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PROSPECTING FOR URANIUM, THORIUM, AND TUNGSTEN IN IDAHO

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FOREWORD

The treatise of this pamphlet, titled "Prospecting for Uranium, Thorium, and Tungsten in Idaho" has been prepared by Dr. Earl Ferguson Cook, Head of the Department of Geology and Geography, University of Idaho.

The Idaho Bureau of Mines and Geology is pleased to issue this material because of its scope and timeliness. It is felt that Dr. Cook's contribution will be of particular usefulness to anyone searching for radioactive and other important more or less allied substances in Idaho.

J. D. Forrester, Director

Idaho Bureau of Mines
and Geology

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Figure 1

Idaho mountains beckon the prospector.

Photograph of newly discovered
Wildhorse Creek tungsten area,
Custer County.

PROSPECTING FOR URANIUM, THORIUM, AND TUNGSTEN IN IDAHO

TABLE OF CONTENTS

Page

Page

TABLE OF ILLUSTRATIONS

INTRODUCTION

Deposits of uranium, thorium, and tungsten have been found in many places in Idaho. In April, 1955, the first shipment of uranium ore in Idaho was made from a deposit a few miles south of Salmon. A commercial placer deposit of uranium minerals, principally euxenite, may soon be yielding uranium from Bear Valley; exploration is proceeding on promising uranium deposits in Lemhi and Blaine Counties; and new deposits are being found by energetic prospectors. Thorium, which may soon become of great value in the atomic energy program of the nation, is being produced as a by-product in the processing of Idaho placer monazite for its rare earth content and may soon be produced from vein deposits of thorite near Lemhi Pass. Idaho has for a number of years been among the leading tungsten-producing states of the Union, and many new deposits of this metal have been discovered in the last few years.

Designed as an aid to Idaho prospectors, this report summarizes the present knowledge of the occurrence of uranium, thorium, and tungsten in Idaho and suggests certain guides to prospecting based on the general geology of the state and the detailed geology of known deposits. Although the general geology and mineralogy of such deposits can be found in such publications as Prospecting for Uranium (1951), U. S. Atomic Energy Commission and U. S. Geological Survey, Minerals for Atomic Energy by R. D. Nininger (1954), Tungsten Mineralization in the United States by P. F. Kerr (1946), and various textbooks, descriptions of the more common uranium, thorium, and tungsten minerals and the types of deposits in which they are found are given here for the convenience of users of this pamphlet.

Why has tungsten been included with the radioactive metals uranium and thorium? Because all three are of strategic importance to the nation, undiscovered deposits of all three undoubtedly exist in Idaho, and the minerals of all three may be prospected for at the same time. The minerals of these metals (none of which occurs as the native metal in nature) were largely unknown to, or overlooked by the early day prospector; even if he had known about them, he would have had a hard time locating them without modern detection devices such as the Geiger counter and the ultra-violet lamp. Minerals of uranium, thorium, and tungsten may occur together in the same area, and do so occur in at least three Idaho localities.

In prospecting for uranium, the possibility of locating valuable deposits of other metals should not be overlooked. Not only are primary uranium minerals usually found with other metallic minerals, but recent research (Gross 1952) indicates that radioactivity in and around granitic rocks can serve as a useful guide to ore deposits of gold, silver, cobalt, and other metals. Many of the vein deposits in which uranium has been found are in parts of ore structures that have been prospected mainly for metals other than uranium. Not only are the chances favorable that some large uranium deposits in the northwestern United States await the industrious prospector but, in the search for uranium, hitherto unknown deposits of other valuable metals may be uncovered.

The author is especially indebted to three people for their assistance in the preparation of this pamphlet: Harold Powers of the Idaho Bureau of Mines and Geology; Paul Weiss of the U. S. Geological Survey, and Dr. William Baker of the Botany Department, University of Idaho.

GEOLOGY OF URANIUM, THORIUM, AND TUNGSTEN

MINERALOGY

There are 90 different minerals in which uranium or thorium are major constituents and 40 more in which these elements are minor constituents. Fortunately for the prospector, most of these 130 minerals are not known to occur in commercial quantities; in other words, there are only a few real ore minerals of uranium and thorium. Of the 17 known tungsten minerals only five or six are of commercial importance.

A mineral is a naturally occurring substance with a characteristic internal structure, and with a chemical composition and physical properties that are either fixed or that vary within a definite range. A knowledge of the characteristic physical properties of minerals (color, hardness, form, cleavage, luster, specific gravity or unit weight, fluorescence and radioactivity) is indispensable to the prospector. In addition, he should know what other minerals are commonly associated with the ore minerals he is searching for, and what rocks and types of deposits they are ordinarily found in.

Physical properties of minerals

Color

The color of minerals is one of their most important physical properties. However, as a means of identification, it must be used with some caution, for minute amounts of impurities or surface alteration may greatly change the characteristic color of a mineral. An example is calcite (the mineral of which limestone is composed), the color of which may range from white to almost black. Nevertheless, in the case of many minerals color is a definite and constant property and will serve as an important means of identification.

Hardness

The hardness of a mineral may be described as its ability to scratch some other substance. Minerals vary widely in their hardness, and determination of the degree of hardness of a mineral is an important aid in its identification. It must be realized that minerals are apt to alter or to be associated with harder or softer minerals and that the apparent hardness may not be the true hardness. Brittle minerals and granular aggregates of minerals may break or crush, making the hardness seem lower than it is. A series of minerals has been chosen as a scale by comparison with which the relative hardness (H) of any mineral may be determined. The scale is as follows, each mineral being harder than those preceding it in the scale.

Hardness	Mineral
1	TALC
2	GYPSUM
3	CALCITE
4	FLUORITE
5	APATITE
6	FELDSPAR
7	QUARTZ
8	TOPAZ
9	CORUNDUM
10	DIAMOND

A few other standards of hardness are: fingernail (H 2.5), copper penny (H 2.5-3), knife blade (H 5), and window glass (H 5.5).

Form

Most minerals have characteristic external shape and form. If crystalline, the individual crystals will have a definite shape (cube, pyramid, prism, etc.) and groups of crystals may have characteristic form (radiating, globular, etc.). Non-crystalline or extremely finely crystalline mineral matter may be compact, banded, etc. When a mineral is composed of compact material with irregular form and does not show any peculiar structure, it is said to be massive.

Cleavage and fracture

Cleavage is the tendency for a mineral to break in certain directions, yielding more or less smooth flat surfaces which reflect light. Some minerals cleave only in one direction, others in two or three directions. However, not all minerals show cleavage. The quality or perfection of the cleavage, the number of directions and their angular relationships are often important aids in the identification of a mineral. Minerals which do not cleave break by fracturing, and the nature of the fracture may be useful in identification. When the fracture has smoothly curved, shell-like surfaces it is said to be conchoidal. When the mineral breaks with rough and irregular surfaces, the fracture is said to be uneven.

Luster

The luster of a mineral is the quality and brilliance of light reflected from its surface. Some of the common terms applied to the luster of minerals are as follows:

Vitreous	----- like glass
Metallic	----- having the appearance of a metal
Resinous	----- having the appearance of resin
Pearly	----- having the iridescent appearance of a pearl
Greasy	----- looking as if covered with a thin layer of oil
Dull or earthy	----- reflects little or no light.

Specific gravity

The specific gravity (G) of a mineral is a number which expresses the ratio existing between its weight and the weight of an equal volume of water. The specific gravity of a mineral which does not vary in its composition is a constant factor, the determination of which is frequently an important aid to its identification. The specific gravity of the common minerals of uranium, thorium, and tungsten ranges from 3 to 10. After a little experience one can judge quite accurately the specific gravity of a mineral by hefting it in the hand. As references, the specific gravities of the following minerals may be of use: quartz, 2.65; pyrite, 5; galena, 7.5; pure silver 10.5 (silver coin, about 10.3).

Fluorescence

Fluorescence is the ability of a mineral to emit visible light when acted upon by ultra-violet (invisible, "black" light) rays. Autunite is the only important uranium mineral which fluoresces brightly. The scheelite-powellite series of tungsten minerals fluoresce vividly, and the ultra-violet lamp is the most useful tool in prospecting for them.

Radioactivity

All minerals which contain uranium or thorium spontaneously emit small particles or rays; this process is called radioactivity and may be detected by means of special instruments, two of which are called Geiger counters and scintillation counters. None of the tungsten minerals are radioactive.

Identification and classification of ore minerals

As an aid to field identification, the chemical composition, physical properties, and geologic associations of each of the more important minerals of uranium, thorium, and tungsten are listed below. Unfortunately, some minerals, especially when mixed with impurities or when in extremely small particles, can be identified only by chemical analysis or microscopic examination. The Idaho Bureau of Mines and Geology maintains a mineral identification laboratory at Moscow, where those specimens may be sent which defy field identification methods.

Ore minerals are divided by geologists into two classes: primary and secondary. The primary ore minerals are those that have been formed by heated (hydrothermal) solutions coming from within the earth. Secondary minerals are those that have been formed by the alteration of primary minerals through the action of surface weathering, ground water, or other natural processes.

Important uranium minerals

Pitchblende (Uraninite)

Uranium oxide, UO_2; 50-85 percent U_3O_8. Color, black (may be grayish or greenish). H, 5 to 6. G, 6 to 9 (pitchblende); 8 to 10 (uraninite). Luster, submetallic or glassy to pitch-like or dull. Form: massive, may show rounded surfaces and banding (pitchblende); massive or in small grains or crystals (uraninite). Uneven and conchoidal fracture. Does not fluoresce. The only important primary uranium mineral. Found in veins, commonly with the sulphides of cobalt, nickel, silver, and bismuth; also in pegmatites; and in bedded sandstone deposits with a variety of copper and uranium minerals. Uraninite is the crystalline form of pitchblende.

Carnotite

Potassium uranium vanadate, $K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$; 50-55 percent U_3O_8. Color, bright yellow to greenish yellow. H, 2 to 3. G, 4 to 5. Luster, commonly earthy; crystals are pearly. Form: earthy masses and thin coatings. Perfect cleavage in one direction. Does not fluoresce. A secondary mineral, probably formed by the action of ground water on primary uranium minerals. Found chiefly in the Colorado Plateau region where it forms irregular, soft, earthy deposits and coatings on quartz grains in sandstone beds. Associated with other secondary uranium and vanadium minerals.

Autunite

Calcium uranium phosphate, $Ca(UO_2)_2(PO_4)_2 \cdot 10\text{-}12\ H_2O$; 60 percent U_3O_8. Color, lemon yellow to apple green. H, 2 to 3. G, 3. Luster, pearly. Form: in small, square, rectangular, or octagonal flat, translucent crystals; flaky, like mica; or earthy. Perfect cleavage in one direction. Fluoresces brilliant yellow or apple green. A common secondary uranium mineral which partially fills or coats fractures and cavities in many types of rocks. Found in the oxidized zones of vein and pegmatite deposits.

Torbernite and meta-torbernite

Copper uranium phosphate, $Cu(UO_2)_2(PO_4)_2 \cdot 8\text{-}12\ H_2O$; 60 percent U_3O_8. Color, bright emerald green to apple green. H, 2 to 3. G, 3 to 4. Luster, pearly. Form: in small, flat, square transparent crystals; or soft micaceous masses. Cleavage in two directions. May fluoresce faint green.

The most common of the secondary uranium minerals in the oxidized zone of primary deposits, especially those associated with copper minerals.

Uranophane

Calcium uranium silicate, $Ca(UO_2)_2Si_2O_7 \cdot 6\ H_2O$; 65 percent U_3O_8. Color, pale greenish yellow to orange yellow. H, 2 to 3. G, 4. Luster, pearly or greasy. Form: finely fibrous or radiating needle-like crystal aggregates or stains and coatings. Cleavage in one direction. No fluorescence or possibly faint green. Occurs as a secondary mineral in veins and pegmatites, in limestone and sandstone, commonly with other secondary uranium minerals. Either autunite or torbernite (or both) is usually found with uranophane.

Tyuyamunite

Calcium uranium vanadate, $Ca(UO_2)_2(VO_4)_2 \cdot nH_2O$; 48-55 percent U_3O_8. Except for a slightly more greenish color and, in some cases, a weak apple green fluorescence, the physical properties and associations of tyuyamunite are the same as those of carnotite, to which it is closely related.

Gummite

A term used for alteration products of uraninite which have not been otherwise identified. Believed to be chiefly uranium oxide with water and lead. Color, variable, commonly yellow, orange, or brown. Forms crusts or soft masses with a conchoidal or uneven fracture. Commonly associated with pitchblende.

Radioactive blacks

The primary uranium minerals, other than pitchblende and uraninite, occur principally in pegmatites and granitic rocks, and in placer deposits. Because all these minerals are dark brown to black in color, and because several of them are commonly found together in placer deposits, they are collectively known as "radioactive blacks." These include the following minerals:

Betafite, an oxide of columbium, titanium, and uranium, $(U,Ca)(Nb,Ta,Ti)_3O_9 \cdot nH_2O$?; may contain 15 to 27 percent U_3O_8.

Brannerite, an oxide of uranium and titanium with calcium, rare earths, thorium and iron, $(U,Ca,Fe,Y,Th)_3Ti_5O_{16}$?; contains 40 percent U_3O_8.

Davidite, a rare earth iron titanium oxide, $Fe^2(Fe^3,Ce)_2Ti_6O_{17}$ plus rare earths and UO_2; may contain 7 to 10 percent U_3O_8.

