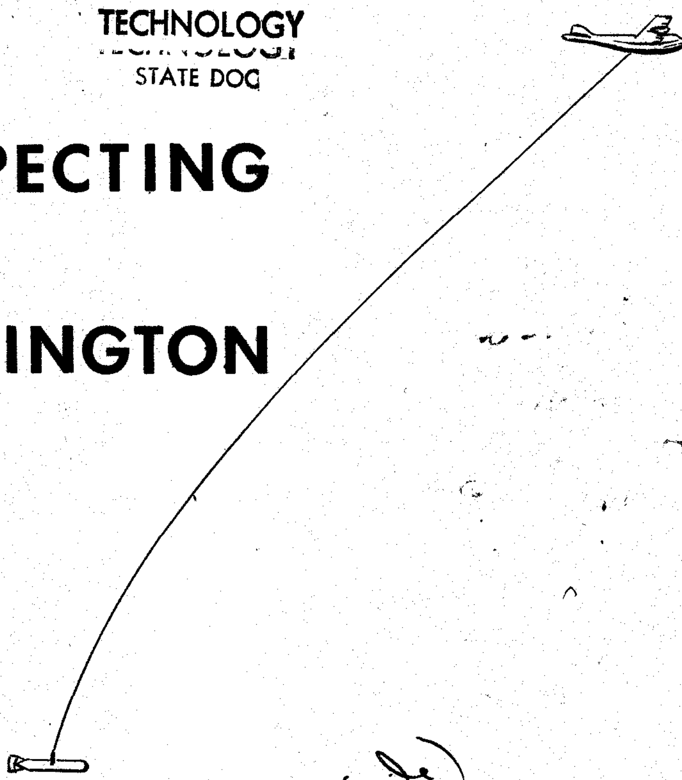

# PROSPECTING IN WASHINGTON

by

Donald L. Anderson



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# FOREWORD

Prospectors and fur traders were the earliest explorers and settlers in the northwest territory that now is Washington. Shortly after gold was discovered in California it also was found along the Yakima River in Washington Territory. Prospectors came to the Territory by the thousands, and in a short time many thousands of claims had been staked. A little later the prospectors' interests widened to include silver and copper, and still later lead and zinc were sought. By the turn of the twentieth century most of the presently known metals had been found in the mountains of Washington. In 1954 uranium was found in a southern Stevens County deposit that was large and rich enough to set off a whole new prospecting rush, this time for uranium.

Prospectors always have been an independent group, relying upon their own skill, persistence, and luck to lead them to ore discoveries. But even in the earliest days they sought advice from their fellow prospectors, and in recent years they have turned increasingly to technically trained geologists and engineers for information and advice.

The Washington Mining Bureau, the forerunner of the present Division of Mines and Geology, was established by the first State Legislature in 1890 to "promote the development of the mineral resources of the State," and to answer the questions of the prospectors of that day. The Division of Mines and Geology in recent years has received thousands of requests for information on prospecting in Washington--where to look for gold, copper, tungsten, uranium, beryl, and scores of other metals and minerals; how does one go about the search for these minerals; and what sources of information are available?

Similar questions have been directed to the mining and geology departments of the State's schools of higher education. The curricula in these schools have included special courses for prospectors. It was logical, then, that the Division of Mines and Geology should turn to a professor who teaches one of these prospectors' courses to write this report, "Prospecting in Washington." The author, Donald L. Anderson, professor of mining in the School of Mineral Engineering at the University of Washington, knows prospecting and mining through firsthand experience as well as through academic training and teaching.

This report should serve as a useful guide to beginning prospectors and to others who have newly turned their interest to prospecting in Washington.

MARSHALL T. HUNTTING, Supervisor
Division of Mines and Geology

March 31, 1959

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By Donald L. Anderson

## INTRODUCTION

The role of the individual prospector today is quite different from that of his counterpart 50 years ago. The search for new minerals which were valueless a few decades ago and the use of geophysical prospecting for the discovery of new ore deposits, combined with rapid communiciation, have changed the prospector from an individualist who discovered and worked his own small mine to one who cooperates with industry in bringing new mines into production.

At the turn of the century many prospectors were searching for placer gold. Today, however, most of the easily accessible gold placers within the continental United States have been discovered and exploited. Despite this, other valuable minerals, such as titanium sands and the rare earths, are being found in placer deposits. These discoveries suggest that many abandoned alluvial deposits are worthy of further investigation.

Because of the advent of modern geophysical prospecting, it has been stated that the individual prospector is doomed to extinction. On the contrary, this is far from true and, in some instances, the geophysicists have followed the prospector, attempting to broaden an anomaly from his original find. Geophysical prospecting is not carried out in a haphazard manner. It is based upon favorable geologic structure, areas of known mineralization, or new prospects found by men in the field, in order to carry out an intelligent survey.

The re-examination of old prospects is an undertaking to which all prospectors should give serious consideration. Certain gold prospects which have been abandoned for years may be worthy of re-evaluation because of new and better metallurgical processes of extraction, such as the cyanide process. Dormant mines and prospects may also contain minerals of tungsten, molybdenum, nickel, uranium, and others which were bypassed or unrecognized by early miners.

Besides the metallic minerals there is another group of minerals, the nonmetallics, with which every prospector should be familiar. Within the past 20 years the value of nonmetallics produced in the United States has increased at such a rapid rate that it now surpasses the value of metallic minerals. Thus deposits of clay, fluorspar, barite, asbestos, mica, gypsum, limestone, and others should be given careful consideration.

A prospector in the field today, with some knowledge of structural geology and the nature of ore deposits, has as much opportunity as did his predecessor of 60 years ago. It should be realized, however, that ore deposits are the exception rather than the rule, and that most prospectors do not make rich finds. Opportunities are not made without the asking, and mines are not found without a search.

## GEOLOGIC FACTORS IN ORE SEARCH

### Rocks

A prospector in the field certainly should have a working knowledge of the common rocks. He is constantly examining rocks when searching for ore bodies, and recognition of the common rock types may aid him in seeking ores of a certain type in a particular area. For example, granitic rocks are host to minerals of tin, tungsten, and molybdenum, whereas basic intrusive rocks may contain ores of chromium, nickel, and the platinum group.

TABLE 1.--CLASSIFICATION OF COMMON ROCKS

| Classes of rocks | Principal types | Common rock-forming minerals that may be present | Way formed |
|---|---|---|---|
| IGNEOUS | | | |
| Intrusive | Granite | Quartz, feldspars, amphiboles, pyroxenes, mica | Intrusion of a magma into the earth's crust |
| Volcanic | Basalt | Feldspars, amphiboles, pyroxenes, mica, olivine | Extrusion of a magma upon the earth's surface |
| SEDIMENTARY | | | |
| Mechanical | Sandstone | Quartz, feldspars, rock fragments | Consolidation of sand by pressure |
| | Shale | Clay minerals and mica | Consolidation of clay by pressure |
| | Conglomerate | Varied, mostly fragments of rocks | Pebbles and small rocks, usually rounded, cemented into rock formation |
| Chemical | Limestone | Calcite | Most commonly precipitated from sea water. Sometimes found as a fresh water deposit |
| | Dolomite | Dolomite | Precipitated from sea water or made from limestone by the addition of magnesium |
| METAMORPHIC | | | |
| | Schist | Varied | Formed from igneous and sedimentary rocks by heat, pressure, and other forces |
| | Gneiss | Varied | |
| | Slate | Varied | |
| | Quartzite | Quartz | |
| | Serpentine | Antigorite and chrysotile | |

TABLE 2.—CLASSIFICATION OF IGNEOUS ROCKS (Abbreviated)

| Rock types | | | | Principal rock-forming minerals contained | Color |
|---|---|---|---|---|---|
| Volcanic rocks | | Intrusive rocks | | | |
| Fine-grained texture (individual crystals of the groundmass cannot be seen with unaided eye) | Porphyritic texture (coarse crystals in a fine-grained groundmass) | Coarse-grained texture | Porphyritic texture (coarse crystals in a fine-grained groundmass) | | |
| Rhyolite .......... | Rhyolite porphyry | Granite and granodiorite 3/ | Granite porphyry | Potash feldspar, quartz, biotite, hornblende, augite | Light-colored, or acid |
| Andesite 1/ ........ | Andesite porphyry | Diorite | Diorite porphyry | Soda feldspar, biotite, hornblende, augite | |
| Basalt 2/ ........ | Basalt porphyry | Gabbro and peridotite 4/ | Gabbro porphyry | Soda feldspar, olivine, augite | Dark-colored, or basic |

1/ Mount Rainier andesite is a typical example.

