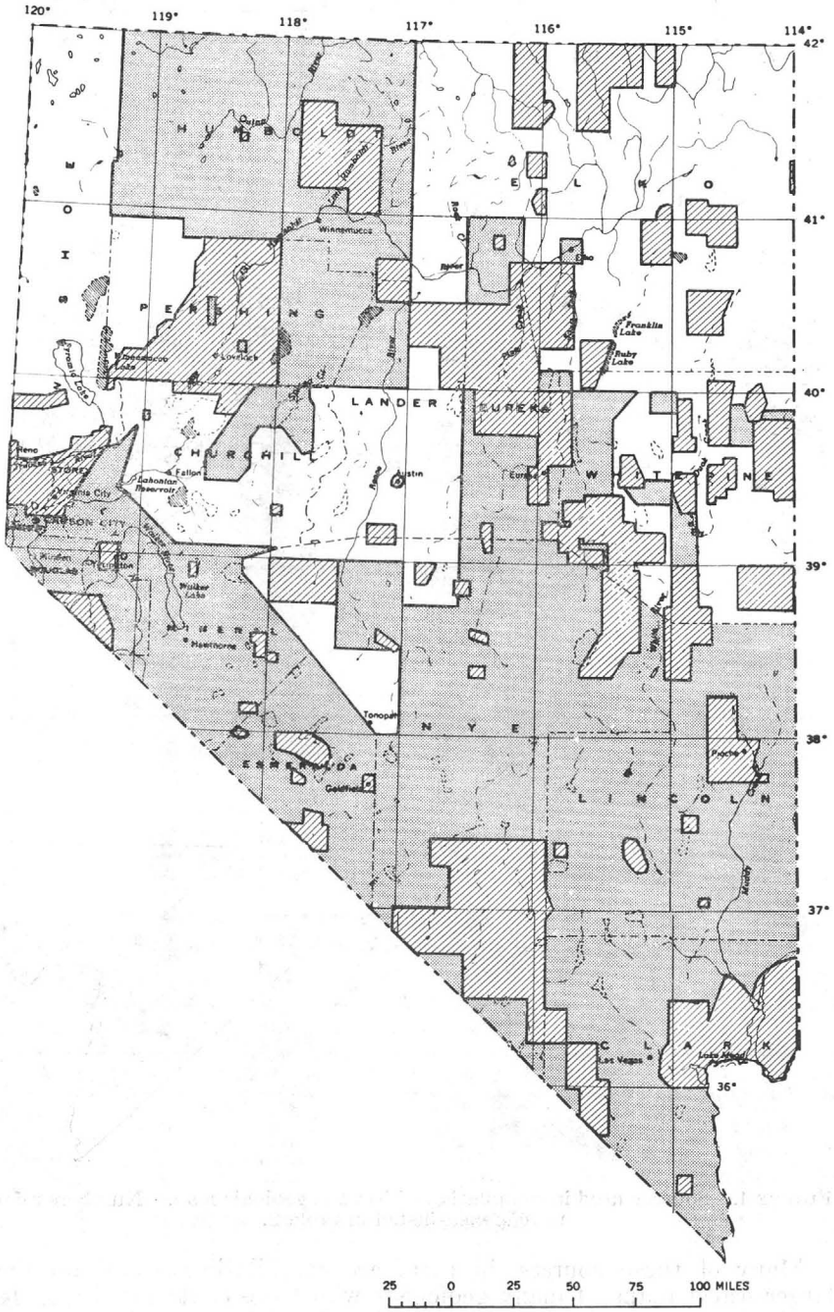

FIGURE 5.—Geologic mapping (including unpublished theses) in Nevada, December 1963. Ruled areas mapped at scales of 1:62,500 or larger; stippled areas mapped at scales ranging from 1:250,000 to 1:62,500.

88TH CONGRESS, 2d Session } SENATE { DOCUMENT No. 87

MINERAL AND WATER RESOURCES OF NEVADA

REPORT

OF THE

UNITED STATES GEOLOGICAL SURVEY

IN COLLABORATION WITH

NEVADA BUREAU OF MINES

PREPARED AT THE REQUEST OF

SENATOR HOWARD W. CANNON

of Nevada

JULY 23, 1964.—Ordered to be printed with illustrations

U.S. GOVERNMENT PRINTING OFFICE

35-837 WASHINGTON : 1964

S. Res. 335

IN THE SENATE OF THE UNITED STATES,
July 23, 1964.

Resolved, That the report entitled "Mineral and Water Resources in Nevada", prepared by the United States Geological Survey and the Nevada Bureau of Mines, shall be printed with illustrations as a Senate document. There shall be printed three thousand three hundred additional copies of such Senate document, which shall be for the use of the Members of the Senate from the State of Nevada.

Attest:

FELTON M. JOHNSTON,
Secretary.

II

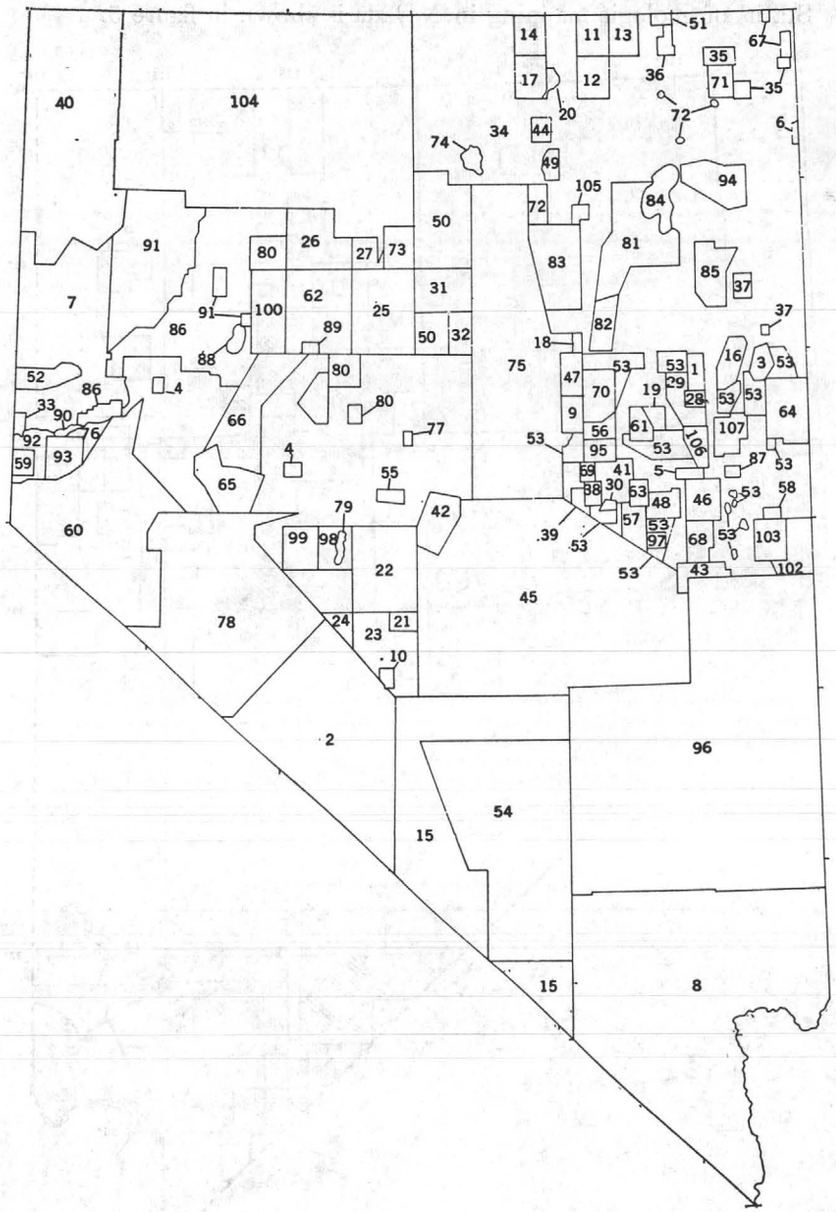

FIGURE 4.—Sources used in compilation of Nevada geologic map. Numbers refer to references listed in table 2.

Many of these sources, in turn, are compilations based on the larger-scaled maps of many geologists who have contributed greatly to the knowledge of the geology of Nevada. The extensive work of T. B. Nolan, H. G. Ferguson, C. W. Merriam, D. F. Hewett, S. W. Muller, and C. R. Longwell in particular supports many of these intermediate compilations from which figure 3 has been prepared.

Index No.
on Fig 4.

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FOREWORD

This report was prepared at my request by the U.S. Geological Survey, in cooperation with the Nevada Bureau of Mines.

It was my desire to have compiled under one cover all significant data on Nevada's mineral and water resources for distribution to interested government, civic, and industrial leaders and to citizens.

Nevada's tremendous economic promise can only be realized if its resources are wisely developed. The material compiled here will help in that achievement.

HOWARD W. CANNON,
U.S. Senator.

Index No. on Fig. 4

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names and ages referred to on this chart do not necessarily follow the usage of the Geological Survey. In general the columns are based largely on published sources, but the Tertiary sections are based largely on unpublished data supplied by H. F. Bonham of the Nevada Bureau of Mines; and J. P. Albers, R. R. Coats, F. J. Kleinhampl, C. R. Longwell, F. A. McKeown, E. H. Pampeyan, J. F. Smith, Jr., D. B. Tatlock, and D. H. Whitebread of the U.S. Geological Survey. Sources used in the compliation of this geologic map are listed in table 2 and shown in figure 4.

TABLE 2.—*References used in compilation of Nevada geologic map.*

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LETTER OF TRANSMITTAL

U.S. DEPARTMENT OF THE INTERIOR,
GEOLOGICAL SURVEY,
Washington, D.C., June 24, 1964.

Hon. HOWARD W. CANNON,
U.S. Senate,
Washington, D.C.

DEAR SENATOR CANNON: I am pleased to transmit herewith a summary report on the mineral and water resources of Nevada, which has been prepared by the Geological Survey in collaboration with the Nevada Bureau of Mines. The report has been prepared in response to your request of May 3, 1963.

Mineral commodities known to occur in Nevada are described in the report, together with information on their manner of occurrence, distribution, and relative importance to the present and future mineral industry of the State. Surface and ground water are described in considerable detail, with particular emphasis on water supply and related water problems. Waterpower resources are described as are the potential sources of natural thermal power. The narrative discussions on various topics are supplemented by maps and other illustrations.

It is hoped that the report will supply you with the information you desire.

Sincerely yours,

THOMAS B. NOLAN, *Director.*

correlation chart for Nevada
N. J. Silberling, and J. H. Stewart

as groups. Italicized terms are informally named rock-stratigraphic units.

5	6	7	8	Geologic Divisions		
Lander, Eureka and northern Nye Counties	White Pine and northern Lincoln Counties	Southern Nye, and western Clark Counties	Eastern Clark, and southern Lincoln Counties			
Alluvium	*Alluvium*	*Alluvium, dune sand*	*Alluvium*	Recent	QUATERNARY	CENOZOIC
Older alluvium *Basalt*	*Older alluvium* *Lake deposits* *Glacial deposits*	*Basalt* *Older alluvium*	Las Vegas Chemehuevi	Pleistocene		
Andesite, rhyolite,			*Basalt* Panaca, Muddy Creek *Basalt*	Pliocene	TERTIARY	
Horse Camp	Panaca	Thirsty Canyon Tuff Piapi Canyon Formation Timber Mountain Tuff Paintbrush Tuff Indian Trail *Welded ash flows* *Lava flows*	*Rhyolitic ash flows and lava flows*			
			Horse Spring	Miocene		
Shingle Pass Needles Range Windous Butte } *Ash flows* Currant Tuff *Ash flows*	Shingle Pass Needles Range Windous Butte } *Ash flows*		*Andesite*	Oligocene		
Conglomerate, limestone and sandstone *Dacite*		*Conglomerate and fanglomerate*	*Conglomerate and sandstone*	Eocene		
Sheep Pass	Sheep Pass			Paleocene		
Newark Canyon *Unnamed volcanic rocks*			Base Line Willow Tank	Cretaceous		MESOZOIC
			Aztec	Jurassic		
			Chinle	Triassic		
	Unnamed marine sedimentary rocks		Moenkopi			
Havallah (Edna Mtn., Garden Valley; Antler Peak, Carbon Ridge; Battle, Ely; Thrust fault)	Gerster Plympton Kaibab Arcturus Pequop Rib Hill Riepe Spring Ely		Kaibab Toroweap *Red beds*	Permian		PALEOZOIC
Pumpernickel ?		Tippipah	Bird Spring Callville	Pennsylvanian		
Tonka (Diamond Peak, Chainman, Joana, Pilot)	Diamond Peak, Scotty Wash Chainman, Peers Spring Joana, Bristol Pass Pilot, West Range	Meiklejohn Eleana	Monte Cristo, Rogers Spring, Chainman	Mississippian		
Slaven (Wenban, Devils Gate, Nevada)	Guilmette Simonson Sevy	Devils Gate Fluorspar Canyon Nevada, Sultan	Muddy Peak	Devonian		
Fourmile Canyon Elder (Lone Mountain, Roberts Mountains)	Laketown	Lone Mountain Roberts Mountains	Goodsprings	Silurian		
Valmy Vinini (Hanson Creek, Eureka, Pogonip Group; Thrust fault)	Ely Springs, Fish Haven Eureka Pogonip Group	Ely Springs Eureka Pogonip Group		Ordovician		
Scott Canyon (Windfall, Dunderberg, Hamburg, Secret Canyon, Geddes, Eldorado, Pioche; Thrust fault)	Mendha, Windfall Dunderberg Highland Peak, Lincoln Peak Chisholm, Pole Canyon Lyndon Pioche, Pioche	Nopah Bonanza King Carrara Zabriskie	*Limestone and dolomite* Chisholm Lyndon Pioche	Cambrian		
Prospect Mountain	Prospect Mountain McCoy Creek Group	Wood Canyon Stirling Johnnie	Tapeats, Prospect Mountain	Upper Precambrian		
	Gneiss and schist		*Gneiss, schist and granitic rocks*	Lower Precambrian		

Table 1.--Generalized stratigraphic
By J. P. Albers, R. J. Roberts,
Terms in roman type are formally named rock formations, except where identified

Area number shown on index map			1	2	3	4
Geologic Divisions			Western Humboldt Washoe, Storey, Ormsby, Douglas, Lyon, and western Mineral Counties	Churchill, Pershing, eastern Humboldt Counties	Elko County	Eastern Mineral, northwestern Nye, and Esmeralda Counties
CENOZOIC	QUATERNARY	Recent	*Alluvium, dune sand*	*Alluvium, dune sand*	*Alluvium*	*Alluvium, dune sand*
		Pleistocene	*Older alluvium, fanglomerate, terrace gravel, lake beds, basalt, diatomite*	*Lahontan lake beds* *Fluvial gravels and sand*	*Older alluvium*	*Older alluvium* *Lake deposits* *Glacial deposits*
	TERTIARY	Pliocene	Lousetown (*volcanics*) *Sedimentary rocks including* Alturas, Morgan Ranch, Truckee, Coal Valley *and* Aldrich Station	*Local fanglomerate* Mesa Basalt	Banbury Hay Ranch Cougar Point Welded Tuff *Dacite flows*	*Basalt* *Welded ash flows* Gilbert Andesite Oddie Rhyolite
		Miocene	Kate Peak Andesite Virgin Valley (*volcanics*) Cannon Rhyolite *and* Hartford Hill Rhyolite	*Lacustrine deposits* *Ash flows* *Basaltic andesite* *Ash flows, tuff, sedimentary rocks*	Carlin *Andesite flows* Humboldt Jarbidge Rhyolite Raine Ranch	Esmeralda *and* Siebert *Ash flows and rhyolite breccia, including* Fraction Breccia
		Oligocene		*Rhyolite flows and breccia*	Seventy Six Basalt Safford Canyon Deadhorse Tuff *Welded ash flows* *Altered andesite*	*Sandstone, shale, and tuff* *Andesite, dacite, rhyolite*
		Eocene		Pansy Lee		*Conglomerate*
		Paleocene				
MESOZOIC	Cretaceous		King Lear *Unnamed volcanic rocks*			
	Jurassic		*Unnamed volcanic and sedimentary rocks*	*Unnamed sedimentary rocks*	Aztec(?)	Dunlap Sunrise
	Triassic			Raspberry Winnemucca Dun Glen Grass Valley Star Peak Group Osobb Cane Spring Augusta Mtn. Favret Dixie Valley Tobin Koipato	Chinle(?) *Unnamed marine sedimentary rocks*	Gabbs Luning Candelaria Excelsior
PALEOZOIC	Permian			Edna Mtn. Havallah (Thrust fault)	Gerster Kaibab Arcturus Pequop	Pablo Diablo
	Pennsylvanian			Antler Peak Pumpernickel Highway, Battle	Strathearn Tomera Moleen Ely	
	Mississippian				Diamond Peak Tonka Chainman	*Limestone*
	Devonian				Devils Gate, Guilmette Nevada Simonson Sevy	
	Silurian			(Thrust fault)	Lone Mtn., Laketown	
	Ordovician			Valmy Comus	Hanson Creek Fish Haven Eureka Swan Peak Pogonip Group	Palmetto
	Cambrian			Scott Canyon Paradise Valley Harmony Preble Osgood Mtns.	Prospect Mountain	Emigrant Mule Spring Saline Valley Harkless Poleta Campito
Upper Precambrian						Deep Spring Reed Wyman
Lower Precambrian						

INDEX MAP OF AREAS IN NEVADA

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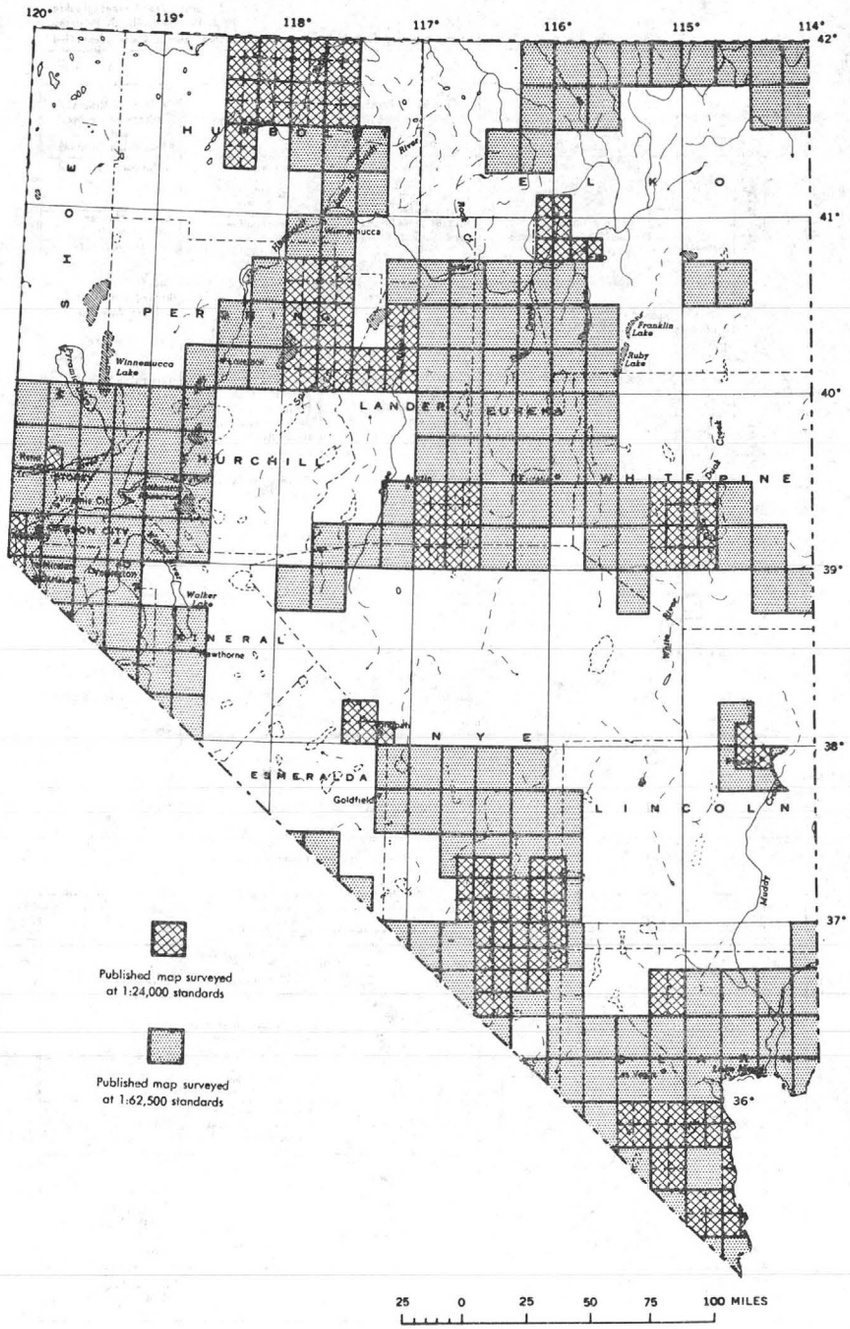

FIGURE 2.—Published topographic maps in Nevada, December 1963.

much of the Appalachian Mountains of the Eastern United States. Representative altitudes of basin floors include: Clayton Valley, 4,300 feet; Black Rock Desert, 3,900 feet; Carson Sink, 3,800 feet; Crescent Valley, 4,700 feet; Ruby Valley, 5,900 feet; and Railroad Valley, 4,600 feet.

The largest river contained within Nevada is the Humboldt River which derives most of its water from the Ruby and East Humboldt Ranges. It flows generally westward then turns southward to end in the Humboldt and Carson Sinks, where its water eventually evaporates. The Walker, Carson, and Truckee Rivers drain the east flank of the Sierra Nevada Mountains in California and flow eastward to undrained basins in Nevada; the Carson River to Carson Sink, the Walker River to Walker Lake, and the Truckee River to Pyramid Lake.

Topographic maps of the entire State of Nevada are available at a scale of 1:250,000 (prepared by the Army Map Service), and maps at a scale of 1:62,500 or 1:24,000 (prepared by the Topographic Division, U.S. Geological Survey) are available for about half (fig. 2) the State All of these maps can be purchased from the U.S. Geological Survey.

STRATIGRAPHY

Stratigraphy, as the name implies, comprises the composition, sequence, and correlation of stratified rocks. Sedimentary rocks are lithified sediments, composed of detrital (pebbles, sand, and mud) and chemical (calcite, gypsum, and salt) components, that accumulate either in bodies of water, or subaerially on the land. Nearshore marine gravels, sand, and mud form delta wedges or layers of conglomerate, sandstone, and shale; farther from shore, carbonate deposits, such as banks of limy mud, reefs of organic remains, or accumulations of shells and corals, form layers of argillaceous or bioclastic limestone. On the continents, coarse to fine detrital rocks form alluvial fans and flood-plain deposits of conglomerate, sandstone, and mudstone. In desert basins or playa lakes, evaporite deposits of salt and borate may form; in large lakes of long duration, petroliferous sediments may accumulate.

Layered rocks provide a record of changes in topography, source of sediment, and environments of deposition through geologic time, and provide clues to subsequent structural and chemical alteration. Intervals of geologic time during which sediments accumulated in geosynclinal basins or on continental margins are separated by mountain building intervals—orogenies—often accompanied by intrusion and extrusion of igneous rocks.

The mineral resources of Nevada are directly related to the metamorphic, sedimentary, and igneous rocks that make up the mountains and valleys. Deposits of salt, oil shale, sand and gravel, perlite, and some metallic and nonmetallic minerals are actually rocks. Some of these can be used directly in industry or commerce, whereas others require beneficiation or concentration. Mineral resources are contained in the rocks, and the major rock units in Nevada, beginning with the oldest, the sedimentary and associated igneous rocks, and the events that affected them, are described briefly in the following pages. The principal rock units are shown on the geologic map (fig. 3) and the principal formational units in the different parts of the State are shown on the stratigraphic correlation chart (table 1). Geologic

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GEOLOGY

Deposits of all types of minerals including the mineral fuels have resulted from various geologic processes and events that have been taking place all through geologic history right up to the present. Therefore, to understand and evaluate mineral resources one must be informed concerning the geological background. The following sections on topography, stratigraphy, and structural evolution are intended to provide such a background, and the section on economic geology summarizes the relation of the mineral commodities to the general geologic features of the State.

TOPOGRAPHY

(By R. E. Wallace, U.S. Geological Survey, Menlo Park, Calif.)

Nevada lies almost entirely within the Basin and Range province, a region characterized by isolated, elongate, subparallel mountain ranges and broad intervening, nearly flat-floored valleys or basins. The Great Basin is another term applicable to most of Nevada and refers to that major subdivision of the Basin and Range province in which drainage leads to enclosed basins rather than discharging into the sea. Drainage finds outlets to the sea only in the southeasternmost part of the State through the Colorado River system, and in the northeastern part of the State through the Snake River system.

Most mountain ranges throughout the State trend north or northeast and many are somewhat arcuate. Many of the ranges are rather regularly spaced about 15 to 25 miles apart. They are 40 to 80 miles long, and from 5 to 15 miles wide at their bases, with range crests between 8,000 and 10,000 feet above sea level. The highest point, 13,145 feet above sea level, is Boundary Peak on the California-Nevada boundary, and Wheeler Peak near the Utah-Nevada boundary is 13,063 feet above sea level.

The intervening basins owe their plainlike surface configurations largely to subaerial deposition of waste from the mountains. Thus broad, coalescing alluvial fans border most ranges, and it might be said that each range is being drowned in its own debris.

Playa lakes occupy the low parts of enclosed basins, and the nearly level floors of some basins are relicts of more extensive lake beds formed during humid periods in the latter part of the ice age or Pleistocene Epoch. Pyramid Lake and Walker Lake are, in fact, remnants of glacial Lake Lahontan which covered a large area of western Nevada during the Pleistocene.

The lowest point in Nevada, about 490 feet above sea level, is along the valley of the Colorado River at the southernmost tip of the State. From there the valley bottoms and basin floors rise toward the north and east so that although low in relation to the surrounding ranges, they stand at altitudes higher above sea level than, for example,

ductive rocks. Buried magnetite-bearing channels in alluvial valleys also can add to the difficulties.

The thickness and variations in thickness of cover should be determined as completely as is economically feasible from wells and mine openings, and from gravity and seismic surveys. Much discussion among exploration personnel involves the search for mineral deposits in pediments—near-smooth surfaces cut into bedrock—but the first step is to determine where pediments exist and then to define their limits. They slope gently away from the bases of the ranges, and the alluvium blanketing such surfaces gradually thickens valleyward. Projecting geologic data, mineral trends and geochemical data into the pediments and running appropriate geophysical surveys may identify attractive exploration objectives. An interesting situation on a pediment sometimes can be recognized from regional aeromagnetic maps. Usually at some distance out in the valley, the gently sloping alluvium-bed rock contact of the pediment is abruptly dropped for several thousand feet by a hidden fault. Some Nevada ranges are bound by steeply dipping faults, and no pediment area exists; the change is an abrupt one from bedrock in the range to deep fill in the valley. In the case of metallic mineral deposits expected in the hidden bedrock, great thicknesses of covering alluvium can make exploration for them impractical under present conditions. In the case of petroleum, thick alluvium is no deterrent to exploration and also may not be critical in seeking sheetlike nonmetallic deposits, especially those recoverable by pumping through drill holes.

This brief discussion is intended to encourage additional prospecting and exploration in the State. Nothing is easy about the task of maintaining sources of supply of the mineral resources, but the great importance of minerals in the economy of Nevada needs to be better appreciated. The State government provides an equable climate for this work. Unfortunately prospectors and exploration companies here and elsewhere are being increasingly hampered by high costs, metal importation, regulation and other problems. The gradual demise of custom mills and smelters also makes marketing of metallic ores more difficult, particularly for the small operator. Much work remains to be done on basic geology, geographic patterns of mineral commodity distribution, exploration methods, and instrumentation. Such steps as are practical to help solve these problems should be taken by the government and private groups involved and should be the concern of the populace in general.

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4. Geophysical and geochemical surveys are undertaken, using methods appropriate to the geologic situation and to the commodity.

5. The information collected is synthesized and analyzed and favorable exploration targets are defined.

6. The promising targets, usually combinations of favorable geologic structures, likely host rocks, and signs of mineralization and alteration, are explored by drilling and excavation. Interesting situations should be appraised thoroughly rather than subjected to superficial examinations every year or so by different people of the same organization.