Euxenite, titanium columbium tantalum oxide with uranium, thorium, and rare earths, $(Y,Ca,Ce,U,Th)(Nb,Ta,Ti)_2O_6$; may contain 1 to 20 percent U_3O_8.

Fergusonite, a columbate-tantalate of the rare earths with minor uranium, $(Y,Er,Ce,Fe)(Nb,Ta,Ti)O_4$; may contain 0 to 8 percent U_3O_8.

Samarskite, a columbate-tantalate of the rare earths, uranium, thorium, calcium, and iron, (Y,Ce,U,Ca,Fe,Pb,Th) $(Nb,Ta,Ti,Sn)_2O_6$; may contain 9 to 19 percent U_3O_8.

These minerals have a hardness of 4 to 7, a specific gravity of 4 to 6, a glassy to submetallic luster, and a conchoidal fracture. They commonly occur in crystals or small grains and they do not fluoresce.

Thorium minerals

All thorium minerals are primary; they do not alter to secondary minerals.

Monazite

Cerium and rare earth phosphate containing thorium, $(Ce,La,Th)PO_4$; 1 to 15 percent ThO_2. Color, golden yellow to reddish brown. H, 5 to 6. G, 4 to 5. Luster, resinous. Form: flattened or tabular crystals, or rounded grains. Good cleavage in two directions. Does not fluoresce. Occurs disseminated in granite, gneiss, and pegmatites; concentrated in placers; and as replacement deposits in metamorphic rocks.

Thorianite

Thorium uranium oxide, $(Th,U)O_2$; 50-90 percent ThO_2; 0-33 percent U_3O_8. Color, black. H, 5 to 7. G, 9. Luster, submetallic, dull, or greasy. Form: small cubes, waterworn in placers. Uneven to conchoidal fracture. Does not fluoresce. Found in placers, pegmatites, granite, and gneiss. Looks like uraninite.

Thorite

Thorium silicate, $ThSiO_4$; 35-70 percent ThO_2; may contain 0-22 percent U_3O_8. Color, black; also reddish-brown, orange, green. H, 4 to 5. G, 4 to 5. Luster, glassy when fresh. Form: small, square, prismatic crystals or massive. Conchoidal fracture. Does not fluoresce. Occurs in placers, disseminated in granite rocks and pegmatites, and in veins.

Allanite

Hydrous silicate of aluminum, calcium, iron, magnesium, cerium, and thorium, $(Ca,Ce,Th)_2(Al,Fe,Mg)_3Si_3O_{12}(OH)$; 0-3 percent ThO_2. Color, dark brown to black. H, 5.5 to 6. G, 3 to 4. Luster, glassy or resinous when fresh. Form: irregular crystals. A minor constituent in pegmatites, granitic rocks, and placer deposits.

Important tungsten minerals

Scheelite

Calcium tungstate, $CaWO_4$; 80 percent WO_3. Color, white, yellow, green, brown. H, 5. G, 6. Luster, vitreous. Form: massive granular or in translucent crystals. Good cleavage. Fluoresces bright bluish white to vivid golden yellow. A small amount of molybdenum in scheelite will change the color of fluorescence to yellow. Scheelite is found in veins and pegmatites but is most common as an ore mineral in high-temperature replacement deposits near granitic rocks (the so-called contact metamorphic deposits) where it is associated with epidote, garnet, quartz, actinolite-tremolite, diopside, etc.

Powellite

Calcium molybdate, $CaMoO_4$, with some calcium tungstate. Scheelite and powellite form a continuous series of minerals, ranging from pure calcium tungstate (scheelite) to pure calcium molybdate (powellite). Actually the end minerals of this series rarely occur; even the first specimen of powellite ever described, from the Seven Devils Mountains in Idaho, was found to contain 10 percent WO_3. By common usage, a scheelite which has a high enough molybdenum content to fluoresce golden yellow is called powellite, although this is not mineralogically correct, for scheelite with only 5 percent included molybdenum will fluoresce the same color as pure calcium molybdate. Powellite (or high-molybdenum scheelite) is soft and powdery, and commonly occurs as small specks or grains rather than distinct crystals. It is usually found in "contact" deposits where it has the same mineral associations as scheelite. Scheelite and powellite do not occur together. If one of the associated minerals is molybdenite, the tungsten mineral will probably be scheelite instead of powellite.

Wolframite group

This is another continuous mineral series ranging from ferberite (iron tungstate $FeWO_4$; 76 percent WO_3) through wolframite (iron manganese tungstate) to huebnerite (manganese tungstate, $MnWO_4$; 77 percent WO_3). Color, black in ferberite to brown in huebnerite. H, 5 to 5.5. G, 7 to 7.5. Luster, submetallic to resinous. Form: in bladed, lamellar, or columnar crystals or massive granular. Perfect cleavage in one direction. Do not fluoresce. Found chiefly in quartz veins and pegmatites. May be associated with cassiterite, scheelite, quartz, arsenopyrite, pyrite, galena, and sphalerite.

TYPES OF DEPOSITS

Uranium deposits

Vein deposits in granitic and metamorphic rocks

Primary vein deposits of uraninite or pitchblende have up to now been the most productive of all the types of uranium occurrences. These veins cut metamorphosed sedimentary and volcanic rocks, as well as granitic rocks. Native silver, fluorite, and minerals containing iron, cobalt, nickel, and copper commonly occur in the veins with the pitchblende. Such vein deposits are of hydrothermal origin, having filled fissures or replaced wall rock along fractures or planes of weakness in the earth's crust. Near the surface the pitchblende is commonly altered to the bright-colored secondary uranium minerals such as uranophane, autunite, and torbernite; sooty or earthy pitchblende may occur in a zone between the unaltered pitchblende and the surficial minerals (Fig. 2).

Vein occurrences of uranium have been found in the Coeur d'Alene mining district; in northern Lemhi County; near Hailey in Blaine County; and near Naples in Boundary County (Fig. 3).

Deposits in sedimentary rocks

Uranium deposits have been found in a variety of sedimentary rocks including sandstone, conglomerate, limestone, shale, lignite (low-grade coal), and phosphate rock. By far the most productive of such deposits are in sandstone; the principal ore mineral is carnotite which is in many places associated with fossil wood and green shale lenses; other uranium minerals which may be present are autunite, torbernite, tyuyamunite, and uraninite. Some of the uranium ore bodies in sandstone are small, irregular masses whereas others are larger, tabular bodies roughly parallel to the bedding of the sandstone.

In the past few years copper-uranium deposits in shale, sandstone, and conglomerate have been discovered in the Colorado Plateau region; the uranium occurs as pitchblende and torbernite, associated with both primary and secondary copper minerals. Recently, pitchblende in sandstone, not associated with copper minerals, has been found in the Plateau region. In South Africa and Canada uraninite occurs in gold-bearing conglomerates.

Low-grade deposits of uranium in black shale, lignite, limestone, and phosphate rock occur over wide areas. In contrast to the typical sandstone deposit, the uranium is spread rather uniformly through an entire layer or bed and is so finely disseminated that it can be discovered and traced only with a Geiger or scintillation counter. The Phosphoria formation throughout southeastern Idaho and lignite beds in Lemhi, Cassia, Twin Falls, and Payette counties contain uranium (Fig. 3).

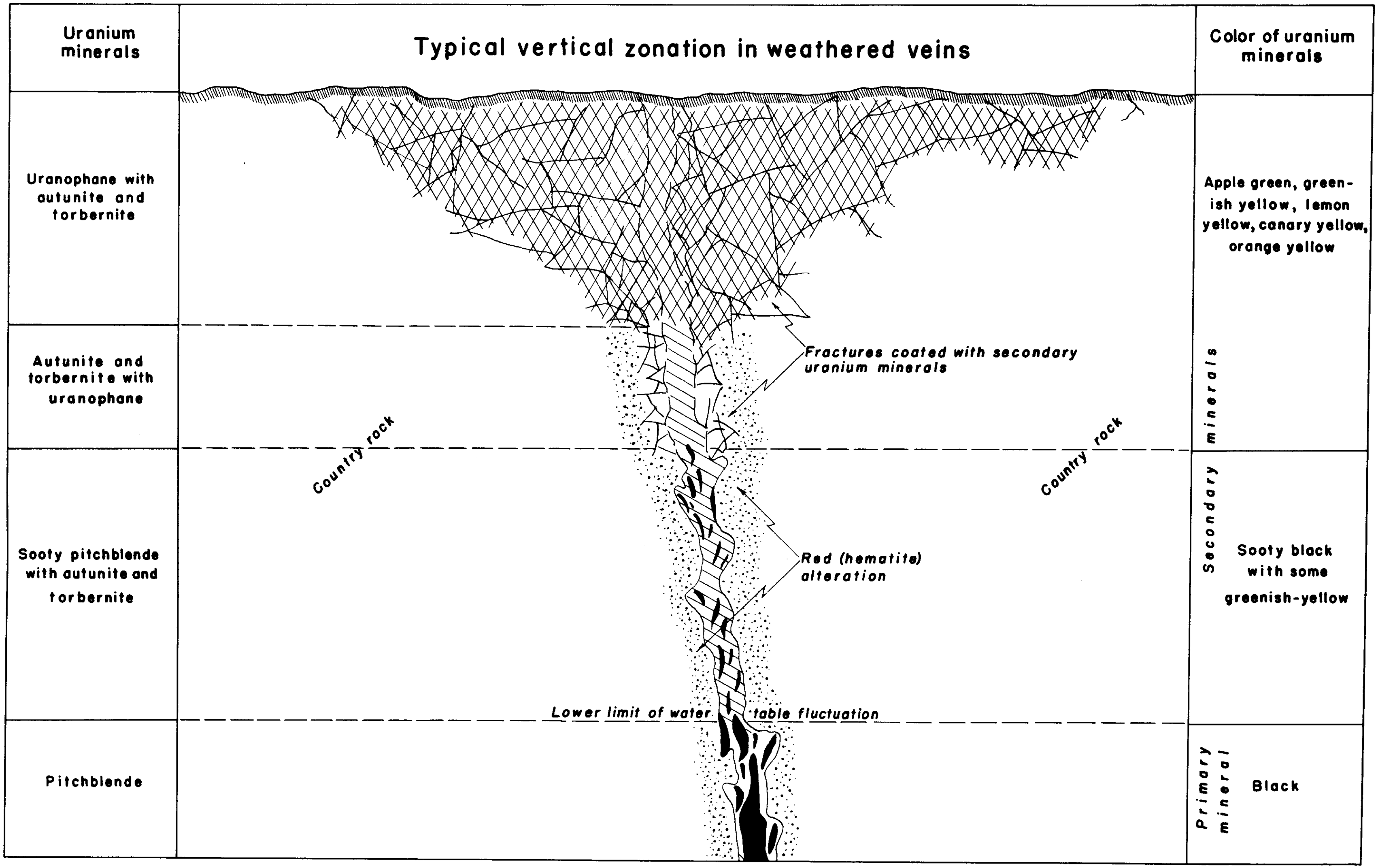

FIGURE 2 -- DIAGRAM SHOWING TYPICAL ZONAL RELATIONSHIPS OF URANIUM MINERALS IN WEATHERED VEINS
Modified from Fig. 14, U.S. Geol. Survey Circular 220.

Deposits in volcanic rocks

In 1951 a deposit of uranium-bearing rhyolitic welded tuff containing veinlets and small irregular pods of higher grade uranium-bearing rock was found near Coaldale, Nevada. Since then, low-grade concentrations of uranium have been found in volcanic rocks in several localities in the southwestern United States.

Early in 1955 a discovery of uranophane in rhyolite of the Challis volcanic formation was made in a road cut about six miles south of Salmon, Lemhi County. The uranium mineral partially fills cavities and small fractures in an iron-stained rock which may be either a rhyolite flow or a consolidated pyroclastic rock. In April of 1955 this deposit yielded the first commercial uranium ore produced in Idaho.

Pegmatite deposits

Pegmatites are coarse-grained, light-colored rocks occurring as lenticular or vein-like deposits in granitic or metamorphic rocks. In simple pegmatites the constituents are those of a granite (feldspar, quartz, and mica) and uranium has not been found in these; in complex pegmatites a great variety of minerals is found, including such primary uranium minerals as uraninite, betafite, fergusonite and samarskite, scattered through the rock. Some uranium has been mined from pegmatites, but most pegmatites contain such a small amount of uranium that they cannot profitably be mined for the uranium alone. Beryl and tourmaline are two of the more common minerals in complex pegmatites.

Samarskite and euxenite occur in pegmatites in Garden Valley, Boise County, and both autunite and meta-torbernite (secondary alteration products of uraninite) have been identified from the mica-bearing pegmatites near Deary, Latah County.

Placer deposits

Because most uranium minerals are not resistant to chemical decomposition and mechanical disintegration, they are rarely found in commercial amounts in placer deposits. Thorium minerals, on the other hand, are frequently found in placers. Most of the monazite placers in Idaho, however, do contain the so-called "radioactive blacks" such as davidite, euxenite, samarskite, fergusonite and brannerite. The best concentration of such minerals so far found is in Bear Valley, Valley County, where the first commercial production in the world of uranium minerals from a placer deposit should commence this year. The minerals in these placer deposits originated in granite and pegmatite, were released by disintegration of the enclosing rock, washed down by streams into the more gently moving portions of those streams, where, because of their greater specific gravity, they were separated from the other minerals and concentrated.

Thorium deposits

Placer deposits

Thorium minerals are widely disseminated in granitic and metamorphic rocks in various parts of the world. Until recently (1950), however, the only commercial accumulations of thorium minerals had been found in placer deposits. By far the most important thorium mineral in placer deposits is monazite, although both thorianite and thorite occur. Associated minerals most commonly are magnetite, garnet, rutile, ilmenite, gold, zircon and cassiterite. Both stream placers and beach placers have been worked for monazite.