2/ Columbia River basalt is a typical example.

3/ Mount Stuart granodiorite is a typical example.

4/ Peridotite in Blewett-Cle Elum River area is a typical example.

Note: For a more complete list of igneous rocks, see Dana's Manual of Mineralogy.

TABLE 3.—GEOLOGIC TIME DIVISIONS

| Eras | Periods | Major physical events that occurred in North America | Life encountered | Age (years) |
|---|---|---|---|---|
| Cenozoic | Quaternary<br><br>Tertiary | Various glaciations<br>Widespread uplift and erosion<br>Basaltic lavas extruded in Washington<br>Washington coal measures formed | Human life<br><br>Mammals other than man | 60,000,000 |
| Mesozoic | Cretaceous<br>Jurassic<br>Triassic | Rocky Mountains uplifted<br>Sierra Nevadas uplifted<br>Granites and granodiorites intruded in eastern Washington | Dinosaurs | 60,000,000 to 185,000,000 |
| Paleozoic | Permian<br>Pennsylvanian<br>Mississippian<br>Devonian<br>Silurian<br>Ordovician<br>Cambrian | Appalachian Mountains formed<br>Climate warm; eastern coal measures formed<br>Inland seas covered most of the U. S.<br>Salt beds formed; oil strata deposited<br>Limestone and other sedimentary rocks formed | Early land animals<br><br>Early invertebrates (clams, snails) | 185,000,000 to 520,000,000 |
| Proterozoic | Keweenawan<br><br>Huronian | Extensive glaciation<br><br>Massive iron ore deposits of the Lake Superior district formed | No fossils. Only indirect evidence of life | 520,000,000 to 2,100,000,000 |
| Archeozoic | Timiskaming<br><br>Keewatin | Large granitic intrusions<br><br>Earliest known sediments | No evidence of life | 2,100,000,000 to 3,310,000,000 |

Rocks derived from the molten magmatic mass from which the earth solidified are classified as igneous. They are further classified as intrusive or extrusive (volcanic), depending on whether they were intruded into the earth's crust or flowed out upon or near the surface as a lava. The intrusive igneous rocks, also referred to as plutonic or deep-seated, cooled slowly, and as a result the crystals are larger and the rocks have a coarse-grained texture. The volcanic rocks, also referred to as extrusive rocks or lavas, cooled rapidly upon reaching the surface of the earth; hence the crystals of volcanic rocks are small and the texture is fine-grained or glassy.

Sedimentary rocks were formed from sediments (mud, sand, gravel) deposited in water and, to a limited extent, in air. These sediments were derived from existing rock masses. Because of their origin, sedimentary rocks are stratified and, at the time of their formation, were horizontal or only slightly inclined. However, due to movement of the earth's crust, such as folding and faulting, many sedimentary beds have been tilted and uplifted until today they have become prominent mountain ridges.

Metamorphic rocks were formed by the alteration of pre-existing igneous and sedimentary rock masses by heat and pressure. This metamorphism, or change, may be only slight, and the texture of the original rock may be recognizable. However, the metamorphism may be so severe as to create an entirely new rock, which can be classified only by laboratory methods.

The principal common rock types are shown in table 1, and the common igneous rocks are shown in table 2.

## Geologic Ages of Rocks

A man actively prospecting in the field should know the major geologic time divisions and their significance with respect to ore deposits. It is unlikely that a prospector immediately can recognize a rock as being formed in a particular geologic period. However, the availability of geologic maps of national, state, and district scope has relieved him of this responsibility. Table 3 shows the eras and periods of geologic time, which are further subdivided with appropriate name, color, and symbol on most geologic maps. Thus a prospector need only locate himself geographically, then check his geologic map to find the rock types, their ages, distance to the nearest contact or major fault, and any other pertinent information which may aid his search for ore bodies.

The geologic map of Washington shows that the southern--particularly the southeastern--part of the State is covered with basaltic lava flows of the Cenozoic era. Although there are exceptions to the rule, most basic lavas such as basalt are unfavorable for ore deposits. This explains the virtual absence of mines and prospects in this area.

As opposed to the barren nature of the basic lavas, the acid volcanics, such as rhyolite and andesite of the Tertiary period, in many places are host to deposits of the precious metals. (Exceptions to this generality are the essentially barren andesites of the Cascade Mountains in southern Washington.) Gold and silver veins have been found in Cenozoic rocks of this type in various places from Canada to South America. In addition, these deposits, even though found over such an extensive area, show a remarkably consistent relationship between the nature of the ore minerals and the character of the enclosing rock.

## Faults and Contacts

Knowledge of the various rock formations, the importance of contacts, and the significance of major faults has made structural geology an important tool to the economic geologist and geological engineer. Ore deposits may occur