One exploration man probably feels as inadequate as the next when he stands at the bedrock-valley fill contact and speculates as to what may lie under the cover and how to go about finding it. It is most logical to concentrate on those covered areas where major mining districts are abundant in adjacent bedrock and occur in alinements that are not merely accidents of erosion, but which can be related to faults, folds, and the distribution of intrusive rocks. For those interested only in finding and disposing of mineral deposits, it could be added that the areas for concentrated exploration might be ones filling all the above requirements and also having the greatest number and variety of important mineral materials. Under such circumstances, the chances of finding something valuable under cover are greater than when only a single commodity is involved. Exceptions would be extensive petroleum reservoirs or widespread, sheetlike bodies of nonmetallic minerals, which may be controlled more by stratigraphic conditions than by structure and positions of intrusive rocks.

In exploring all covered areas the question is presented: Does the prize at the depth expected justify the expenditure required to find and mine it? A typical problem facing those exploring in Nevada for porphyry copper deposits under cover, and a good one for those who like to use computors to assist in solving their exploration problems, is the size and grade that a potential deposit would have to have to justify exploring for it under a blanket of 2,000 feet or more of alluvium.

The physical and chemical characteristics of the commodities sought under cover determine whether geophysical and geochemical methods can aid in the search, and if so, which ones. For example, the ground or airborne magnetometer is most useful and produces the least confusing results of any instrument in exploration for magnetic iron deposits in Nevada but in seeking most deposits of nonmetallic minerals it generally is only an indirect guide to geologic structures and rock types.

The physical and chemical characteristics of the cover, and the inhomogeneities therein, must be evaluated to establish what interferences can be anticipated during geophysical and geochemical work and drilling. Saline ground water can make results of some electrical geophysical methods ambiguous. Buried slabs of volcanic rocks can produce confusing magnetic and gravity anomalies, and the situation is aggravated if the volcanics are tilted. Volcanic rocks also show intricate magnetic patterns that often effectively obscure the magnetic characteristics of underlying ore deposits, or potentially pro-

The abundance and variety of mineral resources in Nevada should continue to be important factors in the expansion of industry in the State in the years ahead. As has been indicated in the preceding discussion, certain commodities, such as copper, iron, and oil, show particular promise of expansion in the future. Renewed mining of tungsten would also undoubtedly result from a rise in price. Substantial resources of other materials, including borates, clays, diatomite, gypsum, dimension stone, lime, and perlite, are available in Nevada and production can be expanded as demand for these items increases in the Pacific Coast market. It is thus apparent that the mineral industry of Nevada will continue to be a vital factor in the State's economy for many years to come.

MINERAL EXPLORATION IN NEVADA

(By S. E. Jerome, Nevada Bureau of Mines, Reno, Nev.)

It will be evident in reading this report that Nevada produces an abundance of mineral commodities and that the mineral industry contributes substantially to the economy of the State through jobs, taxes, freight revenues, support of satellitic industries, etc. Only through constant exploration and discovery can the health of the industry be maintained, for it depends on wasting assets.

To approach the problems of exploration with any hope of consistent success requires a combination of competent personnel, high quality geologic mapping, imaginative thinking, willingness to innovate, sophisticated geophysical instrumentation and geochemical analytical techniques, enlightened management or backers, dollars, intelligent persistence even through dips in the economic cycle, drill holes, and pure luck. In some cases the latter seems to be the only ingredient involved, particularly if one is contemplating the successes of his competitors. Exploration personnel should have a thorough knowledge of the mineral business and must understand the effect of changes in technology, new uses, substitutes, changing market patterns and political attitudes.

Most individuals or companies exploring in Nevada are interested only in a small number of commodities at a particular time. This reflects the fact that many companies are vertical organizations whose businesses depend on only one or two commodities; they explore for them, mine or pump them, process them, and market finished products. Examples include the large copper companies whose business is almost entirely dependent on copper and such byproducts as result from mining and processing copper ores, and companies like those operating in the State on gypsum, diatomite, magnesite, and petroleum deposits. Individuals and nonvertical organizations may be interested only in exploration, production, and marketing a raw material to a processing company. The latter's search ordinarily is directed toward those commodities enjoying a reasonably predictable, favorable economic climate; those in urgent need, with a correspondingly high price, induced by strong consumer demand or by the sudden needs of war; those subsidized for one reason or another, including stockpiling, Government exploration loans, subsidy payments, supported metal prices, and accelerated depreciation; those for which

THE MINERAL INDUSTRY IN NEVADA

(By H. R. Cornwall, U.S. Geological Survey, Menlo Park, Calif.)

Mining started in Nevada about 1855, and for many years production from mines, mainly of gold, silver, and base metals, completely dominated the State's economy. Production of metallic and nonmetallic minerals from 1900 to 1962 are shown in figure 1.[1] In more recent years agricultural and manufacturing output have become significant, but the production of metals and minerals has continued to be dominant. For example, in 1961 total farm marketings amounted to $47,400,000, whereas metals yielded $57,481,000 and nonmetallic minerals $24,052,000 for a total of $81,533,000. Manufacturing yielded $67,591,000 in 1958.

The total value of metals and minerals mined in Nevada from the earliest record through 1962 amounts to nearly $3 billion. Of this $2,561 million (87 percent) resulted from the production of metals, and $382 million (13 percent) from nonmetallic minerals. In the metals, production of gold and silver totaled $1.2 billion and copper production amounted to $1.1 billion. Other metals, mainly lead, zinc, tungsten, iron, mercury, and manganese netted $260 million. This is a minimum figure, because the output of certain metals has not been published in years where such publication would reveal production data of individual companies. The production of tungsten, for example, is estimated to total about $30 million more than the published figures indicate.

In the early days of mining in Nevada gold and silver were the principal metals sought. In 1859 production started from the fabulous gold-silver bonanzas of Comstock lode at Virginia City, Storey County, Production from this district reached a maximum of $36,301,500 in 1877. The total output for the district during the period 1859–1921 amounted to $386,347,000 (Lincoln, 1923, p. 226). Following the Comstock development, other rich gold-silver deposits were soon discovered, such as the Reese River district in 1862. Of the base metals copper, lead, and zinc, which commonly occur with gold and silver, only lead was recovered in the early days of mining in Nevada. Lead production was greatest between 1873 and 1881 when output exceeded 12,000 tons per year, with a maximum of 31,000 tons in 1878.

Mining in Nevada almost ceased between 1890 and 1900. In 1900 the rich ores at Tonopah, Nye County, were discovered. Tonopah was principally a silver-gold district, with silver exceeding gold by a ratio of 3:1. Minor amounts of copper and lead also were recovered. Between 1900 and 1921 production totaled $120,491,000 (Lincoln, 1923, p. 186). Other early producers were Eureka ($40 million in gold, $20 million in silver between 1869 and 1892); Goldfield $84,879,000, principally in gold, between 1903 and 1921); and Reese River ($50 million).

[1] The values on fig. 1 are "constant dollars," based on the 1957–59 dollar. In other words, actual values have been adjusted to reflect the changing value of the dollar in terms of its purchasing power. For the most part, therefore, the curves mark the significant changes in volume of material produced.

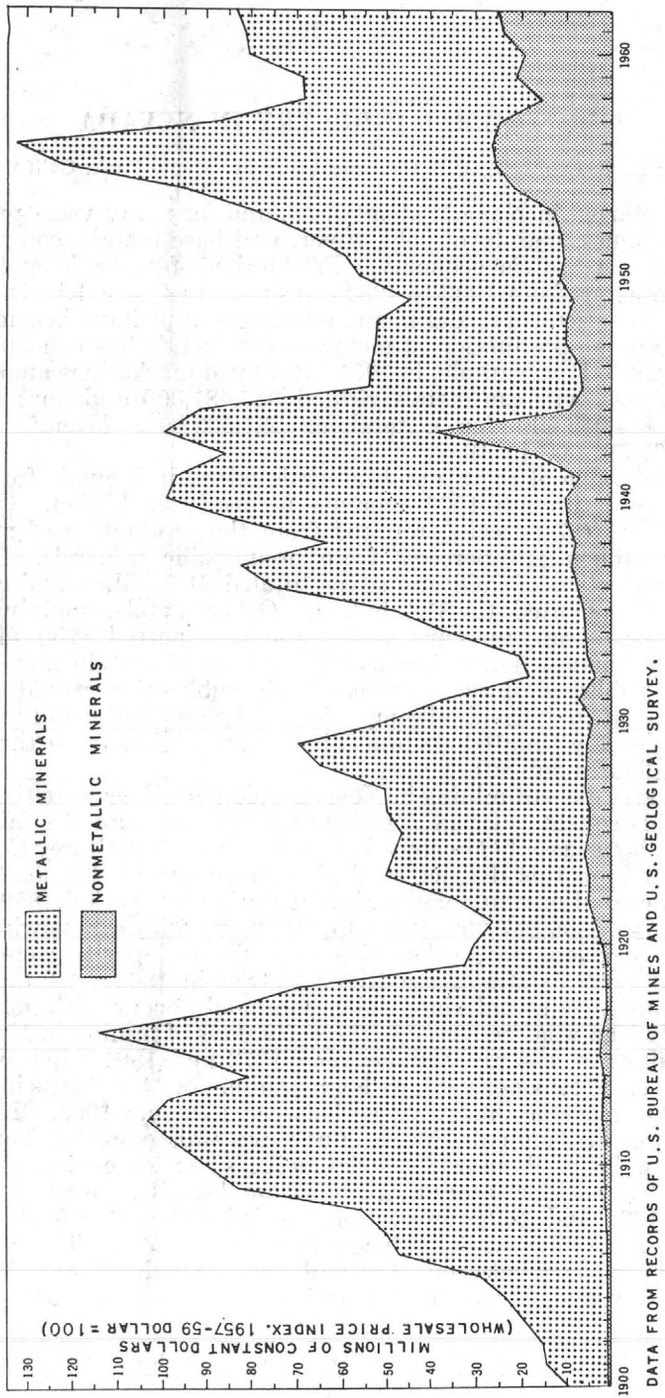

FIGURE 1.—Mineral production in Nevada, 1900 through 1962.

Significant copper production in Nevada started in 1906, and, except for the depression years of the early twenties and early thirties, has gradually increased ever since to a high of 82,000 tons in 1962 (7 percent of the national total). The total production of copper through 1962 was 2,813,338 short tons. The Ely district, White Pine County, has produced over 2 million tons; the Yerington district, Lyon County, 340,000 tons; and the Mountain City district, Elko County, 105,000 tons. Copper production will probably continue to increase in Nevada, particularly in the Yerington district, where major discoveries have recently been made of iron ore with associated copper.

Iron ore production in Nevada has been small. Total production amounts to about 10 million tons, mostly since 1950. Significant new discoveries have recently been made, however, including a large deposit near Yerington, and resources of material containing 40 percent or more iron are estimated to total ½ to 1 billion tons. As the demand for iron and steel increases along the Pacific Coast and in Japan, the Nevada deposits are favorably situated to supply these increased demands. It is probable, therefore, that there will be a substantial increase in Nevada iron-ore production in the near future.

Nevada and California have been the major tungsten producers of the United States. Each has produced about 30 percent of the total of the United States, which is second only to China in world production. The value of production in Nevada has been about $130 million. The greatest periods of production were 1941–49 and 1951–56 when prices were high because of wartime demands. Since 1956 the price has declined and production has dwindled. It is quite certain that renewed demand for tungsten with concomitant increase in price would encourage renewed mining of the metal in Nevada.

The production of nonmetallic minerals in Nevada was practically nil before 1900 and first exceeded $1 million per year in 1920. The yearly production of nonmetallic minerals in terms of constant (1957–59) dollars is given in figure 1. The rate of production has increased rather steadily since 1920 with upward surges during World War II and the Korean war. In 1962 the total production of nonmetallic minerals was slightly over $25 million. The nonmetallic minerals include barite, borates, clays, diatomite, fluorspar, gems, gypsum, lime, perlite, salt, sand and gravel, silica, stone, sulfur, and talc. Yearly production of these individual commodities has commonly amounted to less than $2 million except for sand and gravel ($9,655,000 in 1962), and gypsum ($2,952,000 in 1962).

Production of mineral fuels in Nevada has been small. There are no commercial coal deposits, although attempts have been made in the past to mine low-grade coals in Tertiary lake beds. The outlook for petroleum is more promising. The Eagle Springs field, Nye County, currently has three producing wells, and production to date amounts to 717,000 barrels. The third well, completed in March 1964, is a flowing well with initial production exceeding 2,400 barrels per day.

In the following sections the geology and occurrence of the mineral commodities will be discussed in detail. The great variety of geologic environment and types of occurrence of the individual metals and minerals is strikingly apparent from these descriptions.

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Nevada," by the Nevada Bureau of Mines. The commodity maps of this volume, based on those published by the latter organization, show that some mineral commodities are of widespread, almost random, occurrence; others have a strong tendency to occur in clusters; others are arranged in striking linear patterns; and, some large areas in the State are remarkably free of significant deposits of any kind. These patterns are revealed most effectively on maps showing individual commodities, the procedure usually followed herein.

Although many similarities exist, there are many differences in the exploration methods used for metals, nonmetals, and petroleum. The selection of methods is influenced by two contrasting geologic-topographic situations that characterize the State. In the first, bedrock is exposed, often in substantial relief, over large areas and is susceptible to direct observation and sampling. This is the case in the extensive volcanic plateaus in the northern part, in the Sierra Nevada Province along the southwestern border, and in elongate mountain ranges prominent over a large part of the State. Within these bedrock masses, large areas are obscured by a relatively thin cover of alluvium and vegetation. In the second situation, vast areas are covered with great thicknesses of alluvium and poorly consolidated sediments of varied origin. This condition prevails over about 60 percent of the State in the extensive valleys between ranges. The striking combination of alternating mountain masses and valleys prompts the designation, "Basin and Range Province", for most of Nevada and parts of Utah, California, Arizona, and New Mexico. Throughout this Province exploration problems are similar.

In the bedrock environment it must be determined if the rock exposed is a possible host for the materials being sought, or if it is a concealing cover deposited much later than the materials sought. Thus, while Late Tertiary and younger volcanic rocks in the northern plateaus and in the ranges are potential sources of ash, pumice, perlite, building stone, road metal, and zeolites, and also may contain lake beds with diatomite, salts, and borates, such rocks may also conceal important metalliferous deposits. If those commodities are sought for which the volcanic rocks are host, the exploration problems usually are simpler than the marketing problems and may be limited to direct prospecting, sampling, and drilling. If those materials are sought which the volcanic rocks are likely to conceal, the exploration problems can be extremely difficult and frustrating.

Where rocks are exposed that are likely to have had valuable metalliferous deposits introduced into them, the requirements for discovery are reasonably straightforward and may include all or any combination of the approaches listed below. It is not intended to imply, however, that discovery is the automatic result of such work.

1. A locality known to contain major deposits of a mineral commodity, or many signs of its possible presence, is selected. as mentioned above this is based on study of geologic reports and maps and commodity distribution maps.
2. Rock types, faults, folds, mineralization, and alteration are mapped in considerable detail.
3. The mineralization is sampled and content of valuable minerals established.

INTRODUCTION

(By H. R. Cornwall, U.S. Geological Survey, Menlo Park, Calif.)

The mineral and water resources of Nevada are summarily described in this report. Following a general description of the mineral industry and of the geology of the State as a whole, the occurrence, distribution, and relative importance of individual commodities are discussed in some detail. All mineral commodities are described that are known to occur in Nevada and that might have economic significance in the foreseeable future, whether or not they have been mined.

In the description of the geology of the State, a section on economic geology describes the distribution of the metallic and nonmetallic mineral deposits both areally and with respect to the general geologic features. A knowledge of the pattern of distribution of known mineral deposits of various types is essential to the successful search for new ore bodies. A section on mineral exploration discusses the methods and problems of exploration, and also considers which commodities in Nevada offer the greatest promise of new discoveries in the future.

Water resources are described rather fully in this report; water in this generally arid part of the Great Basin is vital to the economy of the State and to the well-being of its people. Sources of waterpower and geothermal power are also discussed.

This report was prepared jointly by members of the Nevada Bureau of Mines, and of the U.S. Geological Survey. Mr. Paul Gemmill, Nevada Mining Association, and Mr. L. A. Wright, Pennsylvania State University, were invited to write the sections on perlite and talc because of their knowledge of these commodities. Authorship of individual sections is indicated at the head of each chapter. All sections not showing authorship were written by H. R. Cornwall, who assembled the report.

The geologic map was compiled from a number of sources as indicated by an accompanying list of references and index map (fig. 4). Great strides have been made in recent years toward the objective of a complete, accurate geologic map of the State. This progress is in large part due to a concerted, joint program of the Nevada Bureau of Mines and the U.S. Geological Survey to prepare geologic maps of all the counties at a publication scale of 1:250,000.

Mineral production data given in the text, unless otherwise cited, are from the U.S. Geological Survey's Mineral Resources of the United States (1880–1921), the U.S. Bureau of Mines Minerals Yearbook (1922–62), and from other data obtained by the Nevada Bureau of Mines at Reno, and the U.S. Bureau of Mines in San Francisco, and Washington, D.C.

there is speculation of a price increase as is the case with gold; and, those produced in substantial amounts in foreign countries, but for which the political climate is unpredictable.

Commodities found in Nevada and currently high on the list of desirable exploration objectives include: iron, gold, silver, molybdenum, copper, beryllium, petroleum, borate, gypsum, diatomite, clay, glass sand, and various types of "lakebed" salts such as sodium chloride, sodium sulfate, and potassium chloride. Commodities in a transitional stage of improving economic prospects include the perennial problem metals: lead, zinc, and mercury. Those whose fortunes have waned here and elsewhere, but which are certain to return to some importance under stimulation of some of the conditions cited above include: antimony, tungsten, uranium, vanadium, manganese, and fluorite. In considering any mineral, however, it needs to be emphasized that even under an unfavorable economic situation, a deposit unique either in size or quality merits through exploration and possible production. This is especially true if its product could make substantial inroads into established marketing patterns, and provided that a need exists for it in quantity. In contrast, a large, high-grade deposit of cesium-bearing minerals in Nevada might require many years to be fully appreciated and exploited, and today would not be the object of a concentrated, expensive exploration program. One never knows, however, when a scientific breakthrough may catapult a mineral commodity, such as cesium, with a limited market into great demand. Uranium is the outstanding example of our generation.

Some abundant mineral commodities, such as volcanic cinders, sand, gravel, and common stone are of low value and will not stand the addition of substantial freight charges to their exploration and production costs. Processing will upgrade them only to a limited extent. These and similar materials normally are consumed within relatively short distances of points of production. Actually it is the local need that prompts their exploitation in the first place. In a State such as Nevada with a low total population centered in a few cities the exploration for such materials will continue to be a local problem, not attracting major effort. However, such deposits can provide lucrative businesses for small companies or individuals.

Nevada apparently is deficient, or has only meager sources of coal, niobium, titanium, asbestos, nickel, cobalt, vermiculite, aluminum, borax, lithium, and tin; for some of these the optimistic view may be held that the deficiency is apparent and only reflects lack of discovery or the need for a higher price or the need for improved mining and concentrating methods. It is such optimism about these and other commodities that helps maintain a healthy interest in exploration.

Because of the variety of mineral materials found, the entire State is a potential hunting ground, and any geologic environment might yield something that is or may become of economic interest. However, the search for individual commodities often can be restricted to a particular environment in which certain conditions prevail. Decision on a favorable environment results from study of geological reports and maps in combination with commodity distribution maps. To facilitate such studies, new geological mapping and compilation of past mapping is underway as a cooperative project of the U.S. Geological Survey and the Nevada Bureau of Mines. Results to mid-1962 have been published as map 16, "Progress Geologic Map of

secs. 22, 23, 26, 27, 28, 34, 35, and parts of secs. 15, 20, 21, 24, 29, 32, 33, and 36, T. 2N., R. 37 E. The area that appeared most favorable for development included secs. 28, 29, and 33. Diamond drilling failed to disclose any additional coalbeds but did serve to emphasize the structural complexity of the area.

Analyses of the coal showed an ash content ranging from 35 to 85 percent, with an average of 50 percent. Washing tests reduced the ash in the coal tested from about 53 percent to 37 percent with a yield of 33 percent of the mine run material.

Structural complexities, thin beds, low grade coal, and inadequate reserves do not encourage commercial development of the Coaldale coal deposit.

Lyon County

Washington (Lewis Coal mine) deposit (No. 6)

A deposit of low grade coal is located in sec. 36, T. 8 N., R. 27 E. and sec. 1, T. 7 N., R. 27 E., near the mining camp of Washington. The coal occurs in a section of reddish-brown, clay-shales in the upper part of the lower member of the Coal Valley Formation of Axelrod (1956) (Pliocene). The coal has been described as sapropelic. Sapropel is a fluid organic slime originating in swamps as a product of putrefaction. In its chemical composition it contains more hydrocarbon than peat. When dry, it is a lusterless, dull, dark, and extremely hard mass.

In 1919 this coal deposit was developed by the Nevada Coal & Oil Co. during unsuccessful drilling in search of petroleum. The fresh coal is black in color, containing 30 percent volatile hydrocarbons, 40 percent fixed carbon, 16 percent ash, and 14 percent water.

Ormsby County

El Dorado Canyon deposit (No. 5)

A deposit of lignite is located in sec. 7, T. 14 N., R. 22 E., on the northeast slope of Bismark Peak and immediately west of the stream in El Dorado Canyon. The deposit was found by English miners soon after the discovery of the Comstock Lode. It is reported that 9,800 tons of coal were mined prior to 1865 and, following formal organization of a mining company in 1872, an additional 31,400 tons were mined. Two shafts were sunk, one 420 feet deep and the other 85 feet deep. The coal bearing formation has been described as follows:

> For about 300 feet from the surface the formation consists of alternating layers of marl, soft gray sandstones, shales, fire-clay, carbonized vegetable matter, and beds of weathered lignite. There are three beds of lignite which are, counting from the surface, 16 feet, 15 feet, and 6 to 8 feet in thickness.

The deposit has not been worked for many years. During a recent inspection of the mine area the shafts were caved and the dumps were badly weathered and overgrown with sagebrush. In general, it appears that no work has been done since 1900. As the rocks near the mines are of Tertiary age (Miocene and Pliocene(?)), it is probable that the lignite was deposited under conditions similar to those prevailing at the other Tertiary coal deposits.

Precambrian and Lower Cambrian Rocks

(By J. H. Stewart, U.S. Geological Survey, Menlo Park, Calif.)

Lower Precambrian metamorphic rocks.—Strongly folded medium- to high-grade metamorphic rocks are the oldest rocks exposed in the State. Metasedimentary gneiss, schist, marble, and associated intrusive granitic and pegmatitic bodies constitute the main mass of these rocks. The metamorphic character indicates a long history of development including deposition, deformation and regional metamorphism, and erosion. The metamorphic rocks form the basement of the Cordilleran geosyncline, a basin that developed during the late Precambrian, and the basal strata in this geosyncline lie with a prominent angular unconformity on these lower Precambrian metamorphic rocks.

The main exposures of the lower Precambrian rocks are along the eastern part of the State in the Newberry Mountains, McCullough Range, El Dorado Mountains, Gold Butte area, and the Virgin Mountains in the southern part of Lincoln and Clark Counties in the northern Snake Range in White Pine County, and in the Ruby Mountains and East Humboldt Range in Elko County.

Dating of these rocks by the Rb-Sr (rubidium-strontium) and K-Ar (potassium-argon) methods gives from 1.1 to 1.7 billion years on outcrops in Clark County (Lanphere and Wasserburg, 1963; Volborth, 1962; and Armstrong, 1963). These dates indicate the age at which metamorphism and granitic intrusion occurred; the original rocks from which the metamorphic rocks formed are older. In the Ruby Mountains, a schist of presumed Precambrian age has undergone a still later metamorphism and now yields a K-Ar age of 25 million years, and the K-Ar age for a similarly ancient granite is 29 million years (Armstrong, 1963).

Upper Precambrian and Lower Cambrian clastic sequence.—In late Precambrian time (from about 600 to 1,100 million years ago) a broad seaway, called the Cordilleran geosyncline, formed in western Nevada; at first it was a fairly narrow trough elongated north-south, but during the Early Cambrian the seaway spread eastward into central Utah. The upper Precambrian and Lower Cambrian deposits in this seaway are dominantly clastic. These deposits are thin along the eastern flank and thicken fairly abruptly to the west into the central part of the seaway. In eastern and southern Clark County, which lies along the eastern flank of this seaway, the clastic strata are only 200 to 400 feet thick. In southern Nye County, in White Pine County, and in Esmeralda County, all of which lie in a more central part of the seaway, incomplete sections of these strata are 10,000 to 12,000 feet thick. Strata deposited during late Precambrian and Early Cambrian time consist dominantly of coarse quartzite and conglomeratic quartzite along the eastern flank and fine quartzite, phyllitic siltstone, and carbonate layers in the central part. Deposition started in the central part of the trough and extended progressively farther to the east onto the flank of the trough as it was filled. Most of the sediment in this trough was derived from lower Precambrian metamorphic terranes to the east.

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Paleozoic Rocks

(By R. J. Roberts, U.S. Geological Survey, Menlo Park, Calif.)

Following the deposition of sands and shales during the Precambrian and Early Cambrian, the character of sedimentation changed within the seaway (Roberts and others, 1958). In eastern Nevada the sands gradually gave way to carbonates (limestone and dolomite) which were deposited in shallow seas in which lived abundant marine life such as shellfish, corals, and sponges. In central Nevada the carbonates are interbedded with shales and silts in transitional belt (Hotz and Willden, 1955). The transitional rocks grade westward into sequences of siliceous rocks (chert, shale, and sands) and volcanic rocks (lava and pyroclastics). These rocks were formed offshore, partly in deep water, but locally volcanic islands, like present-day Hawaii, were built on the sea floor. The sediments deposited within each of these environments differ in lithology; for convenience in following discussions they will be called assemblages. The three major assemblages, carbonate, transitional, and siliceous and volcanic were laid down in different parts of the seaway without significant interruptions from Middle Cambrian to the end of Devonian time. The boundaries between the assemblages shifted eastward and westward somewhat during this time, but the major belts remained distinct (fig. 6).

In Late Devonian time mountain building during the Antler orogeny in western Nevada was signaled by a flood of coarse detrital rocks that were shed into eastern and western Nevada (Roberts, 1949; Carlisle and Nelson, 1955; and Roberts and others, 1958, p. 2837). The mountain building culminated in the movement eastward of great thrust plates from the uplifted area; these reached points along a line from Austin to Eureka, and then to Mountain City and covered a belt about 90 miles wide (fig. 7).

Subsequent deformation and erosion has resulted in local removal of the thrust plate, thus exposing rocks of the lower plate in windows (Roberts and others, 1958, p. 2821; Roberts, 1960).

Middle Cambrian to Devonian rocks

Throughout eastern Nevada the Middle Cambrian, Ordovician, Silurian, and Devonian rocks aggregate 12,500 to 21,000 feet in thickness (Nolan and others, 1956; Kellogg, 1963). Northwest of Eureka where the carbonate assemblage grades into the transitional assemblage, the section appears to thicken; eastword to the Utah line the section is about the same thickness; southeastward it thins toward the Utah-Arizona shelf.

In eastern Nevada the Middle Cambrian rocks are generally composed of thick dolomite units that grade upward into limestone and shaly limestone of the Upper Cambrian and Lower Ordovician; in western Nevada correlative rocks are mainly interbedded shale, chert, and volcanic rocks (Roberts and others, 1958). Middle Ordovician units in eastern Nevada are vitreous quartzite 300- to 500-feet thick and a little dolomite; equivalents in western Nevada are quartzites that aggregate about 3,000 feet thick, interbedded with shale, chert, and volcanic rocks. Late Ordovician to Early Devonian in eastern Nevada was again a period of dolomite formation but by Late Devonian time limestones predominated; meanwhile, in western Nevada, silt, mud, and chert were being deposited.

County; near Washington, Lyon County; in El Dorado Canyon, Ormsby County; and near Verdi, Washoe County. Deposits in rocks of Paleozoic age occur in Carlin Canyon, Elko County, and in the Pancake Range, White Pine County.

Elko County

Elko deposit (No. 1, fig. 15)

Lignite occurs at several horizons in the Humboldt Formation (Miocene and Pliocene?). The lignite is a light-brown loosely bonded material that usually can be crushed in the hands. It has the appearance of slightly compressed plant remains and is markedly laminated. The beds are seldom more than a few inches thick. Numerous cuts have been opened on these beds in the vicinity of Elko during the past 50 years without finding minable deposits.

Carlin Canyon deposit (No. 2)

A little impure coal occurs west of Molien Canyon, 4½ miles east of Carlin, along the railroad cut in the middle part of a 2,000-foot-thick sedimentary section of Paleozoic age. The coal is in shaly beds at the top of a lower limestone member. This coal was first discovered in 1859, and by 1874 considerable prospecting work had been done. In 1875 the Humboldt Coal Co. was formed to work the coalbeds but made no production. The coal, containing 46 percent carbon, is reported to burn freely, leaving a white ash.