Monazite sands occur in Idaho along the western edge of a large granitic mass called the Idaho batholith (Fig. 4) and monazite is being commercially recovered from some of these placer deposits.

Veins and monazite replacement deposits

Until 1950 significant accumulations of thorium minerals appeared to be restricted to placer deposits. In that year monazite bodies in place were discovered both in South Africa and near Shoup in Lemhi County, Idaho, and since then thorite-bearing veins have been found near Lemhi Pass. The South African monazite deposits are described as veins, but that term does not suit the Lemhi County deposits, which are lenticular monazite bodies formed, not by deposition in definite fractures, but by partial replacement of metamorphosed phosphatic limestone beds. Veins containing both monazite and thorite have been found in California.

Tungsten deposits

Vein and shear zone deposits

Quartz veins and shear zone replacement deposits are important sources of tungsten. Such deposits are generally found in or near granitic rocks; both scheelite and members of the wolframite group (ferberite, wolframite, huebnerite) may be present. The veins may contain only the tungsten minerals and quartz, or any of the following minerals may also be found: gold, pyrite, sphalerite, galena, chalcopyrite, molybdenite, tetrahedrite, fluorite, rhodochrosite, stibnite, arsenopyrite, feldspar, muscovite, sericite, and silver minerals.

Vein tungsten deposits occur in Idaho in the Blue Wing district, Lemhi County, in the Yellow Pine and Big Creek districts of Valley County, and at various localities in Custer, Butte, Blaine, Camas, Valley, Idaho, Shoshone, Bonner and Boundary Counties (Fig. 5).

Contact deposits

Many of the commercial tungsten deposits of the world occur in altered limestone or other limy rocks near the contact of such rocks with a body of granitic rock. At one time most mining geologists be-lieved that such deposits, which may contain other valuable metallic minerals as well as lime silicate gangue minerals such as garnet and epidote, were formed by the physical and chemical action of the granite on the limestone at the time when the former was intruded in a molten state into the sedimentary rock; consequently, they called them contact metamorphic deposits. It has since been demonstrated that not only the metallic minerals but many of the silicates in such deposits originated after, perhaps long after, the solidification of the intrusive rock, and were probably formed from high-temperature hydrothermal solutions. Therefore, the term contact metamorphic, carrying the idea of formation during intrusion, is not correct, and has been shortened to contact, implying merely that these deposits are usually found along granitic contacts.

The tungsten mineral in contact deposits is scheelite or powellite (high-molybdenum scheelite); it may or may not be associated with pyrite, molybdenite, and other metallic sulphides, but is always found with abundant lime silicate minerals such as garnet, epidote, diopside, tremolite-actinolite and wollastonite. The rock which has, in the vicinity of granite, been altered to this mass of lime silicate minerals, may be almost any limy sedimentary or metamorphic rock - limestone, marble, calcareous shale or argillite.

Contact tungsten deposits in Idaho occur in the Seven Devils Mountains of Adams County, and in a zone running from the Lava Creek mining district (near the Craters of the Moon) in the south to the Big Creek district, north of Yellow Pine.

URANIUM, THORIUM, AND TUNGSTEN OCCURRENCES IN IDAHO

URANIUM IN IDAHO

Vein deposits

Coeur d'Alene mining district

In 1949 uraninite was found in the lower workings of the Sunshine and Coeur d'Alene mines in the Coeur d'Alene district and since then has been discovered in three other mines of the district (Locations of uranium occurrences in Idaho are shown on Fig. 3). Most of the uranium-bearing veinlets are found in the quartzite wall rock of the major silver ore bodies, which contain argentiferous tetrahedrite, pyrite, arsenopyrite, chalcopyrite, siderite and quartz. The cobalt mineral gersdorffite has been identified in the Sunshine silver ores. The uranium veinlets are bordered by red, hematite-stained, sericitized quartzite of the pre-Cambrian St. Regis formation. In the Coeur d'Alene mine the radioactive material is found in highly silicified zones, associated with the cobalt mineral erythrite. The width of the uranium-bearing veins in the Sunshine mine ranges from paper-thin seams to 18 inches; these veins lie parallel to the strike of the bedding, according to Thurlow and Wright, and are controlled by fracture cleavage, in contrast to the major veins of the district which are localized along faults and shear zones. The uranium mineralization in the Sunshine occurs from the 2900 to the 3700 levels of the mine.

The age of the Sunshine uraninite has been determined as approximately 750,000,000 years (Kerr and Robinson 1952, p. 124) which would date it as pre-Cambrian on the geologic time scale. It may be much older than the silver-bearing siderite-tetrahedrite veins which, according to Robinson (1950 p. 818), cut the uranium stringers.

Pitchblende associated with red alteration has been found in the Crescent mine in this same district; two channel samples taken in this mine by the U. S. Geological Survey assayed 0.026 percent uranium and 0.048 percent uranium, respectively (Armstrong 1953b, p. 219). Radioactive zones have also been reported from the 2800-foot level of the Galena mine (Armstrong 1954, p. 184).

Gibbonsville district

Uranium occurs in two mines in the Gibbonsville district. Exploration is under way at the Garm-Lamoreaux mine on Allan Creek, a small tributary of Hughes Creek, about 11 miles north of North Fork. According to Vhay (1951 p. 10), the country rock is fine-grained quartzite of the pre-Cambrian Belt series, in most places somewhat micaceous and slightly schistose, interbedded with layers of sandy phyllite or argillite. Uraniferous lead ore is reported to occur in a fracture zone which strikes N 80 W (Trites and Tooker 1953, p. 167). The vein material contains gray and reddish gray

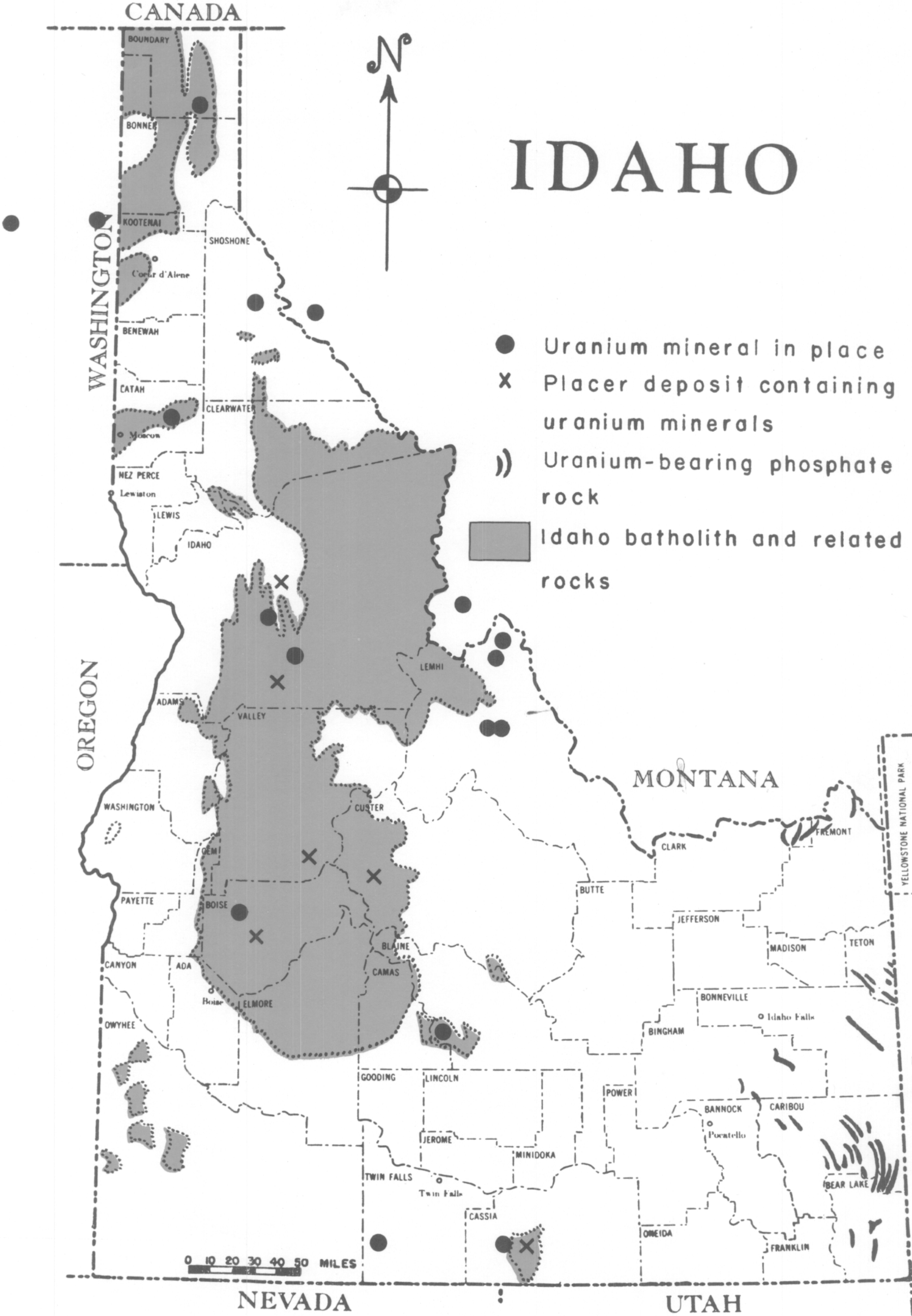

FIGURE 3-URANIUM OCCURRENCES IN IDAHO.

fractured quartz, chlorite, pyrite, hematite, and a little galena and gold. Torbernite crystals occur in the ore, associated with autunite(?). At the Moon claim about 3 miles northwest of Gibbonsville, small torbernite crystals have been found in fractures which cut a N 70 W gold-quartz vein in quartzite and mica schist (Trites and Tooker 1953, p. 168). Selected samples ran 0.14 and 0.45 percent uranium. The investigators felt that additional uranium deposits might be discovered by further exploration.

Other localities in Idaho

Radioactive occurrences east of Naples, Boundary County, were found in 1953 (Armstrong 1953b, p. 220). The radioactive material (gummite?) coats fractures in granite which itself contains disseminated pyrite and pyrrhotite.

The radioactive occurrence near Naples, although not itself regarded as a potential source of uranium, is interesting because of two reported occurrences a few miles to the east. In 1910 the Engineering and Mining Journal carried an item about a mine at Leonia, Idaho, owned by the Idaho Gold and Radium Company, where a vein carrying pitchblende and gold was thought to contain radium. In 1949 a U. S. Geological Survey party examined the Oro property in Montana, a few miles southeast of Leonia, and found a vein (Vhay 1951, pp. 14-15) in which the radioactivity was ten times background; however, the most radioactive material assayed only 0.012 percent uranium. These three reports suggest this portion of Boundary County as a favorable uranium prospecting area.

Uranium mineralization of commercial grade occurs in fractured granitic rock (monzonite) in the Hailey gold belt, 12-15 miles southwest of Hailey, Blaine County. Finely divided uraninite, some of it sooty, is found in fractured bull quartz which also contains some pyrite, gold, galena, and sphalerite. The monzonite has been intensely bleached and silicified. There are no secondary uranium minerals and only slight hematite staining. The property is currently being developed.

Discovery of autunite in mica schist has recently been reported from the Orogrande-Buffalo Hump area, from which years ago (1917) came a report of uranium-molybdenite mineralization.

Uranium minerals, both in place and in placer deposits, have recently been found in the City of Rocks area of Cassia County.

Occurrences near Idaho

In 1954 the first commercial deposit of uranium west of Montana and north of Utah was found on the Colville Indian Reservation northwest of Spokane. The ore occurs principally in mica schist near a granite contact and consists of autunite and uranophane. Pitchblende has been discovered in a nearby molybdenum mine.

In February, 1955, crystalline autunite partially filling fractures in granite was found near the western base of Mt. Spokane, about 20 miles northeast of the city of Spokane and only a few miles west of the Idaho-Washington state line.

Autunite has been found near Saltese, Montana, a few miles east of the Coeur d'Alene district.

Deposits in sedimentary rocks

Uranium in phosphate rock

The Phosphoria formation, which contains beds of uranium-bearing phosphate rock, is widespread throughout southeastern Idaho, from Bear Lake County to the Centennial Range on the Montana-Idaho line. The uranium content of these phosphate beds increases westward from Wyoming into Idaho and reaches its maximum in the vicinity of Bear Lake (Nininger 1954). The uranium is believed to be contained in fluorapatite, a phosphate mineral; rarely are stains of secondary uranium minerals found, although all the phosphate rock is radioactive.

Uranium in lignite and coal

Low-grade uranium-bearing lignites occur in the Salt Lake formation of Pliocene age in Payette, Twin Falls, and Cassia Counties (Nininger 1954, p. 138). This formation has been examined by the U. S. Geological Survey in the Goose Creek district in the southern part of Cassia County. The lignite and carbonaceous shale is interbedded with fresh water limestone, greenish gray shale and bentonite in a dominantly volcanic sequence of ash beds, rhyolite flows and welded tuff. The radioactive zone occurs directly below the lowest welded tuff. The top few inches of the radioactive beds contain as much as 0.03 to 0.09 percent uranium (Hail and Gill 1952, p. 34); these beds are a potential low-grade source of uranium.