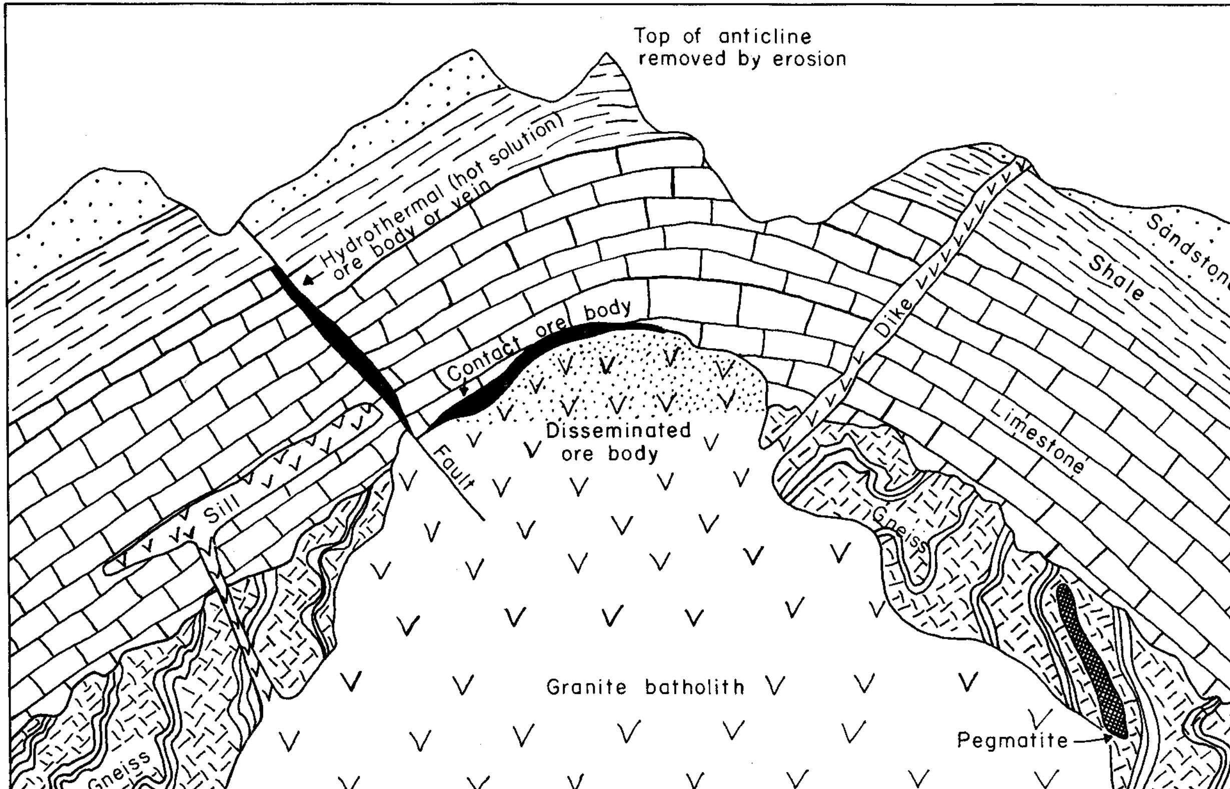


FIGURE I.—DIAGRAM SHOWING COMMON TYPES OF ROCKS in almost any type of rock, but regardless of the rock there must be a favorable structure through which the ore-bearing solutions can migrate. In other words, for hydrothermal deposits there must be an open fissure or a zone of weakness into which the mineral-bearing solutions can enter. The minerals are then precipitated out of the solution by a decrease in temperature or pressure, as by reaction with the wall rock.

The best known and publicized breaks in the earth's crust are faults. Although it is true that most major faults are not mineralized, it is generally conceded that major faults give rise to secondary faults and joint cracks that may contain ore bodies in the near vicinity or adjacent to the main structure. Thus, a major fault when identified should be examined even though it may appear to be barren of ore minerals.

Contacts between two different types of rocks provide a potential break or zone of weakness that can be host to an ore deposit. Some contacts, such as those between two sedimentary rocks or between an older igneous and a younger sedimentary rock, may be of limited importance. However, the contact between an older sedimentary and a younger igneous should be given attention. In this instance a molten magmatic mass has been forced into an existing rock with the result that the contact area is altered and fractured, producing conditions favorable for ore deposition. 1/

Trained geologists make other uses of structural geology beyond the scope of a prospector. However, a prospector can and should prospect intelligently by using a geologic map and investigating such features as faults and contacts.

## MINERALS

### Definition

A mineral is generally defined as being a naturally occurring inorganic substance with a definite chemical composition and physical properties. It usually consists of two or more elements, such as quartz ($SiO_2$), or may consist of a single element such as gold (Au).

To the prospector, minerals may be considered as being composed of two broad groups:

(1) Minerals which are of economic importance, such as:

Chalcopyrite ($CuFeS_2$), copper iron sulfide

Scheelite ($CaWO_4$), calcium tungstate

Pitchblende (Complex formula containing $[U_3O_8]$, uranium oxide, as the valuable constituent)

(2) Minerals which generally are not of economic importance and which combine to form rocks, such as:

Hornblende ($Ca_2Na[Mg,Fe]_4[Al,Fe,Ti]Si_6O_{22}[O,OH]_2$), a metasilicate

Plagioclase feldspar ($[Na,Ca]Al[Al,Si]Si_2O_3$), sodium, calcium, aluminum silicate

Biotite mica ($K[Mg,Fe]_3AlSi_3O_{10})(OH)_2$, hydrated potassium, magnesium, iron, aluminum silicate

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1/ An example is the contact of Loon Lake Granite and Deer Trail group, Midnite mine, Stevens County, Washington.

TABLE 4.—CLASSIFICATION OF MAJOR NONMETALLIC MINERALS

| Mineral | Way formed | Characteristics of deposit |
|---|---|---|
| Asbestos (chrysotile) | Alteration of serpentine ... | Found in ultramafic igneous and metamorphic rocks |
| Barite ....... | As bedded deposits, gangue in veins, or as residual masses | Economic deposits usually found as bedded deposits |
| Calcite (limestone) | Chemical deposition ........ | Economic deposits found in beds, sometimes of great thickness |
| Clay ......... | Decomposition of silicate minerals | Residual deposits |
| Diatomite .... | Accumulation of siliceous fossilized plant remains | Bedded deposits |
| Dolomite ..... | Alteration of limestone beds | Bedded deposits |
| Feldspars .... | As widely distributed rock-forming minerals | Pegmatite dikes and massive deposits |
| Fluorite ..... | Deposition from hydrothermal solutions | In veins, and as replacements in limestone |
| Gypsum ....... | Chemical deposition ........ | Bedded deposits |
| Magnesite .... | Replacements, also alteration of serpentine | In metasedimentary rocks, and in veins |
| Mica ......... | As constituent of pegmatite dikes | In sheets or books within dike |
| Olivine ...... | Magmatic segregation ....... | Massive deposits |
| Perlite ...... | Vulcanism (glassy product) | Massive deposits |
| Phosphate rock | Sedimentary deposition ..... | Usually bedded deposits |
| Pumice ....... | Volcanic eruption (glassy, siliceous product) | Usually surface deposit of limited depth |
| Quartz ....... | As common rock-forming mineral | Veins, massive deposits, and quartzite beds |
| Talc ......... | Alteration of silicate minerals | Veins and massive deposits |

## Physical Mineralogy

Regardless of their economic importance, all minerals exhibit certain physical characteristics such as cleavage, hardness, specific gravity, luster, color, streak, fluorescence, and magnetism.

Cleavage may be defined as the tendency of a mineral to break along a definite plane surface. Some minerals, such as feldspar, have smooth cleavage planes which serve to distinguish them from similar-appearing minerals such as quartz, which has no cleavage planes, but when fractured leaves jagged, irregular surfaces.

The hardness of a mineral may be defined as its ability to withstand being scratched. The handiest and most common tools for hardness tests are one's fingernail, a copper coin, and a knife blade. Hardness is classified in a scale that ranges from 1 (the softest) to 10 (the hardest). Thus, because the hardness of talc is 1, it can be easily scratched by the fingernail, which has a hardness of slightly over 2; the hardness of calcite is 3, and it may be scratched by a copper coin, which has a hardness of slightly over 3; the hardness of chalcopyrite is about 4, and it can easily be scratched by a knife, which has a hardness of 5. The hardness of quartz is 7, and it will readily scratch glass. The hardest mineral known is diamond, which tops the scale at 10.

The specific gravity of a mineral is its weight compared to the weight of an equal volume of water. Most of the nonmetallic minerals, such as quartz, feldspar, and calcite, have specific gravities of about 2.7; whereas the metallic minerals, such as pyrite, have specific gravities of about 5.0.

Luster is the appearance (independent of color) of the surface of a mineral in reflected light. Common subdivisions of luster are:

Metallic - having the hard appearance of a metal, as in pyrite.

Vitreous - having the luster of glass, as in quartz.

Greasy - having the appearance of being covered with a thin film of oil, as in serpentine.

Silky - having the appearance of silk, as in asbestos.

Resinous - having the appearance of resin, as in sphalerite.

The color of a mineral may be an important physical characteristic, and, of course, it is the first feature noticed by a person in the field. A prospector should recognize that many secondary minerals exhibit a display of bright colors which may be guides in the search for more valuable ores.

