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OREGON "SUNSTONES"

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Introduction

Within Oregon there is a small but unusual occurrence of semiprecious gems known as "sunstones." The locality is in the Rabbit Basin of southeastern Lake County, and the "sunstones" occur as phenocrysts (large crystals) of gem-quality feldspar in a basaltic lava flow.

Specific field information about the sunstone occurrence was gathered by the author during three days late in the summer of 1972. Bob Rogers and George Marshall of Portland, Oregon; Don Sellers of Lakeview, Oregon; Truman Mitchell of Milwaukie, Oregon; and Mrs. T. Mapes of Klamath Falls, Oregon, were very helpful in providing information about local geography and about sunstone mining and collecting in general. They also furnished specimens for study and photographing.

Definition of Sunstones

"Sunstone" is the name given to a certain variety of feldspar that exhibits a brilliant pink to reddish metallic glitter or shimmer. The metallic glitter results from the reflection of light from myriads of minute flat scales of hematite or other mineral impurities. The enclosed scales are so small and thin they appear transparent; however, their reddish color can be seen plainly by examining a thin piece of the feldspar with a magnifier. The mineral inclusions are usually arranged parallel to the direction of perfect cleavage in the feldspar crystal, so the glittering reflection is only seen when looking at the cleavage surface. The glitter or shimmer is called "aventurescence;" crystals of feldspars exhibiting aventurescence are called aventurine or more commonly sunstones.

Sunstones in general occur in both orthoclase and plagioclase feldspars. At the Oregon locality, however, the sunstones consist of crystals of calcic labradorite (one type of plagioclase feldspar); the colors range from red to green as well as the coppery aventurescence.

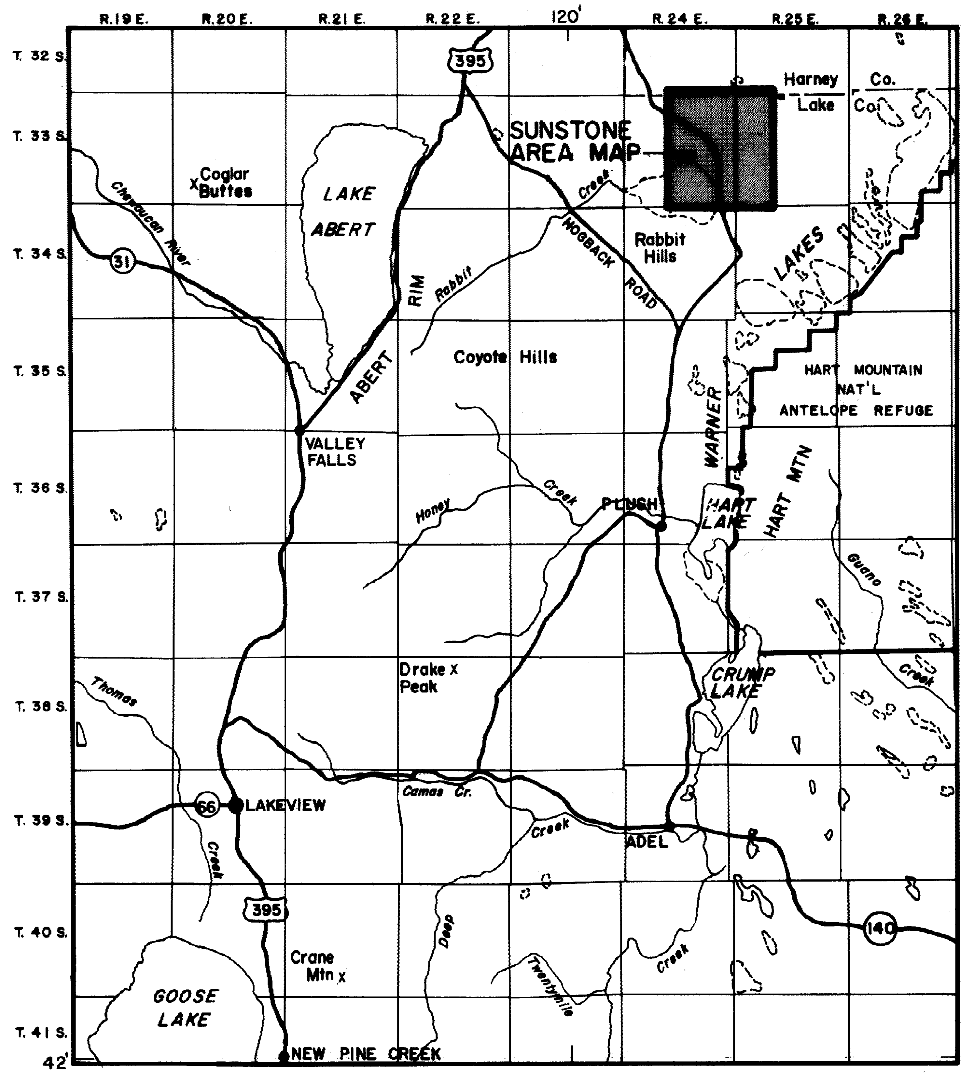

Figure 1. Index map of a part of Lake County, Oregon, showing routes to the sunstone locality and area of geologic map, Plate 1.

In most gemology references, sunstone is listed with the feldspar group as a semiprecious gemstone. In the early 1800's, sunstone was considered extremely rare and was very costly, but with subsequent discoveries in Sibera, Norway, and other parts of the world, it has become more available and less expensive. In the United States sunstone occurs at several locations, a partial list of which is given in Table 1.

Location and Geographic Setting

The Oregon locality is a small area of about 7 square miles in the northern part of the Rabbit Basin in Warner Valley, about 25 miles north of Plush (Figure 1). The area is in the northwestern part of the Rabbit Hills NE quadrangle, Oregon (7.5 minute series, U.S. Geol. Survey topographic map, 1966).

The area can be reached from Lakeview by following State Highway 140 north and east for 20 miles, then proceeding north on a paved county road to Plush. From Plush, gravel and dirt roads continue northward to the sunstone area; signs at road junctions give directions. An alternate route reaches the area via the Hogback Road, which leaves U.S. Highway 395 near the Hogback Summit about 50 miles north of Lakeview. About 14 miles east, at a marked junction, a dirt road leads eastward to the sunstone area. Roads beyond Plush are only periodically maintained, so travel to and from the area is only practical from late spring to early fall.