Esmeralda County

Coaldale deposit (No. 7)

Coal was first discovered near Coaldale in 1893. Many attempts were made to mine the coal during the early 1900's, none being successful. Four to six zones of bituminous shale and coal, designated as beds A, B, C, and D by Hance (1913), crop out near the base of a rhyolite escarpment and extend northeast-southwest with considerable regularity for about 2 miles. In general, the beds dip steeply northeast from the outcrop. Coarse sandstone, tuff, volcanic ash, siltstone, and shale members comprise the strata above the coal zones; shale, sandstone, and sandy tuff constitute the strata intervening between the beds. Some of the coaly zones have been intruded by rhyolite. Beds of bentonite and shale have been encountered in drilling. These sedimentary deposits are regarded as early Tertiary in age, and they exhibit a great deal of irregularity, both on account of variable depositional conditions and because of subsequent folding, faulting, and igneous intrusions.

The thicknesses of the coal-bearing beds vary, where mined or penetrated by mining. Bed A is about 3 feet thick with a total coal thickness of 10 inches; bed B is 7 feet thick and contains 24 inches of coal; bed C is 9 feet thick with the proportion of coal to total thickness varying from 20 to 80 percent; bed D has a maximum thickness of 7 feet with coal seams constituting 45 percent of the total thickness.

The coal deposits were explored and tested during World War II (Toenges and others) in connection with general investigations of mineral deposits essential to the war effort. Reconnaissance included

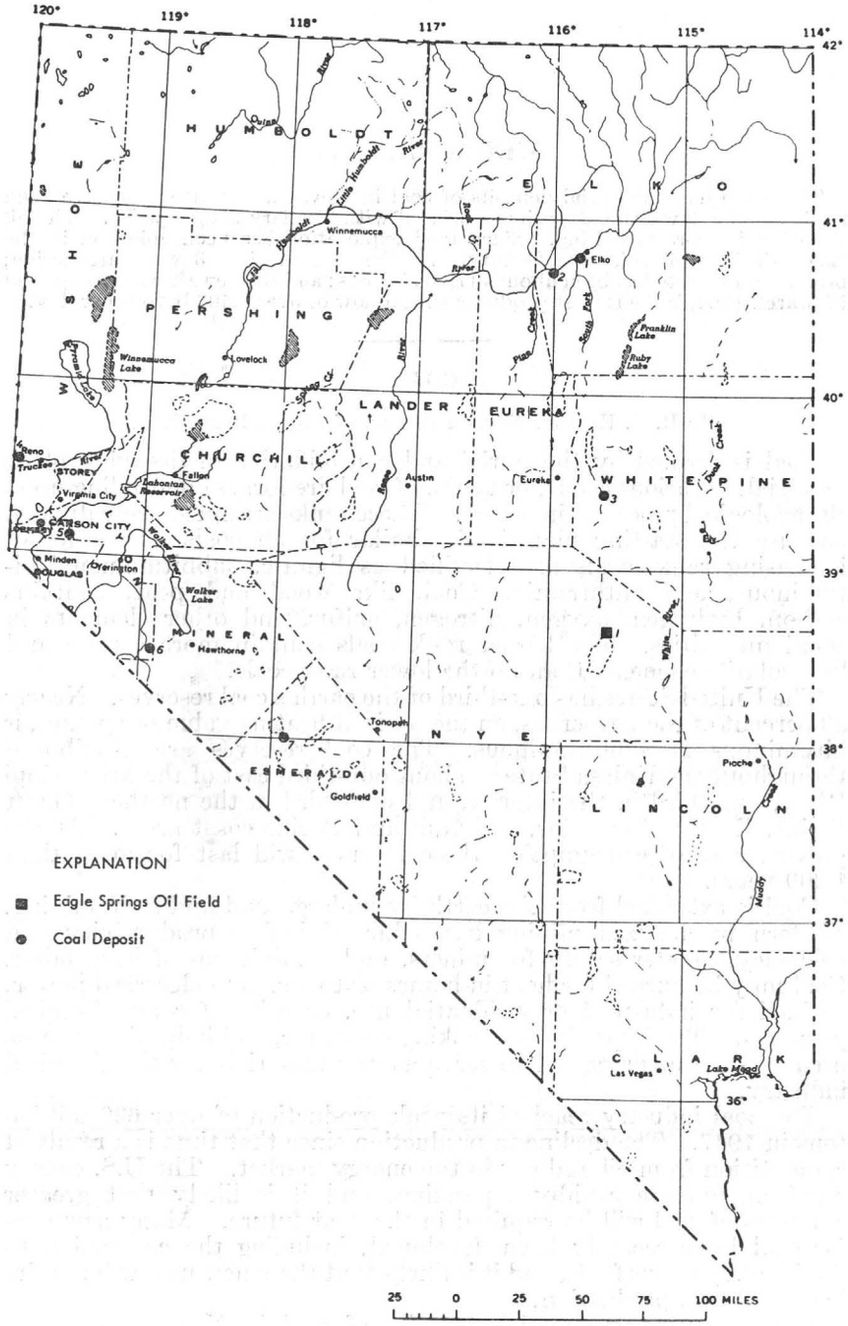

FIGURE 15.—Coal and oil in Nevada (numbers refer to deposits described in text).

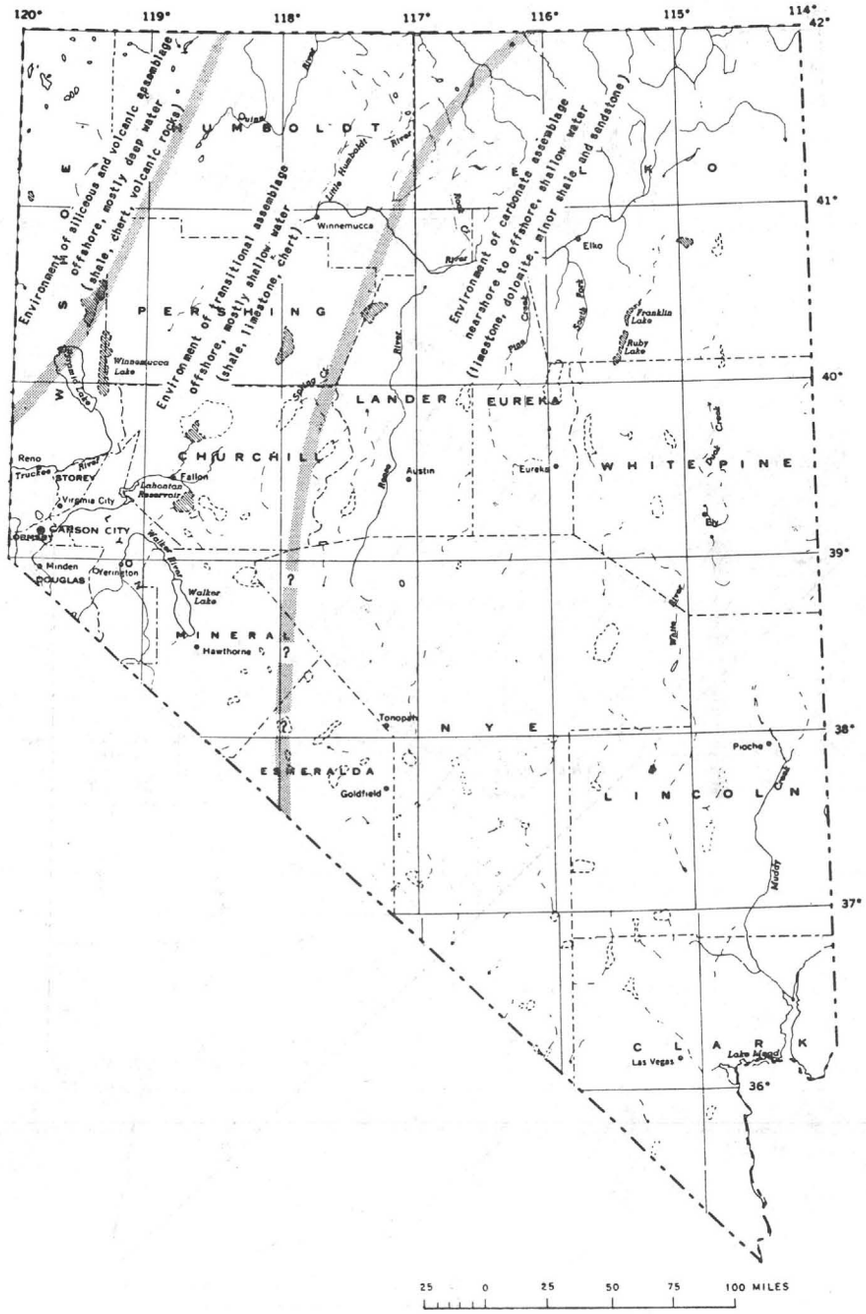

FIGURE 6.—Original depositional environments in Nevada during early and middle Paleozoic time (Middle Cambrian to Late Devonian).

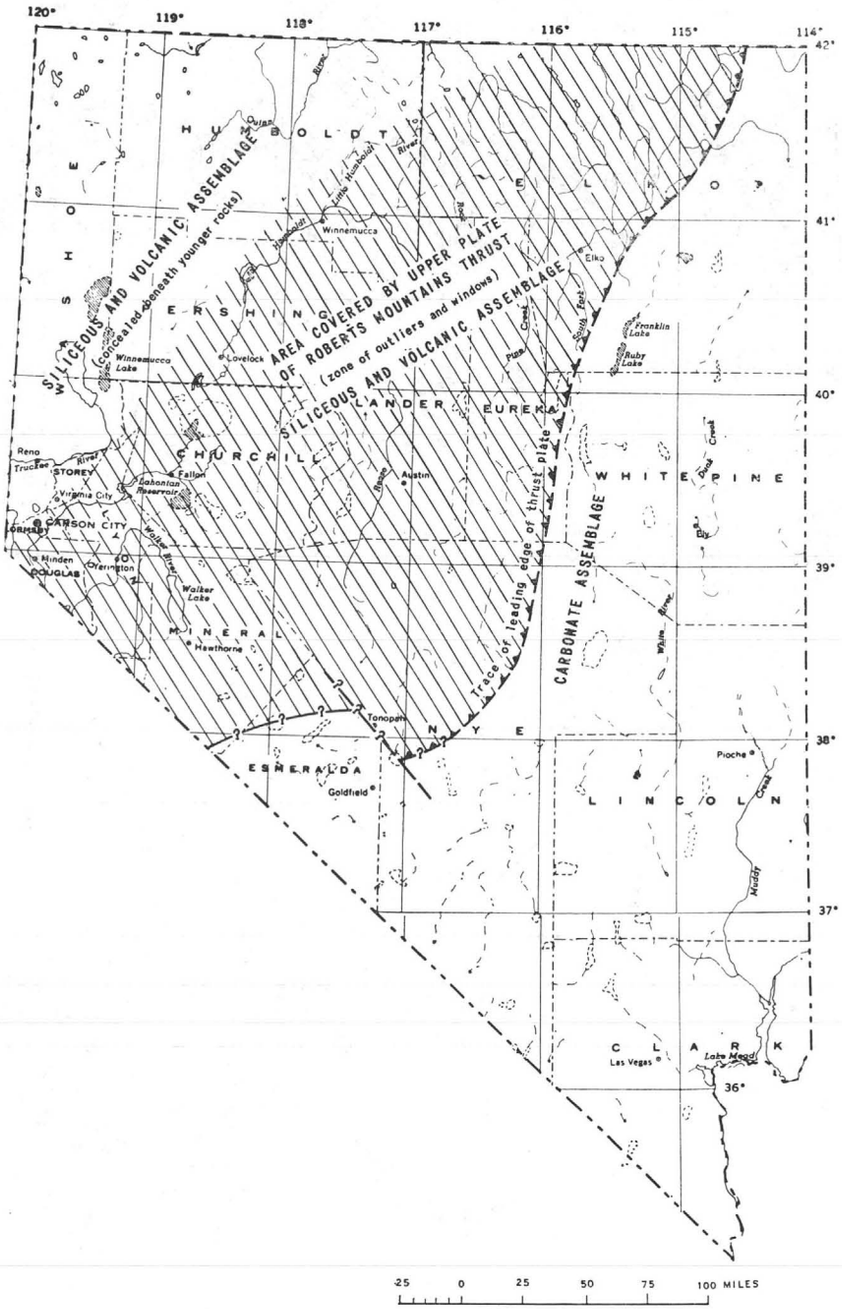

FIGURE 7.—Distribution of Paleozoic facies after thrusting in Early Mississippian time.

MINERAL FUELS

There are no commercial deposits of coal in Nevada, but attempts have been made to mine low-grade deposits associated with Tertiary lake deposits. The oil situation is more promising. Since 1954 exploration has been going on in the Eagle Springs oilfield, Nye County. At the present time 3 wells are active; production to date has been about 717,000 barrels; and the newest well, completed in March 1964, is the largest producer with a flow of over 2,400 barrels per day.

COAL

(By R. C. Horton, Nevada Bureau of Mines, Reno, Nev.)

Coal is formed by the burial and consolidation of decaying plant material. Various ranks, or types, of coal are formed depending upon the geological processes involved. These ranks are not sharply divided because the starting material is similar for all coals. In order of increasing rank, coals are classified as lignitic, subbituminous, bituminous, and anthracitic. Coal, like wood and peat, contains carbon, hydrogen, oxygen, nitrogen, sulfur, and other elements in small quantities. The higher rank coals contain more carbon and less volatile elements than do the lower rank coals.

The United States has one-third of the earth's coal reserves. Nearly 80 percent of these reserves, on the basis of heating value per pound, is bituminous or subbituminous. The coal reserves are distributed throughout the United States—about one-third east of the Mississippi River, one-third in the interior, and one-third in the northern Great Plains, Rocky Mountains, and Gulf and Pacific coast areas. At the present rate of consumption these reserves will last for more than 1,200 years.

Coal is extracted from the earth by underground and strip mining. Modern mechanized mining has achieved higher productivity and efficiency, greater safety for miners, and a minimum of hard labor. Coal may be burned for heat in homes or to generate electrical power, gasified for industrial or residential use, or coked for metallurgical purposes. The byproducts of coking—gas, tar, and light oils—can be used as such or processed to serve as raw materials for the chemical industry.

The coal industry reached its peak production of over 630 million tons in 1947. The decline in production since that time is a result of competition from oil and gas in the energy market. The U.S. energy requirements are rapidly expanding, and it is likely that greater amounts of coal will be required in the near future. Many new uses for coal have recently been developed, including the conversion to liquid and gaseous fuels, and it is likely that these new uses will require increased coal production.

There are no commercial deposits of coal in Nevada, although attempts have been made to mine low-grade deposits associated with lake deposits of Tertiary age. As shown on figure 15, deposits of this type are found near Coaldale, Esmeralda County; south of Elko, Elko

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Mississippian to Permian rocks

During and following mountain building (Antler orogeny, p. 56) that lasted from Late Devonian to Early Pennsylvanian time, great thicknesses of detrital sediments were laid down in central and eastern Nevada. These sediments overlap the (mountain-building) belt and flanking older beds, and have been called the overlap assemblage (Roberts and others, 1958) (fig. 8).

In the area around Eureka (Nolan and others, 1956), in the Chainman-Diamond Peak trough, these total about 7,000 feet in thickness; eastward they thin and grade into finer sediments that are about 1,000 to 2,000 feet thick near the Utah State line. During this period of mountain building detrital sediments were also deposited in western Nevada, where they aggregate 10,000 feet or more in thickness in the Pumpernickel-Havallah basin.

By Middle Pennsylvanian the Antler orogenic belt had been largely eroded, leaving only a few islands projecting above the sea. In Late Pennsylvanian and Early Permian even the islands had disappeared, and limestone was being deposited over much of Nevada. In Late Permian, uplift and mountain building in western Nevada began again and culminated in a movement of another major thrust plate eastward onto the roots of the Antler orogenic belt. This younger period of mountain building, the Sonoma orogeny, also resulted in a flood of coarse clastics into the marine waters that still covered eastern Nevada (Silberling and Roberts, 1962). At the end of Permian time much of eastern and central Nevada was uplifted just above sea level. Uplift was not sufficient to cause deep erosion, though erosion may have been locally significant.

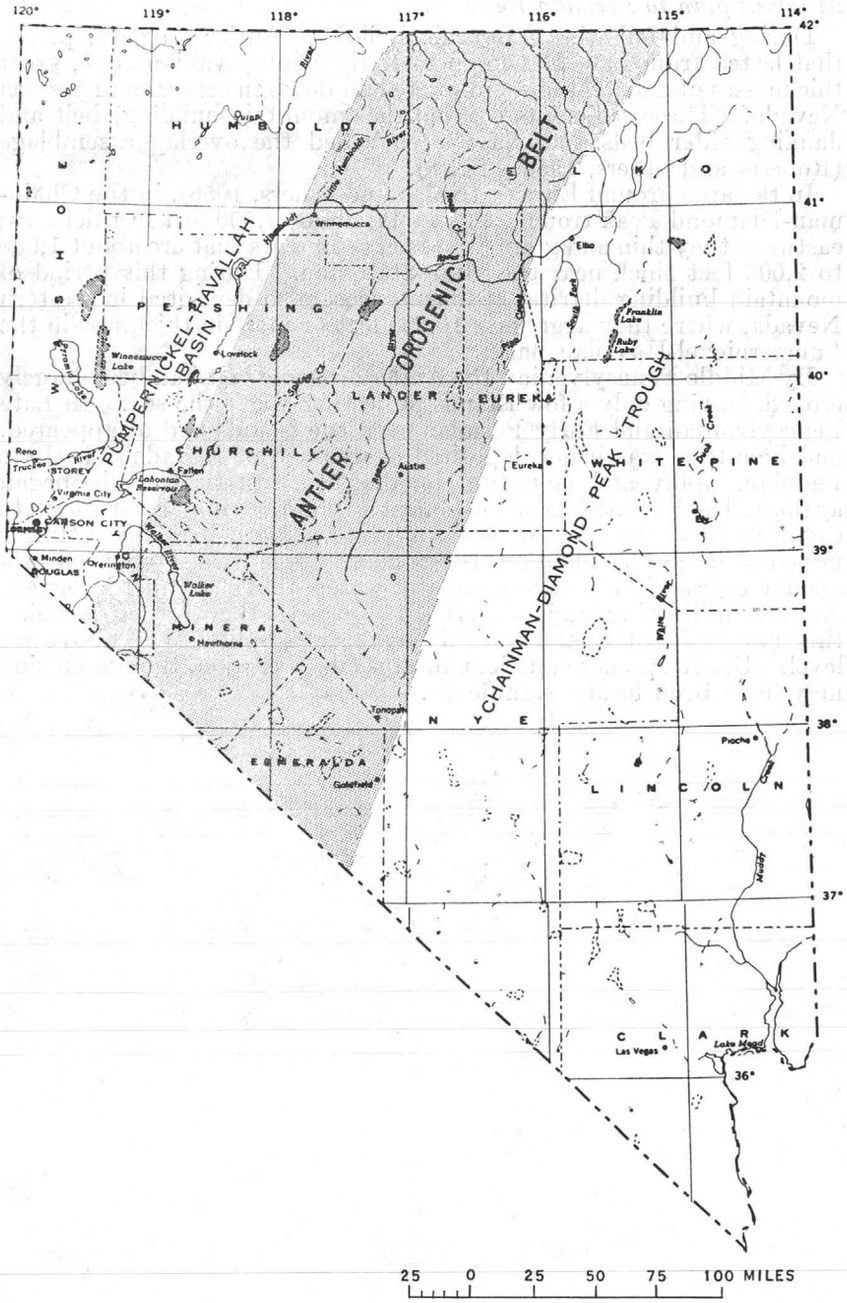

FIGURE 8.—Inferred extent of Antler orogenic belt and flanking basins in Nevada during Mississippian and Pennsylvanian time.

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veins along faults (Ketner, 1963). Some replacement deposits contain significant tonnages and have excellent future potential.

Clay deposits in Nevada are widespread, and include ceramic, filter, and specialty clays. Past production has been small, but reserves in several deposits of kaolinite and bentonite are large and future production may be significant. Diatomite is one of the principal nonmetallic commodities produced in Nevada. The diatomitl deposits were formed in fresh-water lakes and many are of high purity.

Dimension stone production in Nevada has been relatively small. Flaggy sandstones have been quarried in southern Nevada, and volcanic tuffs in northern Nevada. These operations are presently hampered by high haulage costs, but as Nevada's population grows, increased local use is likely. Sand and gravel deposits constitute one of Nevada's inexhaustible resources. Gravels along streams in western Nevada and fans in central and eastern Nevada will furnish adequate supplies for future needs.

Fluorspar deposits are scattered throughout western Nevada, but production has been small.

Turquoise is the principal gem mineral found in Nevada. Production from deposits in Esmeralda, Nye, Eureka, and Lander Counties has been significant and at times has dominated the U.S. market. Opal has been produced in northern Nevada from Tertiary beds in the Virgin Valley.

Gypsum production in Nevada during recent years has been significant, and is gradually increasing. Reserves are large, especially in southern Nevada, but production is hampered by high haulage costs.

Refractory silicates produced in Nevada include dumortierite (aluminum borosilicate) and pinite (muscovite and pyrophyllite). During recent years production of these minerals has been small, as cheaper synthetic substitutes have been found.

Reserves of magnesite, which occur as replacement deposits in dolomite near Gabbs, are large. Sedimentary magnesite deposits are also found near Currant and Overton. Limestone for cement and lime is widespread and abundant in Nevada. Dolomite of good quality is also abundant.

Pegmatites in Clark and Elko Counties have been explored for feldspar, mica, and beryl. Feldspar production has been small, the mica is mostly scrap quality; the beryl has been low grade. Deposits of phenacite at Mount Wheeler are potentially significant.

Silica has been mined in Nevada principally for glass and foundry sand. Reserves of high-purity sand are small, but quartzite is widespread and adequate for future silica needs. Sulfur occurs at several localities in western Nevada and in Tertiary beds and in spring deposits; the bodies thus far found have been relatively small, and only a few tons have been mined and shipped. Talc pods in dolomite in southwestern Nevada has been mined on a small scale for many years; the future potential for increased production is not promising. A vermiculite deposit in southern Nevada has been intermittently worked and a small tonnage shipped; others are known but not yet evaluated.

Nevada ranks second in the United States in perlite production. The principal deposits are in Pershing and Lincoln Counties and appear to have ample reserves for the foreseeable future. The outlook is good for increasing use of perlite in deposits near centers of population.

Mesozoic Rocks

(By N. J. Silberling, U.S. Geological Survey, Menlo Park, Calif.)

Mesozoic strata are sporadically and unevenly distributed in Nevada and are extremely diverse in character. Mesozoic time (from about 230 to 65 million years ago) is subdivided from oldest to youngest, into the Triassic, Jurassic, and Cretaceous periods, and though the record is fragmentary and, for the later part of Mesozoic time, quite incomplete, each of these major subdivisions is at least partly represented in Nevada by sedimentary and volcanic rocks. The nature and geographic distribution of these rocks closely reflect the tectonism, or crustal instability, that with varying intensity was active in the region throughout the 165-million-year duration of Mesozoic time. During the early Mesozoic crustal instability was generally limited to gentle uplifting or subsidence affecting large portions of the region more or less uniformly. These events took place independently, and to some extent alternatively, on either side of a belt trending somewhat east of north through the middle of Nevada, and thus the record of subsidence, marine transgression, and sedimentation in northwestern Nevada differs from that in the southern and eastern parts of the State. More intense tectonism in the form of orogenic, or mountain building deformation affected the region beginning in Jurassic time and continuing in one place or another during the rest of the Mesozoic. The strata deposited earlier were uplifted and eroded away from large parts of the area they originally blanketed, and renewed deposition was restricted to the local accumulation of land-laid volcanic rocks and the sedimentary filling of ephemeral, nonmarine, orogenic basins. On the basis of this brief historical review, the Mesozoic strata of Nevada are described below in three parts: the lower Mesozoic of northwestern Nevada, the lower Mesozoic of eastern and southern Nevada, and widely scattered upper Mesozoic stratified rocks.

Lower Mesozoic of northwestern Nevada.—Lower Mesozoic strata are widely exposed in northwestern Nevada west of the 118th meridian and north of the 38th parallel. The oldest of these are mainly altered volcanic rocks whose scattered exposures represent the final stages of what is thought to have been a single episode of largely submarine volcanism during the Late Permian and earliest Triassic. The principal outcrops of these old volcanics are in eastern Pershing County (Koipato Group), northwesternmost Nye County (Pablo Formation), and eastern Mineral County (Excelsior Formation). These rocks are characteristically heterogeneous and include more or less altered volcanic tuffs, breccias, and flows, of both siliceous and mafic composition, and much volcanic-derived sedimentary material. What proportion of these were deposited just after the beginning of Mesozoic time, and what proportion just before, is generally indeterminate, but their total thickness may exceed 10,000 feet in places. These are the host rocks for a number of quartz vein mineral deposits, notable examples of which are the silver deposits of the Rochester district in the Humboldt Range.

Deposition of these Permian and Triassic volcanic rocks was followed by a period of gentle uplift, tilting, and erosion in northwestern Nevada, after which marine sedimentation was resumed

near the beginning of the Middle Triassic and continued through Early Jurassic time. The Triassic and Lower Jurassic strata so formed are now found in isolated and structurally jumbled exposures, but they originally formed a thick, laterally and vertically continuous body of rocks. Their present outcrops still roughly delimit the eastern and southern extent into Nevada of the marine basin in which they accumulated. Although more than two dozen different formations have been established to express the complex variety among these rocks, some larger and more generalized lithologic subdivisions can be recognized among them.

The sections exposed in westernmost Nevada, closest to California and the Sierra Nevada, include a large proportion of altered volcanic rocks. Owing in part to metamorphism by igneous intrusion, their composition and stratigraphy is not well known, but they are correlative, and in some places can be seen to interfinger, with nonvolcanic Middle and Upper Triassic strata farther east in northwestern Nevada. Thick sections of this volcanic facies of the Lower Mesozoic are exposed in Douglas, Lyon, and Mineral Counties.

The more eastern, nonvolcanic facies of the Lower Mesozoic in northwestern Nevada comprises mainly shallow-water marine sedimentary rocks, but the lower and upper parts of this succession are significantly different. The lower part is mainly composed of carbonate rock, whereas argillaceous and sandy rocks form most of the stratigraphically higher parts. Deposition of the marine carbonate rocks at the base of this succession began at different times within the Middle and Late Triassic reflecting transgression of the sea eastward and southward into northwestern Nevada. Except for local basal conglomerate and subordinate amounts of noncalcareous clastic rocks derived from adjacent land areas, this part of the section is mainly relatively pure limestone and dolomite. These rocks are formed in large part of the shells and broken-up calcareous hard parts of marine organisms that accumulated on slowly subsiding banks and shoals to thicknesses of several thousand feet in places. Most of the exposures of these carbonate rocks are in a belt a few tens of miles wide extending from eastern Pershing County (e.g., Star Peak Group) south to eastern Mineral County (e.g., Luning Formation). Among the variety of limestone replacement ore deposits found in these rocks are the extensive magnesite deposits near Gabbs in the Paradise Range.

Deposition of the argillaceous and sandy rocks that characterize the higher parts of the Lower Mesozoic in northwestern Nevada began abrubtly during the Late Triassic and continued into Early Jurassic time. Though some of these rocks are calcareous, and limestone, or more rarely, gypsum is interbedded with them in places. Argillaceous rocks with some siltstone and sandstone predominate in contrast to the underlying thick sections of relatively pure carbonate rocks. The thickest and least calcareous sections of these predominantly argillaceous rocks (e.g., the Grass Valley and overlying formations) crop out in eastern Humboldt County and central Pershing County where their original thickness probably exceeded 20,000 feet. In most places they have been altered to argillites, slates, and phyllites by low-grade metamorphism. Farther south, in northwestern Nye County and eastern Mineral County, the corresponding sections are more calcareous and thinner (e.g., the Gabbs and Sunrise Formations), though

base metal deposits in northwest-trending belts, and the sygenetic manganese deposits of northern Nevada in the north-south belt, extending from Winnemucca to Austin, occur mostly in rocks of siliceous and volcanic facies.

Two inferred east-west belts on figure 13 are named the Cherry Creek and Pioche belts. The Cherry Creek contains the Cherry Creek (tungsten, silver), Aurum (gold, lead, copper, zinc), and Granite (gold, copper, lead, zinc) districts. The Cherry Creek belt extends into Utah, where it coincides with the Deep Creek-Tintic mineral belt (Hilpert and Roberts, 1964). The Pioche belt contains the Delamar (gold, silver), Pioche (zinc, lead, silver, manganese), and Tempiute (tungsten); it extends into Utah where it coincides with the southern part of the Wah Wah-Tushar belt.

