A Learning Guide on the GEOLOGY OF THE CISPUS ENVIRONMENTAL CENTER AREA, LEWIS COUNTY, WASHINGTON

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GEOLOGY OF THE CISPUS ENVIRONMENTAL CENTER AREA, LEWIS COUNTY, WASHINGTON

By J. Eric Schuster

INTRODUCTION

The purposes of this report are to present a geologic map and generalized description of the rocks in the area around Cispus Environmental Center, to set forth the geologic history of the area, to suggest some exercises that the grade school or high school teacher might find useful, and to present an explanation of terms used in this report.

A geologic map of the area around Cispus Environmental Center is included at the end of this report. Sample locations mentioned in the text are included on this geologic map. A display that includes rock samples, photomicrographs of rocks, a topographic map, and a geologic map based on aerial photographs is mounted in the Education Building. The geologic map with this display shows all locations where rock samples were collected.

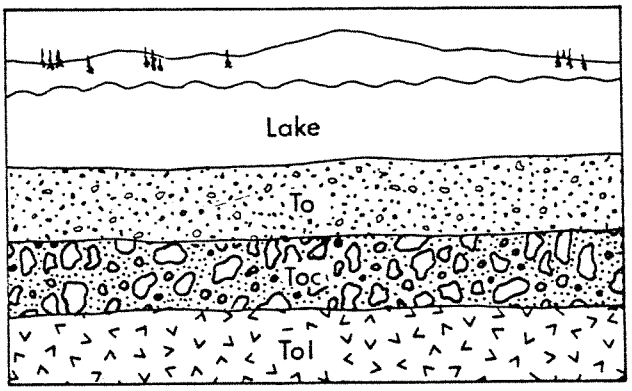
GEOLOGIC HISTORY

GENERAL

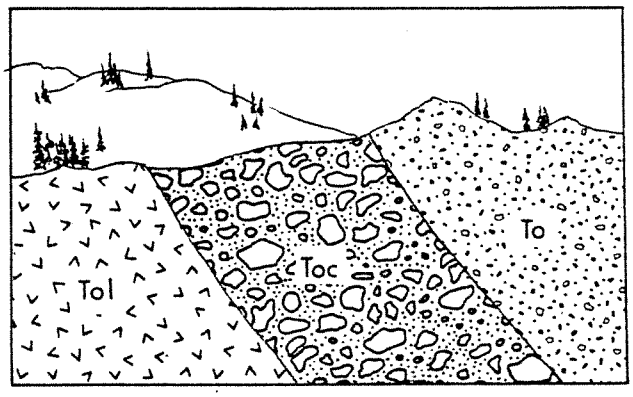
Geologic history as recorded in the rocks near Cispus Environmental Center is long in terms of recorded history but short in comparison to the age of the earth. The oldest rocks exposed at the surface are those of the Ohanapecosh Formation of Eocene age—no older than about 47 million years. The earth is estimated to be about 4.5 billion years old, so only the last 1 percent of geologic time is represented at Cispus Environmental Center. If we represent the age of the earth as a 24-hour day, then the rocks of the Ohanapecosh Formation began to form at about 11:45 P.M. Man, however, has been on the earth for only the last 30 or 40 seconds of this 24-hour day.

Rocks of the Ohanapecosh Formation that are exposed in the area of Cispus Environmental Center are andesite and basalt flows, andesitic tuff-breccia, and volcanic conglomerates. The total thickness of the Ohanapecosh Formation is in excess of 10,000 feet at some places in the area of Mount Rainier National Park (Fiske, Hopson, and Waters, U.S. Geol. Survey Prof. Paper 444, p. 4), and these rocks were probably deposited in a lake after eruption from volcanoes in the area. Some of these were underwater volcanoes. During deposition, the rocks of the Ohanapecosh Formation grew thicker and the lower parts were heated and subjected to the pressure of the overlying rock. This caused some of the original minerals to break down and secondary minerals (zeolites) to form.

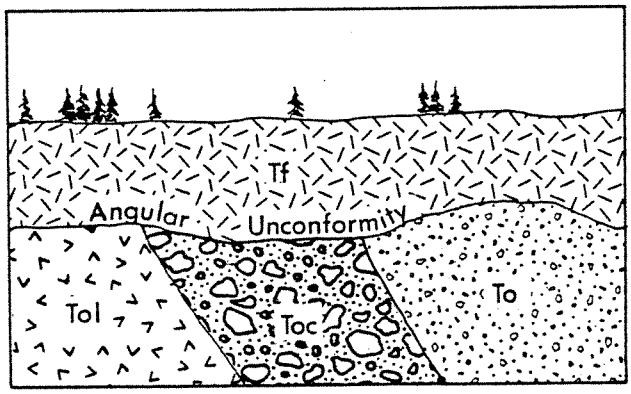
Subsequent folding caused the rocks of the Ohanapecosh Formation to be tilted, and erosion began to remove the upper parts of the pile of rock. After a considerable portion of the Ohanapecosh Formation was removed by erosion, the Fifes Peak Formation was deposited on the upturned edges of Ohanapecosh strata. This break in the geologic record is an unconformity (Fig. 1). In Mount Rainier National Park another series of rocks, the Stevens Ridge Formation, is present between Ohanapecosh and Fifes Peak rocks. At Cispus Environmental Center the Stevens Ridge Formation was either not deposited or was removed by erosion before deposition of Fifes Peak rocks. In the Cispus Center area, the Fifes Peak rocks are andesitic and basaltic flows and related rocks. The flows may have erupted through large cracks in the earth's crust



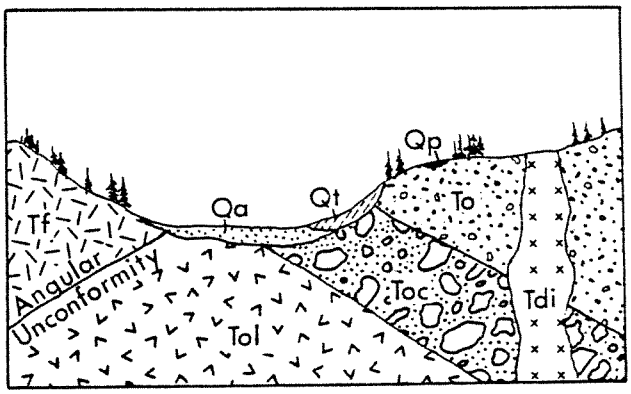
1. Horizontal deposition of Ohanapecosh rocks in a large lake.



2. Folding of Ohanapecosh strata followed by erosion results in upturned beds with truncated ends.



3. Deposition of Fifes Peak rocks on the upturned edges of Ohanapecosh strata creates an angular unconformity—a time gap that represents folding and erosion followed by renewed deposition in the Cispus Center area.



4. Renewed tilting or folding, erosion of the Cispus River valley, igneous intrusion to form Tower Rock, glaciation, and deposition of pumice from Mount St. Helens have created the geology that we see in the Cispus Center area today.

FIGURE 1.— The formation of an angular unconformity.

where molten rock rose to the surface. The diabase dike east of Stump Creek (sample 40) is probably an example of such a feeder. Fifes Peak rocks were deposited to a thickness of more than 2,400 feet in the Mount Rainier National Park area.

During Miocene or Pliocene time, perhaps about 17 million years ago, Ohanapecosh rocks were intruded by the igneous body that now makes up Tower Rock. This molten rock solidified at a shallow depth—probably only a few hundreds of feet. The intrusive rock is probably related to the Tatoosh pluton found in Mount Rainier National Park.

Igneous intrusion was probably followed by a fairly long period of erosion. The stream courses and major topographic features that we now see began to develop at this time.

Beginning possibly as long as 2.5 million years ago, glaciation began to affect the northwestern part of the United States. Large glaciers extended from the north into the Puget Sound area, but did not reach the Cispus Environmental Center area. The area was, however, affected by glaciers that extended for many miles down the major stream valleys of the Cascades. Valley glaciation was at its maximum extent about 18,000 years ago, and considerably modified the topography. The steep face of Tower Rock was carved by a valley glacier that plucked and scoured rock from its face as the ice moved down the valley. The lower parts of the other valley walls were also steepened by glaciation, and all of the steep cliffs in the area owe their present form to glaciation.

The presence of ice in the valley of the Cispus River probably caused the river to leave its valley and flow out through the drainage divides in the Stump Creek area; this is shown by gravel deposits that are now 300 feet or more above the level of the Cispus River.

As the glacial ice melted, the Cispus River became choked with the gravel released from the glacier. This caused the valley to fill with alluvium to an elevation at least 100 feet higher than the present river level, as shown by deposits about 2.5 miles west of Cispus Center and south of the Cispus River.

After the retreat of the valley glacier several thousand years ago, normal processes of erosion caused rock to spall from the faces of the steep cliffs, especially Tower Rock, forming talus deposits at the foot of the cliffs. Soil formation, deposition or removal of material by flowing water, and formation of talus are some of the geological processes in action at the present time.

The last volcanic event recorded in the area is deposition of two or three layers of pumice that were erupted from Mount St. Helens about 1,200 years ago. Layers of pumice can be found on the gentler slopes in greater abundance than shown on the geologic map. Although Mount Rainier, to the north of Cispus Center, and Mount Adams, to the southeast, are larger volcanoes than Mount St. Helens, there was little or no pumice erupted from them.

If reading this simplified geologic history of the area near Cispus Environmental Center

has created the impression that the earth is "alive," its purpose is fulfilled. The earth is, indeed, a dynamic, changing body of rock even though we see relatively few measureable changes during a single lifetime.

TOWER ROCK

The top of Tower Rock is 3,335 feet above sea level and about 2,000 feet above the Cispus River valley. This elevation is not particularly high when compared with other peaks in

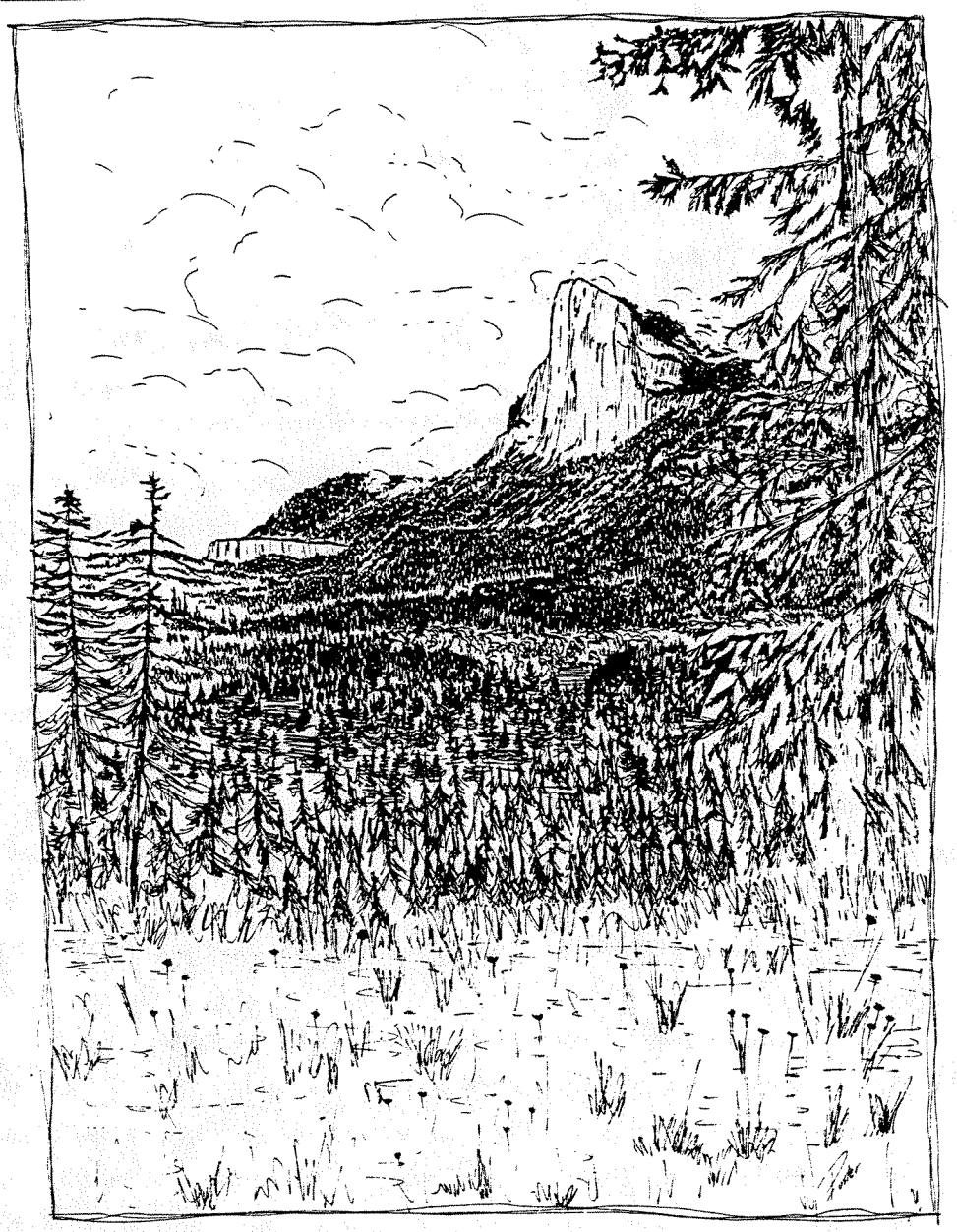


FIGURE 2.—Tower Rock as seen from the opposite side of the Cispus River valley. View is toward the southeast.

the area, but the side of Tower Rock that faces the Cispus River valley is an imposing 1,000-foot nearly vertical cliff. Beneath this cliff is a steep slope covered by loose rock that accounts for an additional 1,000 feet of elevation above the valley floor.

About 17 million years ago, a mass of molten igneous rock formed in the earth's crust in this part of Washington. The hot, fluid rock forced its way up through the crust until it was only a few hundred feet below the earth's surface, where it began to cool and crystallize. This magma came to rest where Tower Rock now stands, and the cooled, solid rock now makes up Tower Rock. This once-liquid rock is more resistant to erosion than the lava flows and other volcanic rocks that surround it.

Over a period of several million years, erosion removed the several hundred feet of rock that covered Tower Rock, and the Cispus River began to construct the valley in which it now flows. About 3 million years ago, Tower Rock was probably a rounded, tree-clad hill that projected slightly into the Cispus River valley. The vertical face of Tower Rock was yet to be created.

Then, beginning about 2.5 million years ago, climatic changes caused a glacier to form in the upper part of the Cispus River valley. This glacier gradually grew and moved down the valley until it extended beyond Tower Rock. The passing glacier pried, plucked, and abraded rock from the flank of Tower Rock. When glaciation ended about 10,000 to 15,000 years ago, Tower Rock was left with almost its present form. The rock probably had a fairly smooth, polished face shaped like one-half of the letter "U". The lower part of Tower Rock's face sloped outward toward the valley floor, while the upper part was left as a vertical or nearly vertical cliff.

During the last 10,000 years or so, the lower part of Tower Rock's face has been covered by rock debris that has broken away from the upper part, and forests have grown over the more gently sloping areas. This has softened the profile of Tower Rock but not erased the grandeur that makes it a unique landmark in southwestern Washington.

ROCK DESCRIPTIONS

OHANAPECOSH FORMATION

Rocks of the Ohanapecosh Formation crop out on the mountainside south and east of Cispus Environmental Center and on the low hill west of the Cispus River bridge, about one-half of a mile north of the Center.

On the geologic map Ohanapecosh rocks are divided into three groups: andesitic tuff-breccia, basalt and andesite flows, and volcanic conglomerates. The andesitic tuff-breccia is composed of subangular fragments of andesitic tuff incorporated in a fine-grained matrix of the same composition. Under the microscope plagioclase and magnetite make up most of the rock; hornblende or other dark-colored minerals that were originally present have been completely altered to a fine-grained mass of secondary clay minerals.

Basalt and andesite flows, the second group of Ohanapecosh rocks, are fine grained because they cooled rapidly from hot fluid magma, and they sometimes contain frozen gas bubbles called vesicles. Minerals present in the rocks are plagioclase, clinopyroxene, hornblende, and opaque minerals, mostly magnetite. In some of these rocks the mineral grains are aligned (Fig. 3)—a feature caused by flow of the rock just before final solidification. Alteration of

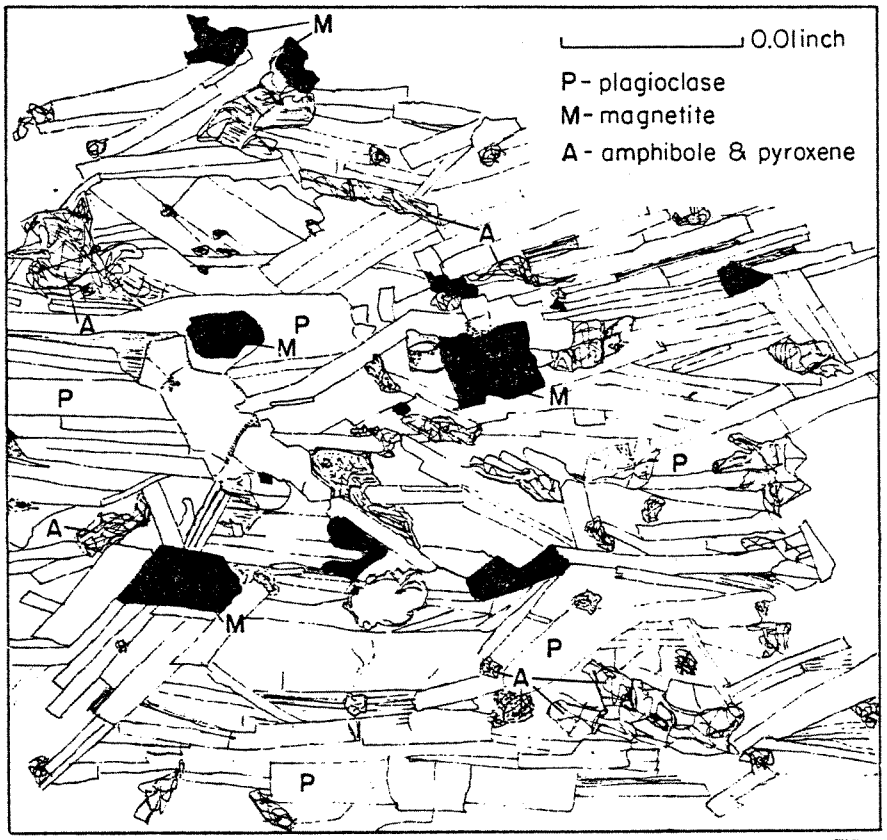


FIGURE 3.—Line drawing showing alignment of mineral grains due to flow in molten rock.

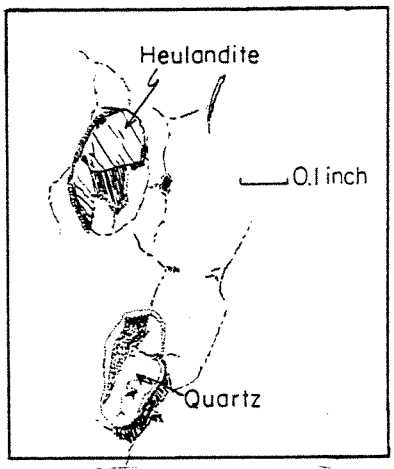


FIGURE 4.—Line drawing of quartz and heulandite filling vesicles in flow rock.

the rocks consists mostly of development of clay minerals. At sample location 21, however, quartz and the zeolite mineral heulandite fill vesicles in the flow rock (Fig. 4). The heulandite and quartz probably formed by precipitation from hot solutions that circulated through the rock when it was deeply buried.

The third type of Ohanapecosh Formation rock in the area around Cispus Environmental Center is volcanic conglomerate. This rock is made of debris from andesitic tuff-breccia and flows that had been previously laid down or erupted in the area. Mudflows or landslides removed parts of these older rocks, thoroughly mixed them together, and redeposited them. Because of abrasion during transport in mudflows or landslides, the fragments of tuff-breccia and flow rock are rounded. The rounded fragments are set in a matrix of fine-grained material. These rocks weather easily and are soft and nonresistant in outcrop.

FIFES PEAK FORMATION

Rocks of the Fifes Peak Formation are generally less altered than those of the Ohanapecosh Formation. Basalt and andesite flows, andesitic tuff, and a shallow-seated diabase dike are present in the Fifes Peak Formation in the Cispus Center area. The basalt and andesite flows were probably very fluid when erupted; evidence of this is that samples of the rock contain few crystals and are mostly chilled glass (sample 42). At sample location 43, a good example of pillow lava is visible in the roadcut. Pillow lavas are produced when hot fluid lava or tuffaceous rock is erupted underwater or, on land, flows into standing water or swampy areas and creates steam. The steam escapes violently through the hot rock causing rounded, pillow-shaped structures to form in the rock.

At sample location 41 the zeolite minerals natrolite and anaclime fill vesicles in a glassy flow rock. These zeolites probably formed from hot solutions derived directly from the cooling rock rather than as a result of deep burial, since the rocks of the Fifes Peak Formation have not been deeply buried.

The vesicular diabase dike in the Fifes Peak Formation is made of plagioclase and clinopyroxene. The vesicles represent gas bubbles that were trapped in the rock when it cooled and solidified. This indicates that the rock cooled very near the earth's surface—at a greater depth the gas bubbles could not have formed due to the high confining pressure of overlying rock. The diabase is the freshest bedrock exposed in the Cispus Environmental Center area; practically no alteration of the minerals that make up the rock has taken place except that some of the plagioclase grains have been slightly altered to clay.

TATOOSH? PLUTON

Diorite porphyry and andesite porphyry make up the small intrusive igneous rock body that forms Tower Rock and underlies adjacent parts of the mountainside south of Cispus Environ-

mental Center. These rocks are probably related to the Tatoosh pluton that crops out in and near Mount Rainier National Park. The rocks contain plagioclase, clinopyroxene, hornblende, a trace of quartz, and minor opaque minerals. Some of the plagioclase and pyroxene crystals are larger than the surrounding grains and are called phenocrysts. The phenocrysts probably began to form before the rock was intruded upward toward its final position; then the partly molten rock cooled rapidly and the phenocrysts were frozen into a mixture of finer grained, late-forming crystals. The fine-grained matrix shows that final cooling was relatively rapid, and the intrusive rock was probably injected to a fairly shallow depth in the earth's crust where the surrounding rocks were quite cool.

QUATERNARY ROCKS

The Quaternary deposits in the Cispus Environmental Center area were formed after glacial ice had melted from the valley. Stream deposits cover the valley floor near Cispus Center and were carried in by the Cispus River and its tributaries. These deposits are gravels that were rounded by grinding and abrasion during transport by flowing water. In the gravel deposits, examples can be found of most of the types of rock that crop out in the area. The weaker rocks, however, are found less often because they are not able to withstand the rigors of stream transportation. Weak rocks are worn down to sand-sized grains, sometimes so small that they are carried all of the way to the ocean where the fine particles form deposits on the ocean floor.

Talus deposits like that at the foot of Tower Rock also formed after the glaciation. Rocks found in talus are the same type of rock as the cliffs from which the talus was derived.

The youngest rock in the area is pumice. The pumice is about 1,200 years old and was derived from Mount St. Helens. An explosive eruption of Mount St. Helens hurled large quantities of pumice and other rock debris thousands of feet into the air where wind currents carried it for many miles before all of it settled to the earth's surface. Pumice is a frothy igneous rock that is generally light colored and very light in weight. Very often pumice will float on water, and it is not difficult to see how wind currents could transport it for long distances. The pumice forms a blanket on all upland areas around Cispus Environmental Center where erosion has not carried it away. A thin cover of organic material covers the pumice in many places, but it is well exposed in roadcuts on the Burley Mountain road south and west of Cispus Center.