Uraniferous coal, carbonaceous shale and limestone occur in the Bear River formation of Early Cretaceous age in the Fall Creek area of the Caribou Mountains east of Idaho Falls in Bonneville County (Vine and Moore 1952). The highest assay obtained was 0.053 percent uranium; the upper foot of one of the seven radioactive coal beds investigated averaged 0.045 percent uranium. No uranium minerals were identified; the carbonaceous material may have adsorbed uranium in the ionic state. It is believed by Vine and Moore that the uranium was leached by descending groundwater from overlying, mildly radioactive silicic volcanic rocks (including welded tuff) and deposited in the carbonaceous rocks.

Deposits in volcanic rocks

The only known occurrence of uranium in volcanic rocks in Idaho is the deposit of uranophane in iron-stained rhyolite of the Challis volcanic formation which was found in 1955 a few miles south of Salmon, Lemhi County.

Autunite has recently been reported in rhyolite dikes in pre-Cambrian rocks in western Montana.

Pegmatite occurrences

Samarskite and euxenite occur in pegmatites in Garden Valley, Boise County, and both autunite and meta-torbernite have been found in beryl-tourmaline-mica pegmatites near Deary, Latah County; in neither of these areas, however, have commercial deposits of uranium minerals yet been found.

Placer deposits

Bear Valley

Commercial production of uranium from placer sands in Bear Valley, in the southeast part of Valley County, appears imminent. The good deposits, in Big Meadow, result from the blocking of Bear Creek by a glacier during the late Pleistocene (Mackin and Schmidt 1953, p. 15). The Bear Valley placer sands consist of material eroded from granite and pegmatites of the Idaho batholith and they contain uranium-bearing euxenite, magnetite, ilmenite, garnet, sphene, quartz, feldspar, hornblende, allanite, biotite, epidote, limonite, hematite, sericite, ilmenorutile, and very small amounts of monazite, columbite, spinel, rutile, zircon, octahedrite, and pyrite (Shelton and Stickney 1955, p. 6). Two bucket-line dredges have been moved into Bear Valley and it is planned, by beneficiation of these complex sands, to recover the minerals which contain uranium, columbium, and tantalum (principally euxenite and ilmenorutile). The monazite content of the placers in Bear Valley is much less than in the Long Valley district and it is unlikely that even the best placer ground in Bear Valley could be worked for monazite.

Uranium in monazite placers

The uranium-bearing radioactive black minerals are found in most of the gold-monazite placers of central Idaho. In fact, brannerite was first described from a gold placer in Kelley Gulch, Stanley Basin, Custer County. The monazite is an accessory mineral in the granitic country rock; the radioactive blacks occur in pegmatite dikes (Mackin and Schmidt 1953, p. 4).

A placer deposit with radioactive blacks and monazite in the Whitehawk Basin, just west of Bear Valley, was drilled in 1952. The gravels are thin and have a low monazite content but may yet prove to be valuable for their radioactive black content (Armstrong 1953a, p. 222).

A columbite placer deposit at Dismal Swamp in Elmore County contains radioactive blacks. Although the U. S. Geological Survey does not consider this deposit a potential source of uranium, thorium or columbium (Armstrong 1953b, p. 217), beneficiation tests by the U. S. Bureau of Mines (Shelton and Stickney 1955, pp. 1-3) show encouraging results. The sand contains columbite and monazite, with small amounts of samarskite and fergusonite. Tests show that the columbite and samarskite can be readily recovered, and that monazite and zircon concentrates could be produced as by-products.

Euxenite, brannerite, samarskite, and betafite have been identified in the jig concentrate of a gold dredge on Red River southeast of Elk City, Idaho County. These radioactive blacks, however, are apparently not economically recoverable even as by-products of gold dredging. Shannon (1926, p. 405) mentions fergusonite in placer sand at Idaho City. A recent report of a rather high percentage of radioactive blacks in the jig concentrate of a dredge on the American River near Elk City suggests that this area is a potential source of uranium.

Euxenite occurs in the monazite placers in Long Valley (Shelton and Stickney 1955, p. 15). Samarskite, polycrase, fergusonite, and uranophane have been reported from the Boise Basin (Schrader, Stone, Sanford 1917, p. 121; Shannon, 126, pp. 390, 405, 408, 410).

Euxenite has been reported (Bell 1914, p. 29) from the same Kelley Gulch in the Stanley Basin where brannerite was first recognized; however, Shannon (1926, p. 410) believes the reported euxenite may have been brannerite.

THORIUM IN IDAHO

Monazite placer deposits

Monazite was first recognized in Idaho in placer sands of the Boise Basin by Waldemar Lindgren (1897a; 1897b; 1898); since then, monazite has been found in placers from Owyhee County in the south to Clearwater County in the north (see map of thorium occurrences in Idaho, Fig. 4). Although this thorium and rare earth mineral was early reported from numerous localities along the western portion of the Idaho batholith (Day and Richards 1905; Hill 1912; Sanford and Stone 1914; Schrader, Stone, and Sanford 1917), it has only been in recent years, with a greatly increased demand for the rare earths, that it has become profitable to dredge these sands for their monazite content. About 1910 a little was recovered as a by-product of gold dredging in the Boise Basin. Day and Richards (1906) reported monazite from 37 localities in ten Idaho counties; Shannon (1926, p. 411) regarded some of these reports as in error because he re-examined some of the samples and failed to detect monazite. Staley (1948) examined monazite deposits throughout Idaho. Some of the monazite placer localities from these reports are:

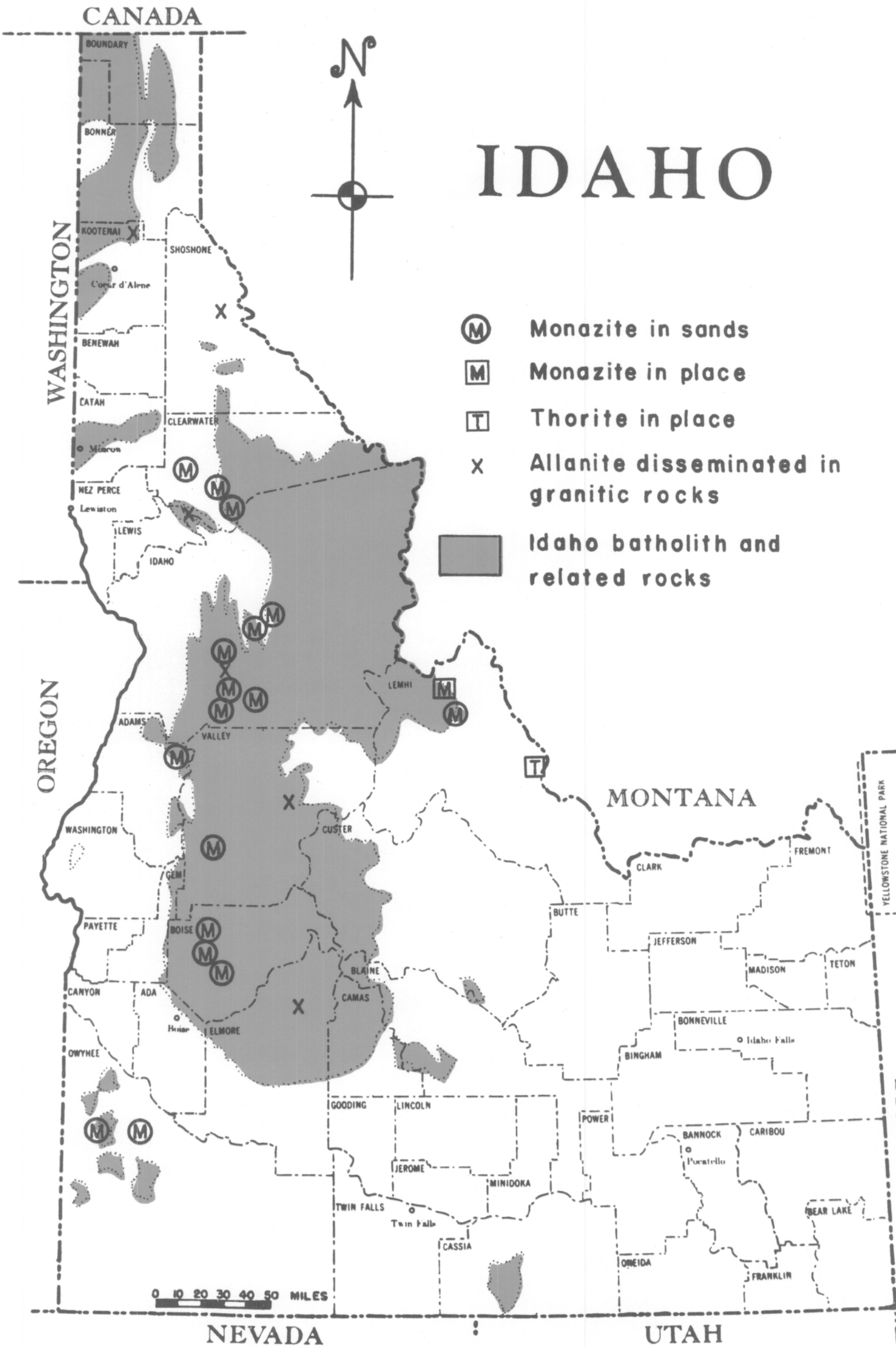

FIGURE 4. THORIUM OCCURRENCES IN IDAHO.

Adams County	:	Meadows
Boise County	:	Boise Basin; Garden Valley
Clearwater County	:	Dent; Orofino; Pierce; Musselshell Creek
Custer County	:	Stanley Basin (rare)
Elmore County	:	Featherville (rare)
Idaho County	:	Elk City district; Marshall Lake district; Baker Gulch on Crooked River; Whitebird
Lemhi County	:	Leesburg and Leesburg Basin
Owyhee County	:	Oreana; DeLamar
Valley County	:	Big Creek; Burgdorf; Warren; Donnelly; Cascade

Among the richest and most productive of the monazite placers are in Long Valley, especially near the mouth of Big Creek in the vicinity of Cascade. The heavy minerals here include monazite, euxenite, columbite, ilmenorutile, garnet, zircon, and ilmenite. Strangely enough, the most extensive monazite-bearing gravels have only traces of gold.

Schrader (1910) described a fairly extensive occurrence of monazite sands along Musselshell Creek east of Weippe in Clearwater County. Here he first noted a feature that other investigators were to report later from other monazite placer deposits, namely that the monazite appears to be more abundant in "ancient" gravels than in recent.

In the Warren district Reed (1937, p. 32) reported that monazite was the most abundant mineral in all the placer concentrates he studied; in some samples it appeared to form more than 50 percent of the bulk. At that time monazite was not in great demand and Reed estimated that a single dredge in the Warren district could probably produce in a few days as much monazite as the United States used in 1935. In 1937, however, the monazite-rich concentrates were being turned back into the dredge ponds and buried.

Monazite sands are reported from Grouse Creek, a short distance east of Florence in Idaho County (Reed 1939, p. 27) and from several localities near Burgdorf (Capps 1940, pp. 32, 34, 37). Capps mentions that the sluice box concentrates of a placer operation at Ruby Meadows (near Burgdorf) contained large quantities of monazite and considerable cinnabar; at this locality monazite was found both in stream gravels and in glacial moraine.

Staley (1948) reported samples from Ruby Meadows running as high as 0.71 percent monazite; this area has since been the site of a monazite dredging operation.

Vein and monazite replacement deposits

In 1950 thorium lode deposits began to be discovered in Lemhi County. Thorium-rich, blackened fracture zones, quartz-hematite veins with thorite, and copper veins with thorite were found near Lemhi Pass in pre-Cambrian argillaceous quartzite. These deposits average less than 1 percent ThO_2; one of them is now being actively explored.

In the northern part of Lemhi County, along the Salmon River between North Fork and Shoup, lenses and disseminated crystals of monazite were found in thin beds of marble (Abbott 1954). Monazite, allanite and thorite(?) have been identified in pegmatites of the North Fork-Shoup area, but the only considerable thorium-bearing deposits are in pre-Cambrian marble interbedded with schist and gneiss. The beds strike roughly northwest and monazite has been found along the strike of the calcareous beds both north and south of the river for several miles. Abbott (1954, p. 23) states that it is a reasonable speculation that within this area is a bed of marble 300 feet long, 200 feet deep, and three feet wide, containing 10 percent monazite; if such a body is found, a mining operation at the present market value of rare earth oxide plus thoria should prove profitable.

Occurrences of allanite

Allanite, a complex silicate which may contain up to 3.2 percent thorium, $(Ca,Ce,Th)_2(Al, Fe,Mg)_3Si_3O_{12}$ (OH), occurs as disseminated crystals in some granitic rocks and pegmatites and in some placer sands. Localities from which allanite has been reported (Gillson 1927; Anderson 1942, 1949; Johnson 1947; Kauffman, Mortimer, and Hess 1950; Abbott 1954) have been plotted on the map of Idaho thorium occurrences; although it seems unlikely that allanite itself will ever be valuable, its distribution may give a clue to likely areas in which to prospect for other thorium minerals.

TUNGSTEN IN IDAHO

Vein and shear zone deposits

Northern Idaho

Scheelite has been found in the gold-quartz veins of several mines in the Murray area (Blake 1889; Auerbach 1908; Hess 1917; Shannon 1938). According to Auerbach, in the days of the Murray gold rush a prospector uncovered a 2-foot vein of scheelite; because of the weight of the mineral he mistook it for an ore of lead, but when an assay showed none of that metal he abandoned the vein. Scheelite was frequently found in the sluice boxes during gold placer operations. Masses of pure scheelite weighing as much as 100 pounds were found in the Golden Chest mine, from which about 50 tons of the mineral had been mined by 1908. During the First World War some tungsten ore was produced.