Deposits within the mineral belts as indicated in figure 13 account for more than 95 percent of the production of copper, lead, zinc, gold, and silver in Nevada. In addition, they also account for most of the molybdenum, largely from copper ore in the Robinson (Ruth) district at Ely; much of the tungsten, principally from the Nevada-Massachusetts, and Osgood districts; almost all the minor metals such as arsenic, bismuth, cadmium, platinum, selenium, and tellurium that are recovered as smelter byproducts; and most of the antimony deposits in western Nevada.

Inasmuch as the mineral belts contain most of the principal mining districts, it seems that the belts should be the best places to look for new ore deposits. In exploration for a certain commodity one should be certain he is in favorable terrain. Nolan (1952) has emphasized that concealed areas adjacent to major districts may be good places to explore. Roberts (1960, 1964) has suggested that geophysical and geochemical methods be used as tools to further pinpoint exploration targets along the mineral belts. Not all geophysical anomalies are associated with ore deposits, but these are generally the best places to start the search. Geochemical sampling in areas of geophysical anomalies may outline favorable areas for further exploration.

Nonmetallic Deposits

Nonmetallic deposits including salines, clays, building stone and gravel, diatomite, perlite, limestone, and sulfur have contributed a small but significant production to Nevada's mineral industry. With increasing population and improvements in transportation, deposits of these minerals will play more important roles in the future.

Saline deposits that offer future potential include borate deposits in Clark and Esmeralda Counties (Hewett and others, 1936). These deposits are mostly colemanite (calcium borate) and ulexite (sodium and calcium borate) which cannot compete with borax deposits in California at present, but ultimately may be worked. Sodium carbonate, sulfate, and chloride are in places associated with borax in playas and also occur in bedded deposits of Cenozoic age. Several deposits have been operated on a small scale. The source of the salines was ultimately hot springs associated with volcanism; favorable areas are mainly in southwestern Nevada.

The barite deposits in northern Nevada are of two types, replacements of limy beds in the western siliceous and volcanic facies, and

of the eastern province. The association at Buckhorn of gold peripheral to the Cortez base metal deposits may reflect either zoning of metals, metallization at different times, or a combination of these two factors.

Another major belt is the Virginia City-Tonopah (fig. 13), which contains major gold, silver, and copper districts. This belt has been long recognized as a metallogenic belt (Billingsly and Locke, 1941; Albers, 1963) related to the Walker Lane, a northwest-trending structural feature that has been active for a long time. Districts along the belt include: Goldfield (gold-silver), Tonopah (silver-gold), Aurora (gold-silver), Silver Peak (gold-silver), Candelaria (silver-gold-copper), and Virginia City (silver-gold). The belt probably also extends northwestward into California and may include the copper-gold deposits of the northern Sierra Nevada.

Other possible but less clearly defined, parallel or subparallel, northwest-trending belts (fig. 13) in Nevada that also contain significant ore deposits are the Lynn-Railroad, Lovelock-Austin, Ely, and Fallon-Manhattan. The Lynn-Railroad belt is coincident with the Carlin and Lynn windows; it contains the following districts: Lynn (gold-turquoise), Railroad (silver-lead-copper), Gold Circle (gold), and Carlin (gold). Neither Carlin nor Lynn has yielded significant production to date, but exploratory work was being carried on in both districts in 1962–63 and the outlook for future gold production is promising. The Lovelock-Austin belt includes the following districts: Austin (silver-gold), Unionville, Rochester, and nearby gold-silver districts, the Sutherland and many other antimony deposits in the West Huboldt Range and the Seven Troughs. The Ely belt contains the Robinson district (copper, gold, lead, zinc) and the Minerva district (tungsten). The Fallon-Manhattan belt includes the Rawhide and Gabbs (tungsten), other districts in northwestern Nye County and southern Churchill County, the Manhattan (gold-silver) district, and Tybo district.

Metallogenic belts of other trends have also been noted. A northeast-trending copper belt that extends from Yerington to Mountain City appears to be significant; between these extremities the Antelope, Battle Mountain, and a host of lesser districts have been plotted by Horton and others (1962). Major barite deposits also follow a northeast belt (Horton, 1962), apparently parallel to facies trends in the upper plate of the Roberts Mountains thrust fault. Major iron ore deposits in central Nevada follow a general N. 70° to 75° E. trend from Yerington to Lovelock, thence through the Cortez Mountains (fig. 12). This belt roughly parallels and may be related to the east-west metallogenic belts recognized by Hilpert and Roberts (1964) in Utah. Individual iron deposits near Lovelock appear to be alined northwest along the Lovelock-Austin belt; iron deposits in the Jackson Mountains lie between the Lovelock-Austin and Battle Mountain-Eureka belts. Many mercury deposits lie within the belts as shown in figure 12, but Bailey and Phoenix (1944) and Lawrence and Wilson (1962) show that as a group, the mercury deposits tend to lie in a northward-trending belt that parallels the boundary between the eastern and western metallogenic provinces. The manganese deposits belong to several genetic types and do not give a clear-cut pattern. M. D. Crittenden (oral communication, 1964) indicates that the hydrothermal manganese deposits are mostly associated with

still on the order of thousands of feet thick. These rocks are thought to have resulted from the introduction of vast amounts of mud into the marine basin by a major Upper Triassic and Lower Jurassic stream system draining from the continental areas to the east. Deltaic deposits were formed as the mouth of this ancient stream system migrated back and forth along the shoreline in north central Nevada, and large amounts of fine-grained sediment were also spread throughout the shallow marine embayment in northwestern Nevada by oceanic currents. Associated with these argillaceous, silty, and sandy rocks are a variety of mineral deposits, the most important of which, like the scheelite deposits near Tungsten and the quicksilver deposits of the Pershing district, commonly occur in the more calcareous parts of the section.

In eastern Mineral County and northwestern Nye County the Lower Mesozoic marine section is overlain either conformably or with strong angular discordance by a heterogeneous assortment of conglomerate, nonmarine sandstone, and volcanic rock (Dunlap Formation) of Early and Middle Jurassic age which documents the beginning of Mesozoic orogeny in western Nevada.

Lower Mesozoic of eastern and southern Nevada.—In eastern and southern Nevada, as compared with northwestern Nevada, lower Mesozoic strata are less widely exposed, even though at one time they evidently blanketed much of the area. The most extensive and complete lower Mesozoic exposures from a discontinous belt trending northeasterly through Clark County into southeastern Lincoln County. Farther north in eastern Nevada widely scattered and isolated patches of related rocks occur in northern White Pine County and eastern Elko County.

The oldest of these rocks are calcareous strata deposited during the latter part of Early Triassic time in an elongate, shallow, inland sea that extended from the area of the middle Rocky Mountains southward across western Utah, eastern and southern Nevada, and perhaps through southeastern California. In northeastern Nevada these rocks consist mainly of calcareous shale and siltstone and impure limestone, and the more complete sections of them may exceed 2,000 feet in thickness. In southern Nevada the genetically related rocks (Moenkopi Formation) are also limestone and impure calcareous strata, but they include gypsiferous beds, and especially in the higher parts of the section, they intertongue southeastward with nonmarine red beds. These Lower Triassic rocks were the last marine strata to be deposited in eastern and southern Nevada; the overlying Upper Triassic and Lower Jurassic rocks, where present, are continental deposits like those that characterize the Colorado Plateaus region of Arizona, Utah, and New Mexico.

In southern Nevada these lower Mesozoic nonmarine rocks have been assigned to the Chinle and Aztec Formations. The Chinle Formation, as the name is presently used in this area, includes lacustrine and fluviatile deposits of bentonitic claystone, siltstone, and sandstone which locally aggregate more than 3,000 feet in thickness. A pebbly sandstone in the lower part of the Chinle resembles the Shinarump Member—a well-known unit in Utah and Arizona because of the uranium deposits associated with it. The Shinarump, the oldest of these continental rocks, is commonly dated as Late Triassic, but slow accumulation during most of Middle Triassic time has been

suggested by some authorities. The Aztec Sandstone, equivalent to the Navajo Sandstone of the Glen Canyon Group on the Colorado Plateaus, is a massive, eolian, or wind-deposited sandstone as much as 2,000 feet thick. It is probably Jurassic in age, and is the youngest part of this conformable succession of lower Mesozoic strata.

Nonmarine strata similar to the Chinle and Aztec Formations crop out to the north only in one small area in southeastern Elko County, but their presence here demonstrates that a large part of eastern Nevada was at one time covered by these fluviatile and eolian deposits.

Upper Mesozoic.—Strata of Late Jurassic(?) and Cretaceous age crop out in widely separated parts of Nevada and seem not to reflect any integrated pattern of deposition.

Volcanic rocks, probably land laid and of Late Jurassic or Early Cretaceous age, are known in Douglas County and in northern Eureka County. Heterogeneous nonmarine sedimentary rocks of Early Cretaceous age occur in the Jackson Range (King Lear Formation) in Humboldt County, and near Eureka (Newark Canyon Formation) in the central part of the State, and rocks of late Cretaceous age occur in Clark County (Willow Tank Formation) far to the south. These include both conglomerate and finer grained detrital rocks as well as lacustrine limestone, all of which evidently accumulated in local basins formed during the deformation of the region. Thick deposits of nonmarine sandstone and conglomerate (Baseline Sandstone) in the Muddy Mountains of southern Nevada were evidently derived directly from a local topographic highland during the Late Cretaceous. Other, as yet unrecognized, occurrences of upper Mesozoic volcanic rocks, coarse clastic sedimentary rocks, and lacustrine deposits are to be expected in Nevada.

Tertiary and Quaternary Rocks

(By J. P. Albers, U.S. Geological Survey, Menlo Park, Calif.)

As a consequence of the great period of mountain building during Mesozoic time, Nevada was elevated well above sea level and has not again been covered by marine waters. A profound unconformity separates the Tertiary from older rocks, and the Tertiary and Quarternary Periods are represented exclusively by terrestrial sedimentary rocks and by volcanic rocks erupted from numerous centers. The sequence of rocks thus differs greatly from place to place, and a statewide correlation of individual rock units or groups of rock units is not possible, and correlation over an area of only a few hundred square miles is commonly unsatisfactory. An exception are some of the welded tuff units in eastern Nevada which may correlate over areas as large as 5,000 to 10,000 square miles.

Although exact correlations of Tertiary units throughout Nevada are not yet possible, a summary of major Tertiary events is presented here, based on recent reconnaissance mapping, coupled with intensive study of ash flow tuff units in some areas and radiometric age-dating in scattered localities.

The oldest rocks generally recognized as Tertiary throughout Nevada are conglomerates and breccias made up of fragments of pre-Tertiary rocks. In most areas these coarse clastics are overlain with marked angular unconformity by younger rocks and cannot be

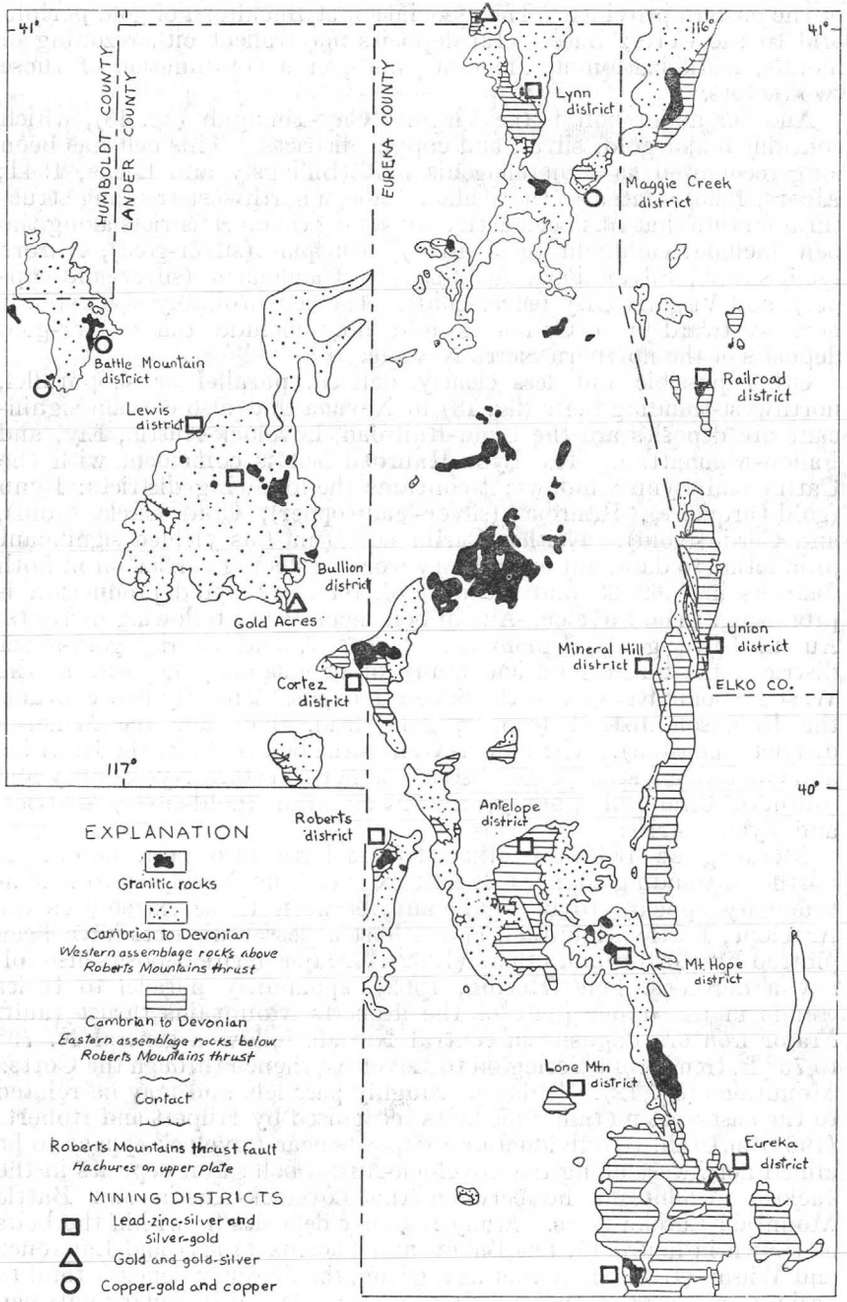

Figure 14.—Alinement of mining districts in the Battle Mountain-Eureka and Lynn-Railroad mineral belts.

Mesozoic siliceous and volcanic rocks and Tertiary volcanic rocks. On the other hand, eastern Nevada is underlain largely by Precambrian metamorphic and sedimentary rocks and Paleozoic carbonate rocks locally covered by Tertiary volcanic rocks (Nolan, 1943, 1962).

These differences in rock types of western and eastern Nevada must reflect fundamental differences within the crust, which are further reflected in the distinctive metal suites of the two areas. Western and eastern Nevada accordingly are two distinct metallogenic provinces (see fig. 12); western Nevada contains the major gold, silver, tungsten, antimony, mercury, and iron deposits thus far discovered (Ferguson, 1944; Nolan, 1950). Eastern Nevada contains the major lead and zinc deposits with associated gold and silver deposits.

The division between the two provinces is not a sharp line, but rather a broad transitional zone that follows along the 117° meridian in southern Nevada, and swings northeastward to the 115° meridian in the northern part of the State (fig. 12). Deposits within the transitional zone include representatives of both provinces; likewise, in eastern Nevada, the base metal deposits are ringed by precious metal and antimony zones. Major copper deposits may be found in both provinces; evidently copper is not so directly related to crustal rock type but may be derived from sources below the crust within the mantle. The sources of metals and their mode of transport upward are yet not clearly understood.

Within the two metallogenic provinces in Nevada, regional structural and lithologic controls were important in localizing districts and ore bodies. On figures 13 and 14 it appears that a number of districts are localized along northwest and northeast trends. These mineral belts in Nevada have been discussed briefly by Roberts (1957, 1960). One extends from Battle Mountain to Eureka; along this belt (Roberts, 1960, p. 18) detailed mapping has shown that the major ore bodies occur in windows of carbonate rocks through the upper plate of the Roberts Mountains thrust and in association with intrusive rocks (fig. 14). The windows represent domal uplifts that began in the Pennsylvanian and were accentuated during intrusive activity in Mesozoic or early Tertiary time. The northwest alinement of windows and associated ore deposits suggests some major structural control for both the domal uplifts and mineral belts. Except for the arching, no displacement is noted along the belt; moreover, the Paleozoic and Mesozoic facies do not seem to be displaced along the belts and it is therefore inferred that the belts are ancient structural features that may be of Precambrian age.

Metallization along the belts varies considerably in type and kind. In the Battle Mountain-Eureka belt, for example, ore deposits in the Osgood Mountains area, 35 miles northwest of Battle Mountain, include gold, mercury, and tungsten deposits; at Battle Mountain, copper, gold, and lead-zinc-silver deposits; at Cortez, silver, lead, and zinc deposits, and at the Buckhorn district, 6 miles east of Cortez, gold deposits (Vanderburg, 1938; H. Masursky, oral communication, 1963). These occurrences may reflect zoning of metals, different metallogenic provinces, metallization at different times, or different levels of erosion. The tungsten and mercury deposits in the Osgood Mountains are characteristic of the western metallogenic province; the silver-lead-zinc deposits at Battle Mountain and Cortez are characteristic

more closely dated than simply "early Tertiary." An exception is the breccia that forms the lower unit of the Sheep Pass Formation in White Pine County. This breccia is overlain conformably by fine-grained sedimentary rocks containing fossils of Eocene age (Winfrey, 1960, p. 126). Based on their stratigraphic position and lithologic similarity to the breccia of the Sheep Pass Formation, the basal Tertiary conglomerates and breccias exposed elsewhere in the State are also presumed to have formed mainly during Eocene time but may actually range from Late Cretaceous to early Oligocene.

The earliest Tertiary volcanic rocks were andesitic flows erupted during latest Eocene or very early Oligocene time, and the volcanoes from which these flows came were in Elko, northeastern Nye, and White Pine Counties. Shortly thereafter, in the same regions, great sheets of rhyolitic to dacitic ash flows were erupted. Most of these ash flows are welded, and one of the oldest gives a potassium-argon age of 39 million years, or very early Oligocene. Other welded tuffs in eastern Nevada give potassium-argon ages ranging from 29 to 36 million years. Some granitic rocks were also emplaced at this time. Locally sedimentary beds are interlayered with this volcanic material. It therefore appears that the bulk of deposits formed during the Oligocene were ash flow sheets, some having a lateral extent of 5,000 to 10,000 square miles according to unpublished data of E. F. Cook. Southern and western Nevada were presumably undergoing erosion while this volcanism was going on in eastern Nevada.

During late Oligocene or very early Miocene time volcanic activity began in the western and northern parts of the State. The principal products initially were rhyolitic ash flows and lava flows, giving rise to such units as the Hartford Hill Rhyolite. Later, andesite and dacite lava flows were erupted, chiefly in northwestern Nevada. At the same time sedimentary formations such as the Horse Spring were being deposited in the extreme southern part of the State, while volcanism in eastern Nevada, where so much volcanic activity was going on during the Oligocene, seems to have been more or less dormant; eastern Nevada was probably undergoing erosion during much of the Miocene. It is also worth noting that the Nevada Test Site area in southern Nye County seems to have experienced neither volcanism nor sedimentation until well along in the Miocene; the oldest Tertiary deposit there, excepting local patches of Eocene conglomerate and limestone, is a welded tuff with a K-Ar (potassium-argon) age of a little more than 16 million years.

The great volcanic activity of Oligocene and early Miocene time apparently was accompanied or shortly followed by much block faulting, thereby producing a landscape of considerable relief and containing many basins which became the sites of lakes during late Miocene and early Pliocene. These lakes, which were present throughout much of the State except the southern part, received large quantities of sediment, giving rise to formations known locally as the Esmeralda, Truckee, and Humboldt. A number of K-Ar ages recently published by Evernden and others (1964) support a substantial amount of paleontologic evidence that the bulk of this sedimentation took place between 8 and 13 million years ago, during the same time that extensive ash flows were being erupted from huge calderas in southern Nye County.

After the main period of Miocene and Pliocene lacustrine and fluviatile sedimentation, renewed volcanism occurred in much of the northern and western parts of the State, giving rise to additional ash flow deposits in some areas, and to thick andesite and dacite flows in others. Lenses of sedimentary rocks, mostly of small areal extent and commonly including diatomite beds, are interlayered with the volcanics in many places. In Clark County the sedimentary Muddy Creek Formation was formed between eruptions of basaltic rocks. Volcanic activity all but came to an end in late Pliocene and early Pleistocene when basaltic rocks were erupted in many parts of the State. Fanglomerates, fluvial gravels, and deposits of glacial Lake Lahontan were formed in many basins, and morainal deposits accumulated on the flanks of the higher mountains during the Pleistocene. Finally, unconsolidated desert alluvium, and locally sand dunes, deposited by wind and water since the Pleistocene, now largely obscure the older rocks in the valleys of Nevada.

Igneous Intrusive Rocks

(By R. R. Coats, U.S. Geological Survey, Menlo Park, Calif.)

Intrusive igneous rocks comprise a large part of the bedrock in westernmost Nevada. Between Reno and Hawthorne, they are nearly continuous and form an eastward extension of the Sierra batholith. Smaller areas are exposed in the northwestern quarter of the State, and additional bodies there may be concealed beneath a cover of Tertiary and Quaternary rocks.

The bulk of these intrusives are of Mesozoic age; a number are known to be Tertiary in age, and a few are Precambrian or Paleozoic. The intrusives range in composition from granite to quartz diorite; the predominant types are granodiorite and quartz monzonite.

The Mesozoic igneous intrusives, which range in age from 80 to 140 million years, are best exposed in western Pershing and Washoe Counties; farther east, in Humboldt and Elko Counties, the intrusive bodies are smaller, presumably the level of post-Mesozoic erosion is shallower to the east.

Several intrusives of Cenozoic age have been found in Humboldt, Eureka, and Elko Counties. Some are porphyries with a fine-grained, dense groundmass; others are porphyritic quartz monzonites, and granodiorites, indistinguishable from the Mesozoic intrusives. Ages in the range of 36 to 40 million years have been found, but younger intrusives may be found. The textural differences may reflect differences in the height to which the intrusions ascended in the crust.

STRUCTURAL EVOLUTION

(By R. E. Wallace, U.S. Geological Survey, Menlo Park, Calif.)

Nevada is characterized by extremely complex geologic structures as a result of superposition, one upon the other, of several periods and types of deformation. The peculiar alternation of elongate mountain masses and intervening flat valleys which characterizes the Basin and Range province reflects a late chapter in the structural evolution of

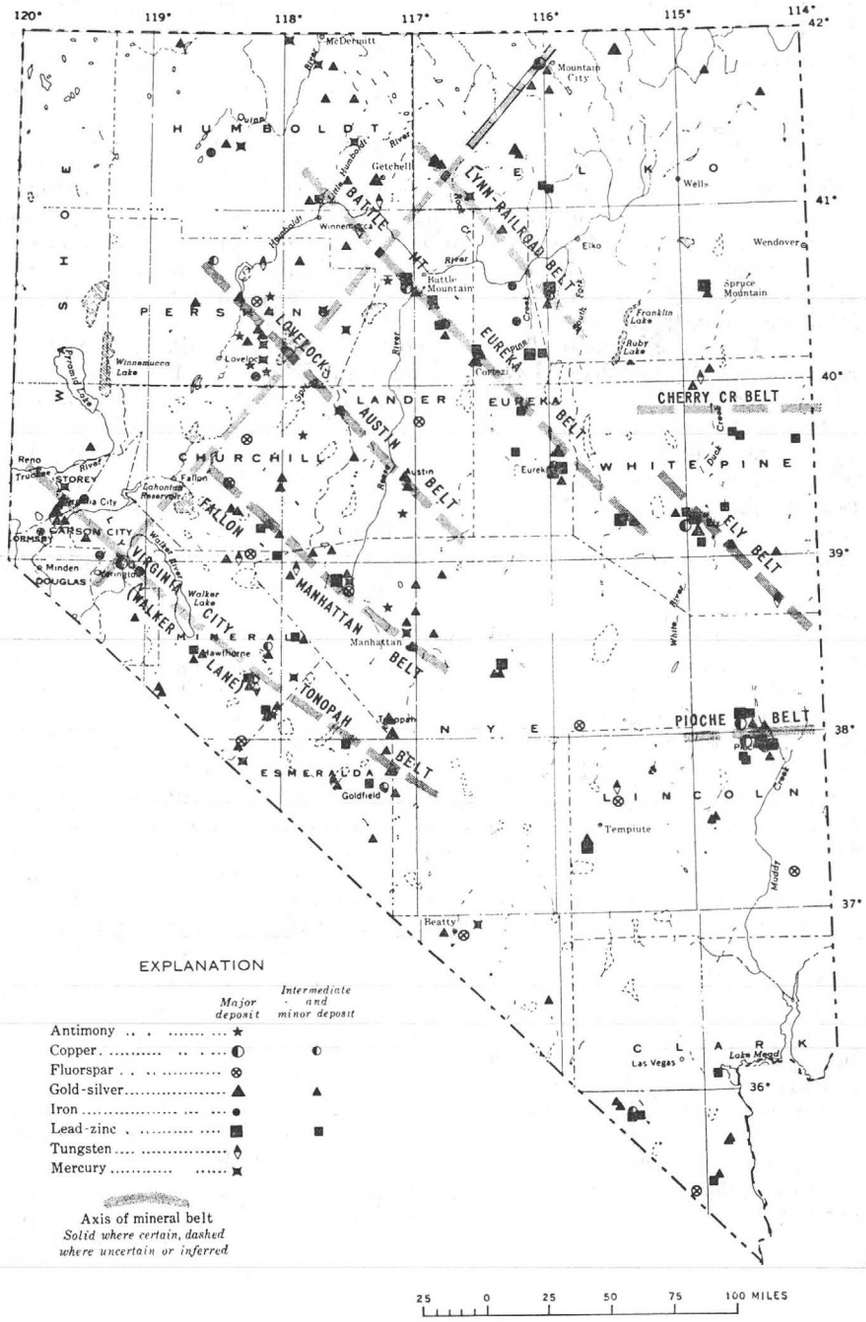

Figure 13.—Mineral belts and deposits in Nevada.

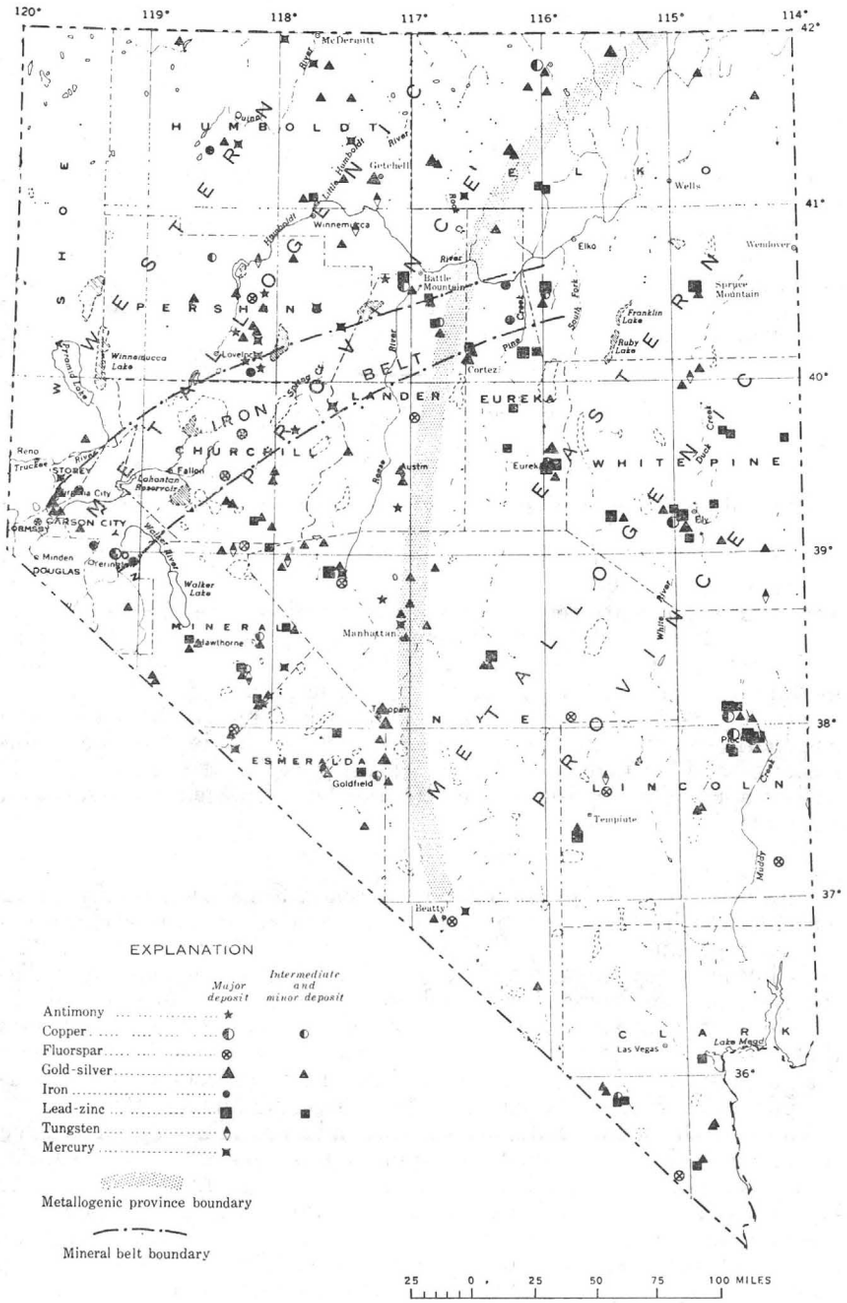

FIGURE 12.—Metallogenic provinces and mineral deposits in Nevada.