Pumice from Mount St. Helens occurs over a large area to the north and northeast of Mount St. Helens. During the time when pumice was erupted, the prevailing winds were from the south and southwest, so the pumice was carried into northern Skamania County and south-

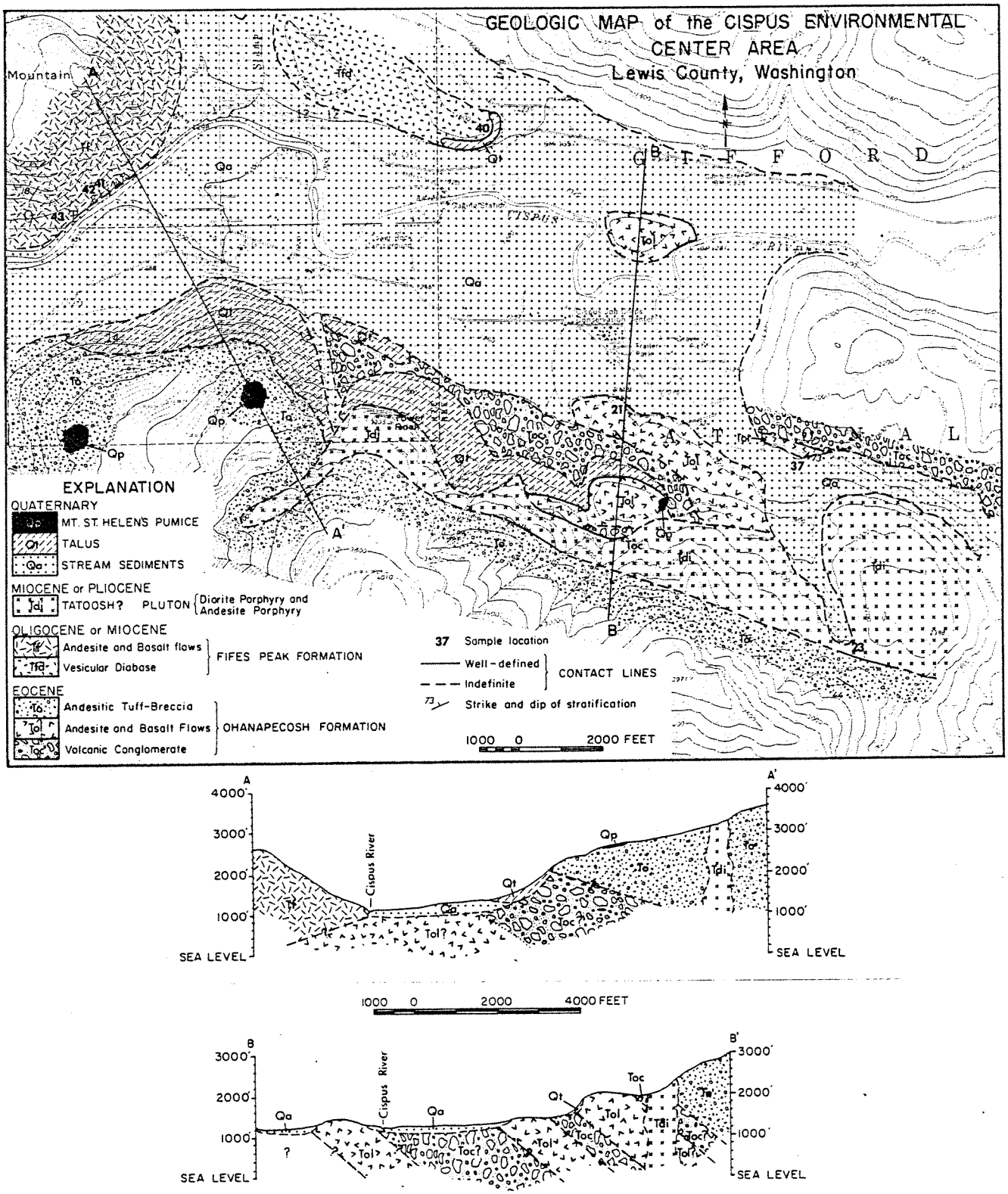


FIGURE 5.—Geologic map and cross sections of the Cispus Environmental Center area, Lewis County, Washington.

eastern Lewis County, and not into areas to the southeast, south or west of Mount St. Helens. Since the prevailing winds are from the south and west today, pumice would be spread over much the same area as before if Mount St. Helens were to erupt again.

SUGGESTED EXERCISES

1. Try to find any man-made or man-fashioned object that did not originate in the earth as mineral or rock. For example, the lumber in the buildings at Cispus Environmental Center did not come from a mine, but saws used to cut the trees and machinery to handle them are made of iron, and iron is mined. This exercise is designed to show the importance of mining to a modern, technological society. You should have a very long list of items before you are able to find one that is not connected in some way with mining.

2. Collect samples of the different kinds of rock that crop out in the area around Cispus Environmental Center. Smash each sample with a hammer (be careful of flying fragments) and note the strength or hardness of each. Then relate the strength of each rock to its topographic position. You will find that, in general, the stronger, tougher rocks, because of their resistance to erosion, form ridges, and the weaker rocks form slopes. For example, samples collected from location 23 are intrusive rocks that are the same as the rock forming Tower Rock, and samples from location 37 are, in part, volcanic conglomerate. The intrusive rock is much tougher than the volcanic conglomerate, so it occupies a more prominent topographic position.

3. Some relatively advanced students may be able to reconstruct the geologic history of the area by studying the geologic map. Those with artistic ability may be able to create scenes of the area showing its possible appearance during different stages of development.

4. Collect rock samples from the gravels of the Cispus River and compare them with the rocks on display in the Education Building. You should find that most of the rocks are similar to those that crop out in the Cispus Environmental Center area, even though some of the Cispus River gravels have been transported from many miles upstream. The conclusion is that the upper drainage basin of the Cispus River consists of rocks similar to those in the area of Cispus Environmental Center.

5. Visit sample location 37. Here there are two different types of rock in contact, an andesite flow and a volcanic conglomerate. See if the students are able to recognize that two rock types are present. If they can, then have them attempt to determine the dip (inclination or slope) of the contact. The contact (interface between the two types of rock) dips steeply toward the south. Since the two rock types were probably deposited nearly horizontally, the steeply dipping contact is evidence that folding has affected the rocks and tilted them out of their original horizontal position.

6. Find as many different uses for minerals or mineral products in the Cispus Center area as possible. This exercise can also be done at your own school. For example: asphalt paving is made from petroleum and sand and gravel or crushed rock; electrical wiring is made from copper or aluminum; concrete is made from sand and gravel and cement (made from limestone and quartzite); paint contains mineral pigments; and light bulbs have tungsten filaments and glass globes made from quartz sand. These are just a few of the many uses for mineral products that you will find at Cispus Environmental Center. The point is that we cannot live in the manner to which we are accustomed without our mines and petroleum products.

7. Map the stream bed and banks along Yellowjacket Creek. Repeat this mapping at yearly intervals and note the changes in configuration of the stream. After a few years of careful, small-scale mapping, changes in position of sand and gravel bars, bank erosion, and channel migration should become noticeable. Correlate precipitation and temperature records with periods of most rapid change in stream configuration.

Streams generally erode most rapidly on the outward and downstream side of bends or meanders, and part of the material removed from these parts of a stream channel is deposited in quieter water, such as pools and the inward parts of bends. In this way the bends or meanders in a stream constantly migrate and change position. Most of this work is done during periods of high water in late spring and early summer when the erosive power of the moving water is much greater than at other times of the year.

EXPLANATION OF TERMS

Entries are paraphrased from Glossary of Geology, American Geological Institute, Washington, D.C., 1972.

Alluvial - Pertaining to or composed of alluvium, or deposited by a stream or running water.

Alteration - Any change in the mineralogic composition of a rock by physical or chemical means.

Analcime - A white or slightly colored zeolite mineral: $NaAlSi_2O_6 \cdot H_2O$.

Andesite - A dark-colored, fine-grained extrusive rock composed primarily of plagioclase and one or more of the mafic minerals (that is, biotite, hornblende, pyroxene).

Basalt - A dark- to medium-dark-colored, commonly extrusive, mafic igneous rock composed chiefly of plagioclase and clinopyroxene in a glassy fine-grained groundmass.

Biotite - A dark-colored mineral of the mica group: $K(Mg,Fe)_3(Al,Fe)Si_3O_{10} \cdot (OH)_2$.

Clay Minerals - A group of hydrous silicates, essentially of aluminum.

Contact - A plane or irregular surface between two different types or ages of rock.

Clinopyroxene - A group name for pyroxene minerals crystallizing in the monoclinic system.

Crystal - A homogeneous, solid body of a chemical element or compound having a regularly repeated atomic arrangement that may be outwardly expressed by plane faces.

Diabase - An intrusive rock whose main components are plagioclase and pyroxene.

Dike - A tabular igneous intrusion that cuts across the planar structures of the surrounding rock.

Diorite - An intrusive rock generally composed of hornblende, plagioclase, pyroxene, and sometimes a small amount of quartz; the intrusive equivalent of andesite.

Dip - The angle that a structural surface, such as a bedding plane, makes with the horizontal, measured perpendicular to the strike of the structural surface.

Erosion - The general process or the group of processes whereby the earthy and rocky materials of the earth's crust are loosened, dissolved, or worn away, and simultaneously removed from one place to another by natural agencies.

Extrusive - Said of igneous rock that has been ejected onto the surface of the earth.

Feeder - A conduit through which magma reaches the earth's surface.

Folding - The curving or bending of a planar structure such as rock strata by deformation.

Formation - A unit of sedimentary, igneous, or metamorphic rocks, generally characterized by some degree of internal lithologic homogeneity or distinctive lithologic features, that is recognizable from place to place within an area, and thick enough to be represented on a map. A formation is named for a geographic location (mountain, lake, creek, etc.) where the unit of rocks is well displayed.

Fresh - Said of a rock that has not been altered.

Geologic Time Table -

Era	Period	Epoch	Age (Million Years)
Cenozoic	Quaternary	Recent	0.01
		Pleistocene	1.5
	Tertiary	Pliocene	7
		Miocene	27
		Oligocene	39
		Eocene	55
		Paleocene	65
Mesozoic	Cretaceous		136
	Jurassic		195
	Triassic		225
Paleozoic	Permian		280
	Carboniferous		345
	Devonian		395
	Silurian		440
	Ordovician		500
	Cambrian		570
Precambrian			4,500±

Geology - The study of the planet Earth. It is concerned with the origin of the planet, the material and morphology of the earth, and its history and the processes that acted (and act) upon it to affect its historic and present forms.

Geomorphology - The study of the classification, description, nature, origin, and development of present landforms and their relationships to underlying structures, and of the history of geologic changes as recorded by these surface features.

Glass - An amorphous noncrystalline product of the rapid cooling of a magma. It may constitute the whole rock or only part of the groundmass.

Groundmass - The interstitial material of a porphyritic igneous rock; it is relatively more fine-grained than the phenocrysts and may be glassy.

Heulandite - A zeolite mineral: $(Na,Ca)_{4-6}Al,Si)_4Si_{26}O_{72}\cdot 24H_2O$.

Hornblende - A dark-colored mineral of the amphibole group: $Ca_2Na(Mg,Fe)_4(Al,Fe,Ti)(Al,Si)_8O_{22}\cdot(F,OH)_2$.

Igneous - Said of a rock or mineral that solidified from molten or partly molten material.

Intrusive - Said of an igneous rock that was implaced in pre-existing rocks below the earth's surface.

Lava flow - A lateral, surficial outpouring of molten lava from a vent or fissure; also, the solidified body of rock that is so formed.

Mafic - Said of an igneous rock composed chiefly of dark-colored minerals.

Magma - Naturally occurring mobile rock material, generated within the earth and capable of intrusion and extrusion, from which igneous rocks are thought to have been derived through solidification and related processes.

Magnetite - A black, strongly magnetic, opaque mineral: $(Fe,Mg)Fe_2O_4$.

Matrix - The fine-grained interstitial material of an igneous rock or the smaller or finer grained material enclosing, or filling the interstices between, the larger grains or particles of a sediment or sedimentary rock.

Mineral - A naturally formed chemical element or compound having a definite chemical composition and, usually, a characteristic crystal form.

Mudflow - A general term for a mass-movement landform and a process characterized by a flowing mass of predominantly fine-grained earth material possessing a high degree of fluidity during movement.

Natrolite - A zeolite mineral: $Na_2Al_2Si_3O_{10} \cdot 2H_2O$.

Opaque - Said of a mineral that is impervious to visible light.

Phenocryst - A relatively large, conspicuous crystal in a porphyritic rock.

Photomicrograph - A photographic enlargement of a microscopic image such as a petrologic thin section.

Pillow lava - A lava displaying a structure that is characterized by discontinuous pillow-shaped masses. Pillow structures are considered to be the result of subaqueous deposition.

Plagioclase - A light-colored group of minerals of general formula: $(Na,Ca)Al(Si,Al)Si_2O_8$.

Porphyry - An igneous rock of any composition that contains conspicuous phenocrysts in a fine-grained groundmass.

Pumice - A light-colored, vesicular, glassy rock that is often sufficiently buoyant to float on water and is economically useful as a lightweight concrete aggregate and as an abrasive.

Quartz - Crystalline silica, SiO_2.

Rock - Any naturally formed, consolidated, or unconsolidated aggregate of minerals, but excluding soil.

Secondary mineral - A mineral formed later than the rock enclosing it and usually at the expense of an earlier formed mineral and as a result of weathering, metamorphic, or solution activity.

Soil - That earth material that has been so modified and acted upon by physical, chemical, and biological agents that it will support rooted plants.

Strike - The direction or trend that a structural surface, such as bedding, takes as it intersects the horizontal.

Subangular - Somewhat angular, free from sharp angles but not smoothly rounded.

Symbols for elements -

Al - aluminum	K - potassium	Ti - titanium
Ca - calcium	Mg - magnesium	
F - fluorine	Na - sodium	
Fe - iron	O - oxygen	
H - hydrogen	Si - silicon	

Talus - Rock fragments of any size or shape (usually coarse and angular) derived from and lying at the base of a cliff or very steep, rocky slope.

Topographic map - A map showing manmade and natural features of a land surface. Its distinguishing characteristic is the portrayal of the position (horizontal and vertical), relation, size, shape, and elevation of the features of the area. Relief is generally shown by means of contour lines (lines of equal elevation).

Tuff - A compacted deposit of volcanic ash and dust.

Tuff-breccia - A type of volcanic breccia in which blocks of volcanic rock are enclosed in a tuffaceous matrix.

Unconformity - A substantial break or gap in the geologic record where a rock unit is overlain by another that is not next in succession. It results from a change that caused deposition to cease for a considerable span of time, and it normally implies uplift and erosion followed by renewed deposition.

Vesicle - A cavity of variable shape in a lava formed by the entrapment of a gas bubble during solidification of the lava.

Volcanic conglomerate - A water-deposited conglomerate containing over 50 percent volcanic material.

Weathering - The destructive process or group of processes constituting that part of erosion whereby earthy and rocky materials on exposure to atmospheric agents at or near the earth's surface are changed in character, with little or no transport of the loosened or altered material.

Zeolite - A term for a large group of white or colorless hydrous sodium, calcium, and potassium aluminosilicates that often occur as secondary minerals in basalts and andesites.

APPENDIX A

Occurrences of Metallic Minerals

in the Area Around Cispus Environmental Center

Lewis County, Washington

Extracted from:

Washington Division of Mines and Geology

Bulletin 37, Inventory of Washington Minerals, Part 2—Metallic minerals, by Marshall T. Huntting, 1956, 495 p.

KEY TO METALLIC PROPERTIES

MAP NO.	NAME	SEE UNDER	PAGE
1	Perry	Gold	28
2	Johnson	Gold	28
3	Primary Gold	Gold	28
4	Bruhn	Gold	28
5	Camp Creek	Gold	28
6	Hudson and Meyers Placer	Gold	29
7	Brown and Livingston	Gold	28
8	Plamondon	Gold	29
9	Young America	Copper	26
10	Sweden	Copper	26
11	Bronze Monarch	Copper	26
12	Norway	Copper	26
13	Yellow Metals	Copper	26
14	Chicago	Copper	26
15	Mount Fairy	Gold	29
16	Commonwealth	Copper	27
17	Grizzly Creek	Gold	29
18	Morning	Copper	27
19	Golconda	Gold	29
20	Samson	Copper	27
21	Germania	Gold	29
22	Polar Star	Copper	27
23	Index	Copper	27
24	Last Hope	Copper	27
25	Cinnabar	Copper	27
26	Snowflake	Lead	30
27	Toledo	Copper	27
28	Bonanza	Lead	30
29	Independence	Copper	27
30	Minnie Lee	Copper	27
31	Minnie Alice	Copper	27
32	Crystal	Copper	27

MAP NO.	NAME	SEE UNDER	PAGE
33	Green River	Copper	26
34	Big Falls	Copper	26
35	Rocky Point	Copper	26
36	Eight-Seventeen	Mercury	31
37	Roy No. 5	Mercury	31
38	Roy	Mercury	31
39	Parmenter	Mercury	31
40	Lytle-Lynch	Mercury	31
41	N. P.	Mercury	31
42	Fisher Lease	Mercury	31
43	Section Thirty-Six	Mercury	31
44	Section One	Mercury	31
45	Spencer	Mercury	31
46	Apex	Mercury	31
47	Barnum-McDonnell	Mercury	32
48	Tilton River, West Fork	Mercury	32
49	Ladd	Mercury	32
50	Tacoma	Gold	28
51	Waterfall	Gold	28
52	Eliza	Lead	30
53	Goldie	Lead	30
54	Mineral Creek	Zinc	38
55	Mashel River	Mercury	32
56	Rushing River	Uranium	37
57	Eagle Peak	Copper	26
58	Paradise	Copper	26
59	Storbo	Copper	26
60	Star	Gold	28
61	Chinook	Copper	27
62	Morse Creek Placer	Gold	29
63	Highland	Gold	29
64	Elizabeth Gold Hill	Gold	29
65	Hidden Treasure	Copper	27
66	Copper Mining Co.	Copper	27
67	Garibaldi	Tungsten	36

MAP NO.	NAME	SEE UNDER	PAGE
68	Reeves	Antimony	23
69	Black Jack	Zinc	38
70	Jug Lake	Antimony	23
71	Summit Creek	Nickel	33

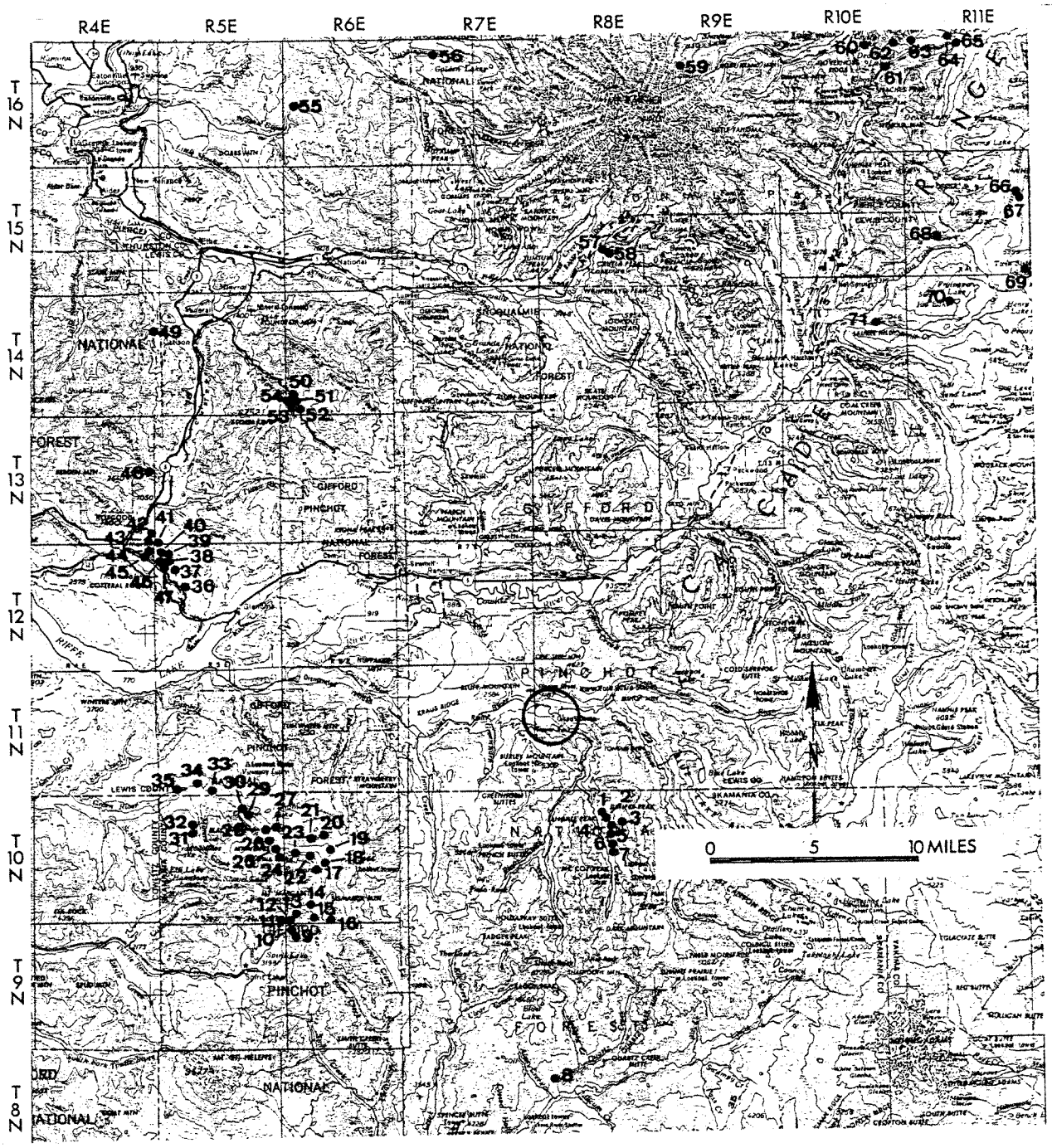


FIGURE 6.—Metallic occurrences in the Cispus Environmental Center area, Lewis County, Washington.

ANTIMONY

Properties—Antimony is chemically similar to arsenic and bismuth. The metal is silver white, exceedingly brittle, and has a hardness (Moh's scale) of 3.0 to 3.5. It is a poor conductor of heat and electricity. Those properties which have important influence on its uses are: expansion on solidifying from a melt, strong diamagnetism (property of repelling a magnetic field), and marked thermoelectric properties. It crystallizes in the rhombohedral division of the hexagonal system. Antimony commonly shows two valences, 3 and 5. With a valence of 5 it acts as a nonmetal, but in the valence of 3 it plays the part of either a nonmetal or a metal. Thus it falls in the class of semi-metals. It is not acted upon by air at room temperatures, but when heated it burns to form white fumes of the oxide Sb_2O_3.

Uses—About half of the antimony used is in the form of antimonial lead, in which the antimony content varies from about 2 to 25 percent, depending upon the use. Listed in decreasing order of importance from the point of view of tonnage, antimonial lead is used as bearing metal, storage battery plates, type metal, sheet and pipe for the chemical and building industries, castings, cable covering, collapsible tubes and foil, and ammunition. In wartime the last mentioned use assumes greater importance, of course. Substitutes for antimony have been developed for many of these uses, but not in the manufacture of type metal. In this application its value lies in hardening the type and especially in the unusual property of expanding when it cools. Antimony has some uses as alloys with other metals—tin, copper, zinc, and aluminum being most common. Chemical compounds of antimony are used in greatest quantities in ceramics but are also important as ingredients of paints and lacquers, in flameproofing textiles, in coloring glass, in manufacturing cellulose acetate, and in miscellaneous uses such as vulcanizing rubber, colorfast dyes, and medicinal products.