The streak of a mineral is its color in powdered form. This streak is usually obtained by rubbing the mineral over a piece of unglazed porcelain known as a streak plate. It should be noted that the streak of a mineral is not always the same as the color of the massive specimen.

Fluorescence is the characteristic of some minerals to become luminous when exposed to ultraviolet light. To observe this fluorescence, the test must be carried out in a darkened room, using an ultraviolet source of light, such as a Mineralight. Common minerals that fluoresce are scheelite, willemite, some forms of calcite, and some secondary uranium minerals such as autunite and schroeckingerite.

Magnetism is the property of a mineral to be attracted to a magnet. Two common magnetic minerals encountered in the field are magnetite and pyrrhotite. (All minerals containing iron become magnetic upon being heated.)

TABLE 5.—ORES AND TYPICAL HOST ROCKS

| Enclosing Rock | Ores | Nature of deposit |
|---|---|---|
| Granite or along granite contacts | Tin, tungsten, molybdenum, copper, uranium | Veins and contact deposits |
| Granite and granite porphyry | Copper, molybdenum ....... | Disseminated deposits |
| Rhyolite and andesite | Gold, silver ............. | Fissure veins |
| Gabbro ............ | Nickel, cobalt, platinum, copper | Replacement veins |
| Peridotite ........ | Chromium, iron, titanium | Magmatic segregations |
| Sandstone ......... | Uranium .................. | Lenses of carnotite (Colorado Plateau type) |
| Sandstone ......... | Mercury .................. | Veins in sedimentary rocks near volcanic rocks |
| Shale and argillite | Lead, zinc, silver ....... | Veins |
| Shale and argillite | Coal beds, manganese, iron | Bedded deposits |
| Limestone ......... | Lead, zinc, silver, copper, gold, and other metallics | Replacement deposits, veins, and contact deposits |
| Limestone ......... | Nonmetallics such as fluorspar, barite | Bedded deposits |
| Pegmatite ......... | Lithium, beryllium, mica | Pegmatite dikes |
| Sand and gravel ... | Placer minerals .......... | Alluvial deposits |
| Sand and gravel ... | Sand and gravel .......... | Alluvial deposits |

## Chemical Classes of Minerals

Minerals occur in several classes of chemical compounds. The most common of these, and the ones of particular interest to the prospector, are the following:

<u>Sulfides</u> - combinations of the element sulfur with various metals. Common examples are pyrite ($FeS_2$), iron sulfide; galena ($PbS$), lead sulfide; and chalcopyrite ($CuFeS_2$), copper iron sulfide.

<u>Oxides</u> - combinations of oxygen with various elements. Common examples are chromite ($FeCr_2O_4$), iron, chromium oxide; and hematite ($Fe_2O_3$), iron oxide. Pitchblende, a complex uranium compound, is also an oxide.

<u>Carbonates</u> - a group of minerals that contain the carbonate radical $CO_3$ (a combination of carbon and oxygen). Common examples are calcite ($CaCO_3$), calcium carbonate; and malachite ($Cu_2CO_3[OH]_2$), hydrated copper carbonate.

<u>Silicates</u> - combinations of silicon and oxygen with various elements such as sodium, potassium, magnesium, calcium, aluminum, and iron. Common examples are the feldspar group, the amphibole group, and the pyroxene group.

In addition to those listed, other chemical compounds are the sulfates, tungstates, halides, nitrates, and borates. The uranium prospector will be interested in the vanadates which contain the valuable uranium mineral carnotite, and the phosphates which contain the valuable uranium mineral autunite.

## Radioactive Minerals

The wealth of material published on radioactive minerals makes any attempt at duplication here inadvisable. The uranium prospector is referred to the publications listed in the "Sources of Information" at the end of this report, and particularly to the publications of the U. S. Government Printing Office.

# ORE DEPOSITS

## Economic Nature of an Ore Body

The commonly accepted definition of an ore is a mineral or combination of minerals, either metallic or nonmetallic, that may be mined at a profit. The key to this definition is the word "profit," and a number of conditions relative to a mineral deposit must be considered before it can be classified as ore. These conditions include quantity, quality, location, nature of the mineral, availability of water and power, and, of course, a market. Of these factors, quantity and quality are paramount and cannot be separated. A small quantity of high-grade mineral does not constitute an ore body, nor does a large quantity of extreme low grade. The conditions must balance so that the material classified as ore will yield a tonnage that may be mined at a profit over a period of years.

In addition to quantity and quality, location is of prime importance, particularly in the Western States. A mineral deposit in the high Cascades may be classified as waste, whereas a deposit of the same character located at sea level could be classified as an ore body.

Before World War II, the prices of metals generally followed business cycles. However, Government price support for strategic minerals has now entered the field, and in some instances ore bodies have been "created" from what were previously low-grade sub-ores.

TABLE 6.--HYDROTHERMAL VEIN CLASSIFICATION 1/

| Zone | Structure | Texture | Common ore minerals | Gangue minerals | Pressure at time of formation | Way formed |
|---|---|---|---|---|---|---|
| Epithermal veins formed at shallow depth | Veins occur as branches, irregular pipes | Very fine grained, or coarse with comblike structure | Cinnabar, native gold and silver, tellurides, stibnite | Quartz, some carbonates, realgar, and orpiment | Low | Essentially by filling of open spaces |
| Mesothermal veins formed at medium depths | Flat veins, massive sulfide veins | Medium-grained | Simple sulfides (galena, sphalerite, chalcopyrite), uraninite | Quartz, carbonates | Moderate to high | Both fill and replacement |
| Hypothermal deep vein zone | Veins occur in lenses | Coarse-grained | Pyrrhotite, cassiterite, scheelite and wolframite, nickel and cobalt minerals | Quartz, silicates, tourmaline | High | Essentially by replacement |

1/ Adapted from Lindgren, Waldemar, 1928, Mineral Deposits: McGraw-Hill.