Nevada, but long before these so-called block mountains were formed, the rocks of the region were crumpled and folded and great slabs of the earth's crust moved as much as 90 miles across other parts of the crust. Deciphering this complex history is essential if we are to understand the distribution of mineral resources and to search successfully for new resources.

Structural history through early Cenozoic time.—Relatively little is known about the earliest part of geologic time in Nevada, because rocks of Precambrian age are exposed only in a few ranges in eastern and southern Nevada. Even from this small sample, however, it is clear that sediments had been deposited in ancient seaways, then lithified and subsequently altered to quartzite, gneiss, and schist before the Paleozoic Era began.

The first part of the Paleozoic Era (from about 350 to 550 million years ago) saw the deposition across the State of tremendous volumes of marine sedimentary rocks in a broad north-northeast trending trough called the Cordilleran geosyncline. In gross pattern, limestone and dolomite, with minor amounts of quartzite and shale, were deposited in a belt covering the eastern part of the State while at the same time siliceous rocks, including chert, shale, and silty sandstone, and volcanic rocks were being deposited in the western part of the State. The carbonate rocks were deposited in a Continental Shelf environment, while the siliceous and volcanic rocks were deposited farther from the continental margin, probably adjacent to an archipelago of volcanic islands. Between the two assemblages, rocks of both types interfinger in a transitional assemblage. The continental shoreline during the Paleozoic Era lay generally to the east of Nevada.

Sedimentation persisted in these three belts throughout the first half of the Paleozoic Era until the end of the Devonian Period (about 350 million years ago) when a north-northeast-trending, elongate welt began to rise medially across the State. Within this welt, the so-called Antler orogenic belt (Roberts and others, 1958, p. 2850), rocks became sharply deformed and the great Roberts Mountains thrust developed (see fig. 9), along which masses of siliceous and volcanic rocks rode eastward at least 90 miles over carbonate rocks. There are suggestions that the thrust mass moved, possibly by gravity sliding, in great lobes, first one part moving eastward for awhile, then another; the toes of at least some lobes were submerged in seas at their leading edges.

While the submerged leading edge of the thrust lobes were being blanketed by wedges of sediments, higher parts to the west were being subjected to erosion. Not until Middle Pennsylvanian time (about 290 million years ago) was the welt subdued to a degree that sediments could again be deposited widely across its axis. For example, at Antler Peak beds of conglomerate named the Battle Formation (of Middle Pennsylvanian age) are found deposited across eroded edges of deformed strata of the siliceous and volcanic rocks and of the transitional rocks.

Another period of deformation appears to have occurred in the Permian Period (about 250 million years ago) in north-central Nevada and has been named the Sonoma orogeny (see fig. 10) (Silberling, and Roberts, 1962) but little is known of the total area effected, although to judge by the sharply discordant structures that were produced, it must have been a period of drastic deformation. The Golconda

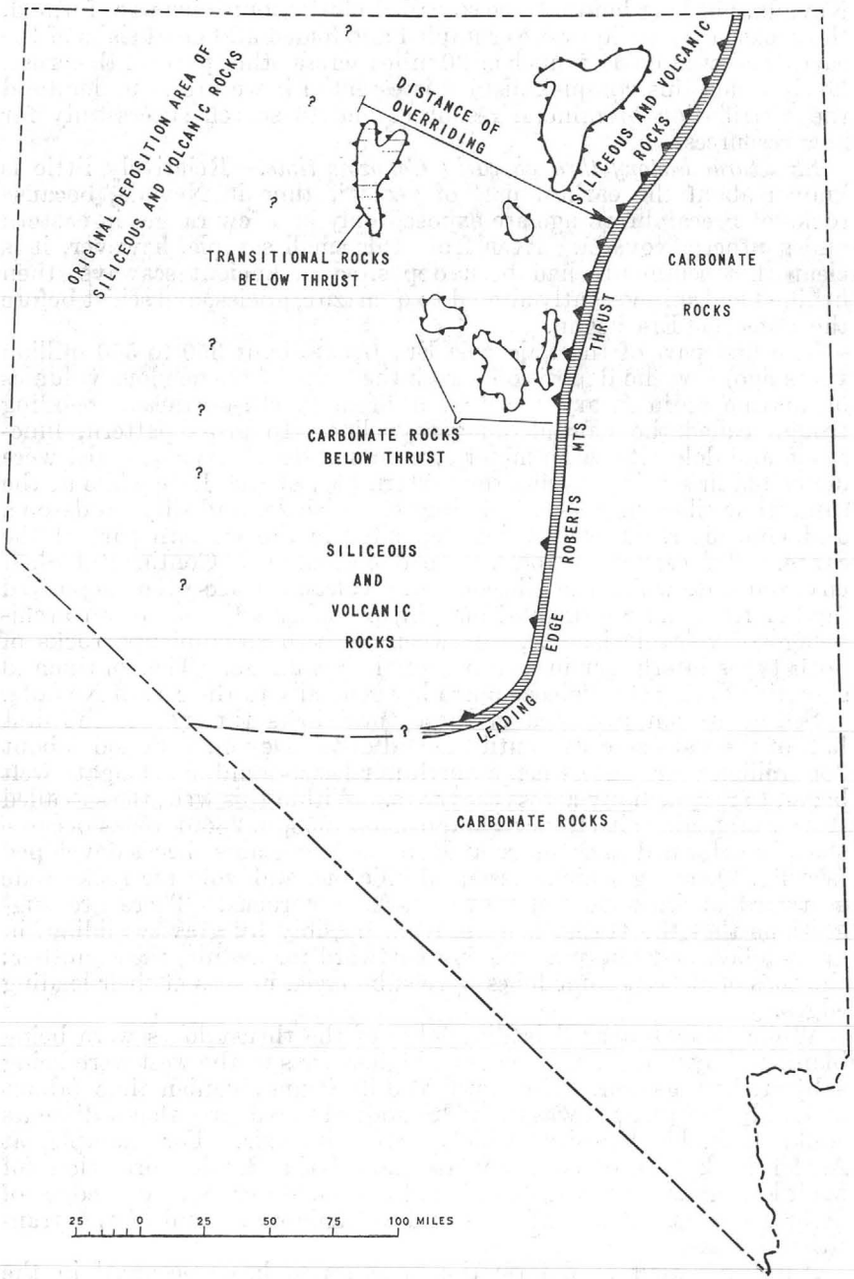

FIGURE 9.—Distribution of early Paleozoic siliceous and volcanic rocks, carbonate rocks, and transitional rocks, and their relation to the Roberts Mountains thrust fault in Nevada.

zone. Another part of the belt which passes under Walker Lake was named the Walker Lane by Billingsley and Locke (1939).

Measurement of local variations of gravity indicate that many of the basins are filled to depths of several thousands of feet by poorly consolidated, low-density gravel, sand, and silt probably mostly of Cenezoic age (65 million years and younger). The bedrock floor under these poorly consolidated sediments is below sea level in some basins, in contrast to the summit altitudes of 2 miles or more above sea level attained by some ranges. For example, the floor of Buena Vista Valley east of the Humboldt Range stands at about 4,000 feet above sea level whereas bedrock is more than 4,000 feet below sea level. In Crescent Valley, which stands at about 5,000 feet above sea level, bedrock is over 2,000 feet below sea level.

ECONOMIC GEOLOGY

(By R. J. Roberts, U.S. Geological Survey, Menlo Park, Calif.)

The mineral deposits of Nevada belong to two major groups: syngenetic deposits formed at the same time as the enclosing rocks, and epigenetic deposits formed later than the enclosing rocks. Intermediate types in which minerals of both groups have been later rearranged or concentrated by circulating solutions, are also locally important. The mineral deposits may also be divided into two compositional groups, the metallic and the nonmetallic deposits. The metallic deposits such as gold, silver, copper, lead, and tungsten are commonly associated with intrusive rocks and mostly belong to the epigenetic group. The nonmetallic deposits include syngenetic deposits of bedded materials such as clays, gravels, borax, and salt, as well as epigenetic deposits of fluorite and barite, which are associated with intrusives.

METALLIC DEPOSITS

The principal mining districts in Nevada are shown on figure 12 and 13, which also show the principal metallic or nonmetallic constituents produced in the districts (Ferguson, 1944; Lincoln, 1923). It is immediately apparent that the districts are not randomly distributed, but that some metals and nonmetals are produced mainly in certain parts of the State and that some deposits are alined along belts that cut northwestward, east-west, and northeastward across the State. This distribution is not accidental; it reflects major stratigraphic and structural controls of the most fundamental kind.

Most of the metallic deposits in Nevada are related to intrusive rocks, generally granodiorite to quartz monzonite in composition, that have been injected into the crust as molten magma and later crystallized. In part the ore-forming solutions may have come from the magma, but in part they may have risen from depths along the same channelways that were earlier followed by the magma. Ore bodies subsequently were formed in the intrusive rock and in adjacent wallrocks.

On the geologic map (fig. 3) it is apparent that western Nevada is underlain by formations that are characterized by siliceous and volcanic rocks (Roberts and others, 1958). These include Paleozoic and

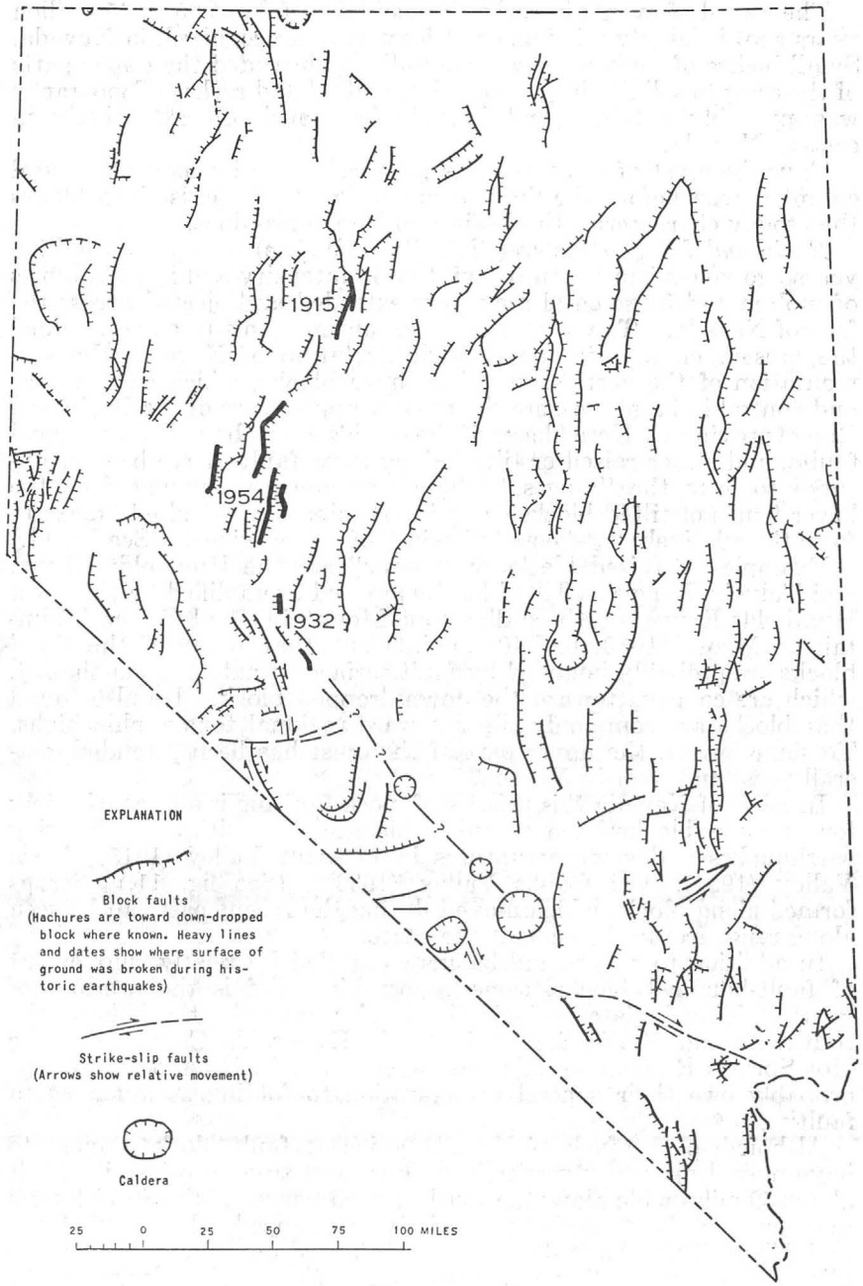

FIGURE 11.—Basin and Range block faults and other selected structures of Cenozoic age in Nevada.

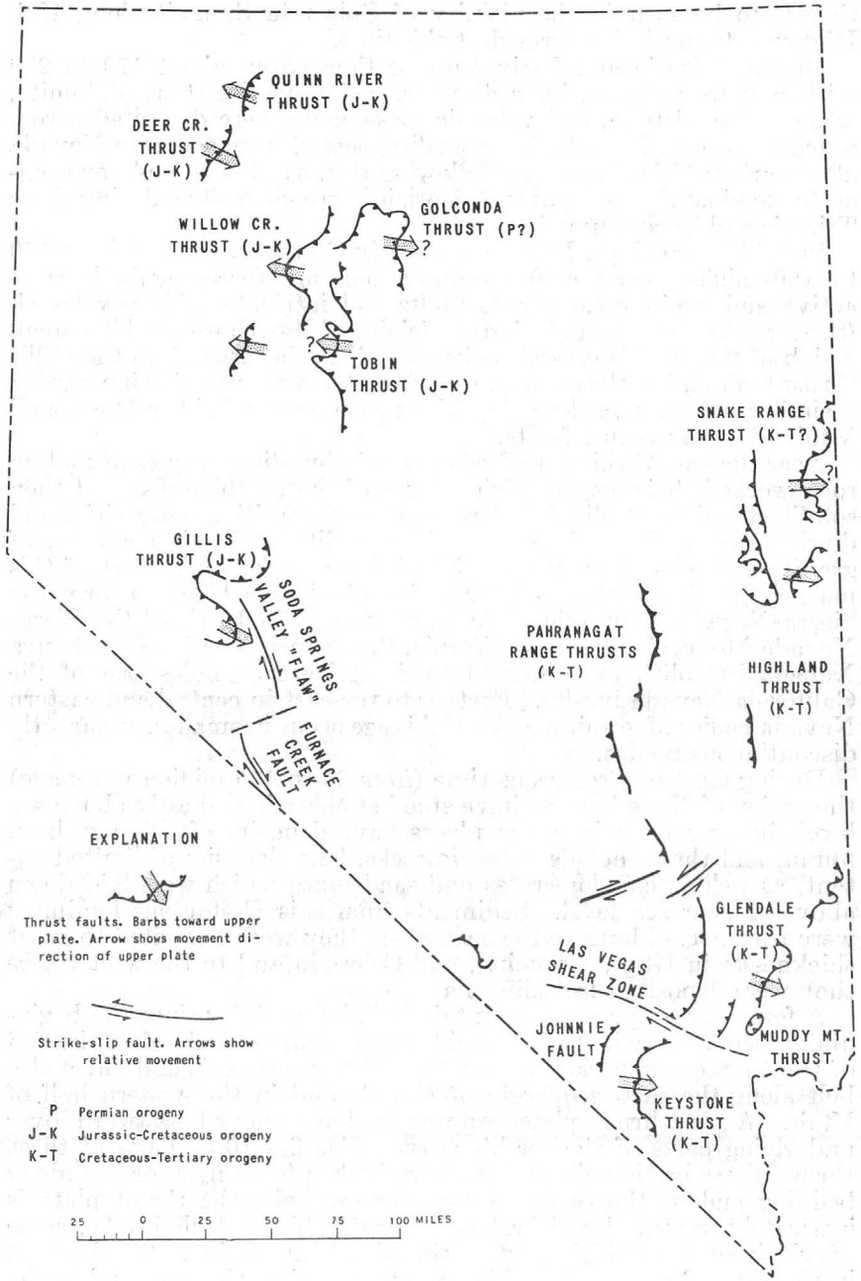

FIGURE 10.—Thrust faults exclusive of the Roberts Mountains thrust fault (shown in fig. 9), and selected strike-slip faults in Nevada.

thrust, to be seen in the vicinity of Golconda Summit along U.S. Highway 40, probably formed at this time.

During Triassic and Early Jurassic time (from about 170 to 230 million years ago) marine sediments, including limestone, dolomite, shale and sandstone, and volcanic rocks again were deposited across much of western Nevada, but seas disappeared from southern Nevada after earliest Triassic time. Following this, sandstone and conglomerate dominantly of continental origin were deposited during Late Triassic and Early Jurassic time.

In Middle and Late Jurassic and Early Cretaceous time (about 140 to 180 million years ago) mountain building forces again became active and again great thrust faults and intricate folds developed. (See fig. 10.) For example, in the vicinity of Hawthorne and Tonopah a slab of the earth's crustal rocks moved southeastward on the Gillis thrust fault and in the Sonoma and East Ranges south of Winnemucca a similar but westward-moving block rode on the Willow Creek and Mullen Canyon thrust faults.

Near the end of this period of mountain building, masses of molten rock worked their way to higher parts of the earth's crust and then solidified and crystallized to form bodies of granitic, monzonitic, and dioritic rocks. The Sierra Nevada batholith which is made up of granite and related rocks came into being at this time. Part of this mass of granitic rock was later to be raised as a block to form the Sierra Nevada Mountains. Although the main block of the Sierra Nevada Mountains lies in California, the eastern margin of the Sierra Nevada batholith may be said to lie at least 50 miles east of the California-Nevada border. Farther to the east in central and eastern Nevada bodies of granitic rocks of this age occur in smaller, apparently discontinuous bodies.

During most of Cretaceous time (from 65 to 135 million years ago) the region of Nevada must have stood at elevations mostly above sea level, because only in a few places have deposits of this age been found, and these include volcanic rocks, lake deposits of limited extent, as well as conglomerates and sandstones which were laid down above or near sea level. Sediments from this Cretaceous landmass were transported both to the east where they were deposited to great thicknesses in Utah, Wyoming, and Colorado and to the west where they were deposited in California.

A fourth great pulse of mountain building activity since the beginning of the Paleozoic, the Laramide revolution, started before the end of the Cretaceous period (about 65 million years ago), and affected a belt along the eastern margin of Nevada and in the western half of Utah. Again thrust plates appear to have moved eastward over underlying parts of the earth's crust. (See fig. 10.) Parts of these thrust plates in Nevada seem to have broken loose more or less along bedding and in the Snake Range, for example, the thrust plate is intricately fractured and broken into a jumble of fault blocks, some of which appear pulled apart as though under tension. To the west in the Egan Range major folds are overturned to the east, and in the vicinity of Eureka multiple plates moved one above another. If one looks west from Las Vegas to the Spring Mountains, a mass of drab-colored Paleozoic sedimentary rocks can be seen resting on brilliantly colored reddish sandstone of Mesozoic age. This juxtaposition of older rocks on younger has been brought about by thrusting along the Keystone thrust fault during the Laramide revolution.

The record of events in early Cenozoic time (about 35 to 65 million years ago) is largely missing, or at least yet unrecognized, in Nevada. Small bodies of molten magma sporadically intruded the upper parts of the crust to solidify into monzonites and related rocks. Topography was probably subdued and lake basins developed extensively in eastern Nevada.

Thus the crust of the earth was prepared as an intricate structural complex even before the final segmentation of the crust into blocks that today characterize the Basin and Range province.

Basin and Range structures (late Cenozoic time).—About 30 million years ago volcanism began to build up in intensity and large volumes of molten and fragmental rock were extruded and ejected across the face of Nevada. The start of this volcanism seems to have heralded the present chapter in the geologic evolution of Nevada, the segmentation of the earth's crust into huge blocks, which characterize and control in large measure the present appearance of the Basin and Range province. Here blocks of the earth's crust, bounded by normal faults, and either raised or tilted along these faults, have been sculptured to form the "ranges," whereas sediment accumulated on the lower flanks of tilted blocks or on intervening down-faulted blocks to form the relatively flat-floored "basins" of the province. (See fig. 11.)

Examples of raised blocks or "horsts" are the Humboldt, Ruby, and Toiyabe Ranges. Tilted blocks are well exemplified by the West Humboldt Range, northern Shoshone Mountains, and Cortez Mountains. Moore (1960, p. B409) points out that many of the tilted blocks are probably bounded by fault surfaces, crudely spoon-shaped, which are concave toward the down-dropped block. He also found that blocks are commonly tilted toward regional topographic highs. To some extent, the upper part of the crust has been extended generally east and west in Nevada.

In parts of Nevada this process of block faulting is still continuing; for example, blocks have moved in historic time with accompanying earthquakes and surface ruptures in Pleasant Valley (1915), Dixie Valley (1954), and Gabbs Valley (1932). (See fig. 11.) Scarps formed along blocks which moved during the recent past can be seen along range fronts throughout the State.

In addition to ranges and basins controlled by relative movement of fault-bounded blocks, some topograhic relief is the product of gentle folding in late geologic time. For example, the hills at the southwest end of Big Smoky Valley in Esmeralda County and the Hot Springs Range and adjacent Eden Valley in Humboldt County, probably owe their general configuration to folding as much as to faulting.

Although over much of Nevada adjacent fault blocks appear to have moved primarily vertically with respect to each other, in a belt about 50 miles wide along the southwestern border of the State lateral movement of blocks has been especially pronounced. Longwell (1960) and Albers (1963) have shown that this lateral movement was accomplished both by bending on a grand scale of range-size blocks and by lateral slipping along bounding faults. The southwestern part of the belt moved relatively northwestward with respect to the northeastern part. Las Vegas Valley lies along the southern part of this belt and Longwell (1960) thus has named the segment the Las Vegas shear

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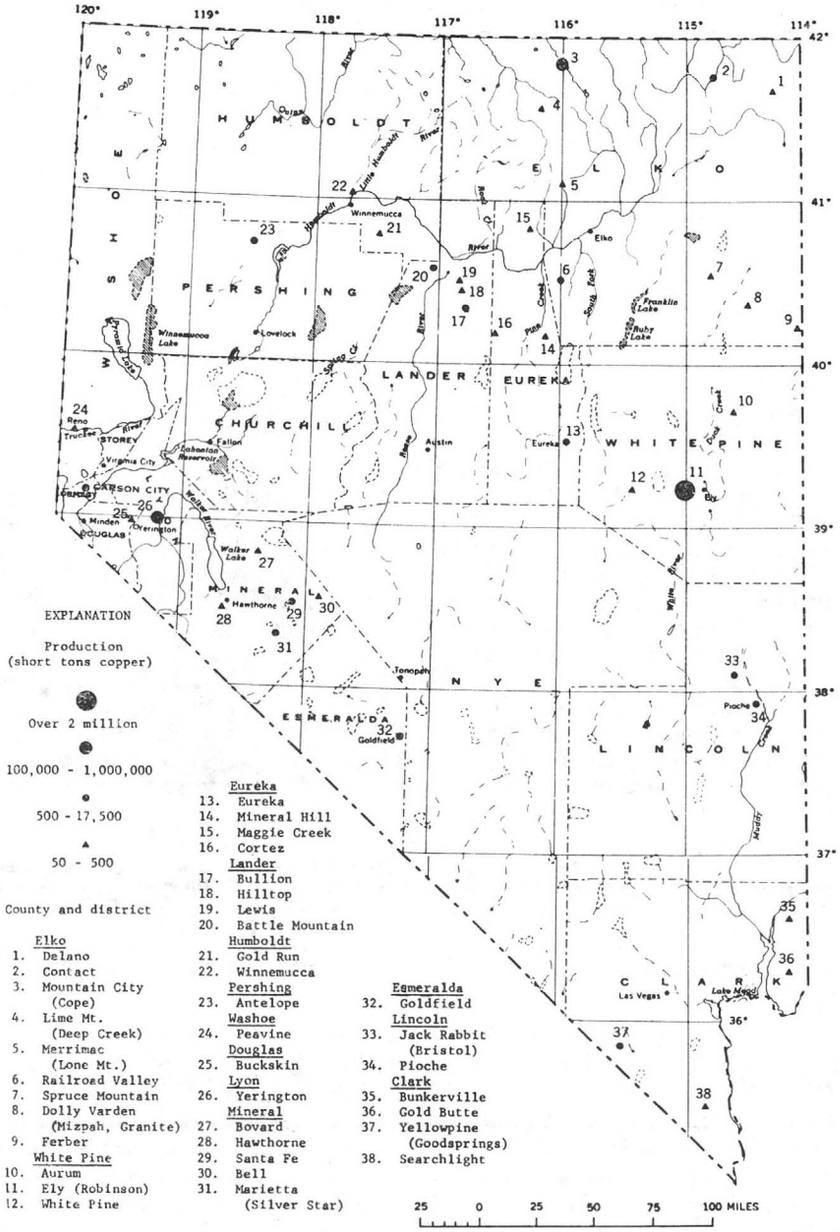

FIGURE 22.—Copper in Nevada.

WASHOE COUNTY

Verdi (Crystal Peak) deposit (No. 4)

Lignite was discovered northeast of Verdi, in secs. 8 and 9, T. 19 N., R. 18 E., in about 1864. Numerous shafts, adits, and cuts were dug to exploit the deposit. No production is known to have been made. The seams of lignite have been described as varying in thickness from a few inches to 2½ feet, with considerable foreign matter mixed with the lignite. The Nevada Carbon Co. examined the deposit in 1943 and analyses were made of the lignite at that time. A fresh sample contained 38.4 percent volatile matter, 25.2 percent fixed carbon, 23.6 percent ash, and 12.8 percent moisture.

WHITE PINE COUNTY

Pancake Summit deposit (No. 3)

The Pancake coal deposit was discovered sometime prior to 1875. It is in sec. 21, T. 18 N., R. 56 E., about 1 mile south of Pancake Summit on U.S. Highway 50. A shaft was sunk to a depth of at least 480 feet and some coal was mined and shipped to Eureka for use in the lead smelters. The seam mined is reported to have been 2 feet thick. Angel (p. 664) describes the deposit as follows:

> A shaft on being sunk 30 feet, found water, and some seams of coal in a vein 4 feet thick. Three distinct veins exist in the locality, which can be traced a distance of 2 miles, and which vary in width from 4 to 6 feet * * *. The veins dip under the mountains to the west at an angle of 40°, and their course is 15° east of south from the point of discovery * * *. The first formation below the vein in which the coal is found is siliceous iron ore; then comes a stratum of limestone, and beneath this sandstone and conglomerate. Above it the formation is bituminous and argillaceous shales; next to the shale, calcareous slate, then red sandstone, conglomerate, and limestone capping the whole formation.

The deposit is located in the area of Paleozoic rocks. If the description by Angel is correct, the coal probably is of Mississippian age. There have been no recent attempts to mine the coal.

CONCLUSIONS

Without exception the coal deposits of Nevada are too small and too impure to support significant mining, although they might satisfy limited local requirements. The high ash content and low heating value even makes local use questionable as mining costs probably would be greater than the cost of coal delivered from Utah. Some use might be made of these deposits if they could be burned in place and the gases generated from the burning collected. However, the individual beds are so erratic that it might be difficult, if not impossible, to maintain combustion.

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PETROLEUM

(By R. C. Horton, Nevada Bureau of Mines, Reno, Nev.)

Oil and natural gas currently supply more than two-thirds of the total energy requirements of the Nation as well as providing raw material for thousands of other industries. The value of crude oil, natural gas liquids, and natural gas produced in 1962 was $10,659,097,000. This represents 57.1 percent of the total value of all minerals produced in the United States.