Production—Antimony was first discovered in Washington probably in 1892 at the Great Republic mine in King County. A little ore was mined there between 1900 and 1905. Other small, sporadic production has been reported from Okanogan and Stevens Counties: an estimated 2,300 tons during World War I; small amounts in 1936, 1937, and 1939; 2 carloads in 1941; 205 tons in 1946; 335 tons in 1947; 48 tons in 1949; an estimated 150 tons in 1951; and an estimated 35 tons were mined and stockpiled in 1952.

Ore minerals—The principal ore of antimony is the sulfide, stibnite, Sb_2S_3, containing 71.4 percent antimony, but most of the normal domestic supply is recovered as a byproduct from smelting copper, silver, and lead ores, in which it occurs most commonly as tetrahedrite, $Cu_{12}Sb_4S_{13}$, containing about 25 percent antimony. Native antimony occurs elsewhere, but it is not known in Washington. Three of the four known antimony oxides, valentinite, Sb_2O_3, cervantite, $Sb_2O_6(OH)$, and stibiconite, $Sb_3O_6(OH)$, are found in this state in small quantities, and in some countries these oxides are important ore minerals. Occurrences have been reported in Washington of the following minerals in which antimony is combined with one or more of the elements, lead, silver, copper, arsenic, iron, and sulfur: kermesite, Sb_2S_2O; pyrargyrite, Ag_3SbS_3, containing 59.7 percent silver, 22.5 percent antimony; boulangerite, $Pb_5Sb_4S_{11}$; stephanite, Ag_5SbS_4; jamesonite, $Pb_4FeSb_6S_{14}$; bournonite, $PbCuSbS_3$; geocronite, $Pb_5(Sb,As)_2S_8$; berthierite, $FeSb_2S_4$; bindheimite, $Pb_2Sb_2O_7nH_2O$; dyscrasite, Ag_3Sb; zinkenite, $Pb_6Sb_{14}S_{27}$; andorite, $PbAgSb_3S_6$; meneghinite, $Pb_{13}Sb_7S_{23}$; and diaphorite, $Pb_2Ag_3Sb_2S_6$.

Geology—The antimony-bearing minerals can form under a wide range of conditions and they occur associated with a great variety of minerals, but stibnite, the only important ore of antimony, is found typically in epithermal deposits. As described by Purdy:[1]

> Stibnite in Washington shows no particular affinity to any individual rock type. Commonly, stibnite occurs, (1) as all or part of the cementing material in breccias, (2) as irregular masses erratically distributed in quartz veins, or as disseminated particles or clusters throughout quartz veins, (3) as replacement deposits associated with fractured and/or silicified areas in limestone, and (4) as small lenticular bodies, veins, veinlets, and disseminated particles throughout hydrothermally altered zones, or it is erratically distributed along shears in those zones. In all of these instances the stibnite proves to be the last sulfide mineral to have formed, which attests to the very low temperature and pressure conditions that seem to be most favorable for its development. As is characteristic of the ephithermal group, the stibnite deposits are erratic and unreliable in the extreme, the majority of them the world around only reaching to comparatively shallow depths, possibly not over 2,000 feet, and containing ore of extremely irregular grade along the strike and dip. Most deposits, probably because of erosion since they were formed, seem to die out within a few hundred feet of the surface.

[1] Purdy, C. P., Jr., Antimony occurrences of Washington: Washington Div. Mines and Geol. Bull. 39, pp. 53-54, 1951.

OCCURRENCES

LEWIS COUNTY

68 Reeves

Loc: Center NE¼ sec. 29, (15-11E), ¾ mi. NW. of Frying Pan Lk. **Elev:** 5,300 ft. **Access:** 7 mi. by trail from Ohanapecosh Hot Springs. **Prop:** 1 claim: High Jack No. 2. **Owner:** Abandoned (1949). W. R. Reeves, Universal Alaska Mining Corp. (1933). **Ore:** Antimony. **Ore min:** Stibnite, stibiconite. **Gangue:** Quartz. **Deposit:** A hydrothermally altered zone in serpentine 10 ft. wide contains a 6- to 8-in. band of stibnite-bearing siliceous breccia. **Dev:** Trench and caved adit (1947).

70 Jug Lake

Loc: Reportedly on the W. shore of Jug Lk. **Access:** Trail up Summit Cr. or up Deep Cr. from Copper City. **Ore:** Antimony. **Ore min:** Stibnite. **Deposit:** Said to be a 2-ft. vein of antimony sulfide exposed in the lake shore and extending into the lake. **Note:** One investigator was unable to find this prospect.

ARSENIC

Properties—Arsenic has been variously classified as a metal, a metal-like solid, a semi-metal, and a nonmetal, but in its appearance and in some of its other physical and chemical properties it has the qualities of a metal. It is a steel-gray, very brittle, crystalline solid having a hardness of 3.5 and metallic luster. It sublimes easily to a yellowish vapor which has a garlic-like odor, and it catches fire at about 180° C. It displays two valences, 3 and 5, in its compounds with other elements. The free element is not considered poisonous, but all its soluble

inorganic compounds are violent poisons.

Uses—Arsenic finds its greatest use in the form of its poisonous compounds, such as the calcium, lead, and sodium arsenates, lead arsenite, and Paris green, for insecticides and weed killers. Arsenic is used in making glass, enamels, wood preservatives, drugs, dyes, and as alloys with lead and copper. In copper it increases the corrosion resistance and raises the annealing temperature, and for shot metal it is added to lead in amounts up to 1 percent to harden and improve the sphericity of the shot.

Production—Little arsenic is produced in the metal form; most of it is made in the form of white oxide, As_2O_3. Washington has the distinction of being the first state in this country to produce white arsenic on a commercial scale. Equipment to recover white arsenic at a smelter in Everett was built in 1901, and for several years it was the only producer in the United States. In its first 3 years of operation it produced 2,052 tons of white arsenic, valued at $135,871, as a byproduct of smelting gold ores, principally from the Monte Cristo district in Snohomish County. The copper smelter at Tacoma began recovering white arsenic in 1907, and it is reported to have produced 3,000 tons in 1920. This plant has produced arsenic intermittently to the present time, and in 1950 it was one of only five producers in this country. Domestic white arsenic is produced principally as a byproduct in smelting ores of copper and lead, and the amount of production depends primarily on the market demand rather than on existing plant capacity. The availability of relatively cheap byproduct arsenic makes it improbable that arsenic mining, as such, will ever be profitable in Washington in normal times, but in the past, two small plants operated briefly on straight arsenic ores. In 1906 a plant near Mineral, Lewis County, used realgar ore, and the same type of ore was treated in 1920 in a 15-ton mill at Reiter, Snohomish County.

Ore minerals—Native arsenic is fairly common but has been reported in Washington only in the vicinity of Goat Lake in the Monte Cristo district, Snohomish County. The most common arsenic minerals are arsenopyrite, FeAsS, containing 46.0 percent arsenic, and the sulfides, realgar, AsS, containing 70.1 percent arsenic, and orpiment, As_2S_3, containing 61.0 percent arsenic. These are widely distributed throughout the mineralized districts of the state. Perhaps the district best known for its arsenical ores is the Monte Cristo camp in Snohomish County, where arsenopyrite was mined for its gold and silver content. Other, less common arsenic minerals are arsenolite, As_2O_3; tennantite, $3Cu_2S \cdot As_2S_3$; proustite, $3Ag_2S \cdot As_2S_3$; the arsenides, löllingite, $FeAs_2$; smaltite, $CoAs_3$; cholanthite, $NiAs_3$; niccolite, NiAs; and many rare sulfarsenides of copper, silver, and lead.

Geology—Arsenopyrite is found in a wide variety of occurrences, as with tin and tungsten in pneumatolitic deposits; in quartz veins with gold, silver, galena, sphalerite, pyrite, chalcopyrite, tetrahedrite, calcite, siderite, and many other minerals; with cobalt and nickel ores; in contact-metamorphic deposits; in pegmatites; and disseminated in crystalline rocks, as schist, gneiss, limestone, and serpentine; but it usually favors deep-zone conditions of origin. On the other hand, realgar, orpiment, and arsenolite are usually found at shallow depths. Arsenolite is always a secondary mineral, but realgar and orpiment may be either primary or secondary.

OCCURRENCES

YAKIMA COUNTY

61 Chinook
(see under copper)

66 Copper Mining Co.
(see under copper)

67 Garibaldi
(see under tungsten)

COBALT

Properties—Cobalt is a silver-white metal which has a pinkish tinge. It is tough and has a hardness of 5.5, slightly harder than iron or nickel. It strongly resembles nickel in appearance and properties, especially in its resistance to corrosion. Cobalt is strongly magnetic, being exceeded in this property only by iron, and it retains its magnetism up to 1150° C.

Uses—The most important use (35 percent in 1950) is as alloys with iron for permanent magnets. The second most important use (27 percent in 1950), and formerly the chief use, is as stellite-type alloys containing 45 to 55 percent cobalt, with chromium, molybdenum, tungsten, and iron. These alloys are hard and strong at high temperatures, even at red heat. They are used for facing machine parts subject to high abrasion and for high-speed tools, surgical instruments, jet-engine parts, and other high-heat uses. Cobalt oxide is a necessary ingredient in nearly all porcelain enamel ground coats, although this use formerly accounted for a larger percentage of consumption than now. Cobalt compounds are used in blue pigments, as driers in paints, and as catalysts in the chemical industries. Small amounts of cobalt are used for plating other metals, and an increasing amount is used as a binder in cemented carbides. A new and increasing use for cobalt is in making the radioactive isotope, cobalt 60, a potent radiotherapeutic agent.

Production—Although the United States is the largest consumer of cobalt, domestic production has remained small and sporadic, but planned production from the Blackbird area in Idaho would supply a sizable portion of the current demand in this country. Most of the imported cobalt now comes from the Belgian Congo, where it is recovered as a byproduct from copper ores. All foreseeable needs for cobalt can be supplied for many years by known reserves in the principal deposits, and few small producers can hope to compete. No cobalt ore has been produced in Washington.

Ore minerals—The principal ore minerals of cobalt are the sulfarsenide, cobaltite, CoAsS, containing 35.5 percent cobalt; the arsenide, smaltite, $CoAs_3$, containing 28.1 percent cobalt; and the sulfide, linnaeite, Co_3S_4, containing 55.8 percent cobalt. Smaltite and linnaeite have been found in Washington, as has also the less common sulfarsenide of cobalt and iron, glaucodot, (Co,Fe)AsS. Near Silverton in Snohomish County is an occurrence of the distinctive pink-colored earthy secondary mineral, erythrite (cobalt bloom), $Co_3As_2O_8 \cdot 8H_2O$. This hydrous cobalt arsenate is seldom abundant enough to make ore,

but it frequently serves to call attention to other less easily recognized cobalt ore minerals.

Geology—Cobalt never occurs native (except in meteorites) and never occurs as the only constituent of an ore. It is very commonly associated with nickel and is found in ores of copper, silver, gold, iron, lead, and zinc. As an arsenide it occurs with nickel in ores that in many places carry high values in silver and gold. As a sulfide cobalt occurs with copper and iron minerals. This type of occurrence is exemplified by the deposits in the Blackbird district in Idaho, which contain 0.4 to 1.0 percent cobalt along with 1 to 2 percent copper, 10 to 15 percent iron, 0.5 to 1.5 percent arsenic, and 3 to 13 percent sulfur. Cobalt ores are found as veins in and near igneous rocks and in residual rocks formed by weathering of basic igneous rocks.

Occurrence

LEWIS COUNTY

57 Eagle Peak
(see under copper)

COPPER

Properties—Copper is the only metal that is red in color. It has a bright metallic luster, is soft (hardness = 2.5 to 3), is highly ductile and malleable, and has good though variable tensile strength, depending on the physical condition of the metal. Copper is resistant to corrosion and has excellent heat and electrical conductivity. It has a higher electrical volume conductivity than any metal other than silver, but aluminum has double the electrical mass conductivity of copper. The metal is an excellent reflector of infrared radiation. Chemically, it exhibits valences of 1 and 2. All the soluble copper salts are poisonous.

Uses—Copper is one of the most widely used metals, both in its pure form and as a base for many alloys, as well as in its compounds. Most of its uses depend upon its good conductivity of electricity and heat, and its strength, durability, and easy workability. About one-third of the consumption is for electrical manufacture, with other uses following in approximately this order: electrical wire and cable, automobile parts, building materials, household appliances, ammunition, and others. The shapes most commonly used are wire, sheet, and tube, but much of the metal is cast, especially as alloys. Copper is alloyed with zinc to make brass, with tin to make bronze, gun metal, and bell metal, with aluminum to make aluminum-bronze, with zinc and nickel to make German silver, with nickel, gold, and silver to make coinage metals, and with these and other metals for other special alloys. Beryllium added to copper gives an alloy of great strength and excellent high-temperature characteristics. Copper oxide and salts are used in special paints, as coloring agents in glass and ceramic glazes, and as antiseptics and insecticides.

Production—Copper production is seventh in value among the metals produced in the United States. Domestic production exceeded consumption for many years prior to 1938, (with the exception of 1932 to 1936) and the excess was exported, but each year since 1939 we have imported copper in substantial quantities. Peak United States production was 1,090,818 tons of metal in 1943, but the 1952 production of 928,000 tons was only about 15 percent less than this figure. Yearly production has varied greatly, depending upon general economic conditions. For example, prior to 1942 the peak production was 997,555 tons of copper in the boom year of 1929, but, during the depression year of 1933, only 4 years later, production had dropped by 81 percent to only 190,543 tons.

The first recorded production in Washington was 39,785 pounds of copper in 1894, after which no copper output was recorded for 5 years until 1899. Since that date production has been continuous but quite variable, ranging from a minimum of less than 3 tons of metal in 1932 to a maximum of 9,612 tons in 1940. Total production in the state through 1952 was 105,605 tons, valued at $32,369,845. In 1950 Washington ranked eighth among the states in production, but 92 percent of the United States total came from the first five states: Arizona, Montana, Utah, Nevada, and Michigan, in that order. The 1952 production of 4,357 short tons of copper, valued at $2,108,788, accounted for 14 percent of the value of metallic ore mined in Washington in that year. Of the large copper mines in this country, the Howe Sound mine in Chelan County ranked eighteenth in 1950, and it contributed 98 percent of the copper mined in the state. In 1950 there were 26 copper smelters and refineries operating, of which 1, owned by the American Smelting & Refining Co., is in Washington, at Tacoma.

Ore minerals—Copper occurs native and as a principal constituent of more than 160 minerals in the form of sulfides, oxides, and carbonates, and less commonly as antimonides, arsenates, phosphates, silicates, and sulfates. Of these minerals, about 16 are of commercial importance, and 6 have accounted for most of the copper mined in North America. The important ore minerals are sulfides, of which the most abundant and widely distributed is chalcopyrite, $CuFeS_2$, containing 34.5 percent copper. Other sulfides are: bornite, Cu_5FeS_4, containing 63.3 percent copper; chalcocite, Cu_2S, containing 79.8 percent copper; covellite, CuS, containing 66.4 percent copper; enargite, Cu_3AsS_4, containing 48.3 percent copper; tetrahedrite, $(Cu,Fe)_{12}Sb_4S_{13}$, containing about 52.1 percent copper; and tennantite $(Cu,Fe)_{12}As_4S_{13}$, containing about 57.0 percent copper. Some of the more important oxidized copper minerals are: cuprite, Cu_2O, containing 88.8 percent copper; tenorite, CuO, containing 79.8 percent copper; malachite, $CuCO_3 \cdot Cu(OH)_2$, containing 57.3 percent copper; azurite, $2CuCO_3(OH)_2$, containing 55.1 percent copper; and chrysocolla, $CuSiO_3 \cdot 2H_2O$, containing 36.0 percent copper. Native copper is the ore mineral in a few deposits, especially in Michigan. All these minerals except enargite and tenorite have been reported in Washington, but by far the commonest here is chalcopyrite.

Geology—Copper is the most abundant of the base metals. Its minerals are numerous and widely though irregularly distributed, and they are associated with many different metals in deposits in various rock types ranging in age from pre-Cambrian to Quaternary. Gangue minerals in the deposits may include quartz, calcite, siderite, barite, rhodochrosite, fluorite, sericite, or tourmaline. The types of deposits in which copper is found include magmatic segregations, contact-metamorphic, hydrothermal, and supergene (secondary) enrichment deposits. All the large copper deposits and most of the smaller ones are of hydrothermal origin, and in most of them replacement

has been dominant over cavity filling. The ores are genetically related to igneous rocks. The host rocks for the huge, well-known "porphyry copper" deposits of the southwest are in stocklike intrusions of monzonitic porphyries or rocks intruded by them. The ore in the larger deposits is disseminated and low grade, seldom averaging as much as 1.5 percent copper and in some instances as low as 0.5 percent. Vein deposits are smaller, and to be profitably operated must be of considerably higher grade. Many copper deposits have been leached near the surface and enriched at a moderate depth by descending surface water, but this supergene enrichment has been absent or of only minor importance in the origin of copper deposits in Washington.

Occurrences

LEWIS COUNTY

33 Green River

Loc: NW¼ sec. 33, (11-5E), Mt. St. Helens dist. **Prop:** 2 claims (part of Big Falls group). **Ore:** Copper.

34 Big Falls

Loc: Secs. 28 and 32, (11-5E), Mt. St. Helens dist. **Ore:** Copper.

35 Rocky Point

Loc: SE¼ sec. 31, (11-5E), Mt. St. Helens dist. **Prop:** 6 claims: Rocky Point Nos. 1 to 6. **Ore:** Copper.

57 Eagle Peak

Loc: Near NW. cor. sec. 27, (15-8E), on W. slope of Eagle Peak, Mt. Rainier area. **Elev:** 3,275 to 3,515 ft. **Access:** 1½ mi. by road above Longmire. 18 mi. to railroad at Ashford. 60 mi. by road to smelter at Tacoma. **Prop:** 2 unpatented claims: Aldula, Paradise. **Owner:** Eagle Peak Copper Mining Co., R. H. Wheelock, Ashford, Wash. (1908——). **Ore:** Copper, gold, silver, cobalt, uranium (?). **Ore min:** Chalcopyrite, pyrite, bornite, arsenopyrite, covellite, scheelite, molybdenite, sphalerite, linnaeite. **Deposit:** Mineralized joints or slip planes in granite. One zone is 6 in. to 5 ft. in width and carries a streak of high-grade ore 1 to 14 in. wide. Gold values are in the arsenopyrite. Ore from near portal of old drift about 15 ft. above present drift level was slightly radioactive. **Dev:** 300-ft. drift, 630-ft. crosscut. **Assays:** 18-ton shipment yielded 8.05% Cu, 0.09 oz. Au, 1.87 oz. Ag. 1% to 5% Co in some samples. **Prod:** 100 tons in 1919. Produced also 1925, 1928. Not over 200 tons total.

58 Paradise

Loc: Sec. 27, (15-8E), adjoining Eagle Peak property on the S., Mt. Rainier dist. **Access:** 2,400 ft. E. of Mt. Rainier highway above Longmire. **Prop:** 2 unpatented claims: Iva Henry Nos. 1 and 2. **Owner:** Paradise Mining Co. (1918-1921). **Ore:** Copper. **Ore min:** Chalcopyrite, bornite, arsenopyrite, pyrite. **Gangue:** Quartz, calcite. **Deposit:** Mineralized slip plane in andesite carries 4 to 8 in. of ore and minor parallel streaks of ore. **Dev:** 440-ft. adit, short drift, and open cut. **Improv:** 2,400-ft. aerial cable. (1921). **Assays:** 40-ton shipment said to assay 10% Cu. **Prod:** Reportedly 40 tons shipped prior to 1921.

PIERCE COUNTY

59 Storbo (Mt. Rainier)

Loc: Approx. sec. 8, (16-9E), at head of Inter Fk. of White R. on N. side of Mt. Rainier. **Access:** Trail. **Owner:** Mount Rainier Mining Co., Inc., Seattle, Wash. (1916——). **Ore:** Copper. **Ore min:** Chalcopyrite. **Gangue:** Tourmaline. **Deposit:** Lenticularly and intermittently mineralized fractures in Keechelus andesite up to 1 ft. thick. **Dev:** 7 adits totaling about 1,500 ft. of workings. **Improv:** 1 cabin (1952). **Prod:** 1915-1917, 1926, 1928.

SKAMANIA COUNTY

9 Young America

Loc: Sec. 6, (9-6E), adjoining Norway and Bronze Monarch properties on the NE., Mt. St. Helens dist. **Prop:** 5 claims. **Owner:** Mining Corporation, Ltd., of Portland (1901). **Ore:** Copper, gold, silver. **Deposit:** Mineralized zone 12 ft. wide is traceable for 2,000 ft. **Dev:** 50-ft. drift.

10 Sweden (Coe, St. Helens)

(see also Norway)

Loc: Near NW. cor. sec. 6, (9-6E), ½ mi. N. of the NE. end of Spirit Lk., Mt. St. Helens dist. **Elev:** 3,340 ft. **Access:** Trail from end of the road on S. side of the lake. **Prop:** 8 claims. **Owner:** Mount St. Helens Consolidated Mining Co. (1905-1943). Mining Corporation, Ltd. of Portland. (1902). **Ore:** Copper, gold, silver, zinc. **Ore min:** Pyrite, chalcopyrite, sphalerite, pyrrhotite. **Gangue:** Quartz. **Deposit:** Fault zone in granite from 6 in. to 4 ft. wide contains sparsely disseminated sulfides. **Dev:** 2,240-ft. adit with 3 crosscuts. Caved at 1,700 ft. (1942). **Assays:** 4 samples from an ore shoot 150 ft. long gave a weighted av. of 2.80% Cu across 3.2-ft. thickness. Another ore shoot 80 ft. long gave a weighted av. from 5 samples of 3.21% Cu across a 4.2-ft. thickness. **Prod:** 2 carloads of ore in 1928.

11 Bronze Monarch (Martha Washington)

Loc: Sec. 36, (10-5E), adjoining the Sweden property on the NW., Mt. St. Helens dist. **Elev:** 3,700 ft. **Access:** ¾ mi. by trail from Sweden property. **Owner:** Mount St. Helens Consolidated Mining Co. (1907-1926). Mining Corporation of Portland, Ltd. (1902). Bronze Monarch Mining Co. (1907). **Ore:** Copper, gold, silver. **Ore min:** Pyrite, lesser amounts of chalcopyrite. **Deposit:** Fault zone in granite 3 ft. wide. Mineralized quartz cements breccia in the zone. **Dev:** 300-ft. adit. **Assays:** Ore said to av. $28 in Cu, Au, Ag.

12 Norway

(see also Sweden)

Loc: Near SW. cor. sec. 31, (10-6E), 1,000 ft. up the mountain from the Bronze Monarch property, Mt. St. Helens dist. **Elev:** 3,648 ft. **Access:** Trail from Sweden mine. **Prop:** 9 claims. **Owner:** Mount St. Helens Consolidated Mining Co. (1907-1942). Mining Corporation, Ltd. of Portland (1902). **Ore:** Copper, gold, silver. **Ore min:** Pyrite, chalcopyrite, pyrrhotite. **Gangue:** Breccia, gouge, quartz. **Deposit:** A brecciated zone 4 ft. wide in granodiorite contains a little disseminated pyrite and chalcopyrite. **Dev:** 350-ft. adit. **Assays:** 5 samples from an ore shoot 50 ft. long gave a weighted av. of 2.44% Cu across 3.9-ft. thickness.

13 Yellow Metals

Loc: Sec. 31, (10-6E), 2½ mi. NE. of Spirit Lk., Mt. St. Helens dist. **Access:** Trail over Norway Pass. **Prop:** Several claims. **Owner:** Mining Corporation, Ltd., of Portland (1901). **Ore:** Copper, gold, silver. **Deposit:** Similar to the Chicago. **Assays:** Max. $60 in Cu, Au, Ag.