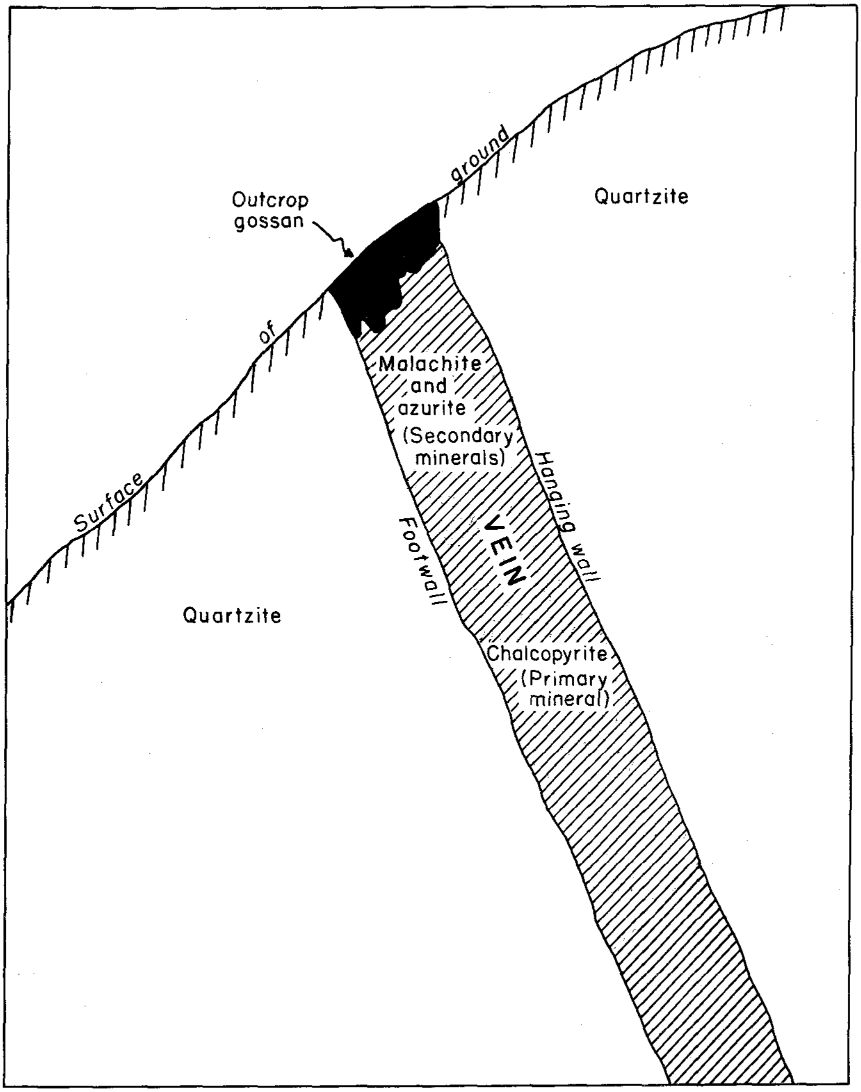



FIGURE 2.—CROSS SECTION OF HYDROTHERMAL VEIN

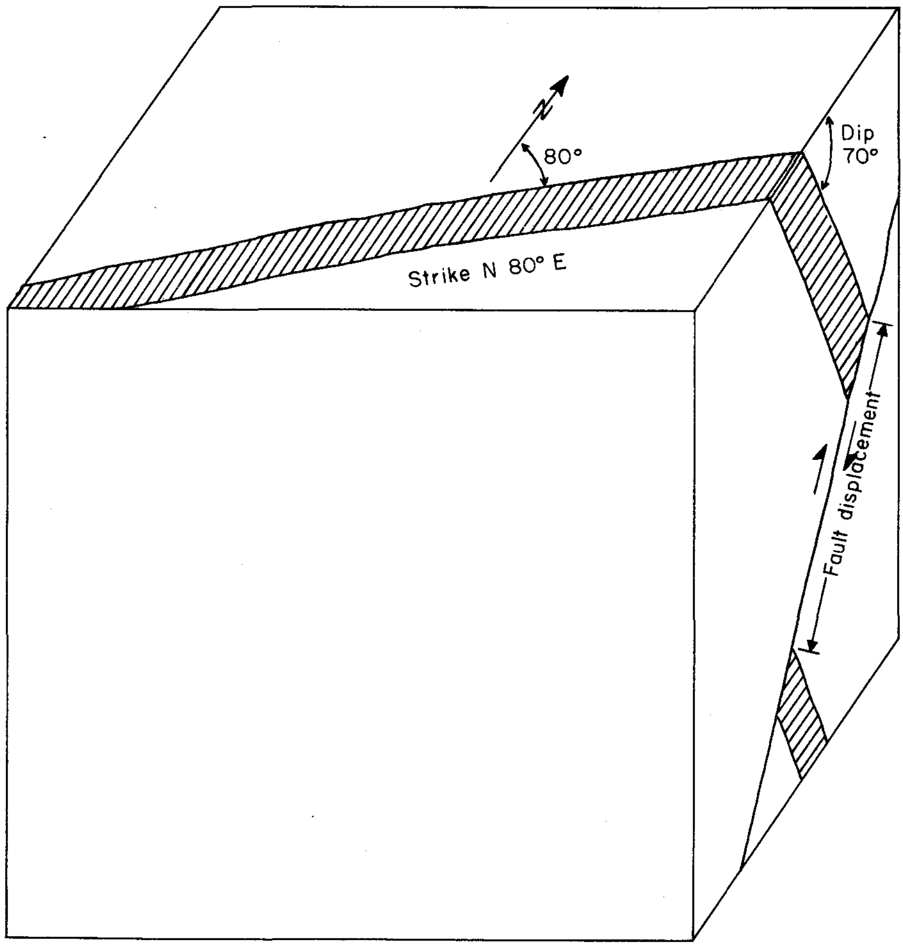



FIGURE 3.— BLOCK DIAGRAM OF A FAULTED VEIN

The concentrates of the metallic minerals, such as copper, lead, and silver, have a constant market in the custom smelters of the West. Nonmetallics, such as fluorspar, on the contrary, do not have an unfailing market, and their bulk makes nearness to industrial markets an important factor.

## Physical Nature of an Ore Body

Metallic ore deposits of a type common in the Western States are those formed by hydrothermal (hot-water) solutions. These hot-water solutions containing ore minerals originate at depth as emanations from a cooling magma. They migrate into the surrounding rock, following fissures, fault zones, and planes of weakness to deposit the minerals as veins and disseminated deposits. These deposits may or may not extend to the surface of the earth. They have certain properties as noted on the vein classification table (table 6), depending upon the heat and pressure at which they were formed.

All veins may undergo some alteration. Common primary iron-bearing minerals, such as pyrite, will become oxidized by circulating ground waters and form secondary minerals. The oxidized outcrop is referred to as a "gossan."

The depth of the oxidized zone, which depends on previous climatic conditions and ground water level, may be only a few feet, as commonly found in western Washington, or it may be more than 100 feet, as found in the Southwest. Leaching may have deprived the oxide, or weathered, zone of all valuable minerals. If the conditions of oxidation were not extreme, secondary minerals may be found that in themselves do not constitute valuable ores. These may, however, indicate the presence of valuable ores in the primary zone at depth. Malachite, a secondary copper carbonate usually of limited value, may indicate the presence of chalcopyrite, a primary copper sulfide, at depth.

The importance of gossan to a prospector cannot be overestimated. In all areas, regardless of whether the oxidation has been extreme or limited, the gossan from a metallic ore deposit will stand out prominently and is one of the best field guides that an individual can use.

A common fallacy to which many prospectors adhere is that of always assuming that values will increase as the deposit is explored at depth. In certain instances, such as in a leached outcrop, this is true; however, if primary sulfides are found on or near the surface, it is wise to assume that the values thus encountered probably will not increase at depth.

Other common types of ore bodies are the lead-zinc replacements in limestone, magmatic segregations, and bedded nonmetallics. Table 5 lists the more important types of deposits, the metals found in them, and their host rocks. A distinct rock formation, which is not a vein but which can be similar to a vein in appearance, is the pegmatite dike. Pegmatites are usually granitic and are generally considered to have been formed during the final stages of solidification of a magmatic mass. They are characterized by large sheets of mica and other crystals, usually quartz and feldspar, which sometimes grow to extremely large sizes. Pegmatites may contain the lithium mineral spodumene and the beryllium mineral beryl, as well as a series of rare earth minerals.

## Placer Deposits

Mining of placer gold within the continental United States has decreased to such an extent that its contribution to the over-all production of gold is small. However, there is still some placer gold produced in the Northwest, and of course the importance of placers in Alaska need not be emphasized. The importance of other placer minerals, on the contrary, has increased. Those of strategic importance which may be found in Washington are underlined in table 7.