In this part of Lake County, extreme seasonal temperature changes and a very low rainfall limit the vegetation to low-growing sagebrush and clumps of desert grass. There is no drinking water available in Rabbit Basin, the closest available supply being at Plush.

Rabbit Basin, at an elevation of 4,600 feet is an area of low relief (Figure 2). Occasional arcuate beach ridges mark levels of an ancient pluvial lake that once occupied the basin. The highest shoreline encircles Rabbit Basin at an elevation of about 4,780 feet. In the northern part of the basin, a low, broad north-trending ridge known locally as Dudeck Ridge (Figure 3) is formed by the lava flows that contain the sunstones.

History of the Oregon Occurrence

It has long been known that sunstones, or aventurine feldspar of appreciable size and good quality occur in the Warner Valley in Lake County, Oregon (Figure 4). Locally the sunstones are referred to as "Plush Diamonds," and it is reported that the old maps of Lake County show the "Sunstone Mine."

The first collectors of Oregon sunstones may have been the Indians that inhabited or traveled through Warner Valley. A group of small stones (Figure 5), some of which show the aventurine glitter, are displayed with the Indian artifacts in the Jacksonville Museum. These sunstones, which

Figure 2. View south across Rabbit Basin from Dudeck Ridge showing the flat surface and sparse, arid-type vegetation. On Rabbit Hills in background, about a quarter of way up slope, can be seen the shoreline of an ancient pluvial lake.

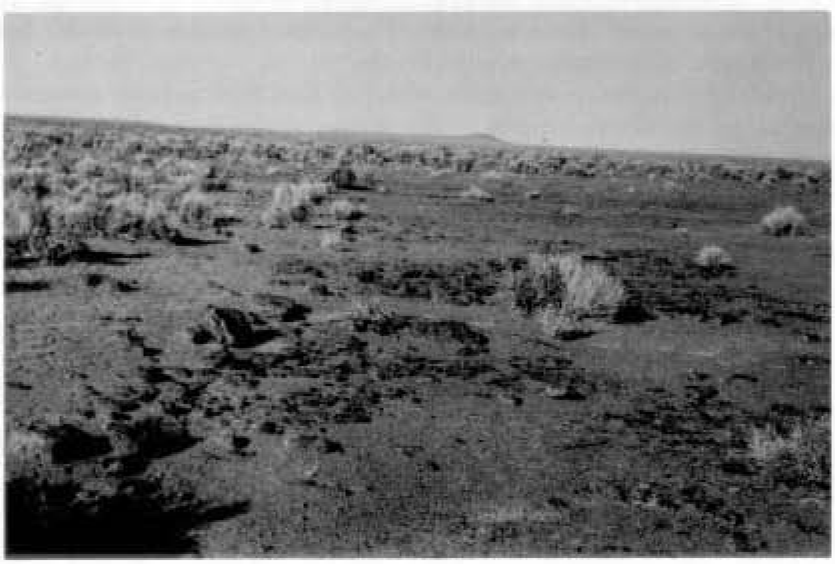

Figure 3. View of the surface of Dudeck Ridge showing the pellet-like residue that accumulates from the weathering of the basalt.

Table 1. Sunstone Localities in the United States

Location	Type of feldspar	Color and quality
Arizona Globe area	Andesine	Pale yellow with bright copper-colored reflections
California Modoc Co.	Labradorite	Clear, colorless, with bright coppery red reflections
New York Crown Point Chappaqua	Orthoclase	Small stones, almost colorless with a marked metallic sheen
North Carolina Medlock Mtn., Bakersville Co. Gold Hill, Rowan Co.	Oligoclase	Hematite inclusions extremely small
Oregon Rabbit Basin, Lake Co.	Calcic labradorite	Clear to amber stones with salmon sheen; clear red and green stones, some exhibit red and green in same stone
Pennsylvania Fairville, Pennsbury Twp.	Oligoclase	Very good sunstone, with fine reflections
Pennsbury, Chester Co.	Oligoclase	Grayish-white with copper reflection
Ashton Township	Oligoclase	Same description
Media, Delaware Co.	Orthoclase	Very fine green and red sunstone
Middletown Twp., Delaware Co.	Orthoclase	In small nodular lumps scattered through the soil
Glen Riddle, Delaware Co.	Orthoclase	A very rich salmon color, quite transparent and streaked with white
Kennett Twp., Chester Co.	Oligoclase	A beautiful variety found with hornblende
Mineral Hill, Delaware Co.	Orthoclase	Greenish orthoclase showing a very good sunstone effect
Virginia Hewlett, Hanover Co. Amelia Court House, Amelia Co.	Orthoclase	Associated with other varieties of feldspar

Figure 4. A large aventurine feldspar fragment (scale in inches) from the Oregon sunstone locality showing typical conchoidal fracture.

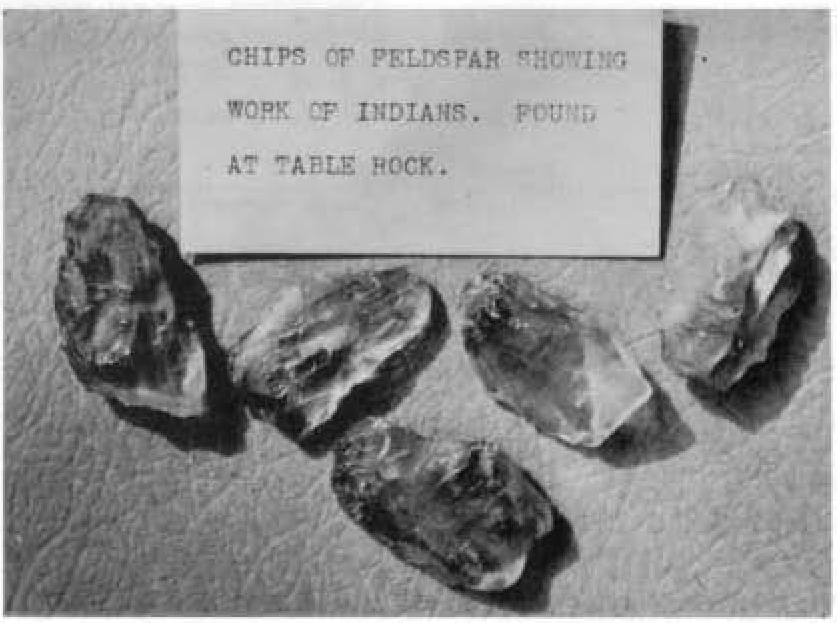

Figure 5. Collection of sunstones in the Jacksonville Museum believed to have been brought into the area by Indians.

are identical to the Warner Valley specimens, were found at Table Rock near Medford in Jackson County by an early resident. Some of the stones appear to have been flaked, and it is probable that the Indians from the Warner Valley traded them with the Rogue Valley tribes.