Since the first production of oil in 1859, concern has been expressed regarding the total petroleum reserves in the United States and the likelihood of exhausting these reserves. Few petroleum economists and conservationists now feel concern for this possibility and most believe that much more oil remains to be discovered than has been produced. Statistics on production and reserves are shown in table 3.

TABLE 3.—*Oil and gas in the United States* [1]

1962

	Crude oil (thousands of barrels)	Natural gas liquids (thousands of barrels)	Total liquid petroleum (thousands of barrels)	Natural gas (million cubic feet)
New reserves found	2,180,896	732,549	2,913,445	19,590,353
Production	2,550,178	470,128	3,020,306	13,552,420
Net change	−369,282	262,421	−106,861	6,037,933
PRODUCTION AND NEW RESERVES FOUND, ALL TIME TO JANUARY 1963, UNITED STATES				
Total reserves	102,133,176	12,773,128	114,906,304	483,918,546
Total production	70,743,953	5,461,611	72,205,564	210,152,942
Proved reserves	31,389,223	7,311,517	38,700,740	272,765,604

[1] The Independent Petroleum Association of America, "The Oil Producing Industry in Your State, 1963."

Proved reserves discovered each year have usually exceeded production. In 1962 fewer barrels of oil were found than were produced, but exploration activity was reduced as compared to previous years. A total of 9,003 wildcat wells were drilled as compared to 9,191 in 1961, 9,635 in 1960, 10,073 in 1959, and 9,588 in 1958. The cost of exploration has increased as deeper wells now are required if a discovery is to be made. The average wildcat well was drilled to a depth of 5,328 feet in 1962 as compared with an average depth of 4,649 feet in 1958.

Interest in Nevada's petroleum dates back to 1907, when wells were drilled in Lyon and Washoe Counties. The first Nevada oil exploration boom occurred in the early 1920's when wells were drilled in a number of counties. The results of the exploration activity, centered in Churchill and White Pine Counties, were not encouraging and interest declined. Current petroleum activity in Nevada began with the drilling of the No. 1 Meridian unit well by the Standard Oil Co. of California and the Continental Oil Co. in the spring of 1950. Other major oil companies became interested in Nevada and on January 11, 1954, the Shell Oil Co. spudded in the No. 1 Eagle Springs

TABLE 6.—*Total copper production in Nevada through 1962*

County	Short tons	Percent of State total	Value	
			Millions of dollars	Percent of State total
White Pine	2,307,000	82	859.8	78
Lyon	340,400	12	203.8	18
Elko	105,600	4	25.0	2
Others	60,300	2	18.3	2
Total	2,813,300		1,106.9	

The interesting relationship of the Lyon and Elko County totals and their percentages of State totals are closely related to the price of copper, and to the period of principal production in the major districts. Production in Lyon County since 1953 benefited from relatively high prices for copper, whereas low prices prevailed during maximum production in Elko County between 1935 and 1947.

In each of the three counties listed above, a single district accounts for most of the copper production—the Ely district (No. 11, fig. 22) with over 2 million tons in White Pine County, the Yerington district (No. 26) with 340,000 tons in Lyon County, and the Mountain City district (No. 3) with 105,000 tons in Elko County. The 38 copper-producing districts with production in excess of 50 tons each are shown in figure 22. Some 134 additional districts have recorded smaller production (Horton and others, 1962; Nolan, 1935, p. 325).

The three major copper districts have had similar histories of development, beginning with exploration and mining of silver and gold. Though copper was present in many of the deposits, its recovery was generally uneconomic. When large-scale copper mining became possible and profitable in the early 1900's many properties were combined and developed by fewer companies with ample financial resources.

Vein and contact metamorphic types of deposits were commonly worked by the early miners of silver and gold. The major copper deposits developed to date in Nevada have been large, disseminated ore bodies, the so-called porphyry deposits, at Ely and Yerington, and the replacement deposit at the Rio Tinto mine in the Mountain City district.

ELY DISTRICT

Like many of the mining districts in the West, the Ely district (No. 11) was mainly a gold and silver producer from the late 1860's to the early 1900's. It was not until 1907–08 that its low-grade, disseminated "porphyry" copper ores were first mined and milled on a large scale. Mining and ore beneficiation techniques developed to exploit the low-grade, porphyry copper ores at Bingham, Utah, and Morenci, Ariz., were adapted to the conditions and the ores in the Ely district.

The practice of exploring low-grade copper ores with churn drills was pioneered in the Ely district in 1906 (Spencer, 1917, p. 97). Improvements over the years in mining, concentrating, and smelting have permitted exploitation of lower grade ores. The copper content of ore mined in the district in 1962 was 15.5 pounds per ton as compared with nearly 50 pounds per ton in 1908.

In the period 1946–62, the value of copper production represented 51 percent of total income derived from minerals and metals, equaled nearly 77 percent of total agricultural income, and 90 percent of income from livestock and related products. If the value of byproducts from copper production is added, the total for copper and associated metals exceeds income from livestock.

Annual mine production of recoverable copper, value of annual production, and the relative value of copper compared to total mineral production, 1904–62, are shown in figure 21.

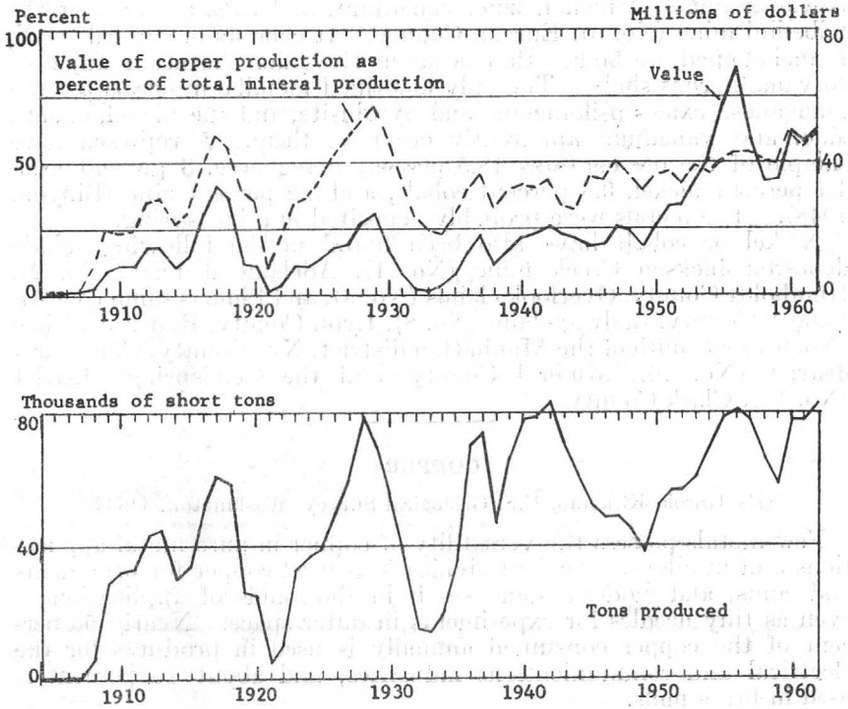

FIGURE 21.—Copper production in Nevada, 1904–62.

Nevada's copper output did not become significant until development in the early 1900's of the flotation process for selective separation of minerals, and adaptation of large-scale, low-cost mining methods that enabled the exploitation of copper deposits formerly uneconomic to mine. Concomitant with copper production has been the byproduct recovery of associated minerals containing gold, silver, lead, zinc, molybdenum, and other metals.

Copper production in three counties accounts for 98 percent of the State total as shown in table 6.

unit well. This well, the first in the Eagle Springs oilfield (fig. 15), was placed on production in June 1954 with an initial rate of 275 barrels per day. Since then four other producing wells have been drilled in the Eagle Springs field. Two of the wells are major producers. Well No. 62–35, placed on production in January 1961, produced over 330,000 barrels through December 1963. In September 1963 the Texota Oil Co. drilled well No. 73–35 in the Eagle Springs field on a farm-out from the Shell Oil Co. This well currently produces 13,000 barrels of oil per month.

In March 1964 the Texota Oil Co. completed a second well, No. 74–35, which was tested at over 100 barrels of oil per hour. Representatives of the company reported that the producing interval extended from 6,725 to 6,800 feet; that the initial marker bed of pyroclastics which was present in the other wells was not found; and that the test produced oil from an entirely new limestone zone not identified with other limestone zones previously drilled in the field. Unlike all previous wells which are produced by pumping, this well flowed oil under considerable pressure. If the producing limestone formation proves to be of Paleozoic age—and such seems likely—then the production potential of at least one Paleozoic formation in eastern Nevada will have been established. The high initial production, equivalent to over 2,400 barrels per day, and the fact that the well is a flowing well, will add impetus to the search for additional productive areas in Nevada.

As of January 1, 1964, the Eagle Springs field had produced 716,765 barrels of oil. The new Texota wells will greatly increase the production during the next few years even if no additional wells are drilled.

Age of the oil at the Eagle Springs field has a direct bearing on further exploration. If it is early Tertiary in age, then additional exploration of similar formations is indicated. If the oil is Mesozoic or Paleozoic in age then the older formations should be explored. Oil at the Eagle Springs field is produced from both Tertiary and Paleozoic age formations and is similar in physical characteristics to the oil produced from early Tertiary sediments in the Uinta Basin of Utah.

A 3,200-foot-thick sequence of nonmarine sedimentary rocks of Eocene age is exposed northeast of the Eagle Springs field, in the South Egan Range. One member in the sequence contains shows of oil and may be the source rock for the Eagle Springs oil. Oil and gas shows in Nevada have also been found in Paleozoic and Mesozoic age rocks. Formations of these ages could also be source rocks for the Eagle Springs oil.

The confusion regarding the source of oil for the Eagle Springs field is not necessarily discouraging, as it appears that Tertiary, Mesozoic, and Paleozoic rocks in Nevada may be productive. Of principal concern in Nevada are the kinds of formations and types of petroleum traps present. There are two basic geologic requirements that must be met if petroleum is to be produced. There must be a source for the petroleum and there must be traps that will contain the oil. Most all geologists agree that petroleum is formed in a sedimentary environment. It is thus pointless to look for petroleum in areas that do not contain sedimentary rocks. Generally, the greater the volume of sedimentary rocks present the greater the likelihood of finding petroleum.

Much of western Nevada is covered by volcanic rocks which overlie plutonic or metamorphic rocks. Petroleum has seldom been discovered in such an environment. The valley basins of western Nevada do contain nonmarine sediments of Tertiary and Quaternary ages but, unless these sediments have petroliferous members, it is unlikely that they will produce petroleum. No petroliferous sediments have been found in rocks of Tertiary or Quaternary ages in western Nevada, and it appears unlikely that any will be found. Small amounts of methane gas have been produced from some of the valley sediments in western Nevada, notably in the Fallon area. It is generally believed that this gas is generated by decomposing vegetation buried in recent lake deposits and that commercial quantities of gas are not likely to be present.

Substantial thicknesses of sedimentary rocks are exposed in Clark County, southern Nevada. Many wells have been drilled in the area without success. However, many of the tests have been shallow and based on limited geologic data. The Shell Oil Co., Bowl of Fire well, found oil shows in rocks of Triassic, Permian, and Mississippian age. These shows are encouraging, and further exploration may prove successful.

The central and northern portions of eastern Nevada appear to offer the best hope for additional discoveries. Thick sections of sedimentary rocks of Paleozoic age are found in the area as well as petroliferous formation of Tertiary age. The presence of oil in this area is no longer questioned. The problem is to find traps in which commercial quantities of oil have accumulated.

The geologic history of eastern Nevada makes finding traps a difficult problem at best. Extensive folding and thrust faulting in the area were followed by normal faulting, dividing the area into mountain and valley blocks. Many geologists believe that any oil once present in the uplifted mountain blocks has escaped. The valley blocks are buried under thousands of feet of Quaternary and Tertiary age rocks, effectively hiding the geology of the potential producing formations. Geophysical techniques can give some information concerning these buried blocks but only drilling can determine the geology with certainty. Additional oilfields will be found in Nevada. The ease with which they are found will depend upon the acquisition and interpretation of geological and geophysical information.

At Cottonwood Canyon (No. 5), Churchill County, small but unusual nickel-cobalt sulfide and arsenide deposits occur at the Nickel and Lovelock mines. These mines were operated between 1882 and 1908. The deposits, described by Ferguson (1939), consist of discontinuous stringers of cobalt and nickel minerals in altered andesite and aplite, adjacent to an intrusive diorite. The mineralogy of the primary nickel-cobalt ores has not been studied and only niccolite has been identified, but oxidized ores near the surface contain the hydrous nickel arsenate annabergite, and the sulfate morenosite.

An unusual small deposit of manganese oxides containing appreciable amounts of nickel, zinc, vanadium, and cobalt occurs at the Gibellini mine (No. 6), Eureka County. It consists of several small, funnel-shaped ore bodies that occur in Devonian limestone adjacent to vanadiferous shale. The only identified metallic minerals are the manganese oxides psilomelane and pyrolusite, and the nickel, cobalt, zinc, and vanadium apparently occur in them. A representative sample of the ore contains 18.5 percent manganese, 3 percent iron, 1.7 percent nickel, 0.3 percent cobalt, and 3.2 percent zinc (Binyon, 1948). The metals were probably deposited in a hot spring.

Nickel or cobalt have also been found in the following sulfide deposits: Jackson Creek mine (No. 1), Adelaide district (No. 2), Humboldt County, Overlook claims (No. 3), and Plumas mine (No. 4), Lander County, Ludwig claim (No. 8), Lyon County, Red Fox claims (No. 9), just south of the Manhattan district, Nye County, Candelaria district (No. 10), Mineral County, and the Goodsprings district (No. 12), Clark County.

COPPER

(By Harold Kirkemo, U.S. Geological Survey, Washington, D.C.)

Few metals possess the versatility of copper in pure metal applications and in alloys. Ancient civilizations used copper for ornaments and coins, and modern man uses it in thousands of applications—even as tiny needles for experiments in outer space. Nearly 55 percent of the copper consumed annually is used in products for the electrical and communications industries, and about 40 percent is used in brass mills.

Copper ranks third after iron and aluminum among the major tonnage metals. Apparent consumption of primary copper in the United States in 1963 was about 1.4 million tons. Consumption is expected to reach 2 million tons annually by 1975.

Nevada ranks fifth among the States in total tonnage of copper mined from earliest record to the end of 1962, with a total of 2,813,338 short tons. In 1962 the State supplied 82,602 tons which was about 7 percent of the national total. From the end of World War II through 1962, Nevada's copper output was about equal to production in Mexico, Japan, or Peru in the same period.

The total value ($1.1 billion) of copper mined in Nevada from earliest record through 1962 accounts for 36 percent of the total value ($3 billion) of the State's mineral and metal output. In comparison, gold accounts for 20 percent; silver, 18 percent; zinc and lead, each 3 percent; and all other minerals and metals, 20 percent.

The importance of copper to Nevada's economy is illustrated further by comparison of income from various products since World War II.

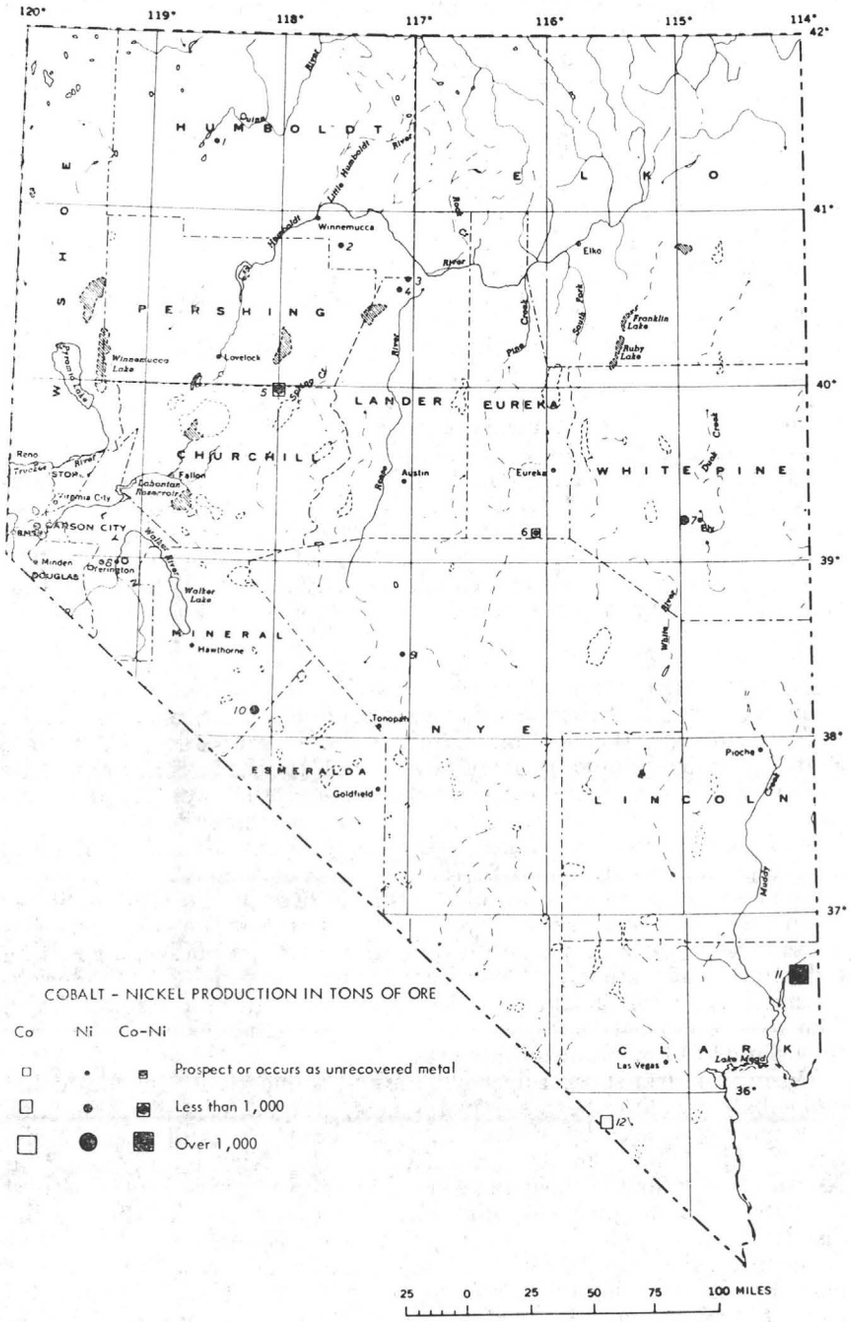

FIGURE 20. Cobalt and nickel in Nevada (numbers refer to deposits or districts described in text).

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monel metal, stainless steels, and permanent magnet alloys. Although less efficient, nickel can be used as an alternate for cobalt as a binder in sintered-carbide tools and armor-piercing projectiles, and nickel-base alloys with low cobalt content can be substituted for some cobalt-base high-temperature alloys.

Virtually all cobalt produced is a byproduct or coproduct of other metals, chiefly copper (Davis, 1956). The ore minerals are cobaltite (CoAsS), smaltite ($CoAs_2$), and a number of sulpharsenide minerals. On the other hand, nickel ores, contain chiefly the following minerals: garnierite—(Ni, Mg) $SiO_3 \cdot nH_2O$; pentlandite—(Fe,Ni)S; niccolite—NiAs; polydymite—Ni_3S_4; violarite—$(Ni,Fe)_3S_4$; and chloanthite—(Ni) As_2. These minerals are commonly associated with pyrrhotite and chalcopyrite and are found in a variety of deposits. These include chiefly deposits resulting from processes of rock decay, massive magmatic bodies, and veins. Sizes of deposits range from narrow high-grade veins containing a few tons of ore minerals to large low-grade bodies having potentials of millions of tons.

The non-Communist world production of cobalt, about 11,000 tons for 1962, was substantially higher than for the previous year. Katanga, Africa, supplied most of the cobalt; only about 3½ percent of the total metal production was from the United States—the only domestic producer being Pyrites Co., Inc., of Wilmington, Del. The recent use of 7 to 9 percent cobalt in maraging steels suggests that the steel industry may become the major consumer of cobalt (Bilbrey, 1963).

Currently the nickel industry is centered chiefly in the Sudbury district, Ontario, and Thompson district, Manitoba, Canada, but about 10 percent of the world's nickel production comes from Russia, Cuba, and New Caledonia. During the last decade, the United States produced annually from less than 1 to nearly 5 percent of its yearly nickel requirements; the U.S. consumption was 120,000 tons in 1962 (O'Connell, 1963). Current metal prices per pound for large lots of cobalt and nickel metals (Eng. and Mining Jour., April 1964) are, respectively, $1.50 and $0.79.

Most of the higher grade nickel sulfide ores in the United States occur in small bodies in widely separated parts of the country. Because of the limited sizes and distribution of these bodies, a smelting industry is not justified. Deposits in this country include: Fredericktown, Mo., Yakobi Island, Alaska, Mouat, Mont., and Riddle, Oreg. The Riddle deposit contains from 1 to 2 percent nickel-silicate ores; the others are low-grade sulfide ores.

During the last several decades, limited tonnages of Nevada nickel and cobalt ores have been shipped, and small quantities of nickel have been recovered as a byproduct from the copper ores of the Ely district, White Pine County (No. 7, fig. 20). Nickel and cobalt in Nevada occur for the most part in sulfide and arsenide hydrothermal deposits. The largest ore bodies have been found in the Bunkerville district (No. 11), Clark County. The Great Eastern and Key West deposits consist of sulfide disseminations and massive pods in dikes of hornblendite that intrude Precambrian granite gneiss. The sulfides present are pyrrhotite, pyrite, chalcopyrite, pentlandite, violarite, possibly also polydymite. As a result of exploration during the period 1939–56, it is reported that several tens of thousands of tons of material containing over 1 percent nickel, have been found.

1885 to 1894, amounted to 2,613 tons of ore. It is not known if any bismuth was recovered from this ore.

Cooper (1962) classes the Black Metal (Jackrabbit) mine (No. 12), Pioche district, Lincoln County, as a relatively important bismuth-bearing deposit. The mine has produced principally lead, copper, silver, and manganese from replacement deposits in Cambrian limestone.

Bismuth occurs in the Montezuma district (No. 13) Esmeralda County, associated with silver, gold, lead, and copper veins and replacement bodies in Cambrian sediments cut by intrusives (Cooper, 1962, p. 9).

Bismuth has been found at the Boss mine (No. 14), Yellow Pine district, Clark County. The ore occurs in a roughly elliptical, continuous pipe and in several smaller bodies in Paleozoic limestone near a Tertiary granite porphyry (Cooper, 1962, p. 9). Hewett (1931, p. 114–118) notes that to 1921 about 3,500 tons of ore valued for gold, silver, platinum, palladium, and copper had been produced from the mine. The material richest in gold, platinum, and palladium was determined by W. T. Schaller, U.S. Geological Survey, to be a mixture of 67.3 percent plumbojarosite, 17.2 percent beaverite, 6.9 percent bismutite, and 6.9 percent quartz.

Rich gold-silver ore from the Mohawk mine in the Goldfield district (No. 15) Esmeralda County, is reported by Lindgren (1933, p. 511–512) to have assayed 2 percent gold (541 ounces per ton), 0.25 percent silver, 2.42 percent tellurium, and 0.35 percent bismuth. In the unoxidized ore two bismuth minerals—bismuthinite and goldfieldite—were associated with pyrite, marcasite, famatinite, native gold, tellurides, and dark gray flinty quartz gangue. There is no record of bismuth production from the Goldfield district, although considerable amounts of bismuth were present in the ore.

COBALT AND NICKEL

(By L. H. Beal, Nevada Bureau of Mines, Reno, Nev.)

Cobalt and nickel are metals of similar appearance, melting point, density, and other physical properties. They are tough, lustrous, silver-white metals. In nature these elements commonly are associated with iron-bearing minerals. Both metals have remarkable abilities to impart great strength and magnetic qualities to certain alloys.

Cobalt uses include permanent-magnet alloys and high-temperature alloys. Permanent-magnet alloys (Davis, 1956) are widely utilized in motors and generators, control devices, communication equipment, meters and instruments, and mechanical devices. Other important cobalt products (Davis, 1956) include: high-speed and low-cobalt alloy steels, alloy hard-facing tools and armor-piercing projectiles, ground-coat frit for porcelain enamel, pigments, catalysts, electroplating, lacquers, varnishes, paints, inks, stock feed, cobalt-deficient soils, and glazes and decolorizers.

Nickel is used widely in industry; large quantities of it are alloyed with copper, iron, and to a less extent with other metals. There are over 3,000 nickel-alloys used today; these contain from less than a percent to nearly 100 percent nickel. Examples include: coinage,

METALLIC MINERAL RESOURCES

The mining of metallic minerals has dominated the State's economy for the past 100 years. Production of metals has yielded about $2.6 billion. Gold and silver production have totaled $1.2 billion, and copper production has amounted to $1.1 billion. The balance of roughly $300 million resulted mainly from the production of lead, zinc, tungsten, iron, mercury, and manganese. In the early days of mining in Nevada, gold and silver were the chief metals produced, but after 1900 copper production became more important and is at present dominant. Large deposits of iron ore have been explored, some very recently, and will doubtless be mined at increasing rates as the market on the Pacific Coast expands. Production of other metals, such as tungsten, will also probably increase in the State when the metal prices become more favorable.

ANTIMONY

(By J. H. Schilling, Nevada Bureau of Mines, Reno, Nev.)

Antimony is a brittle, silver-white metal with a melting point of 630.5° C. Although antimony is produced in only minor amounts when compared with the base metals, it has many important and diverse uses. There are three major uses: (1) as a stiffener in the lead grids of storage batteries, (2) in tin- and lead-base alloys used as antifriction bearings, and (3) in type metal (lead, tin, antimony) used in printing processes, because of antimony's unique property of expanding upon cooling. Antimony oxide is used as a stabilizer and flame-retardant in various plastics; the sulfide in primers for gun cartridges; and the metal and its compounds as black, white, red, and yellow pigments.

Since 1925 the world production in antimony has averaged 35,000 tons per year with peaks of 90,000 and 59,000 tons during World Wars I and II. China has been the biggest producer and has the largest reserves; Bolivia and Mexico also have been big producers and have large reserves. In recent years the United States has consumed nearly half of the world production while producing less than 4 percent of the ore mined. Over half of the antimony that is consumed in the world is recovered from scrap rather than ore.

Antimony ore has been mined sporadically in Nevada since the 1860's; most production subsequent to 1890 has been during wartime when prices rose because of reduced imports. In 1942, 11 mines in Nevada produced ore containing 305 tons of antimony; in contrast, in 1945, 32 tons were produced from 3 mines. In 1962, typical Nevada ores brought 10 to 12 cents per pound of contained antimony.

Throughout the world antimony most commonly occurs as stibnite, Sb_2S_3, or tetrahedrite $(Cu, Fe)_{12}Sb_4S_{13}$, and other sulfantimonides in quartz and calcite fissure veins and replacement bodies in limestone,

calcareous shale, and other rock types. In Nevada, vein deposits predominate and stibnite is the major ore mineral, although some production has come from jamesonite, ($Pb_4FeSb_6S_{14}$), and from antimony oxide minerals, primarily stibiconite and bindheimite. The antimony minerals may occur alone but just as commonly are associated with pyrite, base-metal sulfides, cinnabar, scheelite, gold, silver, and selenium. Antimony mineralization sometimes occurs around the outer margin of gold, tungsten, mercury, and base-metal districts.

Of the 184 occurrences of antimony mineralization that have been described in Nevada (Lawrence, 1963), 41 have produced more than 10 tons of antimony, of which 11 have produced more than a hundred tons and 3 more than a thousand tons of the metal. Most of the more productive deposits are clustered in the Humboldt Range in Pershing County, at the north end of the Clan Alpine Range in Churchill County, and in the Big Creek area of the Toiyabe Range in Lander County forming a northwest-trending belt. Many of the other deposits also occur in clusters and belts. (See table 4 and fig. 16.)

The Sutherland mine (No. 85, fig. 16), just east of Coal Canyon (sec. 15, T. 27 N., R. 33 E.) in the West Humboldt Range, Pershing County, has been the largest producer of antimony in Nevada. An estimated 1,700 tons of antimony (metal) have been produced, mainly during World War I. A 1- to 48-inch-wide vein, striking north and dipping steeply, cuts Upper Triassic shales and interbedded calcareous shale, sandstone, and limestone on the western limb of a northwest-plunging anticline. The vein contains gouge, abundant quartz, stibnite, sporadic pyrite, and yellow and white antimony oxides.

The Bloody Canyon mine (No. 78), on the east slope of the Humboldt Range (sec. 35, T. 31 N., R. 34 E.), Pershing County, has been the second largest producer of antimony ore in Nevada. The mine has produced 1,218 tons of antimony, mainly during 1907, and from 1917 through 1921. Two veins, striking north and dipping steeply in silicified rhyolite flows, average several feet in width and consist of abundant quartz; stibnite as pods, streaks, and single crystals; common pyrite; and rarer chalcopyrite. Locally the stibnite has been oxidized to yellow and white antimony oxides.