TABLE 7.—COMMON PLACER MINERALS

| Mineral | Associate minerals | Type of original rock | Ore of: |
|---|---|---|---|
| Gold (and silver) | Magnetite, quartz, garnet, zircon, mica, ilmenite, cassiterite | Varied ......... | Gold |
| Platinum ..... | Magnetite, other minerals of the platinum group | Basic intrusives | Platinum |
| Cassiterite .. | Wolframite, tourmaline, topaz | Granitic ....... | Tin |
| Ilmenite (oxide of titanium) | Magnetite ............... | Basic igneous .. | Titanium |
| Rutile (oxide of titanium) | Magnetite ............... | Pegmatites ..... | Titanium |
| Diamond ...... | Ilmenite, chromite ....... | Ultrabasic igneous | Diamonds |
| Monazite sands | Magnetite, ilmenite, garnet, zircon | Granitic ....... | Rare earth elements |
| Scheelite and wolframite (oxides of tungsten) | Cassiterite and others ... | Granitic ....... | Tungsten |
| Magnetite (oxide of iron) | Varied .................. | Igneous—varied | .......... |
| Chromite ..... | Magnetite, ilmenite ...... | Basic igneous .. | .......... |
| Cinnabar ..... | Varied .................. | Wide range but usually near volcanics | Mercury |

There are many types of alluvial deposits found throughout the world, but, regardless of the deposit, the minerals all have the following characteristics: They are heavy, relatively hard, and resistant to chemical action (weathering).

Alluvial deposits are formed by the weathering of a mineral-bearing rock at an elevation above stream level, the weathered material being transported by water and gravity to a stream bed, where it is sorted and deposited within the sand and gravel of the river beds.

The presence of placer deposits indicates that there have been (or now exist) mineral-bearing zones in the vicinity. However, it does not necessarily imply that these mineral zones are rich ore bodies. They may have been small veinlets and values contained within the country rock, and these values may have been concentrated over a long period of time to produce the stream deposits that now exist. Despite this possibility, the presence of free gold or any other valuable mineral found in even small quantities as a placer deposit is certainly sufficient evidence to warrant investigation of the upstream valley walls and floor for lode deposits.

Placers may be variously classified as stream, bench, lake, residual, and beach, but with the exception of residual and beach, all placers have similar origins. Many deposits which have been of interest are those that are located along major rivers and on or near beaches, and that contain heavy metallic minerals such as ilmenite and chromite associated with magnetite.

## SAMPLING AND EVALUATION

### Lode Sampling

Undoubtedly the most important action facing a prospector after his discovery is the intelligent sampling of the outcrop. It is an unfortunate but frequent happening that the correct method of procedure is not known. Faulty sampling will show values far in excess of average values. Such a practice will give the prospector a false impression of his findings and subsequent discouragement in future exploration.

It is impossible to find an ore body that is homogeneous. Deposits may contain sections that are high grade, sections that are low grade, and sections that are barren of values and contain only gangue minerals, such as quartz and calcite. Handpicked samples of primary sulfides from an outcrop will obviously give high results; also, handpicked samples from a free-milling gold ore can yield fabulously high values in dollars or ounces per ton, but the sampler would probably have difficulty in finding a ton of such ore.

Most ore bodies and veins are very irregular in nature, making it imperative that the sample be cut by taking a uniform amount of material over its entire length. This is accomplished by using a prospector's pick or a 4-pound hammer and moil. An illustration of a typical sample is shown in figure 4.

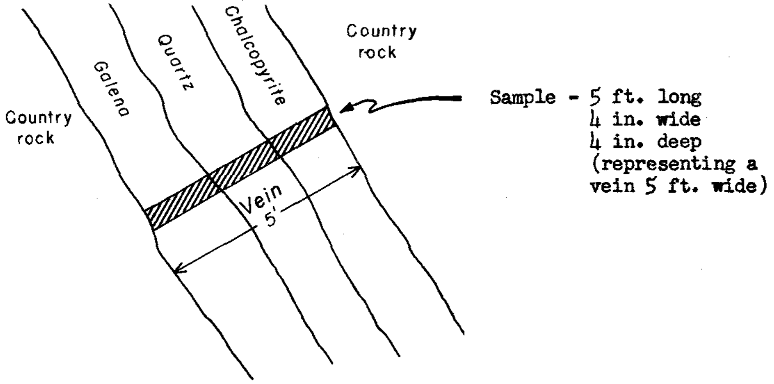
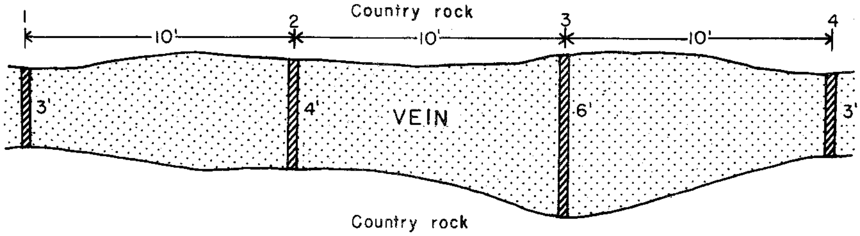



FIGURE 4.—VERTICAL SECTION OF VEIN

The actual quantity or weight of material taken will depend on several factors, such as the nature of the ore and the width of the zone. However, it is common procedure to take 1 pound of ore for each foot of sample length; thus, a 5-foot sample should weigh approximately 5 pounds.

Hydrothermal veins are usually formed by a series of depositions ranging from the introduction of the original barren gangue minerals to the final appearance of the precious metals. The gangue minerals must have fractures and openings to provide access for the valuable constituents to follow. These fractures, and hence the values, follow a rough pattern parallel to the dip of the vein. For this reason it is essential that all samples be cut at right angles to the dip, particularly if the dip is less than 45°.

In addition to the need for proper technique in sampling, it is necessary that the results obtained from the assays be combined in the proper proportion depending on the weight or importance that they bear to the outcrop as a whole. The length of the sample (or width of zone represented) is of obvious significance, and a typical illustration of combining width and value is shown in figure 5.




Plan view of outcrop showing width of samples

| Sample no. | Interval (feet) | Width sampled (feet) | Value in Cu (percent) | Value X width |
|---|---|---|---|---|
| 1 | 10 | 3 | 7 | 21 |
| 2 | 10 | 4 | 5 | 20 |
| 3 | 10 | 6 | 4 | 24 |
| 4 | 10 | 3 | 6 | 18 |
| | | 16 | | 83 |

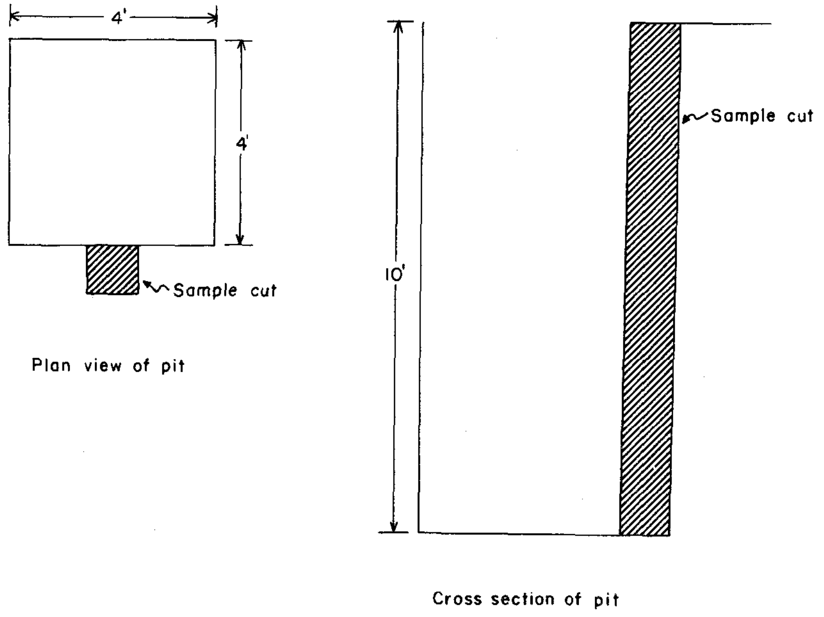
16 ÷ 4 = 4 ft. ave. width   83 ÷ 16 = 5.6% Cu