The reported occurrence of aventurine labradorite from Modoc County, California, listed in Table 1, was described by Olaf Andersen in 1917 and was based on a study of ". . . a number of pebbles and 6 cut stones in the collection of the U.S. National Museum." The properties of the feldspar he describes are almost identical to those of the Oregon labradorite. No recent references to a California occurrence in Modoc County can be found, so it is entirely possible that the material described could have come from Lake County, Oregon.

Aitkens (1931) in his discussion of the gem varieties of feldspar, states, "About 1908, a report of a discovery of a new deposit of labradorite in southern Oregon was made by Maynard Bixby of Salt Lake City, Utah, who stated that this mineral would yield handsome gem material. This labradorite ranges from colorless to a dark variety, showing fine red, salmon, and green tints."

Dake (1938), in describing the semiprecious gemstones of Oregon, indicates that "Good specimens of sunstone suitable for cutting are found in the detrital surface materials at localities in the central part of Lake County." He further reports:

> "The rough gem is sold by the ounce and good material showing the proper amount of included extraneous material brings a price well worth collecting the gem."

Stewart, Walker, and others (1966) describe in detail the physical properties of the transparent calcic labradorite from Lake County. In their study they discuss the petrology and petrography of the feldspar-bearing lava flows, chemical composition, optical properties, unit cell parameters, and thermal expansion characteristics of the feldspar crystals. They do not, however, mention the red or green colors or the avenfurescence to which some of the feldspars owe much of their appeal.

Numerous other short articles giving brief descriptions of the sunstone and information about the locality have appeared in the popular mineralogical journals, lapidary magazines, and rockhound club journals.

Many rockhounds and gemstone collectors have made annual pilgrimages to the sunstone area to search the surface of the ground for stones or to screen the soil cover for buried stones. In 1970 a group of avid collectors discovered that in some places the sunstone-bearing lavas were decomposed beneath the thin veneer of surface soil. They found that by disintegrating the parent material, larger, better-quality, and more colorful sunstones could be recovered. This led to the staking of several mining claims in the area. Subsequently, at the request of organized gem and

Figure 6. Exposure of weathered pahoehoe lava on Dudeck Ridge showing hummocky bulbous flow units of the sunstone-bearing basalt. Fine-grained weathering products are blown away and the coarser fragments accumulate in depressions.

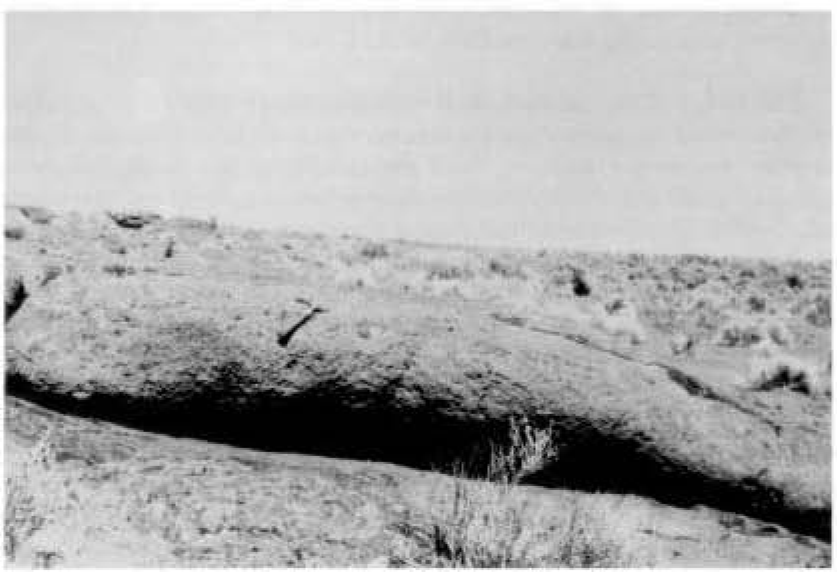

Figure 7. Another view of a thin flow unit of pahoehoe lava on Dudeck Ridge. Extremes in temperature acting on coarse-grained, open-textured basalt produce granular disintegration.

mineral groups, the Bureau of Land Management withdrew 4 square miles from mineral entry so that anyone desiring to look for and collect sunstones could have access to a part of the area. The withdrawal boundary and the approximate location of the original group of mining claims is shown on the geologic map (Plate 1).

Local Geology

A detailed study of the geology of the whole Rabbit Basin and the surrounding hills was not attempted for this report. The approximate extent of the sunstone-bearing basalt and the general distribution of other geologic units are shown on the geologic map.

Most of the bedrock appears to be no older than Pliocene. Two major rock types are present in about equal amounts beneath the basin alluvium, which obscures the bedrock in most places. The older bedrock type is a vesicular to dense black basalt of unknown thickness. Overlying this unit is a gray to buff, pumice-rich ash-flow tuff of variable thickness that is moderately to highly welded. The ash-flow tuff was mapped as Danforth Formation by Larson (1965). In the northern part of Rabbit Basin, thin flows of medium-gray, vesicular pahoehoe lava overlie the older rocks and crop out in Dudeck Ridge (Figures 6 and 7). This is the unit that carries the sunstones.

The sunstone basalt is medium to coarse grained and highly porphyritic. It is mainly feldspathic with lesser amounts of pyroxene, olivine, and magnetite. The characteristic texture is diktytaxitic to intergranular. The flow units appear to have a local source, probably at the north end of the ridge, and to have spread generally southward and westward to form the low, rounded mass as shown on the geologic map. At the thickest place, the pile of basalt is probably no more than 100 feet thick, and it tapers quickly to the edges where the flow units are only a few feet thick.