The scheelite of the Murray area occurs exclusively in quartz veins where it is associated with auriferous pyrite and small amounts of chalcopyrite and galena. The country rock is argillite and quartzite.

A scheelite vein deposit has been mined in recent years on Pine Creek south of Kingston, Shoshone County. In 1916 stolzite (lead tungstate) is reported to have been found in the Hypotheek mine in the same area (Shannon 1926, p. 474).

Scheelite is also found in quartz veins about eight miles east of Copeland in Boundary County (Livingston 1919, pp. 11-14; Kirkham and Ellis 1926, p. 50, 61). The veins cut a large basic sill in metamorphosed sediments near the eastern margin of the Nelson batholith, and the vein material is quartz with minor scheelite, galena, pyrite and pyrrhotite.

Huebnerite and some scheelite are found in quartz veins and mineralized shear zones near Talache, on the west shore of Lake Pend Oreille in Bonner County (Sampson 1928, pp. 16-20). The veins, which also contain lead, zinc, and silver minerals, are near the contact of a granodiorite stock with argillite and quartzite of the pre-Cambrian Belt series.

Idaho County

Tungsten was first discovered in Idaho in 1877 when scheelite was identified by Benjamin Silliman in a specimen of gold quartz from Warren, Idaho County. Since that time scheelite has been reported from several of the gold-bearing veins of the district (Livingston 1919, pp. 26-27). Shannon (1926 p. 470) reports scheelite disseminated in quartz in specimens from the Ten Mile district near Newsome, 14 miles west of Elk City. Scheelite and wolframite have been found in several of the mines at Buffalo Hump (Beckwith 1928; Shenon and Reed 1934, pp. 26-27).

Valley County

Idaho became an important tungsten-producing state with the exploitation of a large body of tungsten ore which was discovered in February, 1941, during the geologic examination of drill cores of gold-antimony mineralization at the Yellow Pine mine, two miles north of Stibnite, Valley County. During World War II, the Yellow Pine Mine became one of the most important tungsten-producing localities in the United States; it has been estimated that 40 percent of the nation's tungsten production during the war came from this one mine. The high-grade tungsten ore has now been nearly exhausted.

The main tungsten ore body was in a shear zone entirely within quartz monzonite of the Idaho batholith (Bradley, Mecia, and Baker 1943; Cooper 1951). The ore minerals were scheelite, stibnite, gold and silver. Dikes and small irregular bodies of pegmatite and aplite are abundant in the mineralized zones. Cooper relates the tungsten deposition to Tertiary igneous activity. The ores have replaced the wall rock monzonite, the ore solutions being guided by shear zones and fractures; the ore apparently is genetically related to the aplite dikes, since these dikes form up to half of the wall rock in the mineralized zone and are not as abundant away from the ore body.

Replacement veins of huebnerite and minor scheelite in quartz are being mined at the MacRae mine, six miles east of Big Creek. These deposits appear to be controlled by transverse fractures in quartzite and are closely associated with pegmatite-aplite rock which also appears to be of replacement origin.

A quartz-scheelite vein is reported on Quartz Creek about two miles north of the town of Yellow Pine; some ore has been produced from this deposit.

South-central Idaho

Vein tungsten deposits have been found in Camas, Blaine, Boise, Butte, Custer and Lemhi Counties (see map of tungsten occurrences in Idaho, Fig. 5), but the only important deposit of this type so far discovered is the Ima mine near Patterson in Lemhi County. Here, tungsten has been found both north and south of Patterson Creek, on the eastern side of the Pahsimeroi Valley in the Lemhi Range. Quartz veins carrying huebnerite and a considerable variety of sulphide minerals cut impure quartzites, probably of pre-Cambrian age (Umpleby 1913; Callaghan and Lemmon 1941; Anderson 1948). An en echelon group of veins has formed in the fracture zone at the crest of an anticlinal fold and the veins extend downward from the quartzite into granite. The granite is believed by Anderson (1948) to have formed by metamorphism of quartzite and to represent an early stage of the mineralization epoch. Ore minerals are huebnerite, pyrite, sphalerite, chalcopyrite, bornite, molybdenite, argentiferous tetrahedrite, and small amounts of scheelite, galena, and chalcocite. Associated with the quartz as gangue minerals are fluorite, orthoclase, rhodochrosite, siderite, muscovite, and sericite.

Two occurrences of wolframite in quartz veins have been reported from a locality four miles northeast of the Deadwood dam in Boise County (Shannon 1926, p. 467). Wolframite in small quartz stringers in granite has recently been reported from Whitehawk Basin, a few miles east of Deadwood Basin.

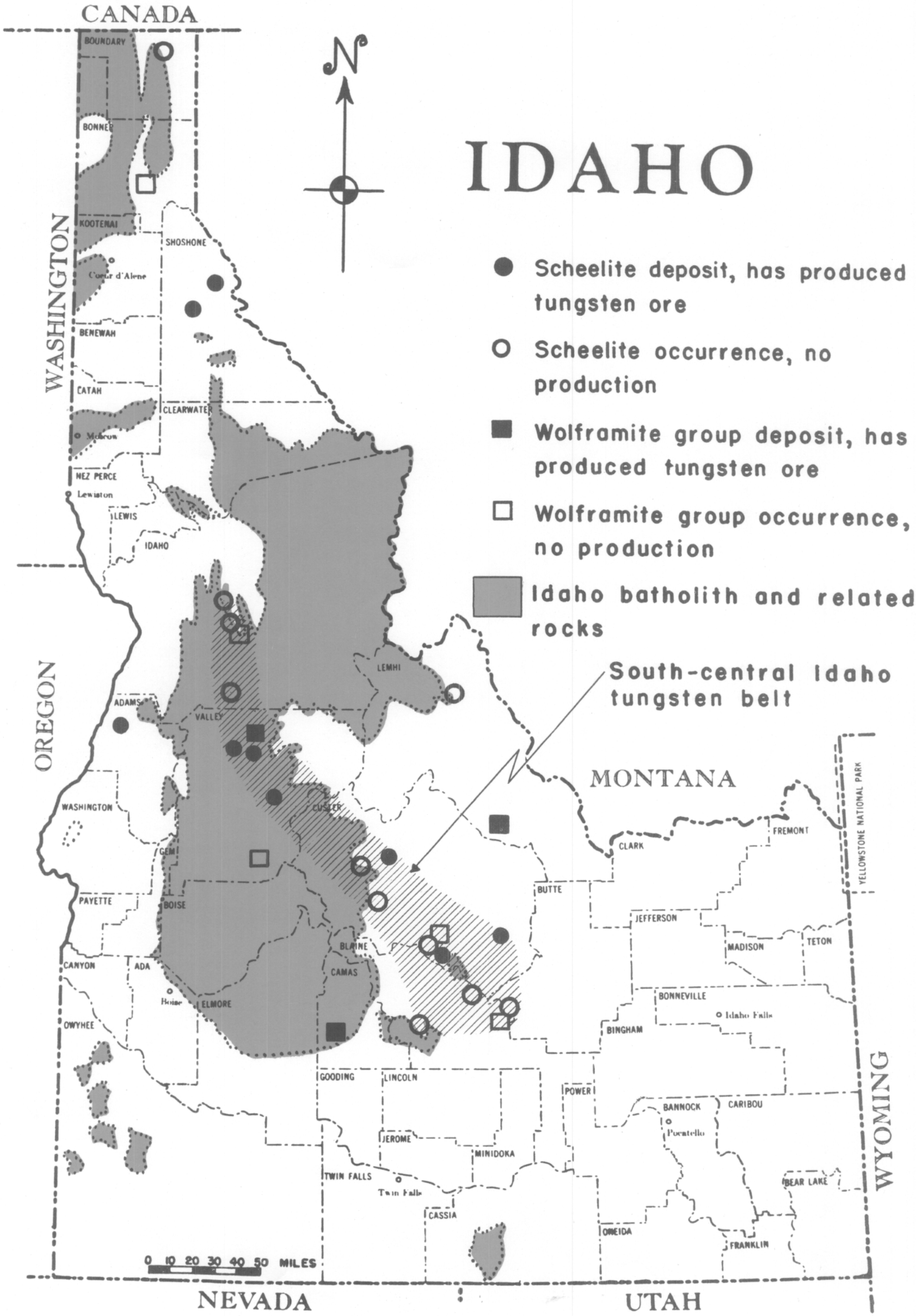

FIGURE 5-TUNGSTEN OCCURRENCES IN IDAHO.

Ferberite occurs in narrow lenticular quartz veins in granitic rock of the Ieaho batholith on Corral Creek south of Soldier Mountain in Camas County. This deposit was worked during the First World War and has been intermittently explored and mined since that time. The ferberite and drusy quartz fill north-east-trending fractures in bleached granite or monzonite.

Huebnerite has been found in a quartz vein near the top of Blizzard Mountain about five miles west of Martin in the Lava Creek district, Butte County (Anderson 1929, p. 34, 46). The quartz is drusy and occurs in a brecciated zone at the contact of sericitized granite and sediments.

Disseminated scheelite occurs along fractures in the Eaglebird mine in the Muldoon or Little Wood River district, Blaine County. The country rock is mainly quartzite and the veins occur near a contact with a granitic stock.

A lens of quartz with local wolframite is found in argillite near the contact with granite near Big Falls Creek just east of Trail Creek summit in Custer County. On Little Falls Creek, about a mile closer to Trail Creek Summit, quartz-scheelite veinlets occur in the marginal portion of the granite and disseminated scheelite is found in calcareous portions of the argillite with which the granite is in contact.

Scattered crystals of scheelite in quartz have been reported from a mine northwest of Salmon City.

Contact deposits

South-central Idaho tungsten belt

All of the contact tungsten deposits in Idaho with the exception of those in the Seven Devils Mountains occur in or near a northwest-trending belt which runs from the Lava Creek mining district just north of the Craters of the Moon to the Big Creek district in northern Valley County. In all deposits the ore mineral is either scheelite or powellite (in the sense of high-molybdenum scheelite) and it occurs in tactite, a mass of lime silicate minerals derived from calcareous sedimentary or metamorphic rocks. All such deposits are found in sedimentary or metamorphic rocks at or near a contact with a granitic rock; aplite dikes are commonly found near the tungsten ore bodies and these aplite dikes are locally pegmatitic. It appears, however, that not all of these associated granitic and aplitic rocks are true igneous rocks, but that some of them at least have been formed by intense metamorphism of sedimentary rocks. In a minority of the deposits, the tungsten mineral is associated with sulphide minerals such as pyrite, chalcopyrite, galena, and sphalerite; such a mineralogic association appears to be largely the result of a favorable structural environment rather than of contemporaneous deposition of tungsten with the sulphides.

The most important contact deposits found to date in this south-central Idaho tungsten belt are near the headwaters of Wildhorse Creek, a tributary of Big Lost River in southern Custer County, about 25 miles southwest of Mackay. The deposits were discovered in August, 1953, mining started the following spring and tungsten concentrates were being produced by August, 1954. Scheelite is found in tactite which consists of varying proportions of epidote, garnet, chlorite, tremolite and other minerals. The tactite has been formed from micaceous marble which is interbedded with biotite gneiss, at places where the marble bands are cut by light-colored dikes of alaskite (a rock similar in composition to aplite and pegmatite but intermediate in grain size between the fine-grained aplite and coarse-grained pegmatite). Four separate deposits have been discovered over a distance of better than two miles along the strike of the metamorphic rocks; all of these tungsten ore-bodies are at intersections of impure marble beds and alaskite dikes.

Low-grade scheelite disseminations in tactite on contacts between calcareous sediments and granitic rocks are found on Croy Creek about ten miles southwest of Hailey in Blaine County; on Phi Kappa Creek about three miles east of Trail Creek summit in Custer County; at a locality about two miles south of the Livingston mine in the East Fork district, Custer County; and at five localities north of the Salmon River between Clayton and Stanley. Of these last-named, two are of potential importance; both are near the headwaters of Thompson Creek about ten miles northwest of Clayton. Tungsten was produced from one of these deposits in 1954 and development was under way at the other property. Both deposits contain finely disseminated scheelite in a vitreous quartz-garnet tactite which has developed from calcareous argillite near a contact with granitic rock.

At least five mines or prospects in the White Knob district just west of Mackay contain some tungsten mineralization. A Tertiary granitic stock which intruded Carboniferous limestone has formed extensive bodies of coarsely crystalline garnet tactite near the intrusive contact. In a number of places good copper mineralization was found in this tactite and most of the underground workings were driven to explore for and exploit the copper deposits. In the early 1940's good tungsten ore was found on one of the lower levels of the Empire mine and one carload of ore was shipped. In recent years, by prospecting with mineral lights, tungsten mineralization controlled by shear zones in the tactite has been found in at least four other old copper properties. Except for the Empire occurrence, where the tungsten mineral is coarse scheelite, the tungsten ore mineral is powellite or high-molybdenum scheelite in small specks and grains.

Finely disseminated scheelite occurs in massive sulphide ore bodies at the Meadowview mine near the headwaters of Fourth of July Creek about 23 miles southeast of Stanley in Custer County. The ore bodies, which are largely composed of pyrrhotite, chalcopyrite and sphalerite, are replacements in marble beds which lie between bands of argillite. The marble has locally and partially been altered to tactite, probably prior to metallization. In places, especially near the ore bodies, the argillite has been metamorphosed to a granitic rock; locally, both marble and argillite have been strongly silicified. Neither dikes nor intrusive contacts appear to be closely associated with the ore. About two miles to the south, in Washington Basin, scheelite occurs sparsely disseminated in part of a massive pyrrhotite replacement deposit in limestone.