FIGURE 5.—EVALUATION OF OUTCROP

## Placer Sampling

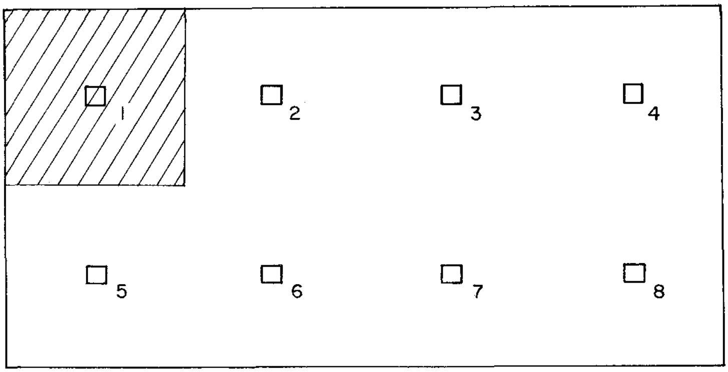
Placer deposits are sampled by using a churn drill in deep or water-bearing ground or by using test pits or augur holes in shallow dry deposits. In a gold placer, the products from the hole or pit are concentrated at the site and the actual determination of the gold content is made in the field. On the contrary, for a placer being evaluated for chromite, ilmenite, or similar minerals, the products from the hole or pit are dried, reduced in size by coning and quartering or otherwise splitting, and the reduced sample is sent to the laboratory for assay.

Regardless of the type of placer deposit the total evaluation should be made, as in lode deposits, giving each sample its proper importance (or weight) that it bears to the whole. The depth of the drill hole, its assay value, and the area of influence are the three most important factors to consider. Test pits or holes should be placed, if possible, at regular intervals. A simple illustration of test pitting a dry shallow sand is shown in figure 6.




(After completing a test pit, the sample should be taken as shown, with a volume not less than half a cubic foot per foot of depth)

FIGURE 6.—TEST PITS FOR PLACER DEPOSITS




Shaded portion is area represented by Pit No. 1

PLAN OF TEST PITS — EXTENDED AREA METHOD

| Hole no. | Depth (feet) | Values in dollars per ton of titanium sands | Value X depth |
|---|---|---|---|
| 1 | 6 | 12 | 72 |
| 2 | 10 | 15 | 150 |
| 3 | 7 | 13 | 91 |
| 4 | 12 | 14 | 168 |
| 5 | 11 | 10 | 110 |
| 6 | 9 | 9 | 81 |
| 7 | 5 | 16 | 90 |
| 8 | 8 | 11 | 88 |
| | 68 | | 850 |

68 ÷ 8 = 8.5 (average depth) 850 ÷ 68 = $12.50 per ton

FIGURE 7.—PLACER EVALUATION

## Diamond Drilling

The use of drills, particularly the diamond drill, for exploration has become standard practice in the mining industry. Ore zones that have strong structural features with good chances of continuity are well suited for diamond drilling. On the contrary, mineralized zones which occur as lenses may not be adaptable to core drilling because of their spotty nature and the large number of holes that would be required to give conclusive results.

The diamond drill is an excellent tool in professional hands. It is used to probe below the surface of the earth for values that, from a geologic study, are believed to be present. The drill should not be used indiscriminately, and should not be used unless qualified personnel are available to direct the work and study the results obtained.

An illustrative example of diamond drill holes is shown in figure 8.

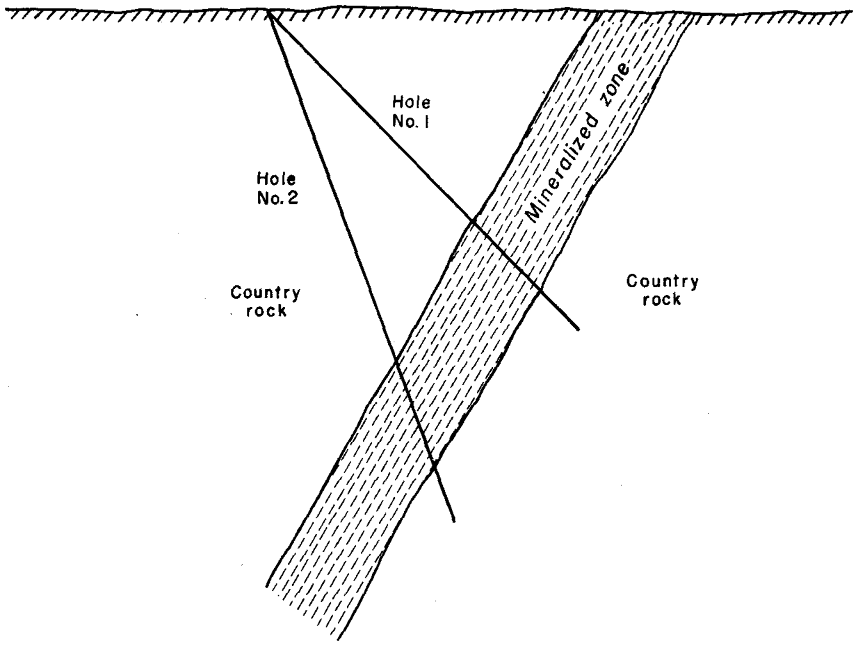



FIGURE 8.— CROSS SECTION SHOWING DRILL HOLES

## MINING LAWS

Mining laws of the State of Washington are well covered elsewhere; 2/ however, for those unfamiliar with the laws, a brief outline of the important points in staking claims is here presented.

A simple classification of areas for prospecting is as follows:

Prospecting on private land

This is accomplished only by negotiation with the owner, and it should be remembered that the surface owner does not always own the mineral rights.

Prospecting on State lands

This is accomplished by obtaining a prospecting permit and lease from the State Commissioner of Public Lands, Olympia.

Prospecting on National Forest and Public Domain Land

These lands are the only lands open to legitimate prospecting and claim staking without prospecting permit or other restriction. It is here that the prospector has his best opportunity.

The steps in staking a lode claim are as follows:

(1) Make a discovery of mineral in place.

(2) Dig discovery pit or do equivalent work of exposure along the outcrop.

(3) Post location notice at discovery point.

(4) Stake out the corners with posts at least 4 in. by 4 in. and 3 ft. above the ground, marked with the name of the claim and the date of location.

(5) Record the notice of location at the office of the county auditor of the county in which the claim is situated within 90 days from the date of discovery.

Notice of Location forms are available from stores that handle stationery and drafting supplies.

Annual assessment work, unless suspended by the Government in times of emergency, must be performed yearly for each unpatented lode mining claim. This annual assessment work consists of $100 worth of improvement for each claim and may be in the form of road building, trenching, diamond drilling, or other similar work which will benefit and improve the claim. Upon completion of assessment work, which must be performed before September 1st, an affidavit of performance must be recorded within 30 days at the office of the county auditor of the county in which the claim is located.

Under certain conditions, mining claims may be purchased (or patented) from the Government. Details of this will be found in Bulletin No. 41 of the Washington Division of Mines and Geology.