In much of the area occupied by the sunstone-bearing basalt, the rock is fairly to moderately susceptible to weathering and breaks down into a residuum of pellet-like fragments (Figure 3). The liberated feldspar phenocrysts resist further weathering and tend to concentrate at the surface. The margins of the sunstone-bearing lava flows were determined by observing the concentration of feldspar fragments in the surface materials. Where the feldspar fragments can no longer be found, the presence of a different bedrock is inferred. In some places, feldspar phenocrysts constitute over 50 percent of the rock. Most phenocrysts are fractured and split into numerous fragments as they are liberated from the parent rock; seldom are phenocrysts recovered intact. The fracture is conchoidal to hackly (Figure 4).

Stewart, Walker, and others (1966) discuss the history of the crystallization of the feldspar and conclude that the labradorite phenocrysts formed by primary crystallization in a magma chamber at depth under relatively uniform conditions at a temperature greater than 1100°C. (The large size

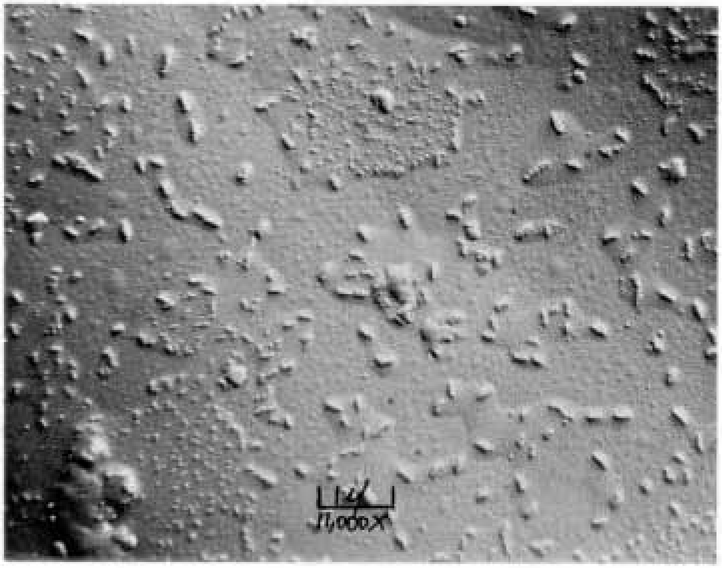

Figure 8. Electron micrograph of a colony of precipitates in straw-colored labradorite with schiller. U.S. Bureau of Mines X11,000

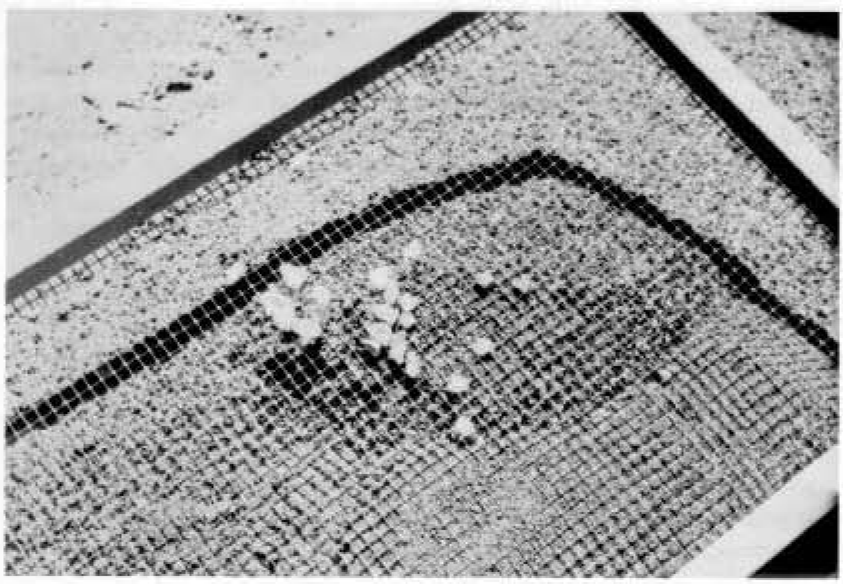

Figure 9. Sunstone fragments are easily separated from surface materials or from decomposed basalt by simple screening with a ¼" screen.

of the equigranular phenocrysts and the inclusions on the growth planes suggest that the growth was relatively rapid.) The lava, with the phenocrysts, was quickly erupted and almost instantly cooled. The mechanical fracturing probably resulted from the rapid and violent flow movement during extrusion.

Source of Color

Most of the references with descriptions about aventurine feldspars attribute the scintillating reflections to inclusions of minute plates of hematite. No discussion of red or green colors in labradorite has been found so far in the literature. To determine why the colors of the labradorite range from colorless through aventurine to red and green or combinations thereof, specimens of each variety were sent to the U.S. Bureau of Mines at Albany, Oregon for a detailed petrographic examination. Their findings are essentially as follows:

> "Pieces of the labradorite crystals showing different colors were mounted and polished and examined with the microprobe. Major element and trace impurity concentrations were found quite uniform on a micro scale and no differences between the clear, red, green, or straw-colored portions could be detected. Fe (iron) is present at a constant level of 0.3 percent and K (potassium) at 0.08 percent. Cu (copper) was not detected at 0.03 percent, Mg (magnesium) not detected at 0.2 percent, and Mn (manganese) not detected at 0.1 percent. Some of the straw-colored crystals have precipitates or inclusions in the size range of 5 to 15 microns (1 micron = .000001 meter). These inclusions are a mixture of which iron oxide and aluminum silicate are major constituents. Some Ti, S, and P were also detected. After microprobe analysis, the mounted crystals were etched with a hydrofluoric acid solution and replicas were made of the surfaces. Replicas were then examined with the transmission electron microscope. Numerous colonies of small precipitates were located in the crystal having schiller (similar to aventurescence). Many of the particles are in the size range of 500 to 1000 angstroms across and are separated 1000 to 2000 angstroms (Figure 8). These dimensions are ideally suited to cause color from optical interference."