The third important antimony mine in the Humboldt Range of Pershing County is the Hollywood mine (No. 86) on the south flank of the range (sec. 2, T. 26 N., R. 34 E.). Ore containing 512 tons of antimony have been mined, mainly during World War I. Several irregular quartz veins containing stibnite, pyrite, calcite, and antimony oxides cut interbedded (Triassic) shale, limestone, and siltstone. The veins vary greatly in thickness and attitude, and are complicated by numerous splits and cross faults. Ore shoots commonly are found at vein intersections. Diabase dikes intrude the country rock near the mine.

The Bray-Beulah mine (No. 46) along Big Creek (secs. 27, 34, and 35, T. 17 N., R. 43 E.) in the Toiyabe Range, Lander County, is the third largest producer in the State. Over 1,000 tons of antimony have been produced, principally during World War I. A 6- to 48-

concentrate contained 0.92 percent bismuth, a 59.4 percent zinc concentrate contained 0.74 percent bismuth, a zinc-lead concentrate contained 2 percent lead and 3.36 percent bismuth, and an essentially lead-free zinc concentrate, with 0.1 percent lead, contained only 0.06 percent bismuth. The two mines were closed in 1957 and have not been reopened. At the Star tungsten mine (No. 2) in the Valley View (Ruby Valley or Ruby Mountains) district, Elko County, native bismuth and bismuthinite are disseminated in the tactite (Hill, 1916, p. 63). Kaiser, Herring, and Rabbitt (1954, p. 82) determined spectographically that 0.006 percent Bi_2O_3 was present both in tungsten mill heads (scheelite) and in the tungsten tailings (scheelite) from the Star tungsten mill. A sample of scheelite concentrates from this mill contained 0.07 percent Bi_2O_3 (spectographic analysis). The mine closed in the late 1950's, owing to low price of tungsten. In the Regent (Rawhide) district, Mineral County, ores from the Nevada scheelite mine (No. 3) contain some bismuth. Tailings at the Nevada scheelite mill, which processed the Nevada ores, contain 0.01 percent bismuth (Kaiser, Herring, and Rabbitt, 1954, p. 83; Geehan and Trengove, 1950). In the Potosi district, Humboldt County (No. 4), scheelite ores from several deposits that were processed at the Getchell mill contained from 0.001 percent Bi_2O_3 in some ores to 0.1 percent Bi_2O_3 in copper and iron sulfide concentrates (Kaiser, Herring, and Rabbitt, 1954, p. 82). Other tungsten deposits that contain bismuth minerals include the Pine Crow prospect (No. 5) near Marietta, Mineral County, and the Garnet group (No. 6) on the east side of the Pilot Range, near Mina. Traces of bismuth are present in the copper-tin ores mined at the Majuba Hill mine (No. 7), Pershing County. Bismuth is associated with sulfides deposited along fissures in faulted rhyolites and as replacements of rhyolite and breccia. The bismuth content of materials analyzed spectrographically ranged between 0.001 and 0.1 percent Bi_2O_3. Some 27,000 tons of copper and 350 tons of tin ore were produced at this mine between 1916 and 1949. Most of the copper ore was shipped to the Garfield Smelter, Utah, but it is not known if bismuth was recovered. Trites and Thurston (1958) note that little known mineralized material remains at the mine, and that future production will depend on finding new reserves.

Bismuthinite (Bi_2S_3) and bismite (Bi_2O_3) accompany gold in the rich ore and placer material of gold mines in the Lynn district (No. 8), Eureka County. The gold occurs in veins in Tertiary rhyolite cut by porphyritic intrusives (Lincoln, 1923, p. 94).

Native bismuth has been reported in White Pine County (No. 9) by Schrader, Stone, and Sanford (1917, p. 191). No additional information is available.

Overton (1947, p. 33) mentions the occurrence of tetradymite (Bi_2Te_3) associated with free gold in the Wellington (Silver Glance) district in Douglas County, at the Gold Mint mine (No. 10).

In the Eureka district, Eureka County, complex gold-silver-lead ores of the Lord Byron and Kelly mines (No. 11) contain bismuth. Selected material has analyzed as much as 40 percent Bi_2O_3 (Hague, 1892, p. 313). The ore at these mines occurs as pods and irregular replacement bodies in brecciated dolomite of Cambrian age. According to Nolan (1962, p. 68) production from the Lord Byron mine, from

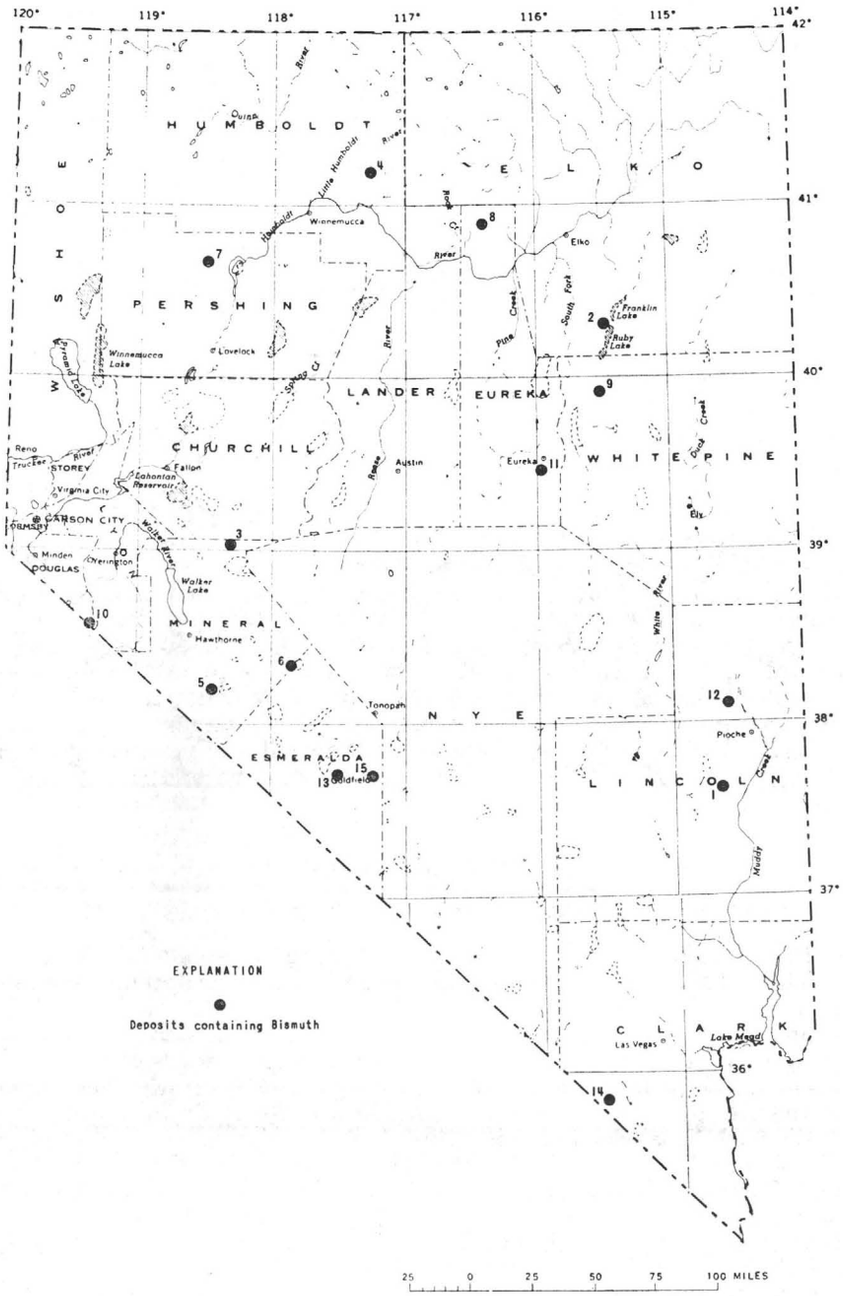


FIGURE 19.—Bismuth in Nevada (number refer to deposits or districts described in text).

inch vein, containing quartz, stibnite, and some graphite and pyrite, strikes N. 30° W. and dips 45° to 85° SW. in highly contorted Silurian(?) shale and slate. Quartz stringers parallel the vein and fold axes in the wallrock. The stibnite is partially altered to yellow and white antimony oxides.

Two other antimony mines near the Bray-Beulah mine in the Big Creek mining district of Lander County have produced over a hundred tons of metal. These are the Antimony King mine (secs. 25, 26, and 36, T. 18 N., R. 43 E.) which has yielded more than 500 tons of the metal, and the Dry Canyon mine (sec. 35, T. 18 N., R. 43 E.) with a production of 165 tons. At the Antimony King mine (No. 46) stibnite occurs with pyrite in quartz veinlets and in silicified limestone breccia in a 2- to 9-foot-wide fault zone, striking N. 55° W. and dipping 55° SW., in limestone. At the Dry Canyon mine (No. 46) stibnite, tetrahedrite, sphalerite, and pyrite occur in a 4- to 12-inch-wide quartz vein, striking N. 35° W. and dipping 55° SW. in arenaceous limestone.

The Potosi mine (No. 59) 1 mile west of Candelaria (sec. 5, T. 3 N., R. 35 E.), in Mineral County, has been the fourth largest antimony producer in the State. In contrast to the other major antimony mines described above, which mined stibnite-bearing quartz veins, the estimated 700 tons of antimony from the Potosi mine has been recovered as a byproduct from silver-lead ores. The vein is 8 to 36 inches thick, strikes N. 70° E., dips 45° N., and is offset by several faults striking N. 20° E. It consists of quartz with pods and veinlets of the antimony minerals jamesonite and bindheimite; pyrite; and minor tetrahedrite, galena, and calcite. Ore produced from 1948 through 1952 contained 0.5 to 0.6 ounces of gold and 8 to 12 ounces of silver per ton, 8 to 12 percent lead, 4 to 6 percent antimony, 0.5 percent copper, and 0.5 percent zinc. The bindheimite (a lead-antimony oxide) is an oxidation product of jamesonite, ($Pb_4FeSb_6S_{14}$); brown, yellow, orange, and green banded bindheimite commonly encloses cores of jamesonite. The vein is along the contact between shales of the (Triassic) Candelaria Formation and "grit" of the (Permian) Diablo Formation which forms the footwall. Rhyolite dikes intrude the country rock.

Over 500 tons of antimony have been recovered from silver-lead ore mined in the Arabia mining district (No. 79) in the eastern foothills of the Trinity Range (mainly sec. 21, T. 29 N., R. 32 E.), Pershing County. The Montezuma mine has been the principal producer. Numerous quartz veins up to 6 feet wide and a thousand feet long cut granodiorite and Jurassic(?) hornfels. The veins generally strike north to northeast and dip to the east. They consist of quartz; locally abundant plumbojarosite, bindheimite, and other antimony oxides; and some calcite, arsenopyrite, jamesonite, and cerussite. Most of the jamesonite ($Pb_4FeSb_6S_{14}$) that originally was present has been oxidized to plumbojarosite, bindheimite and other antimony oxides.

TABLE 4.—*Antimony occurrences in Nevada*

[Numbers identify symbols shown in figure 16]

CHURCHILL COUNTY

1. Lake mining district (Green and Hazel mines)
2. Quick-Tung mine
3. Bernice Canyon area (includes Antimony King, I.H.X., Lofthouse, Drumm, Hoyt, and Arrance mines)
4. Caddy mine

CLARK COUNTY

5. Goodsprings (Yellow Pine) mining district
6. New Deal and Yarmouth mines

DOUGLAS COUNTY

7. Pine Nut Range (includes Danite mine)
8. Fullstone prospect

ELKO COUNTY

9. Blue Ribbon-Boyce mine
10. Mendive and Merritt Mountain prospects
11. Island Mountain mining district (includes Gribble Antimony mine)
12. Charleston mining district (includes Prunty Antimony mine)
13. Valdez prospect
14. Delano mine
15. Cornucopia mining district
16. Hyer, Sage, Hen, Snyder prospects
17. Good Hope mine
18. Rock Creek mining district
19. Tuscarora mining district
20. Burns Basin and Lost and Found mines, and Birds Eye prospect.
21. Bootstrap mine
22. Hunter prospect

ESMERALDA COUNTY

23. Mickspot mine
24. Gilbert mining district
25. Cattle Rock prospect
26. B & B and Red Rock mines
27. Florence mine
28. Mattmueller mine

EUREKA COUNTY

29. Morning Glory mine
30. Stafford mining district
31. Cortez mining district
32. Mineral Hill mining district
33. Blue Eagle mining district
34. Stibnite and Young prospects

HUMBOLDT COUNTY

35. Nevada King mine
36. National mining district
37. Juanita group
38. Amos prospect
39. Getchell mine
40. Snowdrift mine
41. Ten-Mile mining district (Pansy-Lee and W.P. mines)

LANDER COUNTY

42. Battle Mountain district (includes Cottonwood Canyon, Apex, and Mizpah mines)
43. North Shoshone Range, (includes Blue Dick mine)
44. Wildhorse mine
45. Reese River (Austin) mining district
46. Big Creek mining district (includes Bray-Beulah, Dry Canyon, and Antimony King mines)

LYON COUNTY

47. DeLongchamps prospect

MINERAL COUNTY

48. Reservation Hill prospect
49. Happy Return mine
50. Broken Hills mine
51. Lithia mine
52. Lucky Boy mine and Bismark prospect
53. Lowman mine
54. Antimony Blossom, Hartwick, and Julia prospects
55. Beeler prospect
56. Volcanic Peak mine
57. Pilot Mountain mining district
58. Kernick mine
59. Candaleria mining district (includes Potosi mine)

NYE COUNTY

60. Milton Canyon mine
61. Murphy and Teichert mines
62. Last Chance and Dollar mines
63. Antimony Lode and Flower mines
64. White Caps mine
65. King Solomon mine
66. Page mine
67. Morey mine
68. Titus prospect
69. Blackbird prospect
70. Lucky Tramp mine
71. Outlook prospect
72. Reveille Range (Antimonial and Eaton mines)

PERSHING COUNTY

73. Antelope and DeSoto mines
74. Mill City (Nevada-Massachusetts mine)
75. Seven Troughs mining district
76. Bottomley propect
77. Star mine and Motor prospect
78. Star mining district (includes Bloody Canyon and Pflum mines)
79. Arabia mining district (includes Montezuma, Electric, and Jersey mines)
80. Panther Canyon (includes Bradley, Panther Canyon, and Oreana mines)
81. Black Warrior mine
82. Johnson-Heizer, Adriene, and Rosal mines
83. Rochester mining district
84. Muttleberry Canyon mine
85. Sutherland Antimony mine
86. Antelope Springs mining district (includes Hollywood and Cervantite mines
87. St. Anthony mine
88. Green Antimony mine
89. Willow Creek prospect
90. Antimony Ike mine
91. Ore Drag mine
92. Polkinghorne propect
93. Fencemaker mine

WASHOE COUNTY

94. Fox Mountains
95. Angelia prospect
96. Dontelli and Sleepy Joe mines
97. Choates mine and Sunset prospect
98. Steamboat Springs

WHITE PINE COUNTY

99. Bald Mountain mining district (includes Crown Point and Dees mines)
100. Cherry Creek minin district
101. Taylor Creek mining district (Merrimac and Enterprise mines)

very near the earth's surface as well as at the depths represented by hypothermal veins.

Tactites have been found in many places to contain abnormal amounts of beryllium (Warner and others, 1959). Five widely spaced localities which yield tactite samples with at least 0.01 percent BeO are shown on the map. A beryllium-rich mineral has been found in only one Nevada tactite—that in the Railroad district (No. 21). Idocrase was found to be enriched in beryllium in the central Elko County tactite (No. 11) and has been recognized also at the Star mine, father south in Elko County (No. 10). Granite contains unusual amounts of beryllium near its contact with beryllian tactite at the Victory (No. 13) and Star mines.

Beryllian idocrase is a major constituent of several layers of tactite on the east side of the Snake Range, White Pine County (No. 14). Samples from other tactites in the same area contain interesting amounts of beryllium, but the mineralogy of these deposits has not been determined.

The central part of the Railroad district, Elko County, Nevada (No. 21), has yielded samples with 0.02 percent BeO, as well as over 0.1 percent of yttrium and lanthanum (Ketner and Smith, 1963). The samples are of veins that are in tactite, but which resemble mesothermal veins in other districts more than contact metamorphic deposits. Thus they might reasonably be separated from tactite deposits (Ketner, oral communication, 1963). The rare sodium beryllium phosphate beryllonite has been found in oxidized ore of this district. This is the only known occurrence of this mineral outside of pegmatites and is the only occurrence of a mineral containing beryllium as a major constituent in tactite in Nevada.

Beryl has been found in granite in Sawmill Canyon in southern Nye County (No. 9), but the locality has not been studied.

BISMUTH

(By Priscilla Mount, U.S. Geological Survey, Washington, D.C.)

Bismuth is a brittle, silver-white, low-melting-point metal used chiefly in fusable alloys and in pharmaceuticals. It is obtained mainly as a byproduct in the metallurgical treatment of silver, lead, zinc, copper, gold, tungsten, and molybdenum ores. There is no record of production of bismuth in Nevada, principally because byproduct bismuth production is not recorded by source of ores; however, some of the Nevada metalliferous ores are known to contain bismuth.

Bismuth is associated with tungsten deposits in several mining districts in Nevada, including the Tem Piute, Valley View, Rawhide, and Potosi. All of these tungsten deposits are in tactites formed where limestone has been intruded by granitic rocks (Hobbs and Clabaugh, 1946; Geehan and Trengove, 1950). At the Lincoln and Schofield mines in the Tem Piute district, Lincoln County (No. 1, fig. 19), tactite layers and pods in limestone at the contact of a granite stock contains scheelite with associated sphalerite, pyrite, pyrrhotite, and minor galena, chalcopyrite, and fluorite. Bismuth was reported in concentrates obtained during metallurgical testing of this ore (Binyon, Holmes, and Johnson, 1950). The 68.2 percent tungsten

A vein 1 to 4 feet thick on Lynch Creek, in the Toiyabe Range about 10 miles south of Austin, Lander County (No. 17), consists largely of coarse white quartz. Embedded in the quartz are aggregates about one-tenth of an inch across of greenish muscovite flakes, and calcite and feldspar in masses up to 3 inches in diameter (Hall, 1962). Scheelite grains in quartz and in muscovite are about one-eighth of an inch across and green beryl forms prisms up to one-sixteenth of an inch across and 1 inch long. The vein shows no consistent zoning.

One quartz vein at the Pine Crow wolframite and scheelite prospect at Marietta, Mineral County (No. 19), was found to contain beryl. The beryl is in tiny light blue crystals along the granite footwall of the vein (Olson and Hinrichs, 1960, p. 182).

Deposits of beryllium occurring as phenacite and beryl were found in 1959 at the Mount Wheeler mine and the adjacent Jeppson claims on the west side of the southern Snake Range (No. 20). The beryllium minerals, as well as scheelite and fluorite, are associated with quartz veins in a limestone unit, locally known as the "Wheeler Limestone," in the lower part of the Pioche Shale of Cambrian age. The deposits have been explored more extensively than any other in Nevada. In 1959 and 1960, Beryllium Resources, Inc., explored part of the beryllium deposit by extending the older underground workings and by underground diamond drilling. Later, an extensive exploration and development program was conducted by the Anaconda Co. who purchased the mine in 1962. The deposit in the Mount Wheeler mine has been reported to contain an extimated 100,000 tons or more of ore averaging 0.75 percent BeO (Engineering Mining Journal, 1959). Ore mined during the exploration programs has been stockpiled, but, to date, production has been limited to shipments for milling tests.

The Bisoni brothers have located several beryl-bearing veins about 15 miles southwest of Eureka, Eureka County (No. 18) (Holmes, 1963, p. 13). The veins contain abundant fluorite, a fine-grained pale green micaceous mineral, red hematite, and needle-like prisms of white or yellow beryl, most of which are thinner than one-sixteenth of an inch. Many of the crystals are porous and rather soft. The total amount of beryl in the area appears to be large, although the economic importance of individual concentrations is still in doubt.

As yet, no epithermal beryllium deposits have been found in Nevada that are similar to those in altered dolomitic rhyolite tuff that are being explored at Spor Mountain, Utah. A mass of bleached and altered quartz monzonite in the Cherry Creek Range, White Pine County (No. 22) is reported to yield samples containing at least 0.1 percent BeO and may represent a mesothermal or epithermal type of mineralization.

The manganese-rich hot spring deposits at Sodaville, Mineral County (No. 24), and at Golconda, Humboldt County (No. 23), represent a rather novel type of beryllium concentration. Samples of manganese- and iron-rich material contain as much as 0.016 percent BeO, but no beryllium mineral has been recognized in them. Calcareous sinter at Golconda and chalcedony at Sodaville are not beryllium-rich (Warner and others, 1959, p. 64-65, 69–70). There is little indication that the economic potential of such deposits is important, but they illustrate that beryllium has been deposited at or

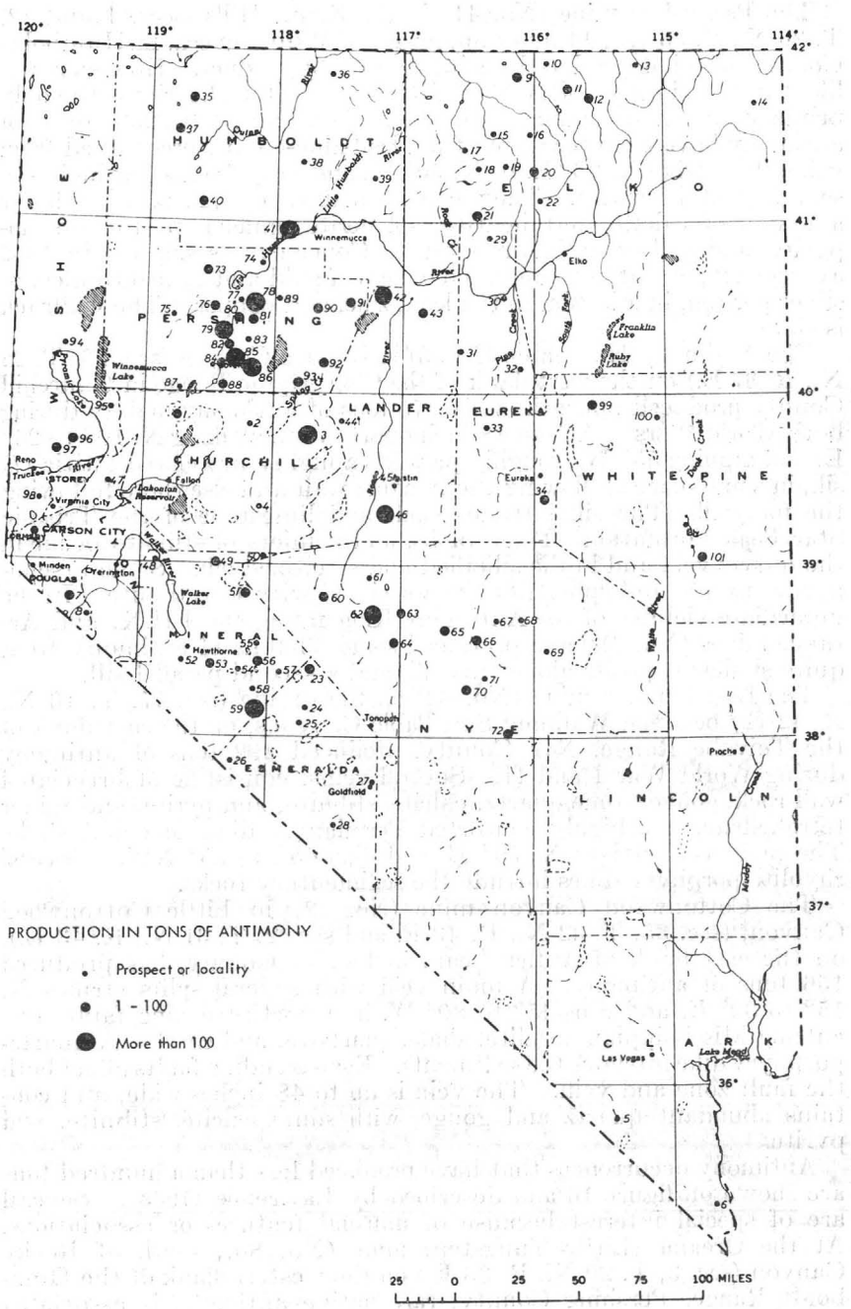


FIGURE 16.—Antimony in Nevada (numbers refer to deposits or districts listed in table 4).

The Pansy-Lee mine (No. 41) in the Krum Hills (secs. 1 and 12, T. 36 N., R. 36 E.), 11 miles northwest of Winnemucca, in Humboldt County, also has produced antimony as a byproduct. However, unlike the Potosi mine and Arabia district above, tetrahedrite is the only primary antimony mineral present. Approximately 200 tons of antimony have been recovered from lead-zinc-copper ores mined from veins that strike N. 20° E. to N. 50° W. and vary from a few inches to several feet in width. They consist mainly of quartz with lesser amounts of calcite, tetrahedrite, sphalerite, galena, pyrite, arsenopyrite, and yellow antimony oxides. Concentrates shipped in 1942 averaged 2 percent antimony, 0.6 ounces of gold and 50 to 60 ounces o silver per ton, in addition to the lead, zinc, and copper. The wallrock is slate.

The Antimony King mine (No. 3) in Bernice Canyon (sec. 23, T. 22 N., R. 37 E.) on the west flank of the Clan Alpine Range in Churchill County produced approximately 175 tons of antimony mainly during both World Wars. A 2- to 48-inch quartz vein, striking N. 10° to 25° E. and dipping 55° W., roughly parallels a highly brecciated latitic (?) sill, in some places following the hanging wall and elsewhere following the footwall. The sill intrudes shale and limestone of the Triassic Star Peak Formation. Pods, blebs, and veinlets of stibnite occur in the quartz vein and in the silicified and sercitized sill. Some arsenopyrite, pyrite, and sphalerite are associated with the stibnite. In the immediate vicinity of the Antimony King mine, the I.H.X. and Arrance mines (No. 3) have produced some 50 tons of antimony from quite similar deposits along this sill, and a second parallel sill.

The Last Chance mine (No. 62) on the divide (sec. 17, T. 10 N., R. 42 E.) between Wall and San Pablo Canyons, on the east flank of the Toiyabe Range, Nye County, produced 192 tons of antimony during World War I and II. Several veins, consisting of brecciated wall rock, gouge, some quartz, calcite, stibnite, and pyrite, and minor tetrahedrite, cut highly contorted Permian(?) limestone and shale. The main vein strikes N. 70° E. and dips 45° to 55° NW. Several rhyolite porphyry dikes intrude the sedimentary rocks.

The Cottonwood Canyon mine (No. 42) in Little Cottonwood Canyon, (sec. 35, T. 32 N., R. 43 E. and sec. 2, T. 31 N., R. 43 E.), on the east flank of Antler Peak, in Lander County, has produced 156 tons of antimony. A main vein with several splits strikes N. 15° to 30° E. and dips 45° to 80° W. in a north-trending fault zone cutting Mississippian argillite, shale, quartzite, and chert. A quartz-porphyry dike intrudes the sediments. East-trending faults offset both the fault zone and vein. The vein is up to 48 inches wide, and contains abundant quartz and gouge, with some calcite, stibnite, and pyrite.