Scheelite has been found in some rather peculiar contact deposits in northern Valley County, one of which is being mined. The Springfield mine, a few miles south of Stibnite, is producing scheelite-pyrrhotite ore from a mineralized zone in granitic rock. At Profile Gap, midway between the towns of Yellow Pine and Big Creek, sparse tungsten mineralization is found in a soft, green "tactite" which may represent altered volcanic rocks, near a granitic contact; some sulphides are found in the "tactite." Sulphide minerals, principally pyrrhotite or pyrite, are found also at another contact deposit in northern Valley County, on Smith Creek about four miles west of Big Creek; the host tactite has formed from limy beds in a sequence of impure quartzite, argillite and amphibolite near a granitic contact.

Seven Devils Mountains

Although tungsten mineralization in the contact copper deposits of the Seven Devils mining district in Adams County has been known for some years, tungsten was first mined in the district in 1952. Garnet-epidote-diopside tactite rims blocks of recrystallized limestone which have been engulfed in quartz diorite. Powellite (in both the strict and the loose sense of the term) occurs in definite zones within the tactite. Tungsten deposition was apparently controlled by shear zones and was not contemporaneous with copper mineralization, although both may be found together. Much of the ore contains as much molybdenum as it does tungsten, and submarginal rock carries even more. Tungsten has been found in at least six mines and prospects of the district, but has so far been produced from only one.

HOW TO PROSPECT

WITH A GEIGER OR A SCINTILLATION COUNTER

Gamma ray detection

All minerals of uranium and thorium are radioactive, that is they spontaneously emit rays and minute particles of matter. Of the several types of radiation which uranium minerals give off, gamma rays are most important to the prospector, for both Geiger and scintillation counters are essentially gamma ray detectors. Uranium minerals also give off alpha and beta particles. These particles have little penetrating power: A thin sheet of paper will stop most alpha particles and a fraction of an inch of solid material will stop beta particles. Consequently, although both types of particles will produce pulses in a counter, most counter walls are too thick to admit them. A special thin-wall counter, in which a portion of the wall is made of glass or thin aluminum will admit about 20 percent of the beta particles given off at the surface of a uranium mineral and thus is a beta-gamma counter. Some counters are provided with mica windows which are thin enough to admit even alpha particles.

Like X-rays, gamma rays can penetrate matter (much farther than alpha or beta particles), but the gamma rays from uranium are stopped by approximately one foot of rock, 2½ feet of water, or several hundred feet of air. An important limitation on the usefulness of a counter, then, is the fact that it measures only the gamma rays from the outer one-foot rock shell and it cannot detect radioactive ores deep within a roock mass. This limitation is even more important in a humid, forested region like northern Idaho where the bedrock is apt to be covered by a thick soil and rock mantle than it is in an arid region where the bedrock may outcrop on the surface. For example Vhay (1951) notes that no abnormal radioactivity was recorded by a Geiger counter above the deeply covered vein at the Garm-Lamoreaux mine near Gibbonsville, although in places on the old dumps radioactivity was 30 times background. Even scintillation counter traverses across the surface projection of the Alhambra fault at the Crescent mine in the Coeur d'Alene district failed to detect abnormal radioactivity (Armstrong 1953b, p. 219) although pitchblende was found in the same fault below the surface.

The Geiger counter is the most common and useful instrument for detecting radioactivity. Although counters vary in design, each consists of two essential parts: a Geiger-Muller tube which detects gamma rays (and beta particles), and an electronic circuit which amplifies the discharges of the tube caused by the gamma rays. The tube, which is filled with gas, may be enclosed in the case of the instrument, or it may be housed in a probe and attached to the electronic circuit by a flexible cable.

Three methods of indicating the tube discharges of a counter are common:

(1) Headphones - tube discharges register as clicks

(2) Neon bulb - tube discharges register as flashes

(3) Meter - rate of tube discharge is read from a meter

An instrument may have only one or any combination of these methods of indication. The number of clicks or flashes, or the deflection of the meter needle, is proportional to the radioactivity.

A Geiger counter detects gamma rays and beta particles by the ionizing effect they have on the gas contained within the Geiger-Muller tube. A scintillation counter, on the other hand, depends upon the ability of these rays to produce small mometary flecks of light (scintillations) in crystals of certain compounds such as sodium iodide. The scintillations are translated into electrical pulses by a photomultiplier and the pulses may then be recorded as in a Geiger counter.

Background count

Most things are slightly radioactive. For this reason and because of cosmic radiation, any counter will give a small count no matter where it may be. This is known as the background count and it must be established before using the counter. The background count is influenced by a number of factors, including such things as the weather, the topography, the strength of the batteries in the counter, and variations in cosmic radiation. For this reason the background count varies, both in space and time. When using a counter the background must be established frequently and preferably over a period of several minutes. The background count varies even between counters of the same make. If batteries or parts are changed in the counter the background should be re-established.

As a general rule, an area that gives two to three times normal background count should be investigated more thoroughly and samples that give four to five times background should be assayed.

Precautions to be observed in using a counter

1. Keep the counter dry. The high voltages may burn it out if it is damp. Some instruments are sealed by the manufacturer against moisture, but unless this has been done, the counter should not be used in a wet mine or in a rainstorm. Some mine waters are radioactive and may contaminate the counter.

2. Protect the counter from contamination by radioactive dust, from ore specimens or clothing.

3. Don't allow the counter to register too fast. If individual clicks can't be distinguished in the earphones or the needle swings to the top of the indicating dial, the radioactive field is so intense that the counter may be damaged. Either move away from the radioactive source or use a less sensitive counter setting.

4. When using the counter, keep it away from any instrument with a luminous dial. The luminous paint is radioactive.

5. Turn the counter off when not in use, to conserve the batteries. On extended trips into the field carry an extra set of batteries.

6. Don't cover the ground too fast or small outcrops may be passed unobserved.

7. Take along a piece of radioactive rock or a watch with a luminous dial in order to periodically check the operation of the counter.

8. Before going into the field, buy and read "Prospecting with a Counter", by Robert J. Wright of the U. S. Atomic Energy Commission. This booklet is available for 30 cents from the office of The Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Much of the material in this section of this report has been taken from this excellent publication.

Limitations of a counter

A counter does not measure uranium directly, because uranium itself does not give off gamma rays. The counter responds to the gamma radiations of some of uranium's decay products, and only when these products are present in amounts proportional to the amount of uranium can the counter give an accurate measure of the uranium present.

Also, a counter reading may be strongly influenced by the size of the sample tested. A large piece of rock gives off more gamma rays than a small piece, and hence different counter readings can be obtained from specimens of different sizes having the same uranium content. This is known as the mass effect. For these reasons, no counter can be used for accurate quantitative work. The most reliable way to determine the uranium content of a sample is to obtain a chemical analysis.

Counters can, however, be used for radiometric assaying if they have been properly calibrated against samples of known uranium content. A set of standards can easily be made up from the rejects of chemical analyses, if such analyses cover a wide range of uranium content. It is important that the standards be in radioactive equilibrium and that equal amounts of the material to be assayed and the comparison standard be used. By having a series of comparison standards, calculations involving background count may be avoided. It must be remembered that such an assay reveals only the amount of uranium in equilibrium with its daughter elements required to give the same counting rate as the assayed sample. If the sample contains thorium or is not in equilibrium, the result will not show the actual uranium content.

No exact rule can be given as to the depth of mantle through which a counter will detect radioactivity. The size, shape, and grade of a deposit will all affect this. In general, however, a few feet of overburden will mask the radioactivity from the richest of deposits. Although the cover masks the radioactivity of bedrock deposits, the soil itself may be radioactive and give a clue to the radioactivity of the rocks below.

Thorium is also radioactive, and a counter cannot distinguish between deposits of uranium and deposits of thorium. The gamma activity of thorium and its decay products is about two-fifths that of the uranium series; in other words, rock containing 0.1 percent uranium activates the counter as much as rock with 0.25 percent thorium.

Use of the scintillation counter

The technique of prospecting with a scintillation counter is essentially the same as that with a Geiger counter, because both instruments measure gamma radiation of uranium and thorium disintegration products. The chief advantage of a scintillation counter is that it responds to a larger proportion of the gamma rays that hit it, and is therefore more sensitive. A scintillation counter cannot detect uranium at any greater depth than a Geiger counter can, but it can detect smaller amounts of radiation at a greater distance from the outcrop. For this reason, it is the chief instrument used in aerial radiometric surveys, the usual Geiger counter not having adequate sensitivity for this air-borne work.

Surface exposures of radioactive mineral concentrations can be detected from the air with a scintillation counter using flight elevations of 25 to 100 feet and air speeds of 60 to 100 miles per hour. This technique is applicable only to deposits which crop out on the surface and does not eliminate the need for ground prospecting. For rapid ground traverses of 100 to 200 miles per day, a counter may be mounted in a car or truck. Automatic alarms are frequently used with car counters. An alarm is an electronic device that can be set to ring a bell or buzzer or to flash a light when a designated counting rate is exceeded.

The same general precautions should be observed with a scintillation counter. Because of the greater sensitivity of the scintillation counter, the possibility of deceptive readings due to mass effect or local concentrations of gamma ray emitting decay products such as radon gas or fission products from nuclear weapons tests is intensified.

WITH AN ULTRA-VIOLET LIGHT

Ultra-violet rays cause certain minerals to glow or fluoresce. Ultraviolet lamps, commonly called mineral lights or black lamps, are the most useful tool in prospecting for these minerals. Autunite is the only uranium mineral which always fluoresces, although occasional specimens of other secondary uranium minerals will fluoresce weakly. The mineral light is an invaluable tool, however, in prospecting for tungsten, because both scheelite and powellite fluoresce brilliantly so that even minor amounts of these minerals can be detected by means of the lamp. Without the help of such a lamp scheelite is difficult to locate because it looks like certain worthless gangue minerals and because it commonly occurs in small grains and crystals.

Probably all of the recent scheelite discoveries in Idaho have been made with the mineral light. In the Yellow Pine mine scheelite ore, hitherto unsuspected in that gold-antimony property, although discovered by microscopic analysis of drill cores, was then searched for by mineral light. The ore body thus outlined made the Yellow Pine mine the largest producer of tungsten in the United States during World War II.

Pure scheelite fluoresces bluish white. A golden yellow fluorescence indicates the presence of some impurity, commonly molybdenum. Many profitable mines are operating on yellow-fluorescing scheelite because the amount of included molybdenum is small. In any prospect, however, yellow-fluorescing scheelite should be assayed for both tungsten and molybdenum, because too much molybdenum may make such a deposit valueless.

Care must be taken that fluorescent calcite not be mistaken for scheelite. Most calcite (the mineral which constitutes all limestone and marble) is not fluorescent, but some of it is, and it may fluoresce almost any color, including bluish white and pale yellow, depending upon impurities it contains. A small, tightly stoppered bottle of dilute hydrochloric acid (obtainable at any drug store as muriatic acid) should be carried by the prospector to test fluorescent material. If the mineral, after being dried, fizzes vigorously under a drop of acid, it is calcite and not scheelite. Most fluorescent calcite forms thin soft coatings on rock surfaces and can easily be distinguished from hard, crystalline scheelite; but some fluorescent calcite is found in disseminated specks and may closely resemble the more finely disseminated forms of scheelite and powellite. To identify the mineral in such a case requires the acid treatment.

Another possible source of error in using the ultra-violet lamp arises from the fact that scheelite quite commonly is deposited in narrow fractures in the inclosing rock and, should the rock chance to break along this fracture after mineralization, an entire wall studded with scheelite crystals would confront the prospector who, turning his mineral light upon this face, might quite understandably leap to the conclusion that he had found a tremendous deposit of tungsten, only to find later that the mineralization was but a thin coating on barren wall rock. As with all mineral deposits, an attempt should be made to determine the orientation and extent of the mineralization before estimating the potential value of the deposit.

Valuable tungsten deposits have been located by fluorescent examination of heavy minerals obtained by panning the sands of streams draining the area of mineralization.

The ultra-violet light is also useful in a simple laboratory test for uranium. Ground ore containing uranium minerals which do not fluoresce in the natural state, when melted with a little lithium or sodium fluoride, will fluoresce yellowish green. Kits may be purchased for making these uranium tests.

Certain models of ultra-violet lights have been designed for use in daylight. The more common type requires the darkness of a mine, a darkened room, or a black covering cloth, to be effectively used.

BY GEOBOTANICAL METHODS

Prospecting for uranium by analysis of plants and by mapping indicator plants has been successful on the Colorado Plateau in finding subsurface deposits which were not detected at the surface by gamma ray counters. Uranium is absorbed through the roots of plants and some of it is carried to the leaves and branches. Although the amount of uranium in the leaves and branches is small, it is detectable and sufficient for reconnaissance prospecting (Cannon 1954, p. 49). Any type of plant may be used for sampling provided the plant is widely distributed and deep-rooted. Even in semi-arid regions few plant roots extend to depths greater than 50 feet. This then, is about the practical depth limit for prospecting by plant analysis. Several ore bodies have been discovered on the Colorado Plateau by this method of prospecting.