The Bureau of Mines also performed emission spectroscopic analysis on these crystals. Trace quantities of copper, iron, manganese, and titanium were detected in addition to the major elements. Trace quantities of transition elements such as these are known to affect the color of a host crystal. A single element with various valence states in solid solution conceivably could result in a variety of colors as well. It is difficult, therefore, to

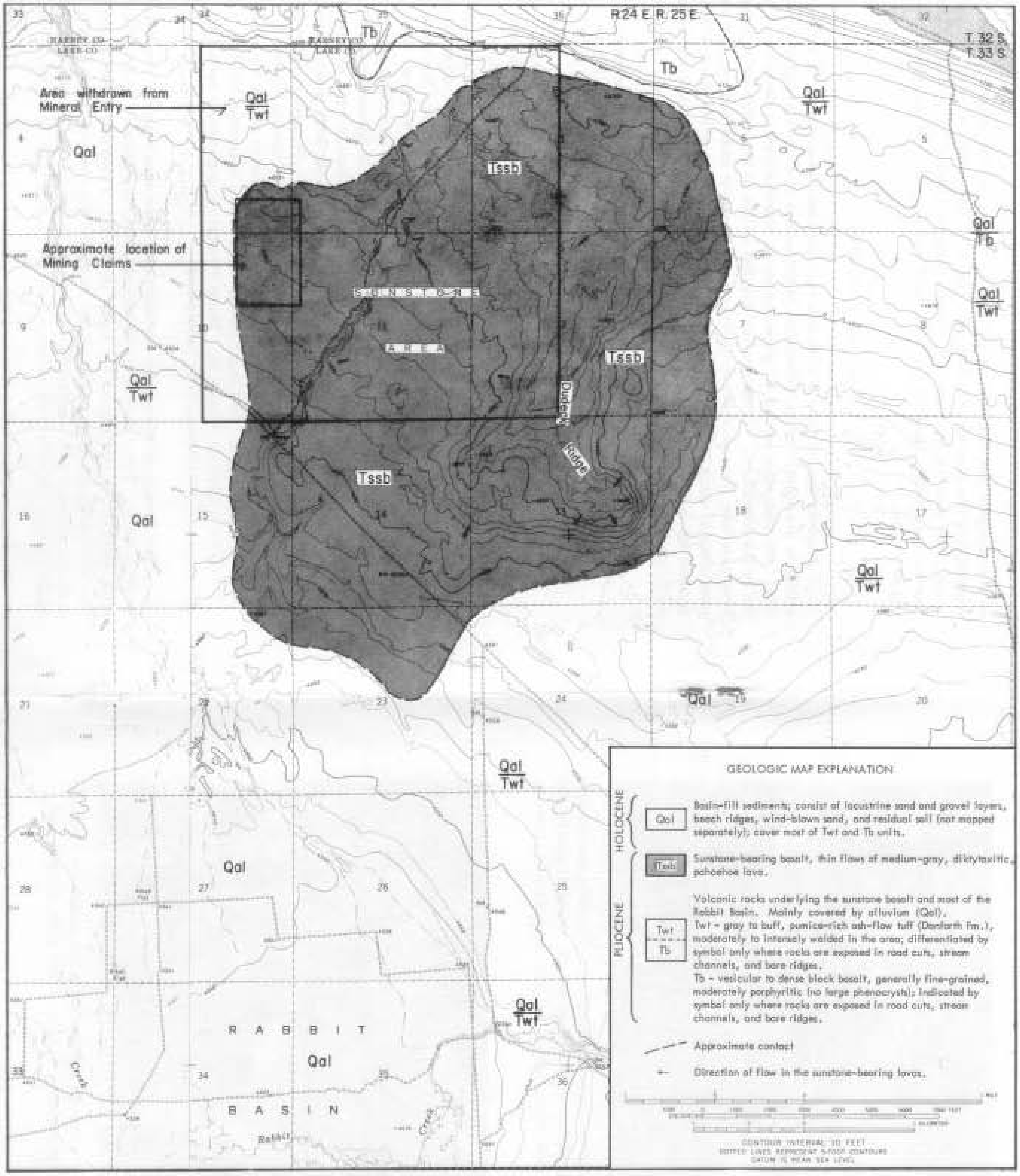

PLATE 1. GENERALIZED GEOLOGIC MAP OF THE OREGON SUNSTONE AREA.

Figure 10. A typical sunstone mining operation. The thin overburden has been removed exposing decomposed basalt, which is easily disintegrated by hand picks and chisels and then screened to separate the sunstones.

Figure 11. This view of a sunstone mining operation shows the inverted cone-shaped area of decomposed basalt. Note piles of screened debris in background.

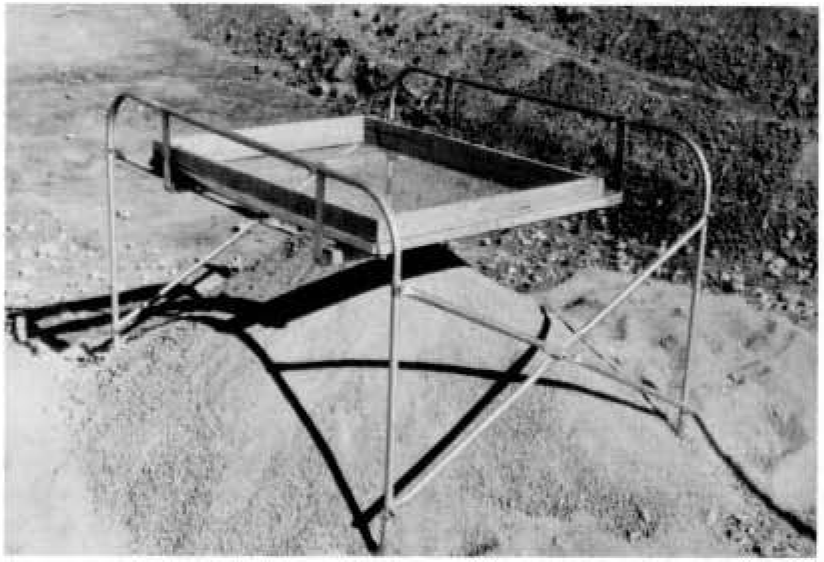

Figure 12. One of the types of screen used to separate disintegrated basalt dug out of the pits.