Mining claims may be staked in National Forest or Public Domain land by all United States citizens or those who have declared their intention of becom-

2/ Washington Div. Mines and Geology Bulletin No. 41, An outline of mining laws of the State of Washington, compiled by Morton H. Van Nuys.

ing citizens. There is no limit to the number of claims an individual or group may stake, provided that all legal requirements are fulfilled. The dimensions of a full-size lode claim are 1,500 ft. by 600 ft., and the dimensions of a placer claim are 1,320 ft. by [redacted] 660 ft. (or 20 acres). An illustration of a lode claim is shown below:

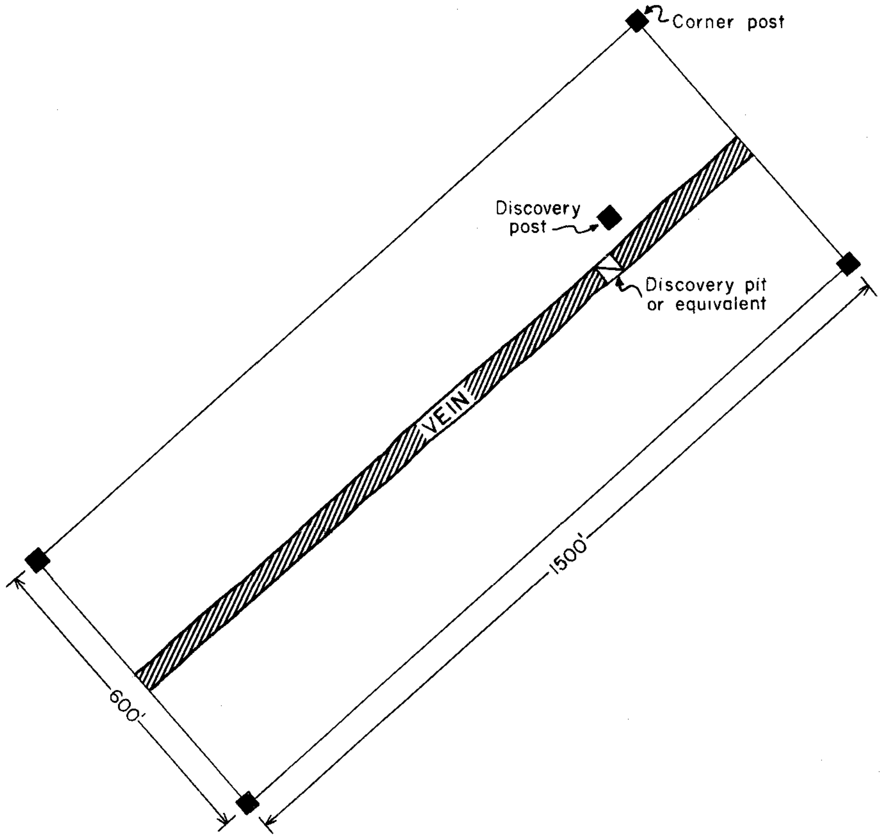



FIGURE 9.—PLAN VIEW OF A LODE CLAIM

## DISPOSAL OF MINING CLAIMS

It has been stated that after a prospector has made a "strike" his problems are just beginning. There may be some truth to this statement; however, after a seeker has made what he considers a good find and has evaluated his find by systematic sampling, he should have no difficulty in bringing it to the attention of interested parties. Mines are developed and brought into production by individuals, syndicates, and mining companies. The capital investment required today for developing large mines and installing plant and equipment is so great that only a corporation is capable of its undertaking.

It should be stressed to all who attempt to dispose of a prospect that unless they themselves have invested in sampling, diamond drilling, and other evaluation, the only thing they have to offer is a prospect. All too frequently the prospector will attempt to put too high a price on his holdings without realizing that the mining company must spend thousands of dollars in preliminary work without any assurance of success.

The Federal Government, through the Office of Minerals Exploration, provides assistance for some properties in the form of participation loans for carrying out exploratory work for strategic minerals. The applications for such loans are carefully studied, and an examination of the company, mine, and area is made by the U. S. Geological Survey and the U. S. Bureau of Mines, who administer the program.

There is no program whatsoever whereby the government, either Federal or State, actively engages directly in mining for strategic or nonstrategic minerals. The business of mining is left entirely to private enterprise.

## CONCLUSION

A major hindrance to prospecting in Washington is the mountainous topography and heavy overburden, particularly west of the Cascade Mountains. The State is well situated with respect to shipping and to custom smelting of copper, lead, and zinc. With the growth of new industry, the demand for nonmetallic minerals will increase. New roads are probing into the mountains, and as communication improves, the opportunities for successful mineral finds are definitely improving.

SOURCES OF INFORMATION

| Source | Publisher | Type of information |
|---|---|---|
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| Minerals and How to Study Them, by E. S. Dana and C. S. Hurlbut, Jr. | John Wiley & Sons New York City | Minerals and mineralogy |
| Rocks and Minerals, by H. S. Zim and P. R. Shaffer (Golden Nature Guide) | Simon and Schuster New York City | Rocks and minerals |
| Handbook for Prospectors and Operators of Small Mines, by M. W. von Bernewitz | McGraw-Hill New York City | General information for prospectors |
| Prospecting for Gold and Silver, by Eros M. Savage | McGraw-Hill New York City | General information for prospectors |
| Small Scale Placer Mining, by D. L. Masson | Washington State Institute of Technology, State College of Washington, Pullman Wash. | Placer mining and prospecting |
| An Outline of Mining Laws of the State of Washington, by M. H. Van Nuys | State Division of Mines and Geology, 335 General Administration Bldg., Olympia, Wash. | Mining laws |
| Uranium in Washington | State Division of Mines and Geology, 335 General Administration Bldg., Olympia, Wash. | Uranium |
| Uranium Ores--Their Occurrence and Detection, by J. W. Crosby III | Washington State Institute of Technology, State College of Washington, Pullman, Wash. | Uranium |
| Minerals for Atomic Energy, by Robert D. Nininger | D. Van Nostrand Co., Inc. New York City | Uranium and associated minerals |
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| Prospecting With a Counter | U. S. Government Printing Office, Washington 25, D. C. | Uranium |
| Facts Concerning Uranium Exploration and Production | U. S. Government Printing Office, Washington 25, D. C. | Uranium |
| Uranium in the Northwest, by L. D. Jarrard and W. S. Moen | Jarrard & Moen, P. O. Box 136, Butte, Mont. | Uranium |

| Source | Publisher | Type of information |
| --- | --- | --- |
| Washington Division of Mines and Geology | 335 General Administration Building, Olympia, Wash. | Reports on geology and mining in Washington. Identification of samples |
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| List of publications of the U. S. Bureau of Mines | U. S. Government Printing Office, Washington 25, D. C. | An index of all publications of the Bureau |
| U. S. Atomic Energy Commission | P. O. Box 1805, Spokane, Wash. | Radioactive minerals |
| U. S. Bureau of Land Management | 680 Bon Marche Bldg., Spokane 1, Wash. | Patented mining claims |
| County Auditor | County Seat | Unpatented mining claims |
| Mining World | 500 Howard Street, San Francisco 5, Calif. | Monthly mining magazine |
| Engineering and Mining Journal | 330 West 42nd Street, New York 36, N. Y. | Monthly mining magazine. Prices for metals and minerals |
| Western Miner and Oil Review | 505 Metropolitan Bldg., 837 West Hastings St., Vancouver, B. C. | Monthly mining magazine |
| British Columbia Department of Mines | Victoria, B. C. | Canadian mining |
| Canadian Department of Mines and Technical Surveys | Ottawa, Ontario | Canadian mining |