14 Chicago

Loc: NW¼ sec. 32, (10-6E), 2½ mi. NE. of Spirit Lk., Mt. St. Helens dist. **Access:** ¾ mi. by trail E. of Norway Pass. **Prop:** Several claims. **Owner:** Mining Corporation, Ltd. of Portland (1902). **Ore:** Copper, gold, silver, zinc. **Ore min:** Pyrite, arsenopyrite, chalcopyrite, sphalerite, native copper. **Deposit:** An 8-in. quartz vein in granodiorite. **Dev:** 200-ft. adit. **Assays:** Two assays showed 0.3% to 2.0% Cu, tr. to 0.10% Pb, 0.5% to 1.8% Zn, 0.11 to 0.12 oz. Au, 0.04 to 0.09 oz. Ag.

15 Mount Fairy

(see under gold)

16 Commonwealth

Loc: Near SW. cor. sec. 33, (10-6E), Mt. St. Helens dist. **Access:** 6 mi. NE. of Spirit Lk. Ranger Station on the Spirit Lk.-Guler trail. **Ore:** Copper, zinc, lead. **Ore min:** Chalcopyrite, sphalerite, galena, arsenopyrite. **Deposit:** Shear zone in basalt contains irregular lenses of quartz as much as 2 ft. wide. Ore minerals occur in the quartz and along fractures in the footwall. **Dev:** 340-ft. drift and a shaft.

17 Grizzly Creek

(see under gold)

18 Morning

Loc: NE¼ sec. 20, (10-6E), Mt. St. Helens dist. **Ore:** Copper.

19 Golconda

(see under gold)

20 Samson (Earl)

Loc: SE¼ sec. 8, (10-6E), at base of Goat Mtn., Mt. St. Helens dist. **Prop:** 20 claims. **Owner:** Mount St. Helens Consolidated Mining Co. (1907-1926). Mining Corporation, Ltd. (1901). **Ore:** Copper, gold, silver. **Deposit:** Large low-grade deposit said to be 500 to 1,000 ft. wide. **Dev:** 600 ft. of adit. **Assays:** Max. $3 in Cu, Au, Ag.

21 Germania

(see under gold)

22 Polar Star

Loc: SW¼ sec. 17, (10-6E), near Black Falls on Green R., Mt. St. Helens dist. **Prop:** 11 patented and 19 unpatented claims. **Owner:** Geo. S. Reid, Portland, Oreg. (1941). Cascadia Mining & Development Co. (1902-1926). Mount St. Helens Consolidated Mining Co. (1907-1926). **Ore:** Copper, gold, silver. **Ore min:** Chalcopyrite, pyrite, malachite. **Gangue:** Quartz, sericite, breccia. **Deposit:** Breccia zone in granite from a few in. to 2 ft. wide is leached, silicified, and sericitized. Mineralization is light and consists mostly of pyrite. **Dev:** 80-ft. adit with an 84-ft. drift, 35-ft. shaft, 900-ft. adit. **Assays:** 4% to 15% Cu, 0.095 oz. Au, 3 to 5 oz. Ag. **Prod:** Small amount prior to 1934.

23 Index

Loc: Near SE. cor. sec. 18, (10-6E), 2½ mi. NW. of the Chicago group, Mt. St. Helens dist. **Prop:** 12 claims: Index Nos. 1 to 12. **Owner:** Mount St. Helens Consolidated Mining Co. (1907-1926). Mining Corporation, Ltd. of Portland (1902). **Ore:** Copper, gold, silver.

24 Last Hope

Loc: Sec. 13, (10-5E), Mt. St. Helens dist. **Ore:** Copper.

25 Cinnabar

(see also Toledo)

Loc: Sec. 13, (10-5E), Mt. St. Helens dist. **Prop:** Part of Toledo group. **Ore:** Copper.

27 Toledo

(see also Cinnabar)

Loc: Sec. 12, (10-5E), Mt. St. Helens dist. **Prop:** Includes Cinnabar property. **Ore:** Copper.

29 Independence

Loc: Secs. 2, 3, 10, and 11, (10-5E), on Black Mtn., opposite the Minnie Lee mine, Mt. St. Helens dist. **Access:** Trail. **Prop:** 6 claims. **Ore:** Copper, gold, silver, lead. **Ore min:** Bornite. **Deposit:** Vein 14 in. to 4 ft. wide in granite. **Dev:** 3 adits, one of which has 125 ft. of crosscut and 275 ft. of drifts. **Assays:** $30 in Au, Ag, Cu, Pb.

30 Minnie Lee

Loc: Secs. 2 and 3 (?), or sec. 18 (?), (10-5E), Mt. St. Helens dist. **Owner:** Mount St. Helens Consolidated Mining Co. (1907-1926). Cascadia Mining & Development Co. (1902-1926). **Ore:** Copper, silver, gold.

31 Minnie Alice

Loc: Sec. 8, (10-5E), Mt. St. Helens dist. **Ore:** Copper, silver.

32 Crystal

Loc: Sec. 8, (10-5E), Mt. St. Helens dist. **Owner:** Messrs. Koontz, Witt, Burbee (1897). **Ore:** Copper. **Dev:** 36-ft. shaft.

YAKIMA COUNTY

61 Chinook

Loc: SW¼ sec. 12, (16-10E). **Access:** On Chinook Pass highway 1½ mi. E. of Chinook Pass. **Prop:** 3 unpatented claims. **Owner:** Hidden Treasure Mines, Inc., Yakima, Wash. (1954——). Orie O. Smalley and H. C. Lawson, Prosser, Wash. (1947). **Ore:** Copper, gold, silver. **Ore min:** Chalcopyrite, with a little arsenopyrite, sphalerite, pyrite, galena, molybdenite. **Gangue:** Granodiorite. **Deposit:** Ore minerals occur in a pocket or lens 4 to 5 ft. wide along the contact of iron-stained granodiorite and andesite. **Dev:** 50-ft. adit, 30-ft. winze with a 15-ft. crosscut, 550-ft. diamond drill hole. **Assays:** 21 tons shipped ran 10% Cu, 27 oz. Ag, $5 Au. **Prod:** 21 tons shipped to smelter in 1941.

64 Elizabeth Gold Hill

(see under gold)

65 Hidden Treasure

(see also Chinook)

Loc: S½ sec. 4, (16-11E), near Morse Cr. **Access:** On Chinook Pass highway 5 mi. E. of Chinook Pass. **Owner:** Hidden Treasure Mines, Inc., Yakima, Wash. (1954——). **Ore:** Copper, gold, silver. **Ore min:** Chalcopyrite, pyrite, pyrrhotite, sphalerite. **Deposit:** Slight mineralization along joints and disseminated in calcareous siltstone near granite contact. **Dev:** 400-ft. crosscut with 2 drifts, 75 to 100 ft. long.

66 Copper Mining Co.

(see also New Find, Pasco under copper, and Bird, Garibaldi under tungsten)

Loc: Secs. 12 and 13, (15-11E), secs. 7, 8, 17, 18, and 19, (15-12E), on Miners Ridge, Bumping Lk. dist. **Elev:** 4,000 to 6,000 ft. **Access:** 70 mi. by road to Yakima. **Prop:** 42 unpatented claims. **Owner:** Copper Mining Co., Yakima, Wash. (1906——). **Ore:** Copper, tungsten, gold, silver, molybdenum. **Ore min:** Chalcopyrite, arsenopyrite, molybdenite, scheelite, pyrite, bornite, malachite. **Gangue:** Quartz, tourmaline, calcite. **Deposit:** Mineralized quartz veins along shear zones in granite. Mineralization rather sparse. **Dev:** 3 Bird adits, Garibaldi adit, 2 New Find adits, Pasco adit, totaling more than 1,000 ft., numerous open cuts. **Assays:** Tr. Au, 0.60 to 2.00 oz. Ag, 1.15% to 3.35% Cu, tr. to 11.50% WO_3, 0.13% MoS_2. **Prod:** 1907; 11 tons copper conc. (1938); 650 lb. scheelite conc. (1941).

GOLD

Properties—Gold is bright yellow when pure, but the color intensity varies to lighter or darker with the amount of silver or copper present. Gold powder produced by precipitation or volatilization is violet, purple, or ruby colored. Gold is very heavy and soft and is the most ductile and malleable of metals. It is a good conductor of heat and electricity, its electrical conductivity being exceeded only by silver and copper. The element is not attacked by air or oxygen and is extremely inactive. It is insoluble in all acids except aqua regia and selenic acid. It is bivalent and tetravalent but combines with only a few other elements to form compounds.

Uses—Gold has little use other than monetary and decorative. Since earliest historical time gold has been

used for currency or as a monetary standard, and at the present time these are the principal uses of the metal. In the arts it is used in the manufacture of jewelry, watches, and gold foil for lettering and decorative purposes. Lesser amounts are used in dental work and in the electrical and chemical industries, and small quantities are used in medicine and photography. Most of the industrial uses stem largely from its resistance to corrosion and its excellent ductility and malleability, but because of its extreme softness as the pure metal, it is often alloyed with silver or copper.

Production—Gold production forms an important part of the total mineral output of the state of Washington. Every year prior to 1916 gold outranked in value all other metals produced, and it has ranked first in many of the years since that date, but in 1952 gold accounted for only 13 percent of the value of metallic production in the state. In general, gold mining has fared relatively well during economic recessions and has been at a disadvantage during periods of general prosperity and high prices. Although placer gold was reported along the Yakima River as early as 1853, and small production was reported from near Colville as early as 1855, the first notable production dates from 1859, and this was from the Similkameen River, in what is now Okanogan County. Lode gold mining began in this area, near the base of Mount Chopaka, in about 1871. The Blewett district was an early producer of both placer and lode gold, and by the end of the nineteenth century most of the presently known gold properties in the state had been prospected. The total gold production of the state from 1860 through 1952 has been 2,570,002 ounces, valued at $68,705,393, which ranks Washington eleventh among the states as a gold producer. The greatest production in any single year since 1900 was 92,117 ounces, valued at $3,224,095, in 1950. In that year 97 percent of the Washington gold production came from three mines: the Holden, Gold King, and Knob Hill, which ranked in production twelfth, fourteenth, and eighteenth, respectively, among the gold mines in the United States. Prior to 1900 most of the gold produced in the state was from placers, but since that time less than 3 percent of the production has been from placers. Twenty-seven counties have reported placer production.

Ore minerals—Gold occurs most commonly as the native metal, which usually is alloyed with varying amounts of silver, generally 10 to 20 percent. Native gold may occur as irregular masses, ranging in size from nuggets weighing several ounces, or even pounds, down to submicroscopic particles. Also, and more rarely, it occurs as well-formed crystals, as in some of the lode deposits in the Swauk district in Kittitas County. Less commonly, gold occurs as one of the tellurides: calaverite, $AuTe_2$; sylvanite, $(Au,Ag)Te_2$; or petzite, $(Au,Ag)_2Te$, containing 43.5, 35.1, and 53.4 percent gold, respectively. Other gold minerals are very rare. In most ores the gold is so finely disseminated as to be invisible to the naked eye.

Geology—Gold occurs in minute quantities in almost all rocks, and sea water has been variously reported to contain from 0.2 to 65 milligrams of gold per metric ton. It occurs in recoverable quantities in most ores of silver, copper, bismuth, and antimony and in many ores of lead and zinc, as well as in many deposits where gold is the only value. It occurs in deposits of various origins but most commonly in quartz veins and usually closely associated with granitic or volcanic rocks of acidic or intermediate composition. Pyrite is the most common associated metallic mineral, and quartz is the most common gangue mineral, but carbonates, fluorspar, tourmaline, barite, and other nonmetallic minerals are not uncommon as gangue. The high specific gravity and resistance to weathering of gold account for the fact that it concentrates in placer deposits, where it commonly is found associated with magnetite, ilmenite, chromite, monazite, rutile, zircon, garnet, and other heavy minerals. Both stream and beach placers are found in Washington.

Occurrences

GOLD, LODE

LEWIS COUNTY

50 Tacoma

Loc: On S. Fk. Mineral Cr. **Owner:** Davis & Evans Mining Co. (1897). **Ore:** Gold.

51 Waterfall

Loc: On Mineral Cr. **Prop:** 14 claims. **Owner:** Davis & Evans Mining Co. (1897). **Ore:** Gold, silver, lead. **Ore min:** Galena, limonite. **Dev:** 30- and 70-ft. shafts, and 4 adits, 20, 40, 100, and 140 ft. long.

57 Eagle Peak

(see under copper)

PIERCE COUNTY

60 Star

Loc: SW¼ sec. 2, (16-10E), Summit dist. **Ore:** Gold.

SKAMANIA COUNTY

1 Perry

Loc: Above the Johnson property on McCoy Cr., probably in sec. 10, (10-8E). **Ore:** Gold. **Ore min:** Arsenopyrite.

2 Johnson

Loc: Sec. 10, (10-8E), a short distance above the Bruhn property on McCoy Cr. **Ore:** Gold. **Ore min:** Free gold. **Deposit:** Gold in a seam 2 or 3 in. wide.

3 Primary Gold

Loc: Sec. 10, (10-8E), on both sides of Camp Cr. **Access:** 4 mi. by trail from the end of Niggerhead road. **Prop:** 18 unpatented claims: Jim Nos. 1 to 6; Inez Nos. 1 to 4; Eva Nos. 1, 2, and 5; Jim No. 8; Ialine; O Bill; Orell. **Owner:** Primary Gold Co., Yakima, Wash. (1938). **Ore:** Gold, silver, and platinum reported. **Deposit:** 30-ft. ledge of coarsely crystalline pyrite in quartz gangue. This carries only traces of gold, but narrow stringers of free gold in quartz cut the pyrite. **Dev:** Numerous open cuts, some placering. **Assays:** Said to range from $2.10 to $1,500.00 per ton. **Prod:** Has produced (probably small amount).

4 Bruhn

Loc: Sec. 10, (10-8E), adjacent to property of Camp Creek Metals Mining Co., McCoy Cr. dist. **Ore:** Gold. **Ore min:** Sulfides. **Deposit:** 2-ft. gouge seam.

5 Camp Creek

Loc: Center sec. 10, (10-8E), on Camp Cr., a tributary to McCoy Cr. **Owner:** Camp Creek Metals Mining Co. (1934). **Ore:** Gold. **Ore min:** Free gold. **Deposit:** Quartz stringers in an oxidized zone 300 ft. wide. **Prod:** $75,000 prior to 1934.

7 Brown and Livingston

Loc: On Granite Cr., a tributary of McCoy Cr., 3 mi. above the mouth of McCoy Cr., probably in sec. 15, (10-8E). **Ore:** Gold, silver. **Assays:** $6.00 to $30.00 Au, Ag.

8 **Plamondon**
Loc: SW¼SE¼ sec. 7, (8-8E), on N. side of Quartz Cr. **Elev:** 2,800 ft. **Access:** 3½ mi. by trail from end of road. **Prop:** 26 unpatented claims (1943). 3 unpatented claims (1954). **Owner:** Plamondon Brothers Mining Co. (1939——). Plamondon Indian Mines, Inc. (1940-1944). **Ore:** Gold, silver. **Gangue:** Chalcedonic quartz. **Deposit:** Chalcedonic quartz in iron-stained tuff is reportedly mineralized. **Dev:** Short adit, open cut. **Assays:** As high as $68 reported.

9 **Young America**
(see under copper)

10 **Sweden**
(see under copper)

11 **Bronze Monarch**
(see under copper)

12 **Norway**
(see under copper)

13 **Yellow Metals**
(see under copper)

14 **Chicago**
(see under copper)

15 **Mount Fairy**
Loc: SW¼ sec. 32, (10-6E), Mt. St. Helens dist. **Ore:** Gold, silver, lead, copper.

17 **Grizzly Creek**
Loc: Near Grizzly Cr. on Black Mtn., probably in sec. 20, (10-6E). **Access:** Trail. **Prop:** 4 claims. **Ore:** Gold, silver, lead, copper. **Deposit:** Vein av. 4 ft. wide in granite. **Dev:** 2 adits and a winze. **Assays:** $50.00 to $60.00 per ton reported from bottom of winze.

19 **Golconda**
Loc: Near W. ¼ cor. sec. 16, (10-6E), Mt. St. Helens dist. **Access:** ½ mi. up the Ryan Lk. trail from the Green R. trail. **Ore:** Gold, zinc, copper. **Ore min:** Pyrite, some chalcopyrite and sphalerite, a little galena. **Deposit:** Quartz veinlets along a fracture zone in granite. **Dev:** Adit. **Assays:** Reportedly $4.00 Au. **Prod:** An 18-ton shipment in 1933 reported.

20 **Samson**
(see under copper)

21 **Germania**
Loc: Secs. 8 and 17, (10-6E), adjoining Polar Star property on the E., Mt. St. Helens dist. **Prop:** 12 patented claims. **Ore:** Gold, copper. **Dev:** 2 adits.

22 **Polar Star**
(see under copper)

23 **Index**
(see under copper)

29 **Independence**
(see under copper)

30 **Minnie Lee**
(see under copper)

YAKIMA COUNTY

61 **Chinook**
(see under copper)

63 **Highland**
Loc: Sec. 6, (16-11E), Summit dist. **Ore:** Gold, silver.

64 **Elizabeth Gold Hill**
Loc: NW¼ sec. 4, (16-11E), Summit dist. **Ore:** Gold, silver, lead, copper.

66 **Copper Mining Co.**
(see under copper)

GOLD, PLACER

PIERCE COUNTY

62 **Morse Creek Placer**
Loc: Near head of Morse Cr. **Ore:** Gold.

SKAMANIA COUNTY

6 **Hudson and Meyers Placer**
Loc: On McCoy Cr., probably in sec. 15, (10-8E). **Ore:** Gold.

LEAD

Properties—Lead is a bluish-gray metal, which on fresh surfaces has a bright luster that soon tarnishes on exposure to air. It is one of the heaviest metals, is very soft and highly malleable, but has only slight tenacity and low ductility. It is a poor conductor of electricity. It is very plastic, tends to flow under very light loads, and may be extruded easily to form wire or tubes. Lead has an unusual and useful combination of properties in having a low melting point but high boiling point. It is chemically inert to common corrosive conditions, and is acted upon very slowly by dilute acids. It forms two series of chemical compounds, in which it shows valences of 2 and 4.

Uses—Lead was probably one of the first metals to be won from its ores by smelting. In 1950 about 52 percent of all lead consumed went into three products—batteries (32 percent), cable coverings (11 percent), and tetraethyl lead for high-octane gasoline (9 percent). About 9 percent of the total consumption went into paint pigments. In the two last mentioned uses the lead is in the form of chemical compounds; other important uses of lead compounds are in dyes, insecticides, ceramic glazes, medicine, matches, oil refining, and gas production. Other uses of lead in the metallic form are for ammunition, calking metal, casting metal, sheet metal, sheet lead, lead plating, collapsible tubes, foil, weights, ballast, shot, and pipe and containers for corrosive liquids. Lead is a constituent of many alloys, antimony being the most common alloying metal, but common also are tin, arsenic, and calcium. Some of these alloys are used as solder, type metal, bearing metal, pewter, and terne metal.

Production—In 1951 there were 11 lead smelters in the country, 1 each in California, Colorado, Idaho, Illinois, Kansas, Missouri, Montana, New Jersey, and Texas, and 2 in Utah. An important factor in the lead market is secondary lead, the recovery of which has exceeded mine production of new lead each year for many years.

The first recorded production of lead in Washington was in 1898, and some lead has been mined each year since then, although the amount has varied greatly from year to year. The record was in 1952, when 11,744 short tons valued at $3,781,568 was produced. The previous record was in 1950, with 10,334 tons, which ranked Washington ninth among the states in lead output, and amounted to 2.4 percent of the total United States pro-

duction for that year. Lead accounted for 26 percent of the value of metallic ore produced in Washington in 1952. Total output from 1898 through 1952 was 124,766 short tons, valued at $25,617,254. Some lead has been mined in each of 10 different counties, but of recent years most has been from the Metaline district in Pend Oreille County and the Bossburg and Northport districts in Stevens County. In 1950 these 3 districts produced respectively 7,445 tons, 2,640 tons, and 237 tons of lead and ranked 10th, 20th, and 41st among the lead-producing districts in the United States. The mine of the Pend Oreille Mines & Metals Co. was the leading lead producer in the state in 1952.

Ore minerals—The principal ore of lead is the sulfide, galena, PbS, containing 86.6 percent lead. Two other fairly common ores of lead are the carbonate, cerussite, $PbCO_3$, containing 77.5 percent lead, and the sulfate, anglesite, $PbSO_4$, containing 68.3 percent lead. Galena is a primary mineral, but cerussite and anglesite are secondary, as are also the less common, yet well-known, pyromorphite, $Pb_5P_3O_{12}Cl$, and wulfenite, $PbMoO_4$, containing 76.4 and 56.4 percent lead, respectively. All these lead minerals have been found in Washington. The metal rarely occurs as the native element. In all, there are more than 150 minerals known in which lead is an essential constituent.

Geology—Lead minerals typically are associated with zinc and silver minerals, and they occur predominantly in limestone and dolomite, generally as disseminated replacement deposits. Deposits of the less common vein type usually are in sedimentary or metamorphic rocks and are associated with intrusive igneous rocks, but most of the replacement deposits usually are of either (1) lead-zinc ores, with no copper, silver, or gold, in a gangue of calcite, dolomite, pyrite or marcasite, and sometimes barite or fluorite, or (2) lead-silver ores, with similar gangue minerals, sometimes containing small amounts of zinc and gold. The vein deposits of lead usually are more complex, mineralogically. The lead is associated with zinc, and the ore carries appreciable values in gold and silver. Chalcopyrite and pyrite are common in the ore, as are also minerals of antimony, arsenic, bismuth, and other copper and iron minerals.

Occurrences

LEWIS COUNTY

51 Waterfall
(see under gold)

52 Eliza
Loc: On Mineral Cr. **Owner:** Mineral Creek Mining Co. (1897). **Ore:** Lead. **Ore min:** Galena. **Dev:** 100-ft. adit.

53 Goldie
Loc: On Mineral Cr. **Owner:** Mineral Creek Mining Co. (1897). **Ore:** Lead. **Ore min:** Galena.

54 Mineral Creek
(see under zinc)

SKAMANIA COUNTY

15 Mount Fairy
(see under gold)

16 Commonwealth
(see under copper)

17 Grizzly Creek
(see under gold)

19 Golconda
(see under gold)

26 Snowflake
Loc: NW¼ sec. 13, (10-5E), Mt. St. Helens dist. **Ore:** Lead, zinc.

28 Bonanza
Loc: Sec. 12, (10-5E), Mt. St. Helens dist. **Ore:** Lead. **Ore min:** Galena. **Deposit:** 2-ft. vein with an 8-in. paystreak.

29 Independence
(see under copper)

31 Minnie Alice
(see under copper)

YAKIMA COUNTY

61 Chinook
(see under copper)

64 Elizabeth Gold Hill
(see under gold)

MERCURY

Properties—Mercury, called quicksilver by most miners, is a silver-white heavy metal (heavier than lead) which is liquid at ordinary temperatures. It solidifies at -39° C. and is then tin-white, ductile, malleable, and soft enough to be cut with a knife. Mercury when pure does not tarnish on exposure to air. It has low vapor pressure and has a regular coefficient of expansion. It is a fair conductor of heat and electricity, the thermal heat conductivity being about two-thirds that of silver. Its vapor conducts electricity and, in doing so, emits radiations rich in ultraviolet rays. Mercury alloys with most metals except iron and platinum, and it combines with sulfur at ordinary temperatures. It is next to silver in the electromotive series and resembles copper in its chemical behavior. It is both bivalent and univalent, and its compounds are poisonous, but in small doses they are medicinal.

Uses—The various uses from year to year consume markedly different proportions of the total United States mercury consumption. In 1950 the most important uses were for electrical apparatus, pharmaceuticals, industrial and control instruments, and agriculture (disinfectants and fungicides), which used respectively 24, 12, 11, and 9 percent of the total consumption. Other uses, in declining order of importance, were in antifouling paint for ship bottoms, catalysts, dental preparations, electrical preparation of chlorine and caustic soda, fulminate for munitions and blasting caps, amalgamation of gold and silver ores, vermillion paint, and minor uses in making mirrors and for mercury salts for wood and fabric preservation, printing, staining, and photography. An increasing use is in a new type of dry battery, and another interesting use is in mercury-vapor boiler power plants, replacing water vapor.