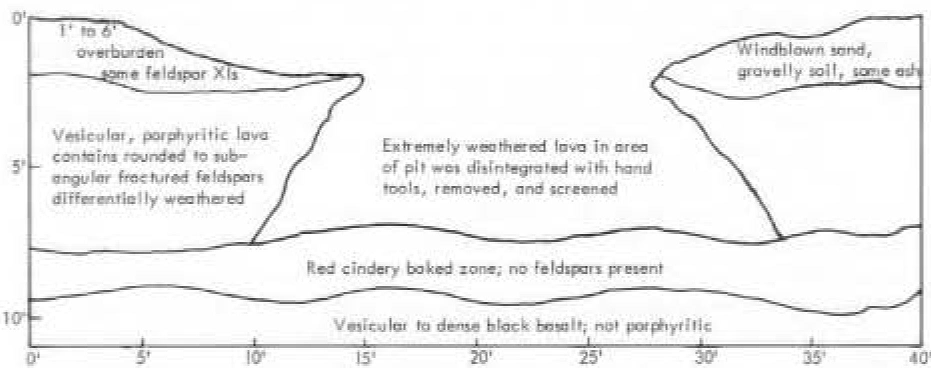

Figure 13. Generalized cross-section of a typical pit showing types of material encountered and the inverted cone shape of the decomposed basalt. The basalt flow varies in thickness from 5 to 9 feet and is always underlain by a red, ashy layer.

determine exact conditions for a particular color. Colors of individual stones are probably the result of several effects. Cyclical precipitation probably could cause the iridescence observed in some crystals and could add to the observed colors.

Although the above analyses are not conclusive, it appears probable that the aventurescence of the Oregon labradorite is produced by reflections from thin scales of mixed precipitates rather than by crystalline hematite as in other described sunstones. We cannot be as certain about the cause of the red or green coloration. However, the influence of transition elements such as iron and manganese is most likely an important factor.

Oregon Labradorite as a Gemstone

In addition to scanning the 7 square mile area and picking up stones that have been weathered from the lava and concentrated at the surface, simple screening of the surface soil is a popular way to collect sunstones (Figure 9). Although serious mining of the parent material has been conducted only since 1970, this method has probably produced more of the larger-sized, higher-quality, and deeper-colored stones than scanning. There are several one-man operations where roughly cone-shaped bodies of decomposed lava are further disintegrated by means of hand tools and the sunstones separated by screening (Figures 10, 11, and 12). Figure 13 shows a cross section of a typical pit and the materials encountered. It is not known why the lava weathers in cone-shaped masses.

The most common variety of crystal fragments are transparent and colorless to amber. Size varies greatly and the minimum collectible size will not pass through a one-quarter inch screen. Intact fragments as large as 3" x 1½" x 1" have been found, and it is reasonable to expect that the original phenocrysts were somewhat larger. Stewart, Walker, and others (1966) observed a giant lath 8.3 cm long, 2.6 cm wide, but only 0.8 cm thick (3½" x 1" x .3").

The next most common variety of stones are those that exhibit the pink to coppery glitter of true sunstone or aventurine. Experienced collectors cite a rule of thumb that for every 100 colorless feldspar stones they will find one true sunstone. Then for every 10 of these pink shimmers they will turn up one transparent red. Clear green stones are even less common, and for approximately every ten reds there is one green. Occasionally a real rarity that exhibits both red and green in the same stone will show up on the sorting screen.

As commercial gemstones, the Oregon sunstone has many of the necessary or desirable properties. Even though the hardness is only 6 and a definite cleavage is present, it is a fairly tough stone which does not seem to damage easily. The clear and amber stones as well as the small pink shimmers and red and green colors in small size are suited for tumbling and are used in key chains, bracelets, pendants, necklaces, and gem sculptures.

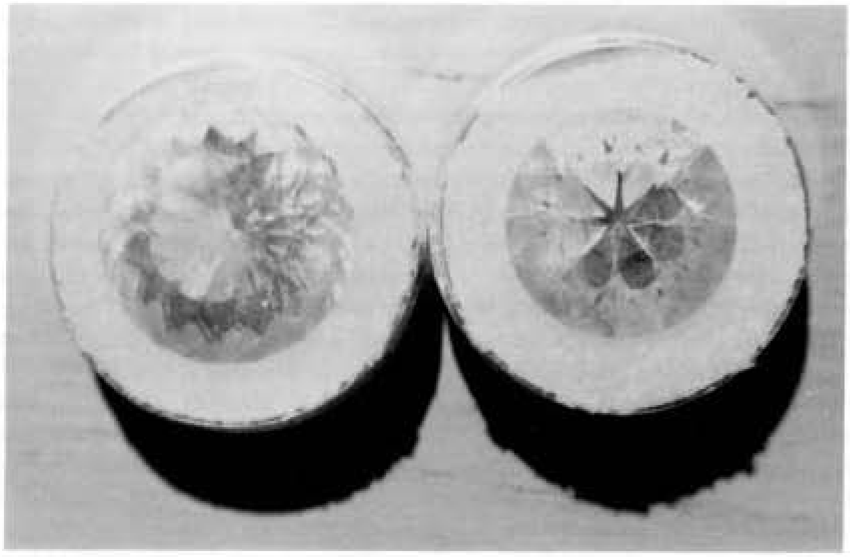

Figure 14. Clear-to-amber labradorite from the Oregon sunstone locality occurs in sizes and quality for faceting. 2X

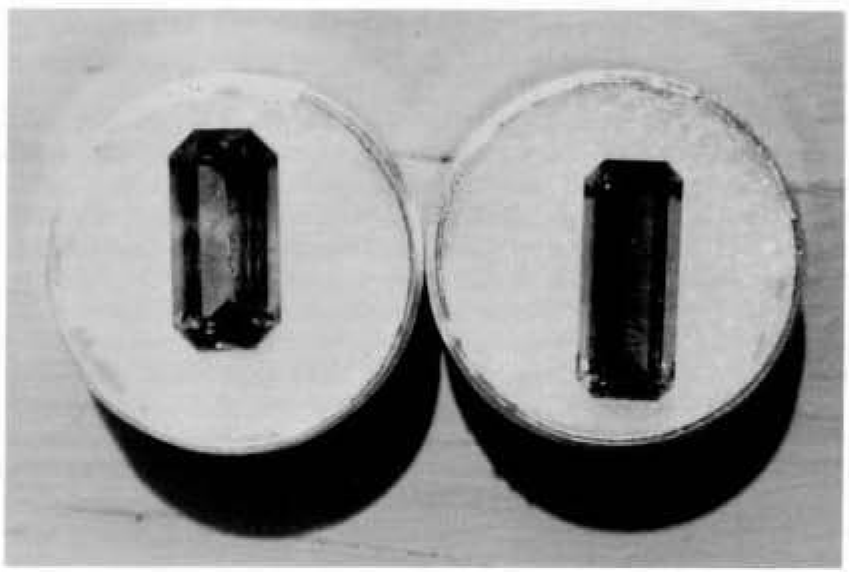

Figure 15. Another pair of faceted labradorites; one is green and the other red. 2X

The larger sunstones or aventurine feldspars are usually cut in cabachon shapes to accentuate the aventurescence. The red and green transparent stones are the most sought after and are almost always sold for faceting (Figures 14 and 15).