Another geobotanical prospecting method is based on the fact that certain plants which require relatively large quantities of either selenium or sulphur are associated with uranium deposits in the southwestern United States. Several orebodies have been discovered under patches of these indicator plants. Indicator plants common in uranium districts, as listed by Cannon, are:

Tumble mustard (Sisymbrium altissimum)

Death camas (Toxicoscordion gramineus or Zigadenus venenosus var. gramineous)

Desert trumpet (Eriogonum inflatum)

Peppergrass (Lepidium montanum)

Prince's plume (Stanleya pinnata)

Wild onion (Allium acuminatum)

Milk vetch (Astragalus confertiflorus, A. preussi, var. arctus, A. thompsonae, A. pattersonii)

Rice grass (Oryzopsis hymenoides)

Woody aster (Aster venusta)

Of these plants, tumble mustard, death camas, peppergrass, Prince's plume, wild onion and rice grass are found in Idaho. The distribution in Idaho of these indicator plants is shown in Figure 6, which is based on research done by Dr. William Baker and the author in the herbariums of the University of Idaho and Washington State College.

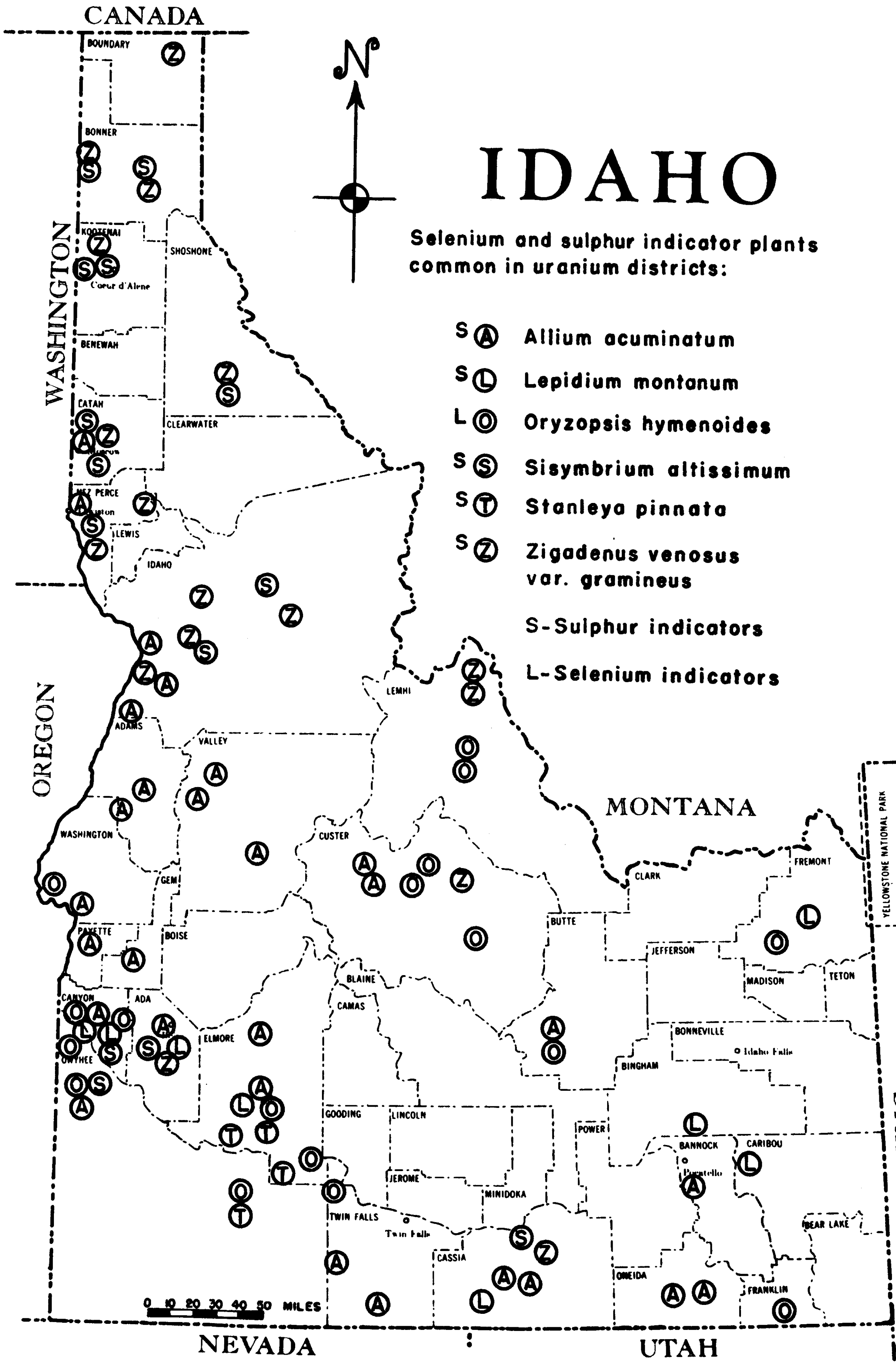

FIGURE 6 - DISTRIBUTION OF SELENIUM AND SULPHUR INDICATOR PLANTS IN IDAHO.

The gamma rays of uranium are stopped by a foot of solid rock. Even the highest-priced scintillation counter cannot detect a deposit buried below several feet of barren overburden. Indicator plants provide one means of prospecting for uranium deposits which counters cannot detect.

BY GEOCHEMICAL PROSPECTING

Minute amounts of uranium from a buried deposit may reach the surface, carried upward by ground water or in the roots of plants. Trace amounts of metals commonly associated with uranium deposits, such as cobalt and copper, may come to the surface in the same manner. These elements may be detected in surface rocks, soil, plants, or even water, by accurate chemical analysis. Maps showing the surface distribution of these trace elements can be useful in prospecting for buried uranium deposits.

WITH GEOLOGIC GUIDANCE

A knowledge of the geology of uranium, thorium, and tungsten deposits will greatly increase the chances of success in prospecting. Much is still to be learned about what controls mineralization, and why mineral deposits are where one finds them; on the other hand, enough is known that geologic guides to prospecting have been formulated which help eliminate time wasted prospecting unfavorable localities and aid in locating valuable deposits. In this regard, a statement in a recent publication of the U. S. Geological Survey on prospecting for carnotite deposits on the Colorado Plateau is pertinent:

> If consideration is given to the much greater depth of Survey drilling and to the higher risk of exploring ground away from known deposits.....the results of Survey exploration using geologic guidance systematically are more than twice as favorable as the results obtained by private industry using little or no geologic guidance (Weir 1952, p. 26).

The following section of this report is based upon the present knowledge of geologic guides to deposits of uranium, thorium, and tungsten minerals. Areas in Idaho where the geologic conditions are favorable to the occurrences of such deposits are pointed out and if, in addition, uranium, thorium, or tungsten minerals have actually been found in such an Idaho area, it is designated as a likely area to prospect.

WHERE TO PROSPECT IN IDAHO

FOR URANIUM

Around the margins of granitic masses

One of the best rules for successful prospecting is to go "from the known to the unknown". This means that it is wiser to start prospecting in an area or a geological environment in which uranium has already been found, and to thoroughly explore such areas before venturing into an area or an environment where uranium has never been found. Uranium occurs in a wide variety of rocks and deposits, and uranium minerals have already been found at widely scattered localities in Idaho. For this reason, almost no area in Idaho is ruled out as a possible source of uranium. On the other hand, there appear to be conditions of geologic favorability which make some areas more attractive for uranium prospecting than others.

All of the known veins, pegmatite, and placer occurrences of uranium in Idaho have been found either within granitic rock or fairly close to it, and all such occurrences which are not in granitic rocks but marginal to it, have been found in metamorphic rock, principally quartzite and mica schist of the pre-Cambrian Belt series. This strongly suggests that good places to prospect are marginal areas of granitic bodies which have invaded pre-Cambrian metamorphic rocks. Such areas are widespread in central and northern Idaho (see Fig. 7).

Nininger (p. 133) states that the possibility of discovering primary uranium ore in moderate amounts in the Coeur d'Alene mining district is considered good. The same might be said for the central portion of Idaho County; the northern part of Lemhi County; and Boundary, Bonner and the western part of Kootenai Counties. In all these areas, masses of granitic rock of batholithic dimensions have invaded pre-Cambrian metamorphic rock, and in all these areas uranium has already been found, although not yet in commercial quantities.

Uranium-bearing pegmatites are probably fairly numerous in Idaho, but pegmatites are not apt to be commercial sources of uranium. Consequently, vein deposits of uranium should be sought in these marginal granitic areas. The Midnight mine on the Colville Indian Reservation northwest of Spokane, the first commercial uranium deposit found west of Montana and north of Utah, is a vein deposit at the contact of mica schist and granite. Crystalline autunite, partially filling fractures in granite, has been found at the foot of Mt. Spokane, in Washington a few miles west of the Idaho line.

The surface expression of such vein deposits is most likely to be fracture coatings of yellow uranophane or green autunite (see Fig. 2), both of which occur at the Midnight mine. Underground, veins of pitchblende are apt to be bordered by reddish, hematite-stained wallrock. In the Sunshine mine, for example, Thurlow and Wright (1950, p. 403) noted that:

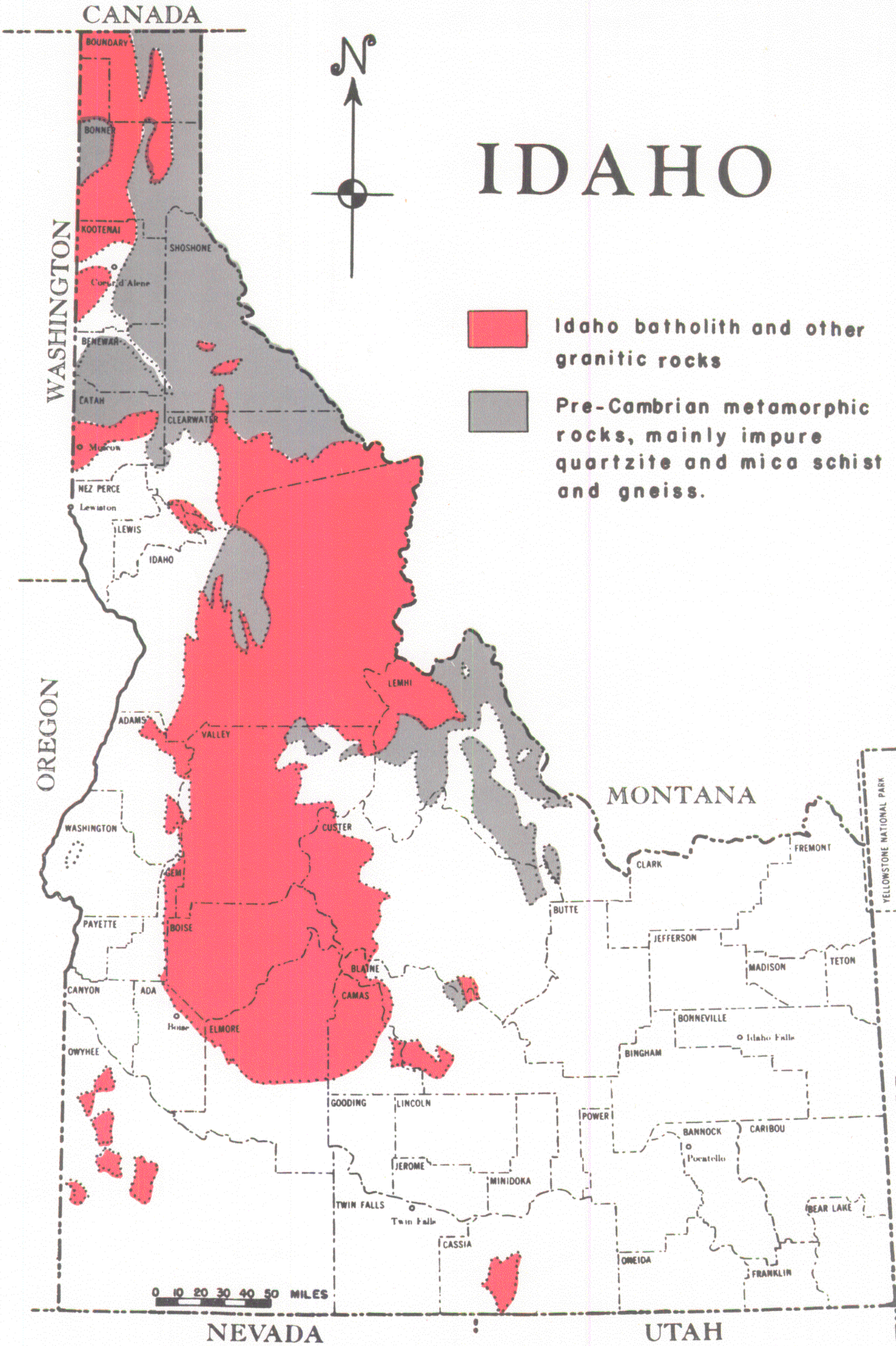

FIGURE 7. DISTRIBUTION IN IDAHO OF FAVORABLE HOST ROCKS FOR URANIUM: A. GRANITIC ROCKS AND PRE-CAMBRIAN METAMORPHIC ROCKS.

> A persistent and striking feature of the radioactive veins.....is the reddish coloration of the adjacent quartzite.....this envelope of coloration is uniquely associated with the uranium-bearing veins; it is not known elsewhere in the mine, and all veins with significant radioactivity are bordered by red-stained wall rock.....from a fraction up to a foot in width.

Red staining of the gangue minerals or the wall rock is closely associated with primary uranium mineralization at two of the world's greatest pitchblende mines, Great Bear Lake in Canada and Joachimsthal in Czechoslovakia.