Production—During periods of high mercury prices domestic mines have been able to supply the demands for the metal, but normally this country is a large importer of mercury. United States production was high during the two world wars and from 1928 to 1931, but since

1943 (highest production since 1882) domestic production dropped off each year until 1950, when the output was lower than in any year since before 1850. With increasing prices in 1951 and 1952, production increased somewhat.

Cinnabar, the ore of mercury, is known to occur in 13 of Washington's 39 counties, but the only production of any consequence has come from the Morton district of Lewis County. The first recorded production there was 75 flasks in 1916. The district later produced 6,438 flasks (76 pounds per flask) valued at $689,656 during the period 1926 through 1942, with production in each year except 1939.

Ore minerals—More than 95 percent of the world's supply of mercury comes from the sulfide, cinnabar, HgS, which contains 86.2 percent mercury. Some ores contain native mercury, others contain metacinnabarite, HgS, and a few other minerals have occasionally been mined for their mercury content. In all, about 25 mercury minerals are known.

Geology—Mercury ores are widespread in their occurrence and are found in rocks of all ages and kinds, but most commonly are in regions of late Tertiary or Recent volcanic activity. They are shallow, less than 2,000 feet deep, and usually much less than that, and were deposited from low-temperature alkaline waters in highly fractured veins and bodies of irregular shape. Common accessory minerals are marcasite, pyrite, and stibnite; and the gangue minerals may be quartz, chalcedony, opal, calcite, dolomite, or barite. The tenor of ore mined in this country in 1950 ranged from 0.15 to 5.1 percent (3 to 102 pounds of mercury per ton of ore), and averaged 0.465 percent, or 9.3 pounds per ton. For comparison, ore mined in 1850 averaged 740 pounds per ton; in 1863, 360 pounds; in 1895, 20 pounds; and in 1928, 7.9 pounds.

Occurrences

LEWIS COUNTY

36 Eight-Seventeen

Loc: SW¼ sec. 8 and NW¼ sec. 17, (12-5E), Morton dist. **Ore:** Mercury. **Ore min:** Cinnabar. **Deposit:** Small amounts of cinnabar. **Dev:** Prospect pits.

37 Roy No. 5

Loc: NE¼SW¼SW¼ sec. 6, (12-5E), about 1,100 ft. N. of the portal of Roy No. 1 adit. **Elev:** 1,381 ft. **Access:** Truck road from the Morton-Kosmos highway. **Ore:** Mercury. **Ore min:** Cinnabar. **Gangue:** Brecciated country rock, sandstone. **Deposit:** Cinnabar occurs as disseminations in coarse white massive sandstone and in a breccia at the junction of two faults. Rocks in the breccia are porphyry, coaly shale, and sandstone. **Dev:** 125-ft. adit driven along a fault. **Assays:** Lean showings of cinnabar.

38 Roy (Fisher, Morton, Gillispie)

Loc: S½SW¼ and NW¼SW¼ sec. 6, (12-5E), 2 mi. SE. of Morton. **Elev:** 1,080 to 1,500 ft. **Access:** ½ mi. of truck road from the Morton-Kosmos highway. 2 mi. to railroad at Morton. **Prop:** 120 acres. **Owner:** Roy Mining Co. (1933-1949). Fisher Mercury Mining Co. (1926). Morton Cinnabar Co. (1926-1930). Washington Cinnabar Co. (1930-1933). Fowler & O'Conner (1938). **Ore:** Mercury. **Ore min:** Cinnabar, pyrite. **Gangue:** Calcite, hydrothermally altered country rock. **Deposit:** Cinnabar occurs along fractures and breccia zones in a series of sandstones, shales, and siltstones cut by igneous dikes and sills. Shear zone has probable max. thickness of 10 ft. **Dev:** More than 6,000 ft. of underground workings on 5 levels. **Assays:** 1931 production av. 5 lb. Hg per ton. **Prod:** About 2,500 flasks 1928-1929, 1,079 flasks 1930, 1,581 tons of ore 1931, recovered 65 flasks of mercury from 1,000 tons of ore 1940, produced 1941.

39 Parmenter

Loc: Near E. line SE¼SW¼ sec. 6, (12-5E); about 2,000 ft. E. of the portal of Roy adit. **Elev:** 1,048 ft. **Access:** About 1 mi. of truck road from the Morton-Kosmos highway. **Prop:** 160 acres. **Owner:** B. H. Parmenter, Morton, Wash., leasing to John Early, Morton (1937). **Ore:** Mercury. **Ore min:** Cinnabar. **Gangue:** Altered country rock. **Deposit:** Sheared zone in shales, coal, porphyry, and sandstone contains a few small stringers of cinnabar. **Dev:** 425-ft. adit. **Assays:** Low grade.

40 Lytle-Lynch (Charlotte Ann, Kropolis)

Loc: NW¼ and N½NE¼ sec. 6, (12-5E), about ¾ mi. N. of the Roy-Barnum-McDonnell workings. **Elev:** 1,610 to 1,725 ft. **Access:** Truck road from Morton-Kosmos highway. **Prop:** 240 acres. **Owner:** Barnum-Patterson Mining Co. (1939). Charlotte Ann Mercury Co. (1931-1932). Baker-Fonsec Co., Portland, Oreg. (1937). **Ore:** Mercury. **Ore min:** Cinnabar, pyrite or marcasite. **Deposit:** Cinnabar occurs as thin seams in fault breccia and rocks adjacent to the fault. Country rock consists of shale, sandstone, coal, and porphyry. **Dev:** 3 adits and at least 2 caved workings. One adit 230 ft., another 110 ft., and the other 70 ft. long. **Assays:** Ore said to av. about $5.00. **Prod:** 1930-1932.

41 N. P.

Loc: SW¼ sec. 31, (13-5E), Morton dist. **Prop:** 200 acres. **Owner:** Northern Pacific Railway Co. **Ore:** Mercury reported. **Dev:** Small amount.

42 Fisher Lease

Loc: NE¼ sec. 36, (13-4E), Morton dist. **Access:** Reached by ½ mi. of trail from the highway. **Prop:** State lease. **Ore:** Mercury. **Ore min:** Cinnabar. **Deposit:** Cinnabar mineralization along a fault zone in sedimentary and igneous rocks. **Dev:** 2 adits.

43 Section Thirty-Six

Loc: SE¼SE¼ sec. 36, (13-4E), about 2,000 ft. NE. of the Spencer workings. **Ore:** Mercury. **Ore min:** Cinnabar. **Deposit:** Cinnabar encountered in one of the old adits and in two trenches. **Dev:** 2 old adits and several trenches. Trenches opened in 1937.

44 Section One

Loc: SE¼ sec. 1, (12-4E), Morton dist. **Ore:** Mercury. **Ore min:** Cinnabar. **Deposit:** Small amount of cinnabar. **Dev:** Prospect pits.

45 Spencer

Loc: NW¼NE¼ sec. 1, (12-4E). **Elev:** 1,365 to 1,500 ft. **Access:** ½ mi. by road N. of Morton Grange No. 1066. **Owner:** Northern Pacific Railway Co. (1937——) leasing to Rainier Mining Co. (1954——). Spencer Mining Co. (1935). **Ore:** Mercury. **Ore min:** Cinnabar, pyrite. **Gangue:** Sandstone. **Deposit:** Cinnabar seams as much as ⅜ in. wide occur along joints in coarse sandstone. Thin cinnabar seams also occur along a 6- to 14-in. breccia zone. **Dev:** 2 caved adits, 6 shallow pits, 7-ft. shaft, caved shaft, bulldozer trenches. **Improv:** Retort. **Prod:** 1934.

46 Apex (Gallagher, Miller, Consolidated)

Loc: SW¼NE¼, NW¼SE¼, and NE¼SW¼ sec. 6, (12-5E), about 800 ft. NE. of Parmenter adit, Morton dist. **Elev:** 1,875 to 2,002 ft. **Access:** About 1,000 ft. by trail from truck road to Parmenter adit. **Prop:** 120 acres. **Owner:** Apex Mercury Mining Co., Tacoma, Wash. (1943). **Ore:** Mercury. **Ore min:** Cinnabar. **Gangue:** Sandstone, breccia. **Deposit:** Cinnabar occurs as disseminations in sandstone and in breccia along a fault zone in coal and shale. **Dev:** 260-ft. adit, two 50-ft. adits, 1,000-ft. adit.

47 Barnum-McDonnell

Loc: N½NW¼ sec. 7, (12-5E), about 2¼ mi. SE. of Morton. **Access:** Morton-Kosmos highway crosses lowermost adit. Other workings accessible by truck road. **Prop:** 320 acres. **Owner:** C. W. Lane and Floyd Ray, Morton, Wash. (1954——). Barnum McDonnell Mining Co. (1916-1929). Consolidated Mercury Mining Co. (1929-1933). Puget Sound Mercury Mining Co. (1935). Hermes Mercury Mining Co. (1936-1937). Cascade Mining Co. (1938). Mercury Corp. of America (American Mercury Co.), (Pacific Mining Co.) (1940-1942). **Ore:** Mercury. **Ore min:** Cinnabar. **Deposit:** Cinnabar occurs in fractures and breccia along fault zones in a series of sandstones, shales, and siltstones cut by igneous sills and dikes. Shear zone has probable max. thickness of 10 ft. Best ore is in tuffaceous sandstone. **Dev:** More than 3,400 ft. of underground workings on 5 levels. **Assays:** 3 to 47 lb. Hg per ton. **Prod:** 75 flasks 1916, 489 flasks 1926, 1,265 flasks 1926-1929, 441 flasks 1931. Also produced 1932, 1934, 1941.

48 Tilton River, West Fork

Loc: Sec. 13, (13-4E), on W. Fk. of Tilton R. **Ore:** Mercury. **Deposit:** Cinnabar float has been found.

49 Ladd

Loc: Sec. 12, (14-4E), N. of Morton. **Access:** Road. **Ore:** Mercury. **Deposit:** Cinnabar float was found when a new road was built to the upper adit of the Ladd coal mine.

PIERCE COUNTY

55 Mashel River

Loc: SE¼SW¼ sec. 18, (16-6E). **Elev:** 2,175 to 2,500 ft. **Access:** 1 mi. from end of logging road. 16 mi. from railroad at Eatonville. **Prop:** Deeded land. **Owner:** St. Paul & Tacoma Lumber Co. has given an option to lease to Joe Bath, Puyallup, Wash. (1951). **Ore:** Mercury. **Ore min:** Cinnabar. **Gangue:** Quartz. **Deposit:** Andesite is cut by several tabular masses of quartz about 100 ft. by 100 ft. by 20 ft. thick which have numerous cavities and joints filled and coated with cinnabar and limonite. **Dev:** Several short adits.

MOLYBDENUM

Properties—Molybdenum is usually prepared as a gray metallic powder, but the pure metal is silvery white and is soft, tough, malleable, and has high tensile strength. Very small amounts of certain impurities make the metal brittle, hard, and darker in color. It can be filed, polished, machined, forged when hot, and drawn into wire, although it was formerly thought to be non-ductile. The properties of strength, toughness, and resistance to repeated shocks are retained at relatively high temperatures. Its melting point is higher than that of all but four other elements: tantalum, rhenium, tungsten, and carbon. Its electrical conductivity is fair but is less than one-third that of copper. Molybdenum is closely related chemically to chromium, tungsten, and uranium. It has valences of 2, 3, 4, 5, and 6, but the compounds in which it acts in the 6 state are the most important.

Uses—In 1950 more than 90 percent of the molybdenum consumption was for metallurgical uses, about 70 percent going into steel and 20 percent into cast iron. The remaining 10 percent was used as the pure metal and in nonferrous alloys and nonmetallic products. Molybdenum may be used as a substitute for tungsten in many steels. Used alone in steel it gives a product which is strong and easily welded, and used with other steel-forming elements it enhances the effects of those elements on the steel. Molybdenum steels are put to such uses as boiler plate, rifle barrels, auto parts, propeller shafts, and tool steel. Added to cast iron, molybdenum adds strength, toughness, and machinability. Nonferrous alloys of molybdenum are not very important, but an alloy with cobalt is useful in having a coefficient of expansion equal to that of glass, and alloys with tungsten make good incandescent filaments. A few other alloys are chromium-molybdenum; nickel-chromium-molybdenum; and the alloy illium, that contains 4 percent molybdenum plus chromium, nickel, copper, manganese, tungsten, and iron. Pure molybdenum metal is used as supports for filaments in electric lights and radio tubes, for X-ray tube elements, for winding resistance units for electric furnaces, and for electrical contact points. Molybdenum compounds are finding increasing uses in lubricants, pigments, printer's ink, leather tanning, enameling of iron and steel, fabric dyeing, and as a catalyst in the hydrogenation of coal and mineral oil.

Production—Molybdenum is the only alloying element used in steel-making in which the United States is self-sufficient, and production in this country in the past 20 years has averaged about 90 percent of world output during that period. Domestic reserves have been estimated to be sufficient to last for 400 years at the 1935 to 1939 rate of use. A few very large mines dominate the production. Of the nine mines producing molybdenite concentrate in this country in 1950 only two were mining molybdenum as the principal product; molybdenum was a byproduct at the other seven mines, six of which were copper mines and one tungsten. United States molybdenum ore production rose from 1,397 pounds of contained molybdenum in 1914 to 861,537 pounds in 1918, dropped to 22,667 pounds in 1923, and rose to an all-time high of 61,406,000 pounds in 1943. Production had dropped to 18,047,000 pounds in 1947 but had risen again to 38,855,000 pounds by 1951.

Washington has numerous occurrences of molybdenum in at least 16 counties, but only a few of the occurrences have been in production, and these only in very small amount. Some production from the Castleman mine in Whatcom County was reported in 1899. During 1901 and 1902 about 20 to 24 tons of molybdenite was produced at the Crown Point mine in Chelan County; this mine for a few years was the only molybdenum producer in the United States. The same mine produced unrecorded amounts in 1903, 1906, 1907, 1914, and 1917. Some of the finest molybdenite specimens to be found in museums all over the country came from this property. One large crystal or cluster of crystals which was recovered weighed 300 pounds. About 22 tons of molybdenite concentrate was produced at the Deer Trail Monitor mine in Stevens County from 1936 to 1939, and in 1941 the Juno-Echo mine in the same county milled 300 or 400 tons of ore, but the molybdenum concentrate produced did not meet purchaser's specifications.

Ore minerals—Molybdenum never occurs free in nature, and its compounds are not numerous. The sulfide, molybdenite, MoS_2, containing 60.0 percent molybdenum, is the only important ore mineral, but minor ore minerals are the lead molybdate, wulfenite, $PbMoO_4$, containing 26.2 percent molybdenum; the oxide, molybdite, $Fe_2O_3 \cdot 3MoO_3 \cdot 8H_2O$, containing about 39 percent molybdenum; and the calcium molybdate, powellite, $Ca(Mo,W)O_4$, containing about 40 percent molybdenum. All these minerals have been found in Washington.

Ore at the Climax mine in Colorado, the largest molybdenum mine in the world, averaged about 0.5 percent MoS_2 in 1947, but a small deposit having molybdenum

as its only recoverable value would have to be several times as rich as this in order to be minable at a profit. Some of the large disseminated copper ore bodies in this country carry about 0.04 percent MoS_2 as a recoverable byproduct.

Geology—Molybdenite almost always is associated with acid igneous rocks. In its economically most important concentrations it occurs as disseminations in replacement deposits. It also occurs in fissure veins, in contact metamorphic deposits, and in pegmatites. Molybdenite is of widespread occurrence in Washington and is found in each of the above types of deposits here, but generally not in sufficient quantity to be profitably recovered. Probably the most common associated mineral is chalcopyrite. Molybdite is an oxidation product of molybdenite, and wulfenite is found in the oxidized parts of some lead veins.

OCCURRENCES

LEWIS COUNTY

57 Eagle Peak
(see under copper)

YAKIMA COUNTY

61 Chinook
(see under copper)

66 Copper Mining Co.
(see under copper)

NICKEL

Properties—Nickel is a lustrous white metal capable of taking a high and lasting polish. It is harder than iron and is tenacious and very malleable and ductile. It is somewhat magnetic and is a fair conductor of heat and electricity, its electrical conductivity being about one-fifth that of copper. Nickel imparts to its alloys toughness and strength as well as desirable anticorrosion and thermal properties. Chemically, it is closely allied with cobalt and iron. Nickel has valences of 2 and 3, but in most of its compounds it is bivalent. The metal is stable in air at ordinary temperatures.

Uses—Although the pure metal is used for electroplating, nickel is chiefly valuable for the alloys it forms with other metals. Over 3,000 alloys of nickel with iron and copper have been developed. Other metals with which it has been alloyed are silver, zinc, tin, beryllium, magnesium, aluminum, and cobalt. The steel and iron industry used about 43 percent of the nickel consumed in the United States in 1950. The leading uses in their order of importance were for nonferrous alloys, stainless steel, electroplating, other steels, high-temperature and electrical-resistance alloys, cast iron, catalysts in hydrogenating organic substances, and ceramics. Minor uses are in coinage, in Edison alkaline storage batteries, and in pharmaceuticals and dyes.

Production—There are few nickel smelters in the world, and most of them do little, if any, custom smelting. Although the United States accounts for more than half of the world nickel consumption, domestic production of the metal amounts to less than 1 percent of that of the world. About 80 to 85 percent of the world production normally comes from Canada. The small domestic output in 1950 was in the form of nickel sulfate and came entirely as a byproduct of copper smelting from five smelters, one of which was the copper smelter of the American Smelting and Refining Company, at Tacoma, Washington.

Although nickel occurrences have been reported in at least 13 counties in Washington, no ore has ever been mined for its nickel content in this state. Some of the lateritic deposits in the Cle Elum River-Blewett area in Kittitas and Chelan Counties are of sufficient size and grade to indicate a potential value as ores of nickel, especially in view of the development of the Riddle, Oregon, deposit (somewhat similar metallurgically), where three electric furnaces in 1954 started production of nickel from local ore.

Ore minerals—Nickel occurs native in meteorites and is combined with sulfur, arsenic, iron, and antimony in many ores. At least 35 nickel minerals are known. The most important nickel ores are nickeliferous pyrrhotite and chalcopyrite, containing up to 6 percent nickel, usually in the form of minute particles of pentlandite, $(Fe,Ni)S$, which contains about 22 percent nickel. Another nickel sulfide is millerite, NiS, containing 64.7 percent nickel. Garnierite, another important ore mineral, is a hydrated silicate of magnesium and nickel having an extremely variable composition. All these above-named minerals occur in Washington in addition to the secondary hydrous nickel sulfate, morenosite, $NiSO_4 \cdot 7H_2O$.

The important ores of Sudbury, Canada, average about 1½ percent nickel and 2 percent copper. The New Caledonian silicate ores run from 2 to 6 percent, and 1940 production averaged 3.8 percent nickel. Cuban laterites, similar to the Cle Elum River-Blewett ores, comprise large ore bodies averaging 0.8 to 1.5 percent nickel and 1 to 2 percent chromium.

Geology—There are relatively few workable deposits of nickel in the world, because, although nickel is more abundant in the earth's crust than copper, zinc, or lead, it generally is not concentrated but is widely and diffusely distributed, especially in magnesium-rich rocks. There are only two important types of nickel deposits—residual nickel silicate concentrations from the weathering of nickel-bearing ultrabasic rocks, and sulfide deposits of nickel and copper formed either by replacement or magnetic injection. The Sudbury deposit is of the latter type. It contains pentlandite closely associated with pyrrhotite and chalcopyrite in the outer, basic, edge of a large spoon-shaped intrusive body of norite-micropegmatite 36 miles long and 20 miles wide. Of much less importance as a source of nickel are the silver-cobalt-nickel vein deposits such as those at Cobalt, Ontario.

OCCURRENCE

LEWIS COUNTY

71 Summit Creek

Loc: Near head of Summit Cr. where Summit Cr. trail forks, one branch leading to Carlton Pass, the other to Cowlitz Pass. Probably in N½ sec. 14, (14-10E). **Ore:** Nickel. **Ore min:** Nickel sulfide. **Deposit:** Said to be a 2-in. vein of nickel sulfide exposed in the trail.

PLATINUM

Properties—Platinum is a silver-gray lustrous metal which is tenacious, malleable, and ductile. It is very heavy and moderately hard. The metal takes a very high and permanent polish. It has a high melting point and low vapor pressure, is a poor conductor of heat and electricity, and has a low coefficient of linear expansion, approximately equal to that of glass. The metal has a high-temperature coefficient of electrical resistivity and has high resistance to spark erosion. It is relatively inert chemically, being highly resistant to corrosion and oxidation; it does not tarnish on exposure to air and is not affected by single mineral acids.

Uses—For many years about half the platinum used in this country has gone into jewelry. Lesser amounts are used in about equal parts in dentistry, electrical apparatus, and chemical industries. The metal and its alloys are used in thermocouples, resistance thermometers, electrodes, electrical contacts, acidproof containers, and laboratory apparatus. It is used as a catalyst in manufacturing high octane gasoline, some acids, and other important chemicals. Minor uses are for pen nibs and for spinnerets for glass fiber and rayon spinning. Platinum compounds have limited uses for platinum electroplating, photographic paper, platinum mirrors, fluorescent screens for X-ray work, etching zinc, and in ceramics.

Production—The United States yearly production of platinum has always been less than one-tenth of the world production and is only a small part of domestic consumption. Alaska has a considerable output of crude platinum, and a small amount is produced as a byproduct of placer-gold operations in California, but much of the domestic production is a byproduct of copper and gold smelting and refining. A very small production of platinum was reported in Washington in 1904, and intermittent small production up to 1934 totaled probably no more than 25 ounces, all as a byproduct of placer-gold mining.

Ore minerals—The principal source of platinum is natural alloys with one or more of the other members of the platinum group—iridium, osmium, palladium, rhodium, and ruthenium—and with copper and iron. Other than the native alloys, only three platinum minerals are known—the arsenides, sperrylite, $PtAs_2$, and cooperite, $Pt(As,S)_2$, and the sulfide, braggite, (Pt,Pd,Ni)S.

Geology—Platinum is widely distributed over the world, but in only a few places is it sufficiently concentrated to be recovered commercially. Most primary platinum is intimately associated either with nickel or chromite in deposits formed by magnetic processes in ultrabasic rocks such as peridotite, pyroxenite, and their metamorphosed equivalent, serpentine. The platinum in placer deposits was derived from rocks of this type.

Occurrence

SKAMANIA COUNTY

3 Primary Gold
(see under gold)

SILVER

Properties—Silver is a pure-white metal having a brilliant, perfect metallic luster. It is a little harder than gold, and is exceeded only by gold in ductility and malleability. Polished silver reflects visible light as well as, or better than, other metals, is a good reflector of infrared radiation, but is inferior to aluminum and many other metals as a reflector of ultraviolet light. Silver is the best of the metals as a conductor of heat and electricity. The molten metal in air dissolves 22 times its own volume of oxygen, which, when the melt cools, escapes with a sputtering sound and a flash of light. Silver is not ordinarily oxidized by air, and resists attack by many chemicals, but it tarnishes readily when contacted by sulfur compounds. The element is univalent.

Uses—Silver has been used since earliest times for coins and ornamental articles, and the largest use is still for monetary purposes. Much of it is simply hoarded, both by individuals and by governments. In the arts and industries the largest use is for sterling and plated tableware. Photography is using increasing quantities, mostly in the form of silver nitrate. Solid silver and alloys and silver plating are used in jewelry, trophies, and as lining in laboratory equipment and in brewing and food-processing machinery. It is used in electrical equipment (especially for its anti-arcing properties at contact points), for dental and surgical instruments, dental amalgams, medicines, and for coating mirrors. Alloyed with lead, zinc, and tin, it is used as bearing metal, and in other alloys as solder and brazing rods. A lead-silver alloy is used as anodes for production of electrolytic zinc. Some silver compounds are used as catalysts in certain chemical industries, and other silver chemicals are used to convert sea water to drinking water. During wartime shortages of copper and aluminum, large quantities of silver were used temporarily for electrical conductors.