Antimony occurrences that have produced less than a hundred tons are shown on figure 16 and described by Lawrence (1963). Several are of special interest because of unusual features or associations. At the Oreana (Little Tungsten) mine (No. 80), south of Rocky Canyon (sec. 3, T. 29 N., R. 33 E.) on the western flank of the Humboldt Range, Pershing County, rare native antimony is associated with scheelite and beryl in a quartz-oligoclase-albite-phlogopite pegmatite body. At Steamboat Springs (No. 98), 10 miles south of Reno in Washoe County, stibnite and "metastibnite" occur with

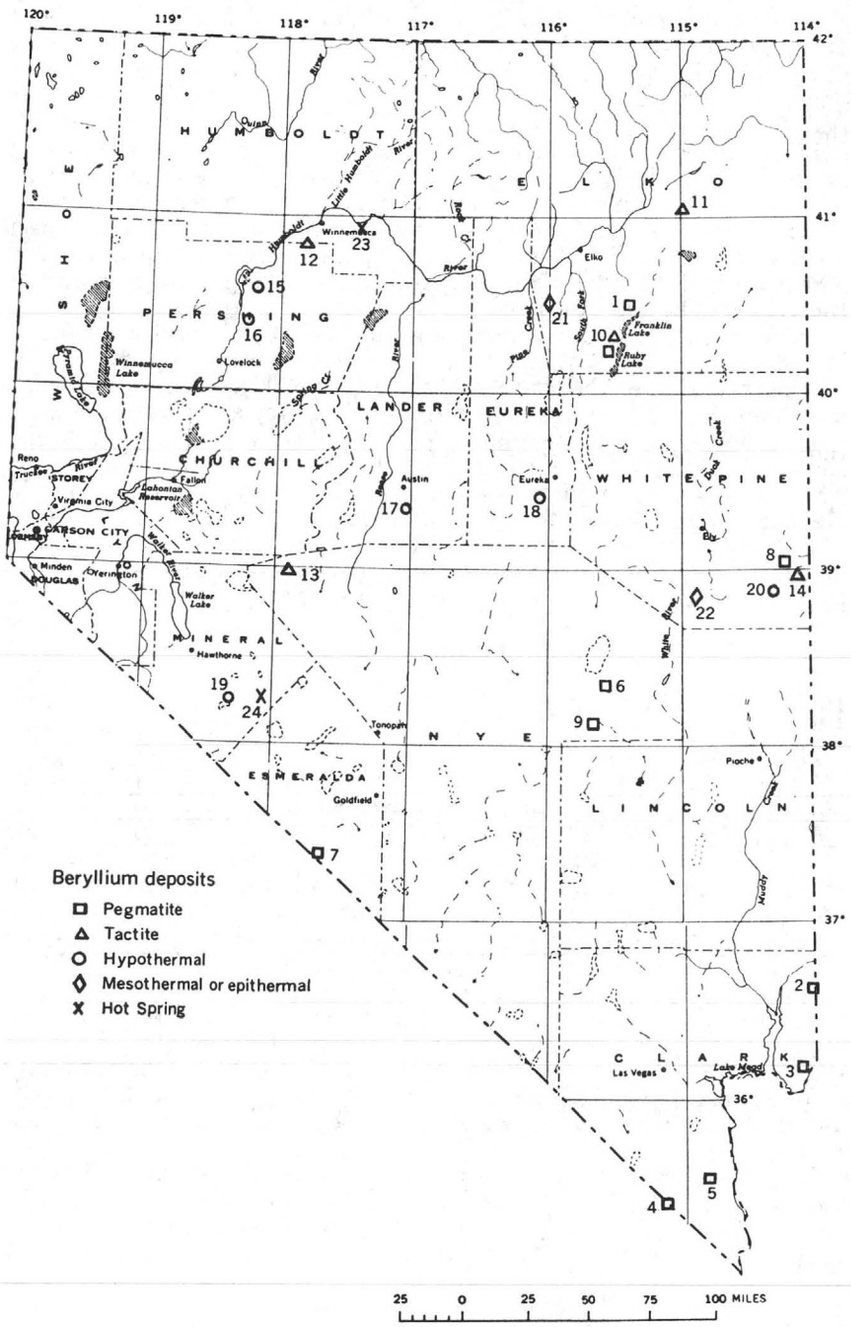


FIGURE 18.—Beryllium in Nevada (numbers refer to deposits or districts listed in table 5).

TABLE 5.—*Beryllium deposits in Nevada*

[Numbers identify symbols shown in fig. 18]

PEGMATITE DEPOSITS	
1. Ruby Mountains	Elko County.
2. Northern Virgin Mountains	Clark County.
3. Southern Virgin Mountains	Do.
4. Crescent Peak area	Do.
5. Eldorado Mountains	Do.
6. Troy Canyon	Nye County.
7. Sylvania district	Esmeralda County.
8. Strawberry Creek	White Pine County.
9. Sawmill Canyon	Nye County.
TACTITE	
10. Star mine	Elko County.
11. Wells area	Do.
12. Rose Creek mine	Pershing County.
13. Victory mine	Nye County.
14. Snake Range	White Pine County.
HYPOTHERMAL VEINS	
15. Lakeview mine	Pershing County.
16. Oreana mine	Do.
17. Lynch Creek	Lander County.
18. Eureka district	Eureka County.
19. Pine Crow claims	Mineral County.
20. Mount Wheeler and Jeppson deposits	White Pine County.
MESOTHERMAL VEINS IN TACTITE	
21. Railroad district	Elko County.
MESOTHERMAL OR EPITHERMAL DEPOSIT	
22. Cherry Creek Mountains	White Pine County.
HOT SPRING DEPOSITS	
23. Golconda area	Humboldt County.
24. Sodaville area	Mineral County.

chalcedony, quartz, opal, pyrite, cinnabar, and arsenopyrite in the sinter deposits formed by the hot springs. At the Green prospect (No. 1), on the northwest flank of the Mopung Hills (sec. 9, T. 23 N., R. 29 E.), Churchill County, stibnite and antimony oxides occur in large, angular boulders of limestone and rhyolite which lie on limestone and ryolite bedrock and are cemented by Quaternary Lake Lahontan tufa; the angularity and size of the rubble blocks suggest that they have not been moved any appreciable distance.

A large number of Nevada antimony deposits contain small amounts that add up to an important potential source of the metal; however higher prices are necessary before this material can be profitably mined. Erratic price fluctuations have discouraged exploration and capital investment. Further exploration at some of the deposits could reveal large-enough tonnages of low-grade material to make mass-mining profitable. The chances of finding a commercial selenium deposit in association with antimony in Nevada are poor.

ARSENIC

(By B. A. La Heist, U.S. Geological Survey, Washington, D.C.)

Arsenic is produced as a by-product of copper and lead smelting and in the recovery of gold and silver. It is recovered only in the form of arsenious oxide (white arsenic), as no metallic arsenic has been produced in the United States since about 1950. The United States ranked as a major producer and consumer of arsenical products in 1962. Other important producing countries in the non-Communist World include Sweden, Mexico, and France. No domestic ores are mined exclusively for arsenic. Before 1907, arsenic was imported and a considerable amount of white arsenic is still imported chiefly from Canada, Mexico, France, and Sweden. The first recorded production of white arsenic in the United States was in 1901. Arsenic is used for manufacturing calcium and lead arsenate insecticides and herbicides, in chemicals for wood preservation, and is added to lead shot and glass. A small amount is used in alloys with lead and copper to increase the hardness of the former and the resistance of the latter to corrosion and erosion. Many uses of arsenic as a toxic agent have fallen off in recent years with the advent of organic compounds such as DDT.

The most commonly occurring arsenic-bearing minerals are the sulfides arsenopyrite, realgar, and orpiment. The latter two minerals are now manufactured artificially for use in pigments, fireworks, and in dyeing and tanning processes. Native arsenic and the arsenic-bearing minerals proustite, enargite, tennantite, scorodite, annabergite, mimetite, erythrite, cobaltite, niccolite and smaltite are rarer occurrences in the United States. Arsenopyrite, the principal source of white arsenic, is commonly associated in veins with the ores of tin, nickel, cobalt, silver, gold, and lead and with other sulfides such as pyrite, chalcopyrite, and sphalerite. Realgar occurs with the ores of silver and antimony and is usually associated with its alteration product orpiment. Realgar is also found in sublimation deposits from hot springs. Native arsenic is found principally in veins associated with silver, cobalt, and nickel ores.

Arsenic has a widespread occurrence in the ore deposits of Nevada but only in a few districts is the concentration of arsenic-bearing minerals of commercial interest. The Getchell mine in the Potosi district (No. 8, fig. 17), Humboldt County, for example, is one of only a few mines in the United States with considerable resources of arsenic which could be recovered directly from the milling or treating of its precious

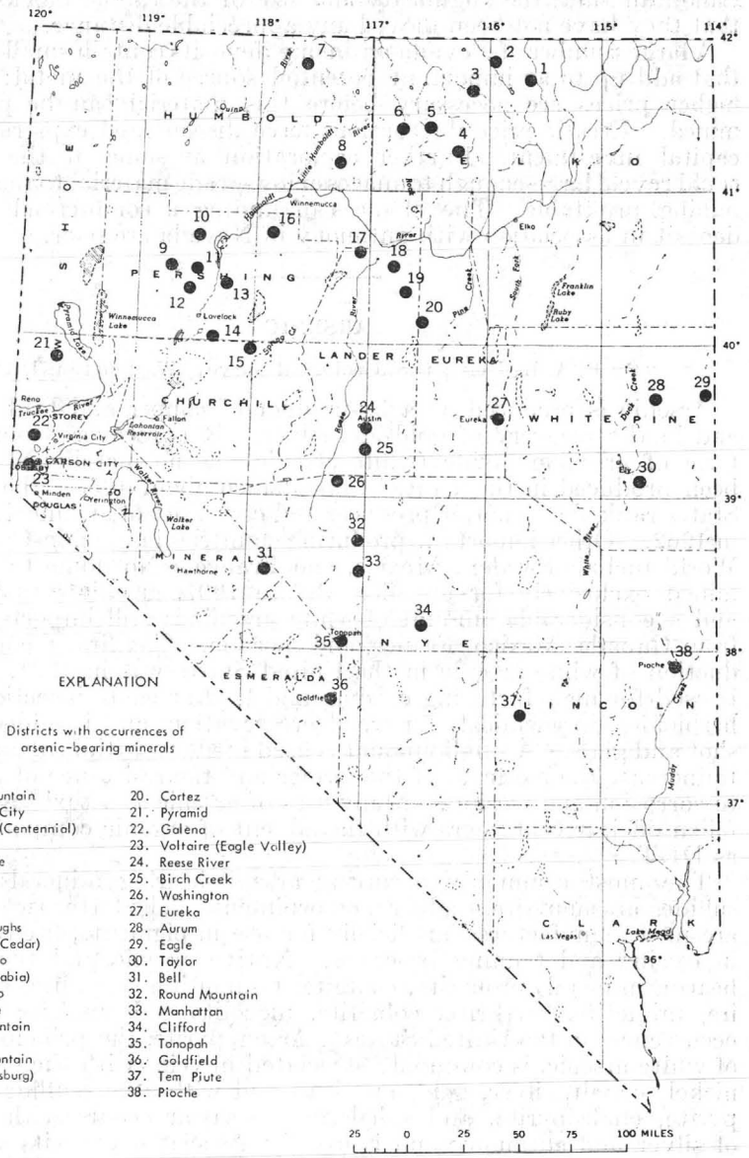


FIGURE 17.—Arsenic in Nevada.

deposits in the Ruby Range (No. 1, fig. 18) and the beryl-chrysoberyl deposits of the northern Virgin Mountains (No. 2) have been explored more than those elsewhere and may contain substantial amounts of beryllium (Olson and Hinrichs, 1960, p. 147–173). The rock at both places is rather fine grained, and the minerals will have to be concentrated by flotation.

Beryl has also been reported in pegmatites in the southern Virgin mountains (No. 3) and near Crescent Peak, in Clark County, but apparently in rather small amounts. And a specimen of beryl was received from the Sylvania district, Esmeralda County (No. 7) (Olson and Hinrichs, 1960, pp. 183, 186, 188). Beryl also has been found in pegmatite in the Troy Canyon area, Nye County (No. 6) and in a composite pegmatite-aplite dike in the Strawberry Creek area, White Pine County (No. 8).

Much of central and eastern Nevada is in the largest nonpegmatitic beryllium province in North America, which extends westward from the vicinity of Eureka, Utah, to Austin and Oreana, Nev. Many occurrences of beryllium minerals have been found in this area, of which those of the Mount Wheeler mines and those near Eureka have been extensively explored and probably contain very substantial amounts of berryllium. No beryllium ore has been sold from any of these deposits up to the present, but the probability of future production is good.

A wide variety of beryllium deposits has been found. Hypothermal veins containing beryl, quartz, scheelite or wolframite, muscovite or feldspar, and fluorite or calcite have been found in Pershing, Mineral, Lander, Eureka, and White Pine Counties. Contact metamorphic deposits containing beryllium have been found in Elko and Pershing Counties. Veins of possible mesothermal character contain beryllium in Elko County and veins of mesothermal or epithermal type in altered quartz monzonite contain beryllium in White Pine County. Manganese- and silica-rich hot spring deposits contain beryllium in Mineral and Humboldt Counties. Some of the hypothermal veins have been called pegmatites, but they differ from pegmatites in occurence, mineralogy, and internal structure.

At the Lakeview mine, Pershing County (No. 15), scheelite and beryl are found in quartz veins and in coarse calcite lenses in limestone near a stock of monzonite. Accompanying minerals are dark blue tourmaline, pyrite, sphalerite, and muscovite (Olson and Hinrichs, 1960, pp. 174–176). Muscovite and white beryl form selvages at the walls of veins of coarse white quartz.

The Oreana mine (No. 16) yielded scheelite from veins in metadiorite that contain quartz, oligoclase, albite, fluorite, beryl, scheelite, phlogopite, and accessory minerals. The main vein was 1 to 5 feet thick and 2,000 feet long. The minerals were erratically distributed through the vein—in places nearly the entire thickness of the vein was scheelite or fluorite. Beryl forms green prisms one-eighth to one-quarter of an inch across that generally are embedded in white oligoclase, with little or no quartz (Kerr, 1938; Olson and Hinrichs, 1960, pp. 176–177).

recent years in that supply far exceeds demand, and the use of arsenical insecticides and pesticides has decreased. More arsenic could be produced if new uses were developed and if economic conditions became more favorable.

BERYLLIUM

(By W. R. Griffiths, U.S. Geological Survey, Denver, Colo.)

Beryllium is a rather rare metal that has a wide variety of uses, both as pure or alloyed metal and in chemical compounds. More than half of all beryllium used is alloyed with copper to make a hard, fatigue-resistant alloy that is much used in springs and other instruments, and in tools that must lack the magnetism and sparking or rusting tendency of steel. Beryllium oxide has long been used as a refractory as it combines high electrical resistance, high thermal conductivity and thermal shock resistance, and a high melting point (4,658° F.). More recent developments are the use of both the metal and the oxide as moderators and reflectors of neutrons in nuclear reactors and as a neutron source in neutron generators. Because of its rigidity beryllium is used in inertial guidance mechanisms of missiles but its brittleness has so far hindered large-scale use as a structural material in missiles and manned aircraft, where its lightness and rigidity would be valuable properties. Beryllium-rich alloys with aluminum were reported in 1963 to have potentially large-scale use in aircraft manufacture. Alloys with alluminum, like those with nickel and magnesium, have already been used on a small scale. Beryllium minerals and compounds are used in the making of special ceramic materials. Speculative uses of the metal include its incorporation in missile fuels and explosives.

The total amount of beryllium used in the United States is not large, as compared with that of other metals. The consumption of ore increased from 1,013 tons in 1946 to an alltime high of only 9,692 tons in 1960. The ninefold increase in consumption, however, is indicative of the increasing industrial importance of the metal.

Adequate and increasing supplies of ore have been obtained by importing the mineral beryl, which contains 10 to 14 percent BeO. This mineral is obtained from pegmatites in South Africa, Brazil, Argentina, India, and elsewhere. Only about 6 percent of our supply is from domestic sources. The low production from domestic pegmatite deposits has caused emphasis in exploration to shift, since 1950, to deposits of other types, some of which are well represented in Nevada.

In general, the pegmatitic deposits of Nevada, though they are of the type that has yielded most of the world's beryl, appear less promising than the nonpegmatitic deposits. No more than a few tons of beryl have been sold from mines in the State. Additional amounts of ore have been extracted during exploration and either stockpiled or used for beneficiation tests.

Beryl has been found in pegmatite deposits in several places in Nevada as listed in table 5 and shown on figure 18. The beryl

metal ores (McMahon, 1960). Arsenopyrite is the most common arsenic-bearing mineral found in metallic ore deposits in Nevada. It is present in (1) hypothermal deposits such a those found at Majuba Hill (No. 10), Pershing County; (2) mesothermal deposits in the Eureka district (No. 27), Eureka County, and Pioche district (No. 39), Lincoln County; (3) epithermal silver deposits such as those in the National district (No. 7), Humboldt County, Tuscarora district (No. 4), Elko County, Goldfield district (No. 36), Esmeralda County, and the Tonopah district (No. 35), Nye County. Complex silver sulpharsenides are abundant wlth the arsenopyrite in these districts; (4) the very productive, predominantly silver- and gold-bearing quartz veins associated with granitic intrusives of western Nevada such as in the Reese River district (No. 24), Lander County; (5) contact-metamorphic deposits in west-central Nevada important for their tungsten and base metal content such as at the Potosi (Getchell) district, Humboldt County, and in the Tem Piute district (No. 37), Lincoln County; (6) replacement deposits which are especially important for their silver, lead, and zinc ores in eastern Nevada such as the Eureka and Cortez (No. 20) districts, Eureka County, and the Pioche district, Lincoln County (York and Ferguson, 1944). Realgar is present in the sublimates of the hot springs deposits at Steamboat Springs, Washoe County.

The first mention of arsenic minerals (realgar and orpiment) having been mined in Nevada was in 1919 by the White Caps Mining Co. of Manhattan (No. 33), Nevada. Resources of this material were considered to be substantial. Early in the 1920's, Nevada was a major supplier of arsenical ores from such districts as Battle Mountain (No. 17), Lander County, and from Manhattan, Nye County, and Eureka, Eureka County. A small arsenic plant at Toulon, Pershing County, produced white arsenic in 1923. This plant continued operations for a number of years using ores from the Irish Rose mine, Battle Mountain district, Lander County. In 1941, equipment was installed at the Getchell mine for roasting gold ore to produce arsenical flue dust. This flue dust was shipped to smelters in Tacoma, Wash., and Murray, Utah, where arsenic was recovered throughout the mid-1940's. In 1949, a new mill designed to treat 1,500 tons of arsenical gold ore per day was completed at the Getchell mine. Since that time most of the arsenic recovered from Nevada ores has come from this property, although the arsenic concentrates are usually stockpiled. In the following paragraphs arsenic occurrences in Nevada are discussed by county, and numbered as shown on figure 17.

Churchill County.—The rare arsenic-bearing minerals annabergite and gersdorffite are thought to occur in association with the nickel, cobalt, copper, gold, lead, silver, and antimony ores of Cottonwood Canyon in the Table Mountain district (No. 15). Ore found in a prospect in this district occurs in fissure veins in andesite at a diorite contact (Lincoln, 1923).

Elko County.—In Elko County, arsenopyrite is associated with several gold, silver, lead, and zinc deposits. It is found in fissure veins in the Burner (No. 6), Edgemont (Centennial) (No. 3), and Mountain City districts (No. 2). It is also found in small quartz veins in the Good Hope (No. 5) and Island Mountain (No. 1) districts. These veins occur in andesite, quartzite, granite and metamorphosed limestone and rhyolite (Lincoln, 1923). In the Tuscarora district

PERSHING COUNTY

128 Antelope Mine
129 De Soto Antimony Mine
130 Bottomley Prospect
131 Electric Mine
132 Jaxrace Jewel Prospect
133 Jersey Mine
134 Montezuma Mine
135 West Group (Arabia District)
136 King George Mine
137 Antimony Star Mine
138 Cervantite Mine
139 Empire Claims
140 Friendship Mine
141 Hollywood Mine
142 Juniper Mine
143 Montgomery Mine
144 Pershing Mine
145 Red Bird Mine
146 Sutherland Antimony Mine
147 Adriene Mine
148 Johnson - Heizer Mine
149 Rosal Mine
150 Rochester District
151 Little Tungsten Mine
152 Bradley Mine
153 Panther Canyon Mine
154 Motor Prospect
155 Star Mine
156 Bloody Canyon Mine
157 Pflum Mine
158 De Soto Mine
159 Black Warrior Mine
160 Mc Crillis Prospect
161 Green Antimony Mine
162 Muttleberry Canyon Mine
163 Antimony Ike Mine
164 Fencemaker Mine
165 Nevada - Massachusetts Mine
166 Ore Drag Mine
167 Polkinghorne Prospect
168 Seven Troughs Mining District
169 St. Anthony Mine
170 Willow Creek Prospect

WASHOE COUNTY

171 Angelia Prospect
172 Choates Mine
173 Fox Mountains
174 Donatelli Mine
175 Sleepy Joe Mine
176 Steamboat Springs
177 Sunset Prospect

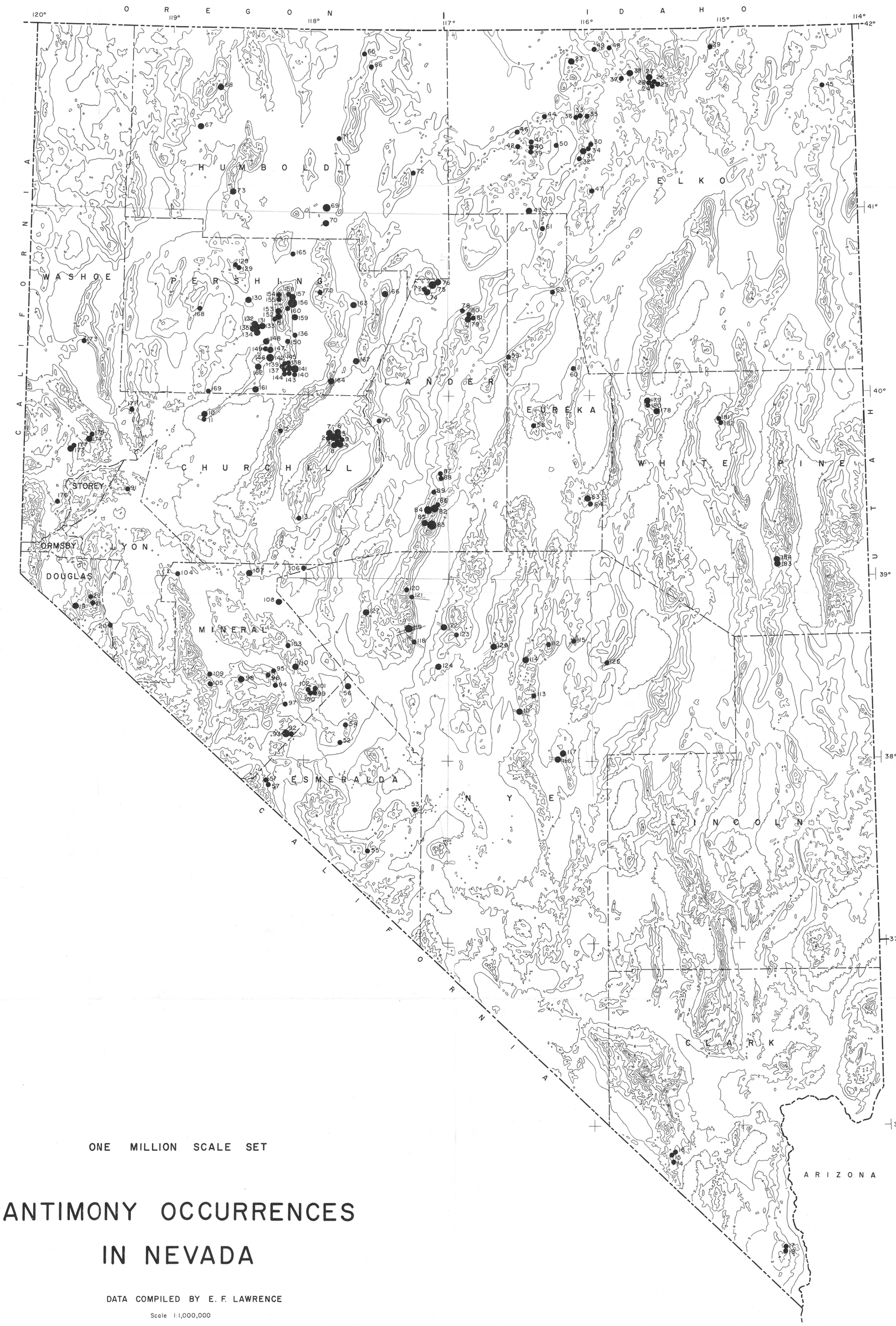
WHITE PINE COUNTY

178 Crown Point Mine
179 Dees Mine
180 Gold King Mine
181 Lage Mine
182 Nevada Antimony Mine
183 Enterprise
184 Merrimac Mine

PRODUCTION IN TONS OF ANTIMONY

- Prospect
- 1 - 100
- 100 - 1000
- 1000 - 10,000
- Over 10,000

NOTE: The placement of prospects, mines or districts in the generalized production categories above is based on figures published by the U. S. Bureau of Mines, U. S. Geological Survey, Nevada Bureau of Mines, technical magazines, and obtained from individual owners, tax records, car loading reports, field examinations and estimation. The groupings are generalized to avoid disclosure of exact production data. Reserves are not included.



CHURCHILL COUNTY

1 Antimony King Mine
2 Arrance Prospect
3 Blue Eagle Group
4 Drumm Mine
5 Far South Marguerite No. 1 Prospect
6 Hoyt Mine
7 I. H. X. Mine
8 Lofthouse Mine
9 Marguerite Group
10 Green Prospect
11 Hazel Mine
12 Quick-Tung Mine
13 Caddy Mine

CLARK COUNTY

14 Antimony Prospect
15 Yellow Pine Mine
16 Lavina Prospect
17 New Deal Mine
18 Yarmouth Mine

DOUGLAS COUNTY

19 Danite Mine
20 Fullstone Prospect
21 Iron Pot Prospect
22 Winters Prospect

ELKO COUNTY

23 Blue Ribbon-Boyce Mine
24 Black Warrior Mine
25 Bounty Claim
26 Graham Mine
27 Prunty Antimony Mine
28 Rescue Mine
29 Valdez Prospect
30 Birds Eye Prospect
31 Burns Basin Mine
32 Eagle Prospect
33 Hyer Prospect
34 Lost and Found Mine
35 Sage Hen Prospect
36 Snyder Prospect
37 Foss Prospect
38 Gribble Antimony Mine
39 Falcon Mine
40 Fisher Prospect
41 Red Cow Creek Prospect
42 Rock Creek Prospect
43 Bootstrap Mine
44 Cornucopia Mining District
45 Delano Mine
46 Good Hope Mine
47 Hunter Prospect
48 Mendive Prospect
49 Merritt Mountain Prospect
50 Tuscarora Mining District

ESMERALDA COUNTY

51 B & B Mine
52 Castle Rock Prospect
53 Florence Mine
54 Gilbert Mining District
55 Mattmueller Mine
56 Mickspot Mine
57 Red Rock Mine

EUREKA COUNTY

58 Blue Eagle Mine
59 Cortez Mining District
60 Mineral Hill Mining District
61 Morning Glory Mine
62 Stafford Mining District
63 Stibnite Prospect
64 Young Prospect

HUMBOLDT COUNTY

65 National Mining District
66 Bell Group
67 Juanita Group
68 Nevada King Mine
69 Pansy-Lee Mine
70 W. P. Mine
71 Amos Prospect
72 Getchell Mine
73 Snowdrift Mine

LANDER COUNTY

74 Apex Mine
75 Cottonwood Canyon Mine
76 Mizpah Mine
77 Weber Mine
78 Betty O'Neal Mine
79 Blue Dick Mine
80 Blue Nose Mine
81 Kattenhorn Mine
82 Antimony King Mine
83 Bray - Beulah Mine
84 Dry Canyon Mine
85 Hard Luck - Pradier Mine
86 Spencer Claims
87 Amador Mine
88 Silver Cliff Mine
89 San Miguel Mine
90 Wildhorse Mine

LYON COUNTY

91 De Longchamps Prospect

MINERAL COUNTY

92 Petrel Mine
93 Potosi Mine
94 Antimony Blossom Prospect
95 Hartwick Prospect
96 Julia Mine
97 Kernick Mine
98 Lowman Mine
99 Drew Mine
100 Lost Steer Mine
101 Mina Development Company Mine
102 Reward Mine
103 Beeler Prospect
104 Reservation Hill Prospect
105 Bismark Prospect
106 Broken Hills Mine
107 Happy Return Mine
108 Lithia Mine
109 Lucky Boy Mine
110 Volcanic Peak Mine

NYE COUNTY

111 Lucky Tramp Prospect
112 Morey Mine
113 Outlook Prospect
114 Page Mine
115 Titus Prospect
116 Antimonial Mine
117 Eaton Prospect
118 Dollar Mine
119 Last Chance Mine
120 Murphy (Ophir) Mine
121 Teichert Mine
122 Antimony Lode Prospect
123 Flower Mine
124 White Caps Mine
125 Blackbird Prospect
126 King Solomon Mine
127 Milton Canyon Mine

ONE MILLION SCALE SET

ANTIMONY OCCURRENCES IN NEVADA

DATA COMPILED BY E. F. LAWRENCE

Scale 1:1,000,000

0 10 20 30 40 50 100 miles

One inch = approximately 16 miles

JULY 1962

Cartography by Barbara Webb

Price 50 cents

Nevada Bureau of Mines
University of Nevada
Reno, Nevada