Most Oregon sunstones are marketed at rock and mineral shows or by mail order through advertising in lapidary magazines. Minor quantities are sold at the diggings. As is true for most gemstones, prices vary greatly. Each dealer usually has his own classification by size and color. One dealer lists field-run stones with some pink and rarely red or green at $6.00 per pound. The red and green small size are sold by the gram and prices range from $2.00 to $4.00 a gram. Selected red and green stones from 1 to 3½ grams in size are quoted at $4.00 to $8.00 per gram. Larger stones of intense color and good transparency are sold individually at negotiated prices. Faceted stones are sold by the carat and, as with other gems, the size, quality, and fashionability determine the price. It may be of interest to note that color photographs of "an unusual red, 14-carat faceted labradorite" and a faceted "record-size 24-carat stone of amber labradorite from Oregon" are shown in The Gem Kingdom by Desautels.

It is difficult to predict what impact the Oregon sunstones will have as a commercial gem. If sufficient quantities of large-size, good-color, high-quality stones continue to be found, they might reach the jewelry-store market. If not, the main market will continue to be limited to individual mineral collectors. Recent trends indicate an increased interest in faceting stones.

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PENROSE OPHIOLITE FIELD CONFERENCE

Len Ramp
Geologist, Oregon Dept. of Geology and Mineral Industries

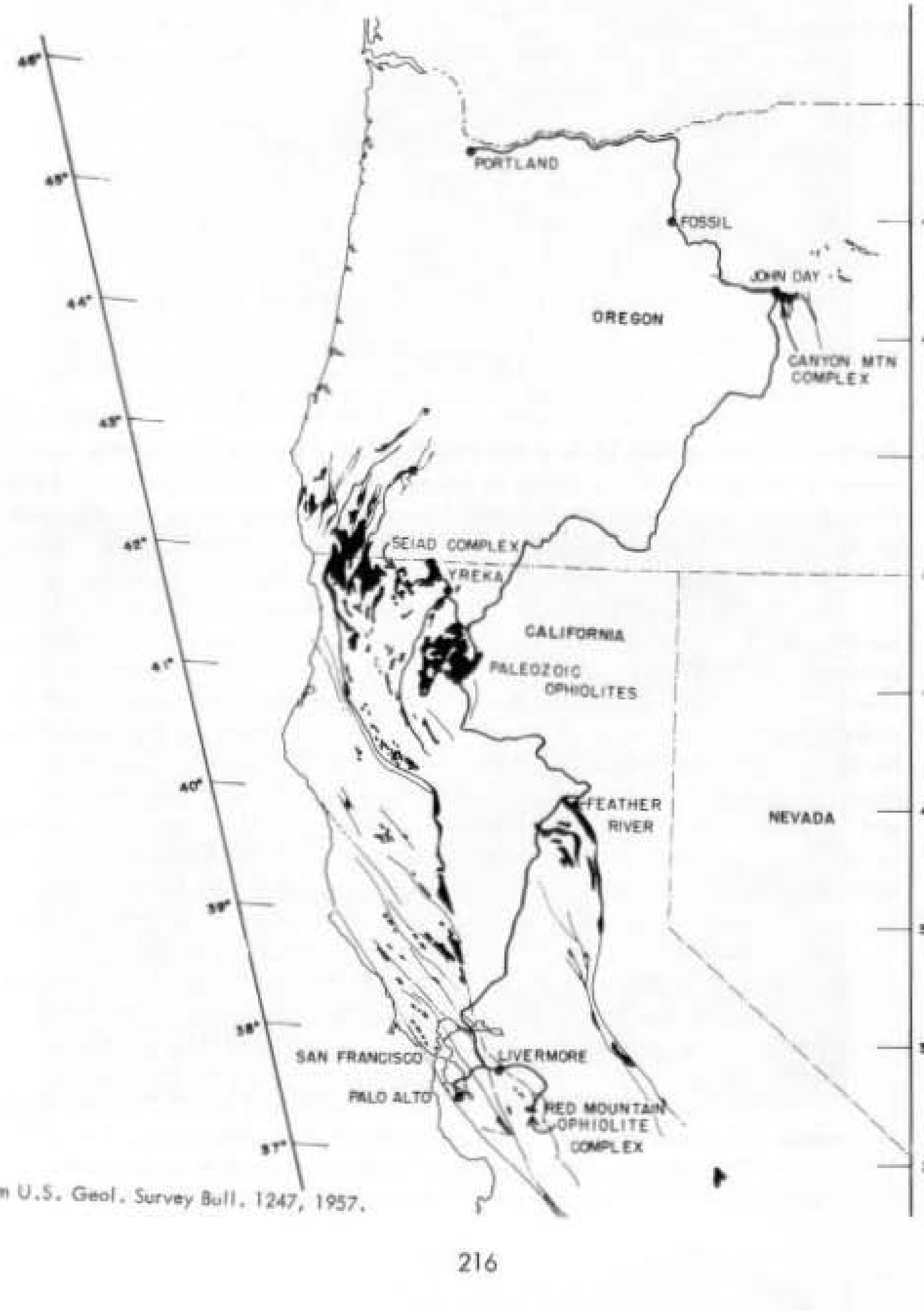
The Geological Society of America Penrose Conference on Ophiolites convened in Portland on the evening of September 14, 1972, and ended in Palo Alto, California, September 24. The 10-day field conference was attended by 55 geologists from 9 countries including Australia, Brazil, Canada, England, France, Italy, Netherlands, Venezuela, and the United States.