Production—In Washington, silver production in most years is outranked by that of gold, copper, lead, and zinc. Maximum annual production was 721,450 ounces, valued at $328,070, in 1902. Production in 1950 was 363,656 ounces, valued at $329,127, and total production through 1952 has been 14,871,542 ounces, valued at $10,957,311. In total silver production through 1952, Washington ranks tenth among the states. In 1950 no Washington mine was among the 25 largest producers of silver in the country. It has been many years since any large mine in this state has produced silver as its principal value, although at one time several mines in the Nighthawk, Nespelem, and Ruby-Conconully districts of Okanogan County and in the Chewelah and Colville districts of Stevens County were notable silver producers. Silver is a byproduct of nearly all gold mines and most copper, lead, and zinc mines. The Knob Hill mine (gold ore) was the leading silver producer in 1950, followed by the Holden mine (copper-gold-zinc ore), Bonanza mine (lead ore), Gold King mine (gold ore), and Grandview mine (zinc-lead ore). These 5 mines produced 94 percent of the state total of silver in 1950.

Ore minerals—Silver occurs native and alloyed with gold, copper, and mercury, and also in at least 55 well-known silver minerals as a sulfide, arsenide, antimonide,

telluride, chloride, bromide, and iodide, and as numerous sulfosalts. The commonest ore is silver-bearing galena, and fairly common are silver-bearing pyrite, sphalerite, and minerals of copper and cobalt. Of the copper minerals which carry silver, perhaps the commonest is the silver-rich variety of tetrahedrite known as freibergite. Some of the chief silver minerals are cerargyrite (horn silver), AgCl, containing 75.3 percent silver; argentite, Ag_2S, containing 87.1 percent silver; stephanite, Ag_5SbS_4, containing 68.5 percent silver; pyrargyrite (ruby silver) Ag_3SbS_3, containing 59.9 percent silver; and proustite, Ag_3AsS_3, containing 65.5 percent silver.

Geology—Although silver occurs in some deposits as the principal value, more commonly it accompanies gold, lead, zinc, and copper, and so its origin and type of deposit may be extremely varied. Most of the silver of the world comes from the North American Cordillera, where it is commonly associated with Tertiary intrusive and volcanic rocks such as diorite, monzonite, granodiorite, rhyolite and andesite. Most of the silver is in fissure veins or related deposits of irregular shape, in which the ores have been deposited from solution in open spaces or by replacement. The lodes may be in almost any kind of rock, and the common gangue is quartz, calcite, dolomite, or rhodochrosite.

Occurrences

LEWIS COUNTY

51 **Waterfall**
(see under gold)

54 **Mineral Creek**
(see under zinc)

57 **Eagle Peak**
(see under copper)

SKAMANIA COUNTY

3 **Primary Gold**
(see under gold)

7 **Brown and Livingston**
(see under gold)

8 **Plamondon**
(see under gold)

9 **Young America**
(see under copper)

10 **Sweden**
(see under copper)

11 **Bronze Monarch**
(see under copper)

12 **Norway**
(see under copper)

13 **Yellow Metals**
(see under copper)

14 **Chicago**
(see under copper)

15 **Mount Fairy**
(see under gold)

17 **Grizzly Creek**
(see under gold)

20 **Samson**
(see under copper)

22 **Polar Star**
(see under copper)

23 **Index**
(see under copper)

29 **Independence**
(see under copper)

30 **Minnie Lee**
(see under copper)

31 **Minnie Alice**
(see under copper)

YAKIMA COUNTY

61 **Chinook**
(see under copper)

63 **Highland**
(see under gold)

64 **Elizabeth Gold Hill**
(see under gold)

66 **Copper Mining Co.**
(see under copper)

TUNGSTEN

Properties—Tungsten is a light-gray to brownish-black metal in its powdered form but is brilliant white when fused. No other element is known to have a lower vapor pressure or higher tensile strength, and only carbon has a higher melting point. Tungsten is one of the heaviest of metals, its density being almost twice that of lead. It is very hard, ductile, strong, and elastic. It conducts heat fairly well, is very stable in acids, and is resistant to chemical action. In artificial compounds it shows valences of 2, 3, 4, 5, and 6, but in its only important natural minerals it has a valence of 6.

Uses—About 90 percent of the tungsten consumption is in ferroalloys, mostly high-speed tool steel; 5 percent goes into tungsten carbide; and the remainder, into nonferrous alloys, unalloyed tungsten metal, and chemicals. The pure metal is used in electric lamp filaments, for which use no satisfactory substitute is known. It is also used for plating special laboratory equipment, for contact points in electrical apparatus, and as a catalyst in certain industrial chemical reactions. The metal's greatest value lies in its property of imparting increased hardness, toughness, elasticity, and tensile strength to steel, but perhaps its most remarkable property is that of making steel retain its hardness when hot, even at red heat. Of the many nonferrous tungsten alloys the most important is stellite, a cobalt-chromium-tungsten alloy that is used to face cutting tools. Tungsten carbide also is used to face cutting tools, it being the hardest artificial material in common use, having a hardness of 9.8 (Moh's scale) as compared with 10 for diamond. Small amounts of tungsten are used in chemicals to flameproof and waterproof fabrics, in dyes, and in other applications.

Production—In most years, imports of tungsten ore into the United States are greater than domestic production, and imports generally have exceeded production in a ratio of about two to one. The first tungsten mined in

Washington was from the Germania mine in southern Stevens County in 1904, and some ore was produced in the state each year thereafter through 1918. After a period of inactivity, production began again in 1930 and has been almost continuous through 1955. Production in this state has never been large, and the maximum was 303 short tons of 60-percent WO_3 concentrate in 1938. Total production from 1900 through 1950 has been 1,326 short tons of 60 percent WO_3 concentrate, which is 1.01 percent of the United States total and causes Washington to rank seventh in output among the states. Many occurrences of tungsten minerals are known in 14 of the 39 counties in Washington, but most of the occurrences are in 3 northeastern counties, Okanogan, Ferry, and Stevens. A few properties have recorded production, but the most constant and largest output has been from the Germania mine and adjacent properties.

Ore minerals—Tungsten does not occur uncombined in nature, and is found in relatively few minerals. Of the sixteen or so known tungsten-bearing minerals only four are of commercial importance, and three of these are members of a single isomorphous series. This series consists of the tungstates of iron and manganese, in which the manganese tungstate, huebnerite, $MnWO_4$, containing 76.6 percent WO_3, is one end member and the iron tungstate, ferberite, $FeWO_4$, containing 76.3 percent WO_3, is the other. Intermediate members are known as wolframite, $(Mn,Fe)WO_4$, and contain from 76.3 to 76.6 percent WO_3. The other tungsten ore mineral is the calcium tungstate, scheelite, $CaWO_4$, containing 80.6 percent WO_3. The brilliant blue-white fluorescence of scheelite under untraviolet light is an aid in prospecting for this otherwise rather inconspicuous mineral. Buyers' tolerances of impurities in tungsten ores are variable, but penalties are generally charged for more than 1.6 percent tin, 0.2 percent arsenic, 0.1 percent copper, 0.05 percent phosphorus, 0.05 percent antimony, 0.4 percent bismuth, or 1.0 percent sulfur. Most ore mined in the United States contains 0.4 to 2.5 percent WO_3.

Geology—Tungsten occurs in veins, replacements, segregations, and contact-metamorphic deposits within or near the margins of siliceous igneous rocks such as granites and pegmatites. It is commonly associated with tin or molybdenum, with pyrite and chalcopyrite, and less frequently with sphalerite and galena. Common associates in contact-metamorphic deposits are copper minerals, molybdenite, magnetite, garnet, epidote, and diopside. The tungsten minerals, because of their high specific gravity, tend to concentrate readily in placer deposits, generally close to their primary source.

Occurrences

LEWIS COUNTY

57 Eagle Peak
(see under copper)

YAKIMA COUNTY

66 Copper Mining Co.
(see under copper)

67 Garibaldi
(see also Copper Mining Co. under copper)

Loc: NE¼ sec. 13, (15-11E), Bumping Lk. dist. **Elev:** 5,700 ft. **Access:** 1,000 ft. N. of the end of the bulldozer road from Copper City. **Owner:** Copper Mining Co., Yakima, Wash. (1906——). **Ore:** Tungsten. **Ore min:** Scheelite (large crystals), arsenopyrite. **Deposit:** Quartz vein less than 6 in. wide in granitic rock. **Dev:** Open cut.

URANIUM

Properties—Uranium is a metal that is hard but ductile and malleable. It is very heavy (2½ times as heavy as steel) and is capable of taking a high polish. The polished metal, however, rather quickly oxidizes to a black surface. In powder form uranium is black and pyrophoric, catching on fire spontaneously upon exposure to air. In its chemical behavior it is most closely related to chromium. Uranium is radioactive, and the isotope U_{235} (present in natural uranium to the extent of about 0.7 percent), is fissionable—properties of utmost importance. Uranium radiates alpha rays, and in its atomic disintegration produces a series of elements including helium, radium, actinium, and lead, which emit alpha, beta, and gamma rays. Pound for pound, fissionable uranium has more than two and a half million times the heat-producing energy of coal.

Uses—By far the most important use of uranium is as a source of nuclear energy, which is utilized in the atomic bombs, and which is being developed for use in power plants for various military and industrial applications. Nonenergy uses of uranium in recent years have been largely in the chemical industries, including use as catalysts and in analytical reagents. Next in importance has been its use in ceramics—in glass for a coloring agent and to regulate the coefficient of thermal expansion of the glass. It has been used in motion picture film manufacture, in electrical equipment, and luminous paint, and it has been alloyed with steel for special uses.

Production—During the years 1945 through 1950 the United States consumption of uranium for nonenergy purposes varied between 1½ and 2½ tons per year. The amount used in the atomic energy program has not been announced. Prior to World War II most of our uranium was imported, but domestic sources now produce large quantities. Data on production and imports and exports are not disclosed. Every producer of uranium ore must be licensed by the U. S. Atomic Energy Commission, and the ore must be sold either directly to the Commission or to a buyer licensed by it.

Ore minerals—More than 100 uranium-bearing minerals are known. In some of these uranium is the principal constituent, but in others it is only a minor part of the mineral. The more important primary minerals are the oxides, pitchblende (50 to 80 percent U_3O_8) and uraninite (65 to 90 percent U_3O_8). Some of the more common secondary uranium minerals are the potassium uranium vanadate, carnotite (50 to 55 percent U_3O_8); the calcium uranium phosphate, autunite (60 percent U_3O_8); the copper uranium phosphate, torbernite (60 percent U_3O_8); the calcium uranium vanadate, tyuyamunite, (48 to 55 percent U_3O_8); and the calcium uranium silicate, uranophane (65 percent U_3O_8). In general, uranium occurs combined as oxides, phosphates, sulfates, arsenates, carbonates, vanadates, silicates, and hydrocarbons. Uranium minerals that have been found in Washington include uraninite, pitchblende, brannerite, autunite, torbernite, uranophane, monazite, and allanite. The latter two minerals are primarily thorium bearing but sometimes contain uranium. Other uranium minerals reported in Washington are

zeunerite, fergusonite, samarskite, euxenite, and cyrtolite.

Geology—Uranium ore deposits occur in a great variety of rocks of igneous, metamorphic, and sedimentary origin. Primary deposits in hydrothermal veins appear to favor felsic intrusive rocks and arenaceous metasediments as host rocks. Within the veins, associated minerals contain, in decreasing order of abundance, iron, copper, cobalt, lead, silver, nickel, and bismuth. Of these, perhaps cobalt, nickel, and bismuth are most indicative. Pegmatites commonly contain uranium minerals but almost never in commercial quantities. The potassium-rich pegmatites, or zones in them, have been indicated as most favorable for the occurrence of uranium minerals. The secondary uranium-mineral occurrences, as low-grade disseminations in the sedimentary rocks—sandstone, shale, and limestone, are currently producing large tonnages of ore in the United States. A very large part of the domestic production comes from sedimentary-type deposits of this kind, largely from the Colorado Plateau in the "four corners" region of Colorado, Utah, Arizona, and New Mexico.

Although fairly large areas in Washington are underlain by Mesozoic and Tertiary continental sedimentary rocks, and some of these areas are being prospected, no sedimentary-type deposits in which carnotite commonly occurs have yet been found here. All the verified occurrences of uranium in Washington are either in granitic rock or in metamorphic rocks intruded by granite. Uraninite and secondary uranium minerals have been found in pegmatite dikes in this state but not in commercial quantities. The more promising uranium deposits in Washington have been found (1) in and near the contact of granite and rock the granite intrudes, (2) in shear zones cutting these rock types, and (3) as secondary minerals impregnating the fractured, decomposed, and disintegrated granitic and metamorphic rocks adjacent to contacts and shear zones. In other words, primary uranium mineralization may be expected to occur under much the same conditions as does copper, gold, silver, lead, zinc, molybdenum, and other ore mineralization.

Recent developments—Uranium prospecting and exploration in Washington expanded very rapidly during the first few months of 1955, especially in Stevens and Spokane Counties. This activity was the direct result of the discovery of substantial quantities of uranium ore at the Midnite Mines property on the Spokane Indian Reservation in southern Stevens County. Many large and small mining companies and thousands of individuals staked claims on open Federal land or obtained mineral leases on State and private lands north of the Reservation throughout Stevens County. Similar exploration activity in the vicinity of Mount Spokane was triggered by the announcement of the discovery of good-grade autunite mineralization on the Dahl farm near Elk in northern Spokane County. Exploration has been active in the whole northern row of counties westward from the Idaho boundary to the western flanks of the Cascade Mountains and in the Cascades about as far south as Mount Rainier. Locations showing radioactivity are known or have been reported in at least 10 counties in this general region, and this area includes all the authenticated uranium occurrences in Washington; however, because of the tremendous interest in uranium prospecting, there probably is no county in the state in which some prospecting has not been done. To date (April 1956) only two uranium properties in Washington have shipped ore—the mine originally operated by Midnite Mines, Inc., and the Daybreak Uranium, Inc. mine on the Dahl farm.

Occurrences

LEWIS COUNTY

57 Eagle Peak
(see under copper)

PIERCE COUNTY

56 Rushing River
Loc: On Rushing R. (or Rushingwater Cr. ?) on W. flank of Mt. Rainier. **Prop:** 38 unpatented claims. **Owner:** Al Nigro, Frank Stankevich, and J. L. Pennington, Tacoma, Wash. (1955). **Ore:** Uranium. **Ore min:** Pitchblende. **Assays:** Samples reported to run as high as 19.8% U_3O_8.

ZINC

Properties—Zinc is a bluish-white lustrous metal that is easily fusible and fairly hard. It is brittle at ordinary temperatures, but when annealed it becomes ductile and malleable and does not become brittle upon cooling, but when reheated to 200° it is again brittle. It is a fair conductor of heat and electricity. Zinc is only moderately resistant to corrosion, but it is better than iron in this respect, and because of this and the very great affinity that zinc and iron have for each other, it is used to coat and protect iron from atmospheric corrosion. The electrochemical properties of zinc account for its use in batteries, and its chemical properties for its use in photoengraver's sheets. Zinc is bivalent in all its compounds.

Uses—The galvanizing industry has long been the largest consumer of zinc, accounting for more than 45 percent of the 1950 consumption. Galvanizing is the placing of a thin coating of zinc, usually on iron or steel sheet, wire, tubes, pipe, fittings, and other shapes. Zinc-base alloys for die castings used nearly 30 percent of the available zinc in 1950, followed by brass (14 percent) for sheet, strip, plate, rod, wire, tubes, castings, and other copper-base products. Rolled zinc accounted for about 7 percent of the consumption; zinc oxide, 2 percent; and 1 percent, for other uses such as wet batteries, desilvering of lead, in light-metal alloys, and chemicals. Zinc oxide and other chemicals are used as pigments, as a filler in rubber, in glass manufacture, in medicines, and in many other minor uses.

Production—Zinc is mined in ten western states, seven central states, and four eastern states, but is smelted or refined in only four states. In the west there are custom zinc smelters in Idaho at Kellogg, in Montana at Anaconda and Butte, and in British Columbia at Trail. Zinc output in the Tri-State district has dropped from 55 percent of the total United States production in 1926 to only 13 percent in 1950, and western production has had a corresponding increase to 59 percent in 1950.

Zinc occurrences have been reported in 18 of Washington's 39 counties, but production has been mainly from Okanogan, Ferry, Stevens, Pend Oreille, and Chelan Counties, the last 3 counties having accounted for almost all the Washington production in recent years. Among the

zinc mines in the United States, the Pend Oreille mine in Pend Oreille County ranked 35th in production in 1949, the Holden mine in Chelan County was 50th, and the Grandview mine in Pend Oreille County was 58th. The following year the Grandview was the leading producer in Washington and ranked 25th nationally. In 1952 the state's leading zinc producers in order of output were the Pend Oreille, Grandview, Deep Creek, and Holden mines. The Van Stone mine in Stevens County began production late that year and was one of the leading producers in 1953. Among the zinc districts in the United States in 1950, the Metaline district ranked 14th in output; the Lake Chelan district, 28th; and the Northport, 33rd.

The first recorded production of zinc in Washington was from the Oriole mine in the Metaline district in 1911. There appears to have been no further production until 1915, but since that time output has been continuous (except for 1919) to the present. Total production in the state through 1952 has been 228,091 short tons of metal, valued at $49,243,324, which is 22.7 percent of the total value of all metals produced in the state during the same period. The record annual output was in 1953, when 32,890 short tons, valued at $7,170,020, was produced. This was more than triple the zinc output in the state 4 years earlier.

Ore minerals—There are no authenticated occurrences of native zinc, but the element has been reported in almost 150 minerals in the Franklin Furnace district of New Jersey, alone. However, only 6 minerals are common sources of the metal, and by far the most important of these is the sulfide, sphalerite, ZnS, containing 67.0 percent zinc. The others are the carbonate, smithsonite, $ZnCO_3$, containing 52.0 percent zinc; the hydrous silicate, hemimorphite (calamine), $(ZnOH)_2SiO_3$, containing 54.2 percent zinc; the oxide, zincite, ZnO, containing 80.3 percent zinc; the silicate, willemite, Zn_2SiO_4, containing 58.5 percent zinc; and the ferrite, franklinite, $(Fe,Zn,Mn)O \cdot (Fe,Mn)_2O_3$, containing from 15 to 20 percent zinc. Of these minerals, the last three are important ore minerals in few, if any deposits other than those in the unique Franklin Furnace district. Of the ore minerals, only sphalerite and smithsonite have been reported in Washington, but the comparatively rare zinc basic carbonate, hydrozincite, $2ZnCO_3 \cdot 3Zn(OH)_2$, occurs in the Covada district and in a few other places in the state.

Geology—Most ores of zinc are ores of lead also, although there are a few straight zinc ores and a few large copper-zinc deposits. In Washington most of the zinc comes from zinc-lead deposits, but the Holden mine produces copper-zinc ore with appreciable values in gold and very low values in silver, and in many smaller deposits zinc is associated with a variety of other minerals in complex ores. Zinc may occur as open-space fillings or replacements in veins, and as residual deposits of oxidized zinc minerals. It may also occur as massive replacement deposits of irregular shape, in which the ore minerals are disseminated in limestone or dolomite and are sometimes accompanied by pyrite and frequently by chert or other forms of low-temperature silica minerals. The disseminated replacements in some districts are near the contact of carbonate rocks with granitic rocks, but in other important zinc districts the igneous sources of the hydrothermal solutions presumably responsible for the metalization are far removed or not exposed at all.

The grade of ore mined varies from a low of about 2 percent combined lead and zinc to a high of 8 percent or more. In 1949 the recovery from western states ore averaged 4.86 percent zinc and 3.20 percent lead, whereas the recovery from the generally larger and less complex ore deposits in the Tri-State district averaged only 1.66 percent zinc and 0.69 percent lead. The 1952 production from one large mine in the Metaline district in Washington averaged 2.29 percent zinc and 1.39 percent lead.

Occurrences

LEWIS COUNTY

54 Mineral Creek

Loc: Lease lots 2 and 4, SW¼ sec. 30, (14-6E), on Mineral Cr. **Access:** 5 mi. SE. of Mineral by logging railroad. **Owner:** State land leased by John M. Allen, Tacoma, Wash. (1949). **Ore:** Zinc, lead, silver, arsenic. **Ore min:** Sphalerite, galena, realgar. **Assays:** Sample said to have been taken across a 300-ft. face assayed 3.80% Zn, 3.60% Pb, 2.56 oz. Ag. **Prod:** Reportedly 1,000 tons of arsenic ore in 1903, some production in 1904 and 1905.

57 Eagle Peak
(see under copper)

SKAMANIA COUNTY

10 Sweden
(see under copper)

14 Chicago
(see under copper)

16 Commonwealth
(see under copper)

19 Golconda
(see under gold)

26 Snowflake
(see under lead)

YAKIMA COUNTY

61 Chinook
(see under copper)

69 Black Jack (Green, Deep Creek)

Loc: Sec. 36, (15-11E), on NW. side of Deep Cr. trail about 100 yd. N. of Little Twin Sisters Lk. **Access:** Trail. **Prop:** 17 claims. **Ore:** Zinc, copper. **Ore min:** Sphalerite, chalcopyrite, pyrite, bornite, chalcocite, galena. **Gangue:** Quartz, calcite. **Deposit:** 3 parallel mineralized stringers from 1 to 3 in. wide separated from one another by 12 in. of country rock. Country rock consists of thin-bedded sandstone, conglomerate, and mudstone. **Dev:** Inclined shaft at least 50 ft. deep, open cuts. **Assays:** Said to assay 20% to 30% Zn where exposed in Deep Cr. Extensions are of much lower grade but said to be of mining grade.

APPENDIX B

Occurrences of Nonmetallic Minerals

in the Area Around Cispus Environmental Center

Lewis County, Washington

Extracted from:

Washington Division of Mines and Geology

Bulletin 37, Inventory of Washington Minerals, Part 1— Nonmetallic minerals, by Grant M. Valentine, revised by Marshall T. Huntting, 1960, 175 p.

KEY TO NONMETALLIC PROPERTIES

MAP NO.	NAME	SEE UNDER	PAGE
1	Gillott	Perlite	49
2	Badger Mountain	Mineral Pigments	48
3	East St. Helens	Pumice	51
4	Swift Creek (C)	Pumice	51
5	Swift Creek (D)	Pumice	51
6	Swift Creek (B)	Pumice	51
7	Swift Creek (A)	Pumice	51
8	Draughon	Pumice	51
9	Ranger Station	Pumice	51
10	S. Spirit Lake	Pumice	51
11	Cedarbrook	Pumice	51
12	St. Charles Lake	Pumice	51
13	St. Helens Lake	Pumice	51
14	Clearwater Creek	Pumice	51
15	Lookout Trail (B)	Pumice	51
16	Green River (C)	Pumice	51
17	Lookout Trail (A)	Pumice	51
18	Strawberry Lookout	Pumice	51
19	Ryan Lake	Pumice	51
20	Golconda	Pumice	51
21	Goat Mountain	Pumice	51
22	Polar Star	Pumice	51
23	Green River (B)	Pumice	51
24	Green River (A)	Pumice	51
25	Deadman Lake	Pumice	51
26	Soda Springs	Mineral Waters	48
27	Dean	Basalt	45
28	Cispus River (H)	Pumice	49
29	Cispus River (G)	Pumice	49
30	Cispus River (F)	Pumice	50
31	Cispus River (A)	Pumice	50
32	Cispus River (B)	Pumice	50

MAP NO.	NAME	SEE UNDER	PAGE
33	Cispus River (C)	Pumice	50
34	"Popcorn"	Pumice	50
35	Cispus River (D)	Pumice	50
36	Cispus River (E)	Pumice	50
37	Cowlitz River	Pumice	50
38	Cowlitz Valley (B)	Pumice	50
39	Cowlitz Valley (A)	Pumice	50
40	Cowlitz Valley (E)	Pumice	50
41	Rainy Valley	Pumice	50
42	Cispus (A)	Pumice	50
43	Cispus (B)	Pumice	50
44	Hunt & Gaines	Pumice	50
45	Cowlitz Valley (C)	Pumice	50
46	Kiona Valley	Pumice	50
47	Cowlitz Valley (D)	Pumice	50
48	Sec. 15 (12-7E)	Sand and Gravel	51
49	Randle	Sand and Gravel	52
50	Kiona Creek (D)	Pumice	50
51	Sec. 12 (12-6E)	Basalt	45
52	Kiona Creek (C)	Pumice	50
53	Smathers	Sand and Gravel	52
54	Kiona Creek (B)	Pumice	50
55	Kiona Creek (A)	Pumice	50
56	Kiona	Sand and Gravel	52
57	Tom Dalton (A)	Pumice	50
58	Rainy Creek (B)	Pumice	50
59	Rainy Creek (C)	Pumice	50
60	Tom Dalton (B)	Pumice	50
61	Fairhurst	Sand and Gravel	52
62	Rainy Creek (A)	Pumice	50
63	Glenoma	Pumice	50
64	Sec. 22 (12-5E)	Sand and Gravel	52
65	Morton (B)	Sandstone	52
66	Morton (A)	Sandstone	52
67	Davis Lake	Peat	49

MAP NO.	NAME	SEE UNDER	PAGE
68	Morton	Coal and Coke	46
69	Sliwa	Basalt	45
70	Morton	Diatomite	46
71	Morton	Sandstone	52
72	Sec. 3 (12-4E)	Sand and Gravel	52
73	Chesser	Sand and Gravel	52
74	Sec. 35 (13-4E)	Sand and Gravel	52
75	Coal Canyon	Coal and Coke	46
76	Lindberg	Sand and Gravel	52
77	Olympia Graphite Mining & Milling Co.	Graphite	47
78	Majestic	Coal and Coke	46
79	Watkins	Coal and Coke	46
80	Pennsylvania	Coal and Coke	46
81	Crystal No. 1	Coal and Coke	46
82	Mineral Creek	Limestone	48
83	Mineral	Peat	49
84	Mineral	Coal and Coke	46
85	Sunburst	Coal and Coke	46
86	East Creek	Coal and Coke	46
87	Ladd	Refr. Clays, Coal and Coke	45, 46
88	Sec. 28 (15-5E)	Sand and Gravel	52
89	Sec. 28 (15-5E)	Sand and Gravel	52
90	Sec. 29 (15-5E)	Sand and Gravel	52
91	Sec. 29 (15-5E)	Basalt..., Sand and Gravel	45, 52
92	La Grande	Refr. Clays	45
93	Pack Forest	Sand and Gravel	52
94	Peterson	Sand and Gravel	52
95	Sec. 17 (16-4E)	Sand and Gravel	52
96	Sec. 20 (16-4E)	Sand and Gravel	52
97	Mashel River	Mineral Pigments	48
98	Wheeler & Reese	Sand and Gravel	52
99	Eatonville	Sand and Gravel	52
100	Mashel River	Basalt...	45

MAP NO.	NAME	SEE UNDER	PAGE
101	Mashel River	Perlite	49
102	Mashel	Coal and Coke	46
103	Ashford	Granite	47
104	Messler	Sand and Gravel	52
105	Shafer Bros.	Sand and Gravel	52
106	Hall	Sand and Gravel	52
107	Longmire Springs	Mineral Springs	48
108	Sec. 12 (16-10E)	Basalt...	45
109	Bumping River	Coal and Coke	46
110	Ohanapecosh Hot Springs	Mineral Waters	48
111	Summit Creek	Coal and Coke	46
112	Summit Creek Soda Spring	Mineral Waters	48
113	Sec. 17 (14-10E)	Sand and Gravel	52
114	Dog Lake	Basalt...	45
115	Dog Lake	Slate...	52
116	White Pass	Basalt...	45
117	Matchett and Pancho	Sand and Gravel	52
118	Warnke	Sand and Gravel	52
119	Packwood	Sand and Gravel	52
120	Sec. 32 (13-9E)	Sand and Gravel	52
121	Packwood Spring	Mineral Waters	48
122	Sec. 15 (12-8E)	Sand and Gravel	52
123	Mount Adams	Perlite	49
124	Mount Adams	Alum, Gypsum, and Sulfur	45, 47, 53
125	Mount Adams	Slate...	52

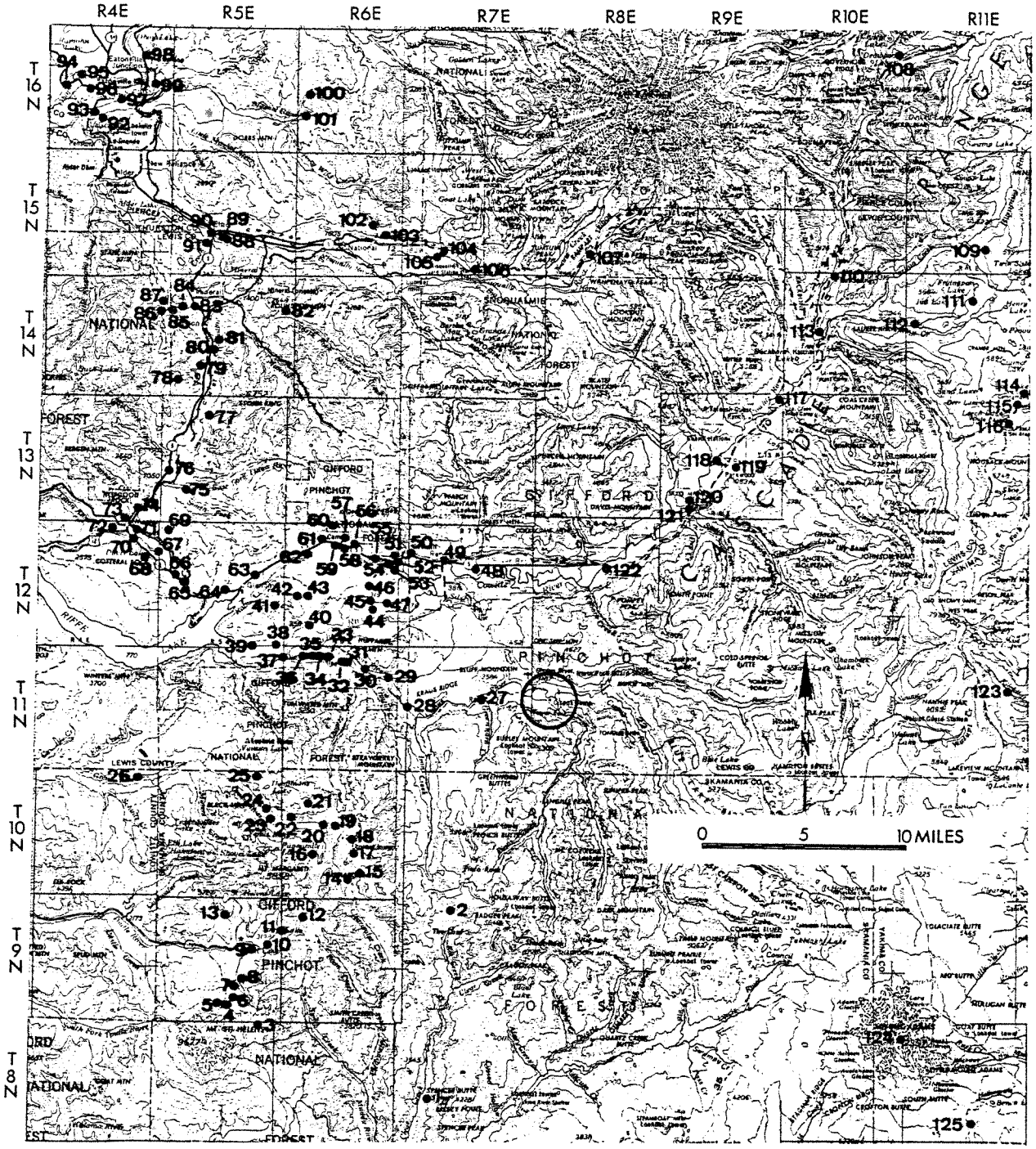


FIGURE 7.— Nonmetallic occurrences in the Cispus Environmental Center area, Lewis County, Washington.

ALUM

Alum is a group name applied to hydrous sulfates of aluminum combined with an alkali metal and 12 molecules of water. Alum minerals identified so far in Washington are not true alums but belong to an allied group. Among them are alumian, $Al_2O_3 \cdot 2SO_3$; alunogen, $Al_2(SO_4)_3 \cdot 16H_2O$; aluminite, $Al_2O_3 \cdot SO_3 \cdot 9H_2O$; and smaller amounts of mendozite, melanterite, copiapite, and blödite.

OCCURRENCE

YAKIMA COUNTY

124 **Name:** Mount Adams. **Loc:** In crater of Mount Adams and approximately 100 feet below top of west crater rim. **Descr:** Various alum minerals, and sulfur, constitute the cementing material in volcanic breccia. **Value:** Commercial separation probably not feasible.

BASALT AND ALLIED VOLCANIC ROCKS

With few exceptions the rocks included under this heading are fine-grained extrusive igneous rocks, principally basalt but also less basic types such as andesite and the acid type, rhyolite. One or two occurrences are of volcanic tuff. As the exact rock name is unimportant to many operators from whom locations are obtained, it may be found that some listed occurrences include intrusive (abyssal and hypabyssal) or even sedimentary rocks.

Basalt and, to a lesser extent, its acidic equivalents are used primarily for road building (for surfacing, in macadam, as ballast, and as asphalt aggregate). They are also used for riprap and breakwaters and have been used in the construction of buildings.

OCCURRENCES

Map no.	Operator or owner	Quarry name	Property location
		LEWIS COUNTY	
27	James P. Dean	Dean	Sec. 15, (11-7E)
51			S½SW¼ sec. 12, (12-6E)
69	Dept. of Highways	Sliwa	Lot 10, sec. 6, (12-5W)
91			SE¼NE¼ sec. 29, (15-5E)
		PIERCE COUNTY	
100	Strong & McDonald	Mashel River	Mashel River area, T. 16 N., R. 6 E.
		YAKIMA COUNTY	
108	Dept. of Highways		Sec. 12, (16-10E)
114	Dept. of Highways	Dog Lake	SE¼ sec. 36, (14-11E)
116	White Pass Mine	White Pass	At Dog Lake

REFRACTORY CLAYS AND SHALES

Refractory clays and shales are those which fuse above pyrometric cone 12. For low-heat duty, the softening point of a clay must be between cones 12 and 19 (about 1335° to 1520° C.); for intermediate-heat duty, between cones 19 and 26 (1520° to 1595° C.); for high-heat duty, between cones 26 and 31 (1595° to 1680° C.); and for superduty, above cone 33 (1745° C.). Factors other than fusion temperature which determine the adaptability of clay to refractory use are resistance to load, abrasion, slagging action, chemical attack, and thermal shock, all under conditions of high temperature.

Refractory clays and shales contain as much as 39 percent alumina, hence constitute potential sources of aluminum. Aluminum has been extracted from clay but not yet at a cost low enough to constitute strong competition with bauxite.

Deposits of refractory clays and shales occur near centers of industry in both eastern and western Washington. Several are being worked, and others will be as the demand increases.

OCCURRENCES

LEWIS COUNTY

87 **Name:** Ladd mine. **Loc:** At Ladd mine in sec. 12, (14-4E). **Descr:** Refractory shale reportedly underlies coal seam. **Value:** Unknown.

PIERCE COUNTY

92 **Name:** La Grande. **Loc:** In cuts and pits along C. M. St. P. & P. R.R., ½ mi. N. of La Grande in sec. 28, (16-4E). **Descr:** Refractory clay exposed to depth of 12 ft. over an area 150 by 100 ft. **Value:** Mined years ago by Denny-Renton Clay & Coal Co.

COAL AND COKE

Coal is carbonaceous sedimentary rock formed from the remains of vegetal matter by partial decomposition. The American Society for Testing Materials groups coal in four major classes. From highest to lowest they are: anthracitic, bituminous, subbituminous, and lignitic. Each class is subdivided into ranks—anthracitic into three, bituminous into five, subbituminous into three, and lignitic into two. Coals of higher rank than high-volatile bituminous are classified according to percentage of fixed carbon on the dry, mineral-matter-free basis. Coals of lower rank are classified by calorific value on the moist, mineral-matter-free basis.

Commercial deposits of each of the four main classes of coal occur in Washington, though only coal of bituminous and subbituminous classes is being produced.

Some coals when heated under conditions of deficient oxygen yield a hard vesicular residue known as coke, and coal capable of yielding the residue is called coking coal. Coke is used primarily by the metallurgical industry for blast furnace and foundry use. Other uses

are in raising steam and in the manufacture of water gas. The principle area of Washington coking coal is the Wilkeson-Carbonado field of Pierce County. Coals from Skagit, King, and Lewis Counties have also been coked but have not produced as satisfactory a product as those from Pierce County. Coal from the Roslyn field of Kittitas County has been coked experimentally. No coke is being produced in Washington at the present time; though it was produced from 1884 to 1937 and for a short time in 1944.

OCCURRENCES

LEWIS COUNTY

MORTON (MINERAL LAKE) FIELD

No mines in this field are producing at the present time, but the following mines have done so in the past:

68 Atlas Coal Co. produced from the Morton mine in SW¼ sec. 12, (12-4E) in 1946.

75 Coal Canyon (Lindberg) mine in W½ sec. 29 or E½ sec. 30, (13-5E).

78 Majestic mine in NW¼ sec. 31, (14-5E).

79 Watkins mine in W½ sec. 29, (14-5E).

80 Pennsylvania mine in secs. 20 and 21, (14-5E).

81 Crystal No. 1 mine in NW¼ sec. 21, (14-5E).

84 The Associated Mining Co. operated the Mineral (Divide) mine in sec. 7, (14-5E).

85 Sunburst mine in sec. 12, (14-4E).

86 East Creek mine in S½ sec. 12, (14-4E).

87 Ladd mine in sec. 12, (14-5E).

111 **Name:** Summit Creek (Carlton Pass) area. **Loc:** Around the headwaters of Cowlitz River. **Descr:** Anthracite and semi-anthracite intimately interstratified with thin shale seams. **Value:** Some shipped at one time, but high shale content made it unsatisfactory as fuel. Probably cannot be economically separated from the associated shale.

PIERCE COUNTY

102 ASHFORD FIELD

This field covers about 40 square miles in Tps. 15 and 16 N., Rs. 6 and 7 E. Propects are numerous, but only the Mashell mine in sec. 22, (15-6E) is known to have produced.

YAKIMA COUNTY

109 **Name:** Bumping River. **Loc:** Near Bumping River trail to Cowlitz Pass in T. 15 N., R. 11 E. **Descr:** Coal claim staked in 1890. Possibly an extension of the Carlton Pass field. **Value:** Unknown.

DIATOMITE

Diatomite or diatomaceous earth is material composed primarily, or entirely, of the frustules of microscopic aquatic plants known as diatoms. These minute forms, which live in all bodies of water, secrete a frustule or casing of silica. When the diatoms die the frustules sink to the bottom and, in time, accumulate as thick beds of diatomite. The frustules are of many shapes and forms but most, if not all, are cellular, a feature which gives diatomite its light weight, heat insulating qualities, and effectiveness as a filtering agent. More than half of all diatomite produced is used in filtration; one-fifth is used as a filler in paper, rubber, and paint; and one-eighth in insulation. The remainder is used as an abrasive and in the manufacture of water glass, glazes, enamel, cement, lightweight brick, and paving materials.

Though many diatomite deposits occur west of the Cascade Mountains, those of greatest purity and largest extent occur in eastern Washington. The eastern ones also account for Washington's production, and it is to them that we can look for future expansion in production.

OCCURRENCE

LEWIS COUNTY

70 **Name:** Morton. **Loc:** NW¼SE¼ sec. 2, (12-4E). **Descr:** A drainage ditch exposes diatomite containing considerable organic matter and some volcanic ash. Bed said to be about 3 ft. thick. **Value:** Might have special use.

GEM AND ORNAMENTAL STONES, AND DECORATIVE STONE

Included under this heading are precious and semi-precious stones which are suitable for cutting and polishing. Also included is decorative stone suited to uses such as stone walls and rockery rocks. Flagstones and platy rocks suitable for such uses as patio paving and fireplace facing are listed under the heading, "Slate and other platy rocks." It is realized that the occurrences listed probably constitute only a small percentage of those known to rock and mineral enthusiasts, but it is hoped that the enumeration will stimulate response from interested parties regarding other collecting localities of gem and decorative stones.

OCCURRENCES

YAKIMA COUNTY

125 **Name:** Mount Adams,
under Slate and other platy rocks.

115 **Name:** Dog Lake,
under Slate and other platy rocks.

GRANITE

In a restricted sense, granite is a plutonic igneous rock composed chiefly of quartz and orthoclase feldspar and containing minor quantities of dark minerals, usually biotite or hornblende. Under this topic heading, however, is included not only true granite but various light-colored plutonic rocks. The red basalt being quarried near Camas has been included here because it is being used as architectural stone.

The occurrences listed include only those deposits having a record of production. Probably many more have been utilized for fill, riprap, or macadam, but it is believed that the cited occurrences include most of those which have been used for architectural or dimension stone.

OCCURRENCE

PIERCE COUNTY

103 **Name:** Ashford (U. S. National Park) quarry. **Loc:** At Ashford. **Descr:** Granite. **Value:** Formerly quarried and used for road metal.

GRAPHITE

Graphite is one form of the element carbon (C); another is diamond. Unlike diamond, which is the hardest of known substances, graphite is one of the softest. Crystalline graphite is iron-black to dark steel-gray, is easily scratched by the thumbnail, is usually in thin flexible inelastic flakes, and has a greasy feeling. It can be distinguished from molybdenite by its black streak when rubbed on glazed porcelain; the streak of molybdenite is greenish-gray. So-called amorphous graphite is actually crystalline graphite in which individual crystals are of microscopic size.

Most large flake graphite is used in the manufacture of crucibles, though some is used in the manufacture of retorts and in lubricants. Not only must graphite of crucible grade be in large flakes (plus 50 mesh) but the flakes themselves must be resistant to mechanical breakdown during the mixing process used in making crucibles. Graphite of other grades is used in commutator brushes, electrodes, bearings, lubricants, pencils, and batteries.

Washington deposits, like other domestic ones, cannot compete with foreign material of lower price and better grade, under normal conditions.

OCCURRENCE

LEWIS COUNTY

77 **Name:** Olympia Graphite Mining & Milling Co. **Loc:** Reportedly in Lewis County at base of main range of Cascades at an altitude of 1,500 ft. **Descr:** Said to be a 15-ft. ledge of "trap" rock, traceable for 1,000 ft. and containing segregations of graphite as much as 30 pounds in weight. **Value:** In 1893 this company said to be developing a deposit.

GYPSUM

Gypsum is a hydrous calcium sulfate mineral having the composition $CaSO_4 \cdot 2H_2O$. Clear, transparent crystals of gypsum are known as selenite; the fine-grained massive variety is called alabaster; fine-fibrous material having pearly opalescence is called satin spar; and earthy varieties, frequently intermixed with clay or silt, are known as gypsite. All varieties of gypsum can be readily scratched by the thumb nail. Selenite is characterized by one excellent cleavage which yields thin inelastic laminae.

Anhydrite is the anhydrous calcium sulfate mineral $CaSO_4$.

In 1952 about 93½ percent of the gypsum consumed in the United States was used by the building industry in the form of plasters, Keene's cement, and prefabricated building materials; 2.2 percent was consumed in industrial uses; and 4.3 percent, in uncalcined form, as a soil conditioner and as a retardant in portland cement.

OCCURRENCE

YAKIMA COUNTY

124 **Name:** Mount Adams. **Loc:** In crater of Mount Adams. **Descr:** Gypsum occurs as cavity filling and as cementing material of volcanic breccia associated with native sulfur. **Value:** Inaccessibility and small quantity make commercial exploitation questionable.

LIMESTONE

Limestone is a sedimentary rock composed principally of calcium carbonate (calcite) in which individual crystals of calcite are not visible to the unaided eye. Marble is a limestone that is recrystallized, with the result that individual calcite crystals are readily visible. In commerce the term limestone includes any rock composed principally of calcium carbonate, regardless of its crystallinity. Similarly, the term marble is used to include any crystalline carbonate rock or mixture of carbonate rock and serpentine that will take a polish.

Uncalcined limestone is used as a flux, as a soil conditioner, as an ingredient of portland cement, in sugar

refining, and in the manufacture of paper. Calcined limestone or lime (CaO) is used as mortar and finishing lime in the building trade, as a flux in the steel industry, in paper manufacture, in water purification, in glass manufacture, in calcium carbide manufacture, and as a soil conditioner. Marble is used as a building and decorative stone and, when of proper composition, for the same uses as limestone.

Washington limestones are nearly all of pre-Tertiary age, and through folding and faulting subsequent to deposition they have almost all become marble. They vary in composition from pure calcium carbonate to high-magnesia varieties and dolomite. The largest deposits occur in eastern Washington, but those of western Washington have been worked more extensively because of their nearness to industry and market along Puget Sound.

OCCURRENCE

LEWIS COUNTY

82 **Name:** Mineral Creek. **Loc:** NE¼SW¼ and NW¼SE¼ sec. 12, (14-5E), on Mineral Creek. **Descr:** Limestone or travertine, one sample of which shows 5.10 percent insoluble, 0.50 percent R_2O_3, 90.00 percent calcium carbonate, and 1.00 percent magnesium carbonate. **Value:** Unknown.

MINERAL PIGMENTS

Mineral pigments are used to give color, body, or opacity to paints, stucco, plaster, cement, mortar, linoleum, rubber, plastics, or other materials. Pigments may be divided into three classes, (1) natural pigments, (2) pigments made by burning or subliming natural minerals, and (3) chemically manufactured pigments. Included here are members of only the first class. A number of standard colors are sold on the market, but nearly all consist of limonite ($2Fe_2O_3 \cdot H_2O$), hematite (Fe_2O_3), or mixtures of these minerals with manganese oxide and/or clay. Ocher is a mixture of iron oxides (usually hydrated) and clay. Sienna consists of hydrated iron oxide and clay but in addition contains manganese oxide, which gives it a brown color. With an increase in manganese oxide content, sienna grades into umber.

In Washington several deposits of pigments have been worked commercially in the past, and several others show promise of being commercial. Failure of operation in most cases was due to lack of experience on the part of the operators, inadequate equipment, weak market, or a combination of the three, rather than to poor quality of source material.

OCCURRENCES

PIERCE COUNTY

97 **Name:** Mashel River. **Loc:** Sec. 22, (16-4E). **Descr:** Large bed of ferruginous shale. **Value:** Mashell Paint Co. formerly produced a pigment similar to Italian burnt sienna; considerable amount sold.

SKAMANIA COUNTY

2 **Name:** Badger Mountain (A). **Loc:** Reported at foot of Badger Mountain on Niggerhead Creek. **Descr:** Sample of brown residual clay reportedly from this location gave good umber color when ground with oil. **Value:** Warrants investigation.

MINERAL WATERS

Nearly all water occurring on the earth's crust as lakes, streams, springs, and in wells contains dissolved mineral matter. Included here, however, are only those waters which contain sufficient mineral matter to give them a noticeable flavor, odor, or medicinal effect.

Mineral springs and lakes are abundant in Washington, particularly in its mountainous regions. Many are popular for bathing, others for their reported curative effect on certain ailments, and some for their palatability, either alone or mixed with other beverages. A number have been developed as resorts where cabins, hotels, camping facilities, and natatoriums are available. At various times, waters of certain springs and lakes have been bottled and sold. One group of carbon dioxide-charged springs furnishes the raw material used in the manufacture of solid carbon dioxide or "dry ice."