Dr. R. G. Coleman and Dr. T. P. Thayer of the U.S. Geological Survey, Dr. L. G. Medaris of University of Wisconsin, and Dr. E. Moores, University of California, Davis, arranged the conference for the purpose of viewing and discussing, both in the field and in seminar, the assemblages of rocks termed "ophiolites." The rapid development of plate tectonic theories has brought this term out of the older literature and into general usage by those working in areas of ultramafic rocks. It refers to assemblages of mafic and ultramafic rocks and their hydrated equivalents. Ophiolites are believed to represent ancient oceanic crust and subjacent mantle. The goals of the conference were to examine the following features of ophiolites:

1. Contacts between country rock and ophiolite complexes. Contacts examined are depositional, tectonic, and metamorphic.
2. The relationships between plutonic (peridotites and gabbros) and volcanic (pillow lavas, diabase, tuffs, etc.) rocks with particular attention to contrasting petrographic types with varied deformational histories.
3. The occurrence of diorites, albite granites, trondhjemites, and keratophyres as part of peridotite-gabbro-basalt complexes.
4. To determine the presence or absence of stratigraphic continuity and the implied relations to oceanic crust-mantle sequences.

Penrose Ophiolite Conference Map

Approximate route and location of principal areas visited. The black areas represent ultramafic rocks, and include gabbro, serpentinite, peridotite, and related rocks.



From U.S. Geol. Survey Bull. 1247, 1957.

5. The metamorphic nature of certain complexes (contact metamorphism vs. regional metamorphism).

6. The regional structural setting as it helps to explain how upper mantle rocks have been moved into their present positions in the crust.

Some of the more interesting ideas and theories this geologist obtained from the conference were related to the occurrence of nickel sulfides and chromites in the ultramafic rocks. For example, Dr. A. J. Naldrett, University of Toronto, observed that all known commercial deposits of nickel sulfides in the world are older than 1.7 billion years. It is presumed that the source of sulfur in the mantle of the earth must have become depleted by this period in its history.

Mechanisms of emplacement of ultramafic rocks containing very large bodies of high-grade, massive chromite were discussed, but it appears that much remains to be learned about these deposits and their origin in light of the global plate tectonics interpretations.

Another very interesting concept presented is that the coarse skeletal olivine crystals in ultramafic rocks of Canada and Australia are comparable to quench textures that can be produced in the laboratory. From this and other textural evidence, it is presumed that these rocks may actually be submarine ultramafic lava flows.

The itinerary followed is outlined below.

On September 15 the group traveled by bus to John Day via the Columbia River Gorge, Arlington, Condon, Fossil, and Picture Gorge (see accompanying map of route). This portion of the tour was guided by Dr. John E. Allen of Portland State University and Dr. T. P. Thayer of the U.S. Geological Survey, Washington, D. C.

On September 16 and 17, the group, guided by Dr. Thayer, visited the Canyon Mountain Complex. Each evening a seminar related to the problems seen in the field was conducted.

On September 18 the group traveled to Yreka, California with a few brief stops to view Oregon's volcanic terrain. Stops included Lava Butte, Newberry Caldera, and the Klamath graben in south-central Oregon.

The 19th was spent in the field, under the guidance of Dr. L. G. Medaris of the University of Wisconsin, observing rocks of the Seiad Complex. On the 20th Dr. Eldridge Moores of the University of California at Davis and Mrs. N. L. Griffin, student at Oregon State University, led the group in an examination of Callaghan Ophiolite.

On September 21 the geologists traveled from Yreka to Lake Almanor at the head of the Feather River. The route took them through Mt. Lassen National Park and included some interesting stops in the Sierra Nevada Foothill Belt. On the 22nd, the group traveled down the Feather River Canyon through the Foothill Belt and central valley of California to Livermore. This portion of the tour, guided by Dr. Eldridge Moores and Dr. R. G. Coleman, included a few stops in the metamorphic and ultramafic rocks.

On Saturday September 23, the group, guided by Dr. Coleman, spent its last day in the field at Red Mountain Ophiolite Complex south of Livermore, and then traveled to Palo Alto for the final seminars that evening and Sunday morning. At this time the committee in charge of defining the term "ophiolite" reported; revisions and additions were made by the entire group. The final result of their efforts is quoted as follows:

> "Ophiolite", as used by those present at the G.S.A. Penrose Conference on Ophiolites, refers to a distinctive assemblage of mafic to ultramafic rocks. It should not be used as a rock name or as a lithologic unit in mapping. In a completely developed ophiolite, the rock types occur in the following sequence starting from the bottom and working up:
>
> Ultramafic complex, consisting of variable proportions of harzburgite, lherzolite and dunite, usually with a metamorphic tectonite fabric (more or less serpentinized).
> Gabbroic complex, ordinarily with cumulus textures commonly containing cumulus peridotites and pyroxenites and usually less deformed than the ultramafic complex.
> Mafic sheeted dike complex.
> Mafic volcanic complex, commonly pillowed.
> Associated rock types include:
>
> An overlying sedimentary section typically including ribbon cherts, thin shale interbeds, and minor limestones; podiform bodies of chromite generally associated with dunite; and sodic felsic intrusive and extrusive rocks.
>
> Faulted contacts between mappable units are common. Whole sections may be missing. An ophiolite may be incomplete, dismembered, or metamorphosed, in which case it should be called partial, dismembered, or metamorphosed ophiolite. Although ophiolite generally is interpreted to be oceanic crust and upper mantle, the use of the term should be independent of its supposed origin.

* * * * *

SOUTHEASTERN OREGON AEROMAGNETIC MAPS AVAILABLE

The U.S. Geological Survey has released on open file the two aeromagnetic maps listed below. Material from which copies can be made at private expense is on file with Oregon Dept. of Geology and Mineral Industries, Portland. Each map is one sheet, and both are at a scale of 1:250,000.

1. "Aeromagnetic map of the Adel and parts of the Burns, Boise, and Jordan Valley 1° by 2° quadrangles, Oregon," by U.S. Geological Survey.
2. "Aeromagnetic map of the Klamath Falls and part of the Crescent 1° by 2° quadrangles, Oregon," by U. S. Geological Survey.

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