OCCURRENCES

COWLITZ COUNTY

26 **Name:** Soda springs. **Loc:** NE¼ sec. 2, (10-4E). **Descr:** Two warm-water springs charged with carbon dioxide and containing some iron. **Value:** No development; reached by Forest Service trail.

LEWIS COUNTY

110 **Name:** Ohanapecosh Hot Springs. **Loc:** SW¼ sec. 4, (14-10E). **Descr:** One large and several small springs flowing water with moderate soda and sulfur content. Temperature ranges from slightly warm to very warm. **Value:** Support a hotel, natatorium, and cottage camp.

112 **Name:** Summit Creek Soda Spring. **Loc:** Near center sec. 18, (14-11E). **Descr:** Single small flow of palatable cold water charged with carbon dioxide. **Value:** A small nonoperating plant on the site.

121 **Name:** Packwood spring. **Loc:** Sec. 32, (13-9E). 10 ft. from Cowlitz River. **Descr:** Sulfur-iron water issues from rock fissures at a temperature of 100° F. **Value:** Undeveloped.

PIERCE COUNTY

107 **Name:** Longmire Springs. **Loc:** Near SE. cor. sec. 29, (15-8E) in Rainier National Park. **Descr:** Group of springs which range in temperature and mineral content from cold carbon dioxide-charged water to hot sulfur-iron water. **Value:** Known since early days, now the site of a hotel.

PEAT

Peat may be defined as vegetal matter in partly decomposed and more or less disintegrated condition. It is formed by accumulation under conditions of excess water and limited access to air. It is made up of different kinds of plants, the kinds depending on local climatic and topographic conditions. Appearance and characteristics depend on the type of plants composing it and the conditions of decay to which they have been subjected.

In 1953, approximately 87 percent of all peat sold in the United States was used for soil improvement and for the manufacture of mixed fertilizers. It is also used as litter for barns and poultry yards, for improvement of lawns and golf courses, in nurseries and greenhouses, and as packing material for plants, fruits, vegetables, eggs, and other fragile articles. No peat was sold as fuel in the United States during 1953, largely because of the availability of better grades of fuel.

In Washington, peat deposits are essentially restricted to areas affected by continental glaciation, particularly in Puget Sound Basin. These are principally small deposits formed in undrained depressions left when the ice receded. Many are made up of sphagnum moss; hence are ideally suited for use as poultry litter and packing for fragile articles. In addition they are used by nurseries.

OCCURRENCES

LEWIS COUNTY

Map no.	Deposit	Location	Area (acres)
67	Davis Lake	Secs. 1, 2, 11, 12, 13, (12-4E), secs. 7, 18, (12-5E)	542
83	Mineral	Secs. 7, 8, (14-5E)	148

PERLITE

Perlite is volcanic glass, usually rhyolitic in composition, which is traversed by numerous curved fractures. Many of the fractures are spherical and enclose small spheroids made up of concentric shells of glass similar to the structure of an onion. Perlite usually contains 2 to 5 percent combined water. Value of perlite depends on its property of expanding when heated, to form a light vesicular material several times its original volume. In commerce, the term perlite is used more generally to include any volcanic glass which will expand when heated, the sense in which it is used here.

Perlite, in its expanded form, is sold primarily for plaster aggregate but is also used as loose-fill thermal insulation and in acoustic tile board. Doubtless other uses for it will develop.

OCCURRENCES

PIERCE COUNTY

101 **Name:** Mashel River. **Loc:** NW¼ sec. 30, (16-6E). **Descr:** Perlite in cliff 15 ft. high and 350 ft. long. **Value:** Rock is porphyritic, hence probably not usable.

SKAMANIA COUNTY

1 **Name:** Gillott. **Loc:** E½ sec. 19 or W½ sec. 20, (8-7E). **Descr:** Perlite reported to be in a 40-ft. adit. Float was found in a stream nearby. **Value:** Unknown.

YAKIMA COUNTY

123 **Name:** Mount Adams. **Loc:** Said to be on the headwaters of Klickitat River in T. 11 N., R. 11 or 12 E. **Descr:** Black perlite. **Value:** Unknown.

PUMICE

Pumice is a fragmental, highly cellular volcanic rock consisting largely of glass that is commonly rhyolitic in composition. It represents rock froth formed in the craters of active volcanoes during expansion of abundant water vapors and other gases and ejected during eruptions.

Because of its hardness and the sharp particles produced when crushed, pumice is an excellent abrasive and, until recently, 80 percent of the pumice used in the United States was used for this purpose. Its light weight and heat insulating value have recently stimulated its use in the building industry for loose-fill insulation, as concrete aggregate, and as plaster sand.

Washington pumice occurs in two regions. The first is a fan-shaped area extending from Glacier Peak, its source, eastward as far as Soap Lake in Grant County. The second extends northward from Mount St. Helens, its source, to Mount Rainier. Since deposition, the blankets of pumice have been dissected by stream erosion, leaving commercial deposits only in protected areas.

OCCURRENCES

LEWIS COUNTY

28 **Name:** Cispus River (H). **Loc:** Near SE. cor. sec. 13, (11-6E). **Descr:** Road cut exposes, from surface down: 2 in. of soil, 22 in. of pumice, 8 in. of silt, and 24 in. of pumice. **Value:** Workable if silt is pumiceous.

29 **Name:** Cispus River (G). **Loc:** Near E. ¼ cor. sec. 11, (11-6E). **Descr:** Railway cuts expose 26 to 35 in. of pumice beneath 1 to 2 in. of soil. **Value:** Warrants investigation.

30 **Name:** Cispus River (F). **Loc:** NE¼ sec. 10, (11-6E). **Descr:** Railway cut exposes 54 in. of pumice beneath 24 in. of overburden. **Value:** Commercial thickness; extent should be determined.

31 **Name:** Cispus River (A). **Loc:** SW¼ sec. 3, (11-6E). **Descr:** Railway cuts for ¼ mi. expose 54 to 60 in. of pumice overlain by 6 to 12 in. of silty soil. **Value:** Workable thickness and extent.

32 **Name:** Cispus River (B). **Loc:** E½SE¼ sec. 4, (11-6E). **Descr:** Open cut exposes 51 in. of pumice beneath 13 in. of overburden. **Value:** Warrants investigation.

33 **Name:** Cispus River (C). **Loc:** Near center W½ sec. 4, (11-6E). **Descr:** Railway cut exposes 4 ft. of pumice mantled by 8 in. of pumiceous soil. **Value:** Workable thickness; extent should be determined.

34 **Name:** "Popcorn" pit. **Loc:** Center sec. 5, (11-6E). **Descr:** Reworked pumice 13 ft. thick. **Value:** Recently operated by Insulrock Products (Layrite Concrete Products), Seattle, Wash.

35 **Name:** Cispus River (D). **Loc:** 300 ft. W. of center sec. 5, (11-6E). **Descr:** Railway cut exposes 3 ft. of pumice overlain by 1 ft. of silty soil. **Value:** Might support small operation.

36 **Name:** Cispus River (E). **Loc:** Near W. ¼ cor. sec. 5, (11-6E). **Descr:** Railway cut exposes 4 ft. of pumice overlain by 1 ft. of silty soil. **Value:** Warrants investigation.

37 **Name:** Cowlitz River. **Loc:** Near W. ¼ cor. sec. 6, (11-6E). **Descr:** Open cut exposes 30 in. of pumice beneath 36 in. of overburden. **Value:** Ratio of overburden to pumice high for economic development.

38 **Name:** Cowlitz Valley (B). **Loc:** Near S. ¼ cor. sec. 36, (12-5E). **Descr:** Pit exposes 5 ft. of pumice overlain by 1 ft. of soil. **Value:** Warrants investigation.

39 **Name:** Cowlitz Valley (A). **Loc:** Near S. ¼ cor. sec. 35, (12-5E). **Descr:** Open cuts expose 4 ft. of pumice overlain by 6 to 12 in. of soil. **Value:** Warrants investigation.

40 **Name:** Cowlitz Valley (E). **Loc:** Near SW. cor. sec. 29, (12-6E). **Descr:** Road cuts expose 42 to 72 in. of pumice overlain by 12 in. of soil. **Value:** Warrants development.

41 **Name:** Rainy Valley. **Loc:** Near S. ¼ cor. sec. 24, (12-5E). **Descr:** Open cut exposes 6 ft. of pumice beneath 6 to 12 in. of soil. **Value:** Warrants investigation.

42 **Name:** Cispus (A). **Loc:** Near center sec. 19, (12-6E). **Descr:** Road cuts expose 4 ft. of pumice overlain by 6 to 8 in. of soil. **Value:** Warrants investigation.

43 **Name:** Cispus (B). **Loc:** Near W. ¼ cor. sec. 20, (12-6E). **Descr:** Open cuts expose 4 ft. of pumice overlain by 6 to 8 in. of soil. **Value:** Warrants investigation.

44 **Name:** Hunt & Gaines pit. **Loc:** E½NW¼ sec. 26, (12-6E). **Descr:** Pumice 3 ft. thick over an area of 40 to 60 acres. Less than 1 ft. of overburden. **Value:** Recently operated by P. F. Hunt and John Gaines, Winlock, Wash.

45 **Name:** Cowlitz Valley (C). **Loc:** SW. cor. sec. 23, (12-6E). **Descr:** Pit exposes 3 to 4 ft. of pumice overlain by 1 ft. of soil. **Value:** Warrants investigation.

46 **Name:** Kiona Valley. **Loc:** SW. cor. sec. 14, (12-6E). **Descr:** Drill hole encountered 3 ft. of pumice beneath 1 ft. of soil and roots. **Value:** Might support small operation.

47 **Name:** Cowlitz Valley (D). **Loc:** Near SE. cor. sec. 23, (12-6E). **Descr:** Road cut exposes 32 in. of pumice. **Value:** Thickness of overburden and extent of pumice should be determined.

50 **Name:** Kiona Creek (D). **Loc:** Near E. ¼ cor. sec. 12, (12-6E). **Descr:** Ditch exposes 41 in. of pumice overlain by 24 to 30 in. of soil. **Value:** Ratio of overburden to pumice too high for cheap mining.

52 **Name:** Kiona Creek (C). **Loc:** S½SW¼ sec. 12, (12-6E). **Descr:** Deposit extends 800 by 300 ft. Two drill holes, 200 ft. apart, encountered 6 and 8+ ft. of pumice beneath 1½ ft. of overburden. **Value:** Warrants development.

54 **Name:** Kiona Creek (B). **Loc:** Near SE. cor. sec. 11, (12-6E). **Descr:** Road cut exposes 30 in. of pumice overlain by 6 to 12 in. of soil. **Value:** Might support small operation.

55 **Name:** Kiona Creek (A). **Loc:** Near E. center SW¼ sec. 11, (12-6E). **Descr:** Road cut exposes 32 in. of pumice overlain by 6 to 12 in. of soil. **Value:** Might support small operation.

57 **Name:** Tom Dalton (A). **Loc:** NE¼SW¼ sec. 4, (12-6E). **Descr:** Two auger holes 60 ft. apart encountered 11 and 13+ ft. of pumice beneath 2 ft. of overburden. Probably covers 2½ acres. **Value:** Commercial quantity.

58 **Name:** Rainy Creek (B). **Loc:** 600 ft. S. of no. 15. **Descr:** Road cut exposes 26 in. of pumice overlain by 14 in. of soil. **Value:** Might be worked in conjunction with nearby deposits.

59 **Name:** Rainy Creek (C). **Loc:** NW¼NE¼ sec. 9, (12-6E). **Descr:** Road cuts expose 3 ft. of pumice beneath 2 to 6 in. of soil. **Value:** Could support small operation.

60 **Name:** Tom Dalton (B). **Loc:** Road cut at toe of slope in SE¼NW¼ sec. 4, (12-6E). **Descr:** Pumice, mantled by 2½ ft. of overburden, covers 1½ acres to an average depth of 6 ft. **Value:** Could support small operation.

62 **Name:** Rainy Creek (A). **Loc:** Near W. ¼ cor. sec. 8, (12-6E). **Descr:** Drill hole encountered 6 ft. of pumice beneath 4 ft. of soil and silt. **Value:** Commercial thickness; extent should be determined.

63 **Name:** Glenoma. **Loc:** Near center sec. 14, (12-5E). **Descr:** Road cut exposes 14 in. of impure pumice. **Value:** Noncommercial.

SKAMANIA COUNTY

3 **Name:** East St. Helens. **Loc:** NW¼ sec. 1, (8-5E). **Descr:** Stream bank exposes pumice intermixed with gravel to depth of 4 ft. **Value:** Usable only if separation of gravel from pumice is economical.

4 **Name:** Swift Creek (C). **Loc:** N½ sec. 34, (9-5E). **Descr:** Gulch exposes 12 ft. of pumice overlain by 2 in. of soil. **Value:** Warrants development.

5 **Name:** Swift Creek (D). **Loc:** NW¼ sec. 34, (9-5E). **Descr:** Gulch exposes 13 to 20 ft. of pumice overlain by 1 ft. of soil. **Value:** Warrants development.

6 **Name:** Swift Creek (B). **Loc:** SE¼ sec. 27, (9-5E). **Descr:** Road cut exposes 4 ft. of pumice. **Value:** Thickness of overburden and extent of pumice should be determined.

7 **Name:** Swift Creek (A). **Loc:** Near NE. cor. sec. 27, (9-5E). **Descr:** Road cut exposes 5 ft. of pumice overlain by 3 to 4 in. of soil. **Value:** Warrants investigation.

8 **Name:** Draughon pit. **Loc:** SW¼ sec. 23, (9-5E). **Descr:** Apparently a large deposit. **Value:** Recently operated by Mutual Industries, Ltd., Tacoma, Wash.

9 **Name:** Ranger Station. **Loc:** Near center sec. 14, (9-5E). **Descr:** Drill hole showed 10 in. of pumice beneath 2 in. of soil. **Value:** Noncommercial.

10 **Name:** S. Spirit Lake. **Loc:** NW¼ sec. 13, (9-5E). **Descr:** Trail cut shows 27 in. of pumice beneath 3 in. of soil. **Value:** Deposit too thin for commercial operation.

11 **Name:** Cedarbrook. **Loc:** E½ sec. 12, (9-5E). **Descr:** Pit shows 2 ft. of pumice overlain by 3 in. of soil. **Value:** Deposit too thin for commercial operation.

12 **Name:** St. Charles Lake. **Loc:** SW¼ sec. 5, (9-6E). **Descr:** Pit exposes, from surface down: 1 in. of soil, 12 in. of pumice, 6 in. of silt, and 56 in. of pumice. **Value:** Warrants investigation.

13 **Name:** St. Helens Lake. **Loc:** SW¼ sec. 3, (9-5E). **Descr:** Trail cut exposes 2 ft. of pumice overlain by 3 in. of soil. **Value:** Pumice bed too thin to support commercial operation.

14 **Name:** Clearwater Creek. **Loc:** NW¼ sec. 34, (10-6E). **Descr:** Trail cuts expose 1 to 3 ft. of pumice contaminated by rotten logs and stumps. **Value:** Quantity and quality below commercial grade.

15 **Name:** Lookout trail (B). **Loc:** SW¼SE¼ sec. 27, (10-6E). **Descr:** Pit exposes, from surface down: 1 in. of soil, 8 in. of pumice, 5 in. of silt, and 44 in. of pumice. **Value:** Warrants investigation.

16 **Name:** Green River (C). **Loc:** Near N. ¼ cor. sec. 29, (10-6E). **Descr:** Trail cuts expose 6 to 12 in. of pumice overlain by 2 to 3 in. of soil. **Value:** Pumice bed too thin for commercial use.

17 **Name:** Lookout trail (A). **Loc:** Near S. line sec. 22, (10-6E). **Descr:** Stream cut exposes 10 ft. of pumice mixed with a little clay, sand, and a few rock fragments. **Value:** Warrants investigation.

18 **Name:** Strawberry Lookout. **Loc:** N½ sec. 22, (10-6E). **Descr:** Pit exposes 2 in. of pumice overlain by 6 in. of soil. **Value:** Noncommercial.

19 **Name:** Ryan Lake. **Loc:** N. center sec. 16, (10-6E). **Descr:** Pit exposes 2 ft. of pumice overlain by 6 in. of silt and pumicite. **Value:** Pumice bed too thin for commercial development.

20 **Name:** Golconda prospect. **Loc:** At portal of Golconda prospect tunnel near W. ¼ cor. sec. 16, (10-6E). **Descr:** Exposed from surface down are: 3 in. of soil, 8 to 14 in. of pumice, 14 in. of silt, and 45 in. of pumice. **Value:** Warrants investigation.

21 **Name:** Goat Mountain. **Loc:** W½ sec. 8, (10-6E). **Descr:** Pit exposes 22 in. of pumice overlain by 6 in. of soil. **Value:** Deposit too thin for commercial development.

22 **Name:** Polar Star prospect. **Loc:** At portal of Polar Star tunnel in N½ sec. 18, (10-6E). **Descr:** 10 to 14 in. of pumice mantled by 3 in. of soil. **Value:** Noncommercial.

23 **Name:** Green River (B). **Loc:** N½ sec. 13, (10-5E). **Descr:** Pit exposes 7 in. of pumice overlain by 6 in. of soil. **Value:** Noncommercial.

24 **Name:** Green River (A). **Loc:** SW¼ sec. 12, (10-5E). **Descr:** Pit exposes 22 in. of stream-worn pumice and silt overlain by 2 in. of soil. **Value:** Pumice too thin for commercial development.

25 **Name:** Deadman Lake. **Loc:** NE¼ sec. 2, (10-5E). **Descr:** Pit exposes 30 in. of pumiceous silt overlain by 6 in. of soil. **Value:** Probably too impure for most uses.

SAND AND GRAVEL

Sand and gravel are widespread in the state and constitute one of its very important resources. They are used largely by the building and heavy construction industries for concrete aggregate, plaster sand, mortar sand, building sand, macadam, and fill. Listed below, under county headings which are arranged alphabetically, are all the sand and gravel pits known to the Division of Mines and Geology. It is realized that the following list does not include all existent pits, for there are many small local pits which operate intermittently and of which no record exists.

OCCURRENCES

Map no.	Operator or owner	Pit name	Property location
		LEWIS COUNTY	
48			NE¼NW¼ sec. 15, (12-7E)

Map no.	Operator or owner	Pit name	Property location
		LEWIS COUNTY—Continued	
49	I. N. DeRossett	Randle	In Randle
53		Smathers	NW¼NW¼ sec. 13, (12-6E)
56	Lewis County	Kiona	W½NW¼ sec. 10, (12-6E)
61	Dept. of Highways	Fairhurst	SE¼SE¼ sec. 5, (12-6E)
64	Do		E½NW¼ sec. 22, (12-5E)
72	Dept. of Highways		SE¼NE¼ sec. 3, (12-4E)
73	Chesser Lumber Co.	Chesser	SE¼SW¼ sec. 35, (13-4E)
74	Dept. of Highways		S½SW¼NE¼ sec. 35, (13-4E)
76	Do	Lindberg	Lots 3 and 4, sec. 19, (13-5E)
88	Dept. of Highways		W½SE¼NW¼NW¼ and S½SW¼NE¼ NW¼NW¼ sec. 28, (15-5E)
89	Do		N½SW¼ and NE¼NW¼NW¼ sec. 28. (15-5E)
91	Do		NE¼NE¼ sec. 29, (15-5E)
113	U. S. Forest Service		SW¼SE¼ sec. 17, (14-10E)
117	Matchett and Panco		NE¼ sec. 1, (13-9E)
118		Warnke	NE¼NE¼ sec. 21, (13-9E)
119	Hayes & Powell	Packwood	At Packwood
120	Dept. of Highways		Lots 4 and 5, sec. 32, (13-9E)
122	Dept. of Highways		Govt. lots 4-9, sec. 15, (12-8E)
		PIERCE COUNTY	
90			NE¼NE¼ sec. 29, (15-5E)
93		Pack Forest	NW¼ sec. 28, (16-4E)
94	Dept. of Highways	Peterson	SE¼SE¼ sec. 18, (16-4E)
95			Sec. 17, (16-4E)
96	Dept. of Highways		NE¼NE¼ sec. 20, (16-4E)
98	Wheeler & Reese		Sec. 11, (16-4E)
99	C. M. St. P. & P. R.R.	Eatonville	SW¼ sec. 13, (16-4E)
104	Elizabeth M. Messler	Messler	NE¼SW¼ sec. 29, (15-7E)
105	Shafer Bros.		NW¼NW¼ sec. 31, (15-7E)
106	Dept. of Highways	Hall	NE¼SE¼ sec. 33, (15-7E)

SANDSTONE

Sandstone is a sedimentary rock composed of cemented mineral grains and rock fragments from 1/16 to 2 mm. in size.

Included under this heading are all sandstones, regardless of use to which they are suited. After crushing, some are suitable for glass sand, molding sand. blast sand, furnace sand, or abrasives. Others are suitable for building stone or grindstones. This classification has been made because uses change; hence a classification by use now might not be applicable a few years hence.

OCCURRENCES

LEWIS COUNTY

65 **Name:** Morton (B). **Loc:** Cut on Morton-Kosmos highway, 4 mi. SE. of Morton. **Descr:** Sandstone containing 84.2 percent silica and 1.8 percent ferric oxide. Washed sample gave spotted gray fusion at cone 14. **Value:** Possibly commercial.

66 **Name:** Morton (A). **Loc:** Cut on Morton-Kosmos highway 3.8 mi. SE. of Morton. **Descr:** Coarse-grained gray iron-stained sandstone. Washed sample gave lightly spotted near-white fusion at cone 16 minus. **Value:** Possibly commercial.

71 **Name:** Morton. **Loc:** Road cut on Morton-Kosmos highway 0.8 mi. SE of Morton. **Descr:** Fine-grained dirty sandstone. Dark-brown fusion at cone 6. **Value:** Probably not commercial.

SLATE AND OTHER PLATY ROCKS

Slate is a metamorphic rock in which preexisting and newly formed platy minerals have been oriented in such a fashion that the rock has acquired a distinct cleavage.

Slate is used for roofing, flagstones, electrical panels and switchboards, school slates, pencils, toys, blackboards, and billiard tables, and is ground to granules and flour for roofing and other building materials.

OCCURRENCES

YAKIMA COUNTY

115 **Name:** Dog Lake. **Loc:** On both sides of Clear Creek from Dog Lake to Tieton River. **Descr:** Light-gray andesite which breaks into long flat tablets of various sizes. **Value:** Suitable for flagstones and patio blocks. Currently operated in a small way.

125 **Name:** Mount Adams. **Loc:** SW. cor. sec. 27, (8-11E). **Descr:** Light pinkish-gray andesite that breaks into sheets from ½ to 3 or 4 in. thick and 6 to 8 ft. across. **Value:** Has been used for flagstones, stone benches, and other decorative purposes. Recently operated by Joe Marsten, Portland, Oreg.

SULFUR

Sulfur, combined with other elements, occurs abundantly in nature. In lesser amounts it also occurs in free, uncombined form. In this form it resembles the sulfur of commerce though it is usually less pure. It is soft, brittle, usually yellow in color, and ignites readily when held in a match flame.

The largest use of sulfur in the Northwest is in the pulp and paper industry. Other important uses are in the manufacture of sulfuric acid, in rubber, plastics, dyes, food products, insecticides, vulcanizing, paints and varnishes, medicinals, and other chemicals.

OCCURRENCE

YAKIMA COUNTY

124 **Name:** Mount Adams. **Loc:** At and near the summit of Mount Adams. **Descr:** Sulfur and alum occur as cavity fillings, veinlets, and cementing material in breccia and tuff. 840,000 tons of 46 percent sulfur said to have been indicated by drilling. **Value:** Commercial quantity, but inaccessibility and altitude make commercial exploitation difficult.