Although uranium mineralization may occur far removed from deposits of other metals, in primary deposits uranium commonly is found associated with minerals of cobalt, copper, nickel, and iron. In fact, it was the presence of cobalt bloom (erythrite) which stimulated the exploration for uranium in the Sunshine and Coeur d'Alene Mines, resulting in the discovery of uraninite. The cobalt mineralization in the Blackbird district of Lemhi County would seem to indicate geologic favorability for uranium, but although one party found low-grade radioactive rock in the Haynes-Stellite mine, about three miles southeast of Calera, Trites and Tooker (1953, p. 171, 176) report that they found no significant radioactivity in this district.

Types of wall-rock alteration which are apparently common to uranium veins are "bleaching" (sericitization and kaolinization) and silicification. Robinson, for instance, in speaking of the Sunshine uraninite veinlets, mentions (p. 818) "accompanying halos of intense silicification and red jasper alteration, up to ten and fifteen feet in width" in a bleached quartzite.

Although fluorite is a gangue mineral frequently associated with uranium deposits, two fluorite deposits west of Challis examined by the U. S. Geological Survey were found not to be potential sources of uranium. On the other hand, a fluorite deposit in western Montana has been found to assay as high as 0.078 percent uranium. The presence of fluorite, when coupled with other favorable features, still may be a geologic guide to uranium deposits.

Specific localities which warrant investigation for vein uranium deposits are (1) the area between Naples and Leonia in Boundary County; (2) the northwest corner of Kootenai County and probably the area around Shasta and Mica Peaks in the western part of the same county; (3) the area between Mullan, Idaho, and Saltese, Montana and the Coeur d'Alene district in general; (4) a belt extending southeasterly from the northwest corner of Benewah County, across Benewah and Latah Counties and into Clearwater County; (5) the area between the South Fork of the Clearwater and the northern part of Valley County, especially the Ten Mile, Buffalo Hump, Florence, Warren, and Marshall Lake mining districts; (6) the North Fork-Gibbonsville area, in the northern part of Lemhi County; and the southern margin of the Idaho batholith, from Boise to Hailey. These suggestions are based upon actual uranium occurrences and geologic favorability. Prospecting for vein deposits of uranium should be encouraged, however, throughout central and northern Idaho.

In acidic volcanic rocks and associated sediments

An association believed to be favorable to uranium is that of carbonaceous sediments with acidic volcanic rocks such as rhyolite flows and welded tuffs. The carbonaceous sediments may be sandstones, conglomerates, or shales bearing woody fragments, or they may be lignites and other coals largely composed of plant remains. Volcanic rocks in many areas appear to have released uranium to circulating groundwater from which it was concentrated in carbonaceous material. This may well be the explanation, not only for the radioactive shale and lignite in Cassia County, but also for the uranium-bearing coal and carbonaceous rocks in Bonneville County.

Acidic volcanic rocks are widespread in Idaho from Lemhi County south. Sediments associated with these volcanics and the volcanic rocks themselves should be investigated for uranium. The recent discovery of uranophane in rhyolite in Lemhi County should stimulate a search for uranium in the Challis volcanics and similar volcanic rocks throughout southern Idaho (see map, Fig. 8).

In sedimentary rocks, especially carbonaceous and phosphatic rocks

Although sedimentary rocks containing woody or carbonaceous matter do seem to have a precipitating action on uranium, the uranium-bearing solutions may not be derived from the leaching of overlying volcanic rocks but may come from some deep-seated source. Therefore, all carbonaceous sedimentary rocks should be investigated. Furthermore, a good deal of the uranium on the Colorado Plateau, although occurring in formations which do contain plant remains, is not directly associated with the carbonaceous matter. It may well be that uranium can occur in almost any sedimentary rock if the rock was near the source of uranium-bearing solutions and had a structure favorable for the entrance of ore-bearing solutions and the deposition of uranium minerals. However, the coarser clastic sedimentary rocks such as sandstone and the presence of carbonaceous matter do seem favorable for uranium deposition.

Because considerable uranium in the Colorado Plateau is associated with copper in sandstone, two low-grade copper deposits in sandstone in Idaho were examined by the U. S. Geological Survey (Gott and Erickson 1952, p. 8-9). Both deposits are in Bear Lake County, southeast of Montpelier; they are in arkosic sandstone of Triassic age and the copper mineralization is associated with carbonized plant material. Although the uranium content was found to be negligible, the fact that radioactivity was detected is significant.

Lignite in Tertiary lake beds near Salmon was also investigated (Hail and Gill 1953, pp. 8-9) and found to contain virtually no uranium. On the other hand, commercial-grade uranium has recently been discovered in similar lake beds

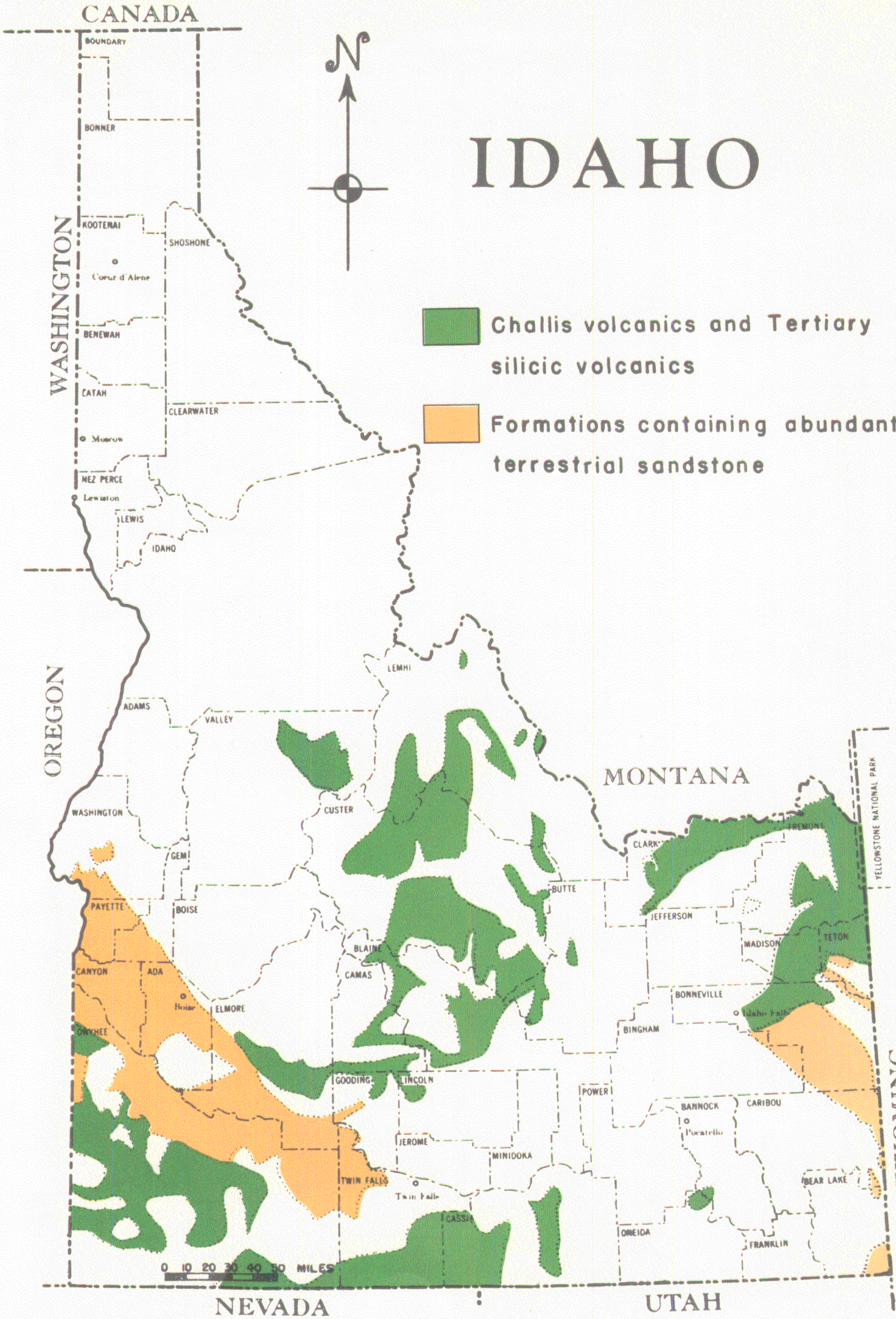

FIGURE 8. DISTRIBUTION IN IDAHO OF FAVORABLE HOST ROCKS FOR URANIUM: B. SILICIC VOLCANIC ROCKS AND TERRESTRIAL SANDSTONES.

near Townsend, Montana. The uranium near Townsend is in silty beds rather than in lignite; in light of this, the Salmon lake beds should probably be re-examined.

Almost all phosphate deposits appear to contain some uranium. This is true of the phosphate of the Phosphoria formation in Idaho, from which assays of as high as 0.06 percent uranium have been obtained. This is not too far below the lowest grade which the government will currently accept, 0.10 percent uranium. The billions of tons of phosphate rock which are available will greatly increase uranium reserves in this country, if the uranium becomes economically recoverable as a by-product in the phosphate operations. The higher grade phosphate rock generally contains the most uranium, but the origin and controls of deposition are not yet known.

The conclusions of Gott and Erickson (1952, p. 9) about copper and uranium deposits in sandstone are worth quoting:

> Variation in the factors that controlled the deposition of copper and uranium minerals apparently has resulted in two general types of deposits: deposits in which deposition of the ore minerals was controlled by permeability and carbonaceous material, and deposits in which the deposition of the minerals was structurally controlled.
>
> The copper and uranium in many deposits have been concentrated by carbonaceous materials.....Most of the enclosing sandstones are light in color, porous, micaceous, often arkosic; and most of the areas of mineralization are near large folds or orogenic belts. In contrast, the structurally controlled deposits are localized along faults, shear zones, and associated joints and fractures where carbonaceous material is not present.

An association of the Colorado Plateau uranium deposits with small Tertiary monzonite intrusive bodies, stocks and laccoliths, has been postulated. Uranium occurs within one such intrusive body, at Marysvale, Utah, and appears to occur more or less radially in sandstone around other intrusions. An interesting age association becomes apparent here: these intrusive bodies are Early or Middle Tertiary in age; the uranium in the sandstones on the Plateau is Late Cretaceous or Early Tertiary; the most extensive of the acid volcanic rocks in Utah, Nevada, and Idaho, are also Early Tertiary in age; and the youngest carnotite-bearing formation is the Eocene (Early Tertiary) Wasatch formation. All this points to an Early Tertiary epoch of volcanic activity and associated uranium mineralization. Small Tertiary granitic intrusive bodies in Idaho, especially if they have intruded porous sandstone, may therefore be good places to look for uranium mineralization.

The most favorable host rocks for primary uranium vein deposits appear to be granitic rocks and sandy metasediments (quartzite and quartz-mica schist).

Pitchblende veins are commonly cavity fillings, and replacement of wall rock is relatively unimportant. Wall rock alteration in many places is a hematite staining; in other places the wall rock has been partially altered to clay. Primary deposits as low as 0.1 percent U_3O_8 are now being mined.

The dominant structural control of carnotite deposits in sandstone seems to be old stream channels. Most of the carnotite ore mined on the Colorado Plateau contains 0.2 to 0.4 percent U_3O_8. Uranium-bearing phosphates that are currently considered significant for possible production of uranium range between 0.01 and 0.03 percent U_3O_8 (Everhart 1951, p. 20).

Bleaching of associated sandstones and mudstones has proved a useful guide to ore on the Colorado Plateau. The ore-bearing sandstones are of stream origin and are generally light-colored near ore bodies, although they may be locally stained by secondary iron oxide. Although much of the uranium is associated with plant remains, recent research (Schopf and Gray, 1954) has shown that there is no definite relation between uranium content and plant microcomponents.

Mine dumps and old workings should be examined with a counter and mineral light. For instance, green uranium minerals may have been regarded as copper minerals and scheelite may have passed unnoticed because it looked like a gangue mineral.

FOR THORIUM

In placers

The principal thorium mineral found in Idaho placers, monazite, can easily be prospected for with the gold pan. With a little practice, the grade of a placer deposit can be estimated by the amount of monazite which remains in the pan after the lighter minerals have been washed out.

There appears to be a north-south orientation in the western part of the Idaho batholith of the good monazite placers, and this may be useful as a guide to prospecting (see map, Fig. 4).

In vein and replacement deposits

Lemhi County offers one of the best prospecting localities for deposits of thorium. Vein deposits of thorite near Lemhi Pass and replacement deposits of monazite in marble in the northern part of the county have already been discovered.

Although primary uranium minerals may contain thorium (and vice versa), in Idaho thorium and uranium deposits do not seem to be closely associated. Although both may occur in the same general area, minerals of both metals are not found in the same deposit (with the exception of some placers). The

Sunshine mine uraninite, for example, assayed 26.9 percent U_3O_8 and no thorium (Kerr and Kulp, 1952). Thorite-bearing veins in the Lemhi Pass area assayed only 0.008 percent uranium (Trites and Tooker 1953, p. 192).

Vein deposits of thorium will probably be found only with the aid of a counter, and then can only be definitely distinguished from uranium deposits by analysis, although the absence of secondary uranium minerals will suggest that a radioactive deposit may contain thorium.

The monazite replacement deposits may be located by use of a counter and by geology; they occur only in crystalline limestone or marble and if one such deposit is located in a particular marble band, others may be expected to occur along the strike of that band. Monazite is rather easily recognized, so that a chemical analysis is necessary only for evaluation of the deposit.

FOR TUNGSTEN

In veins

Tungsten vein deposits are quartz veins, generally in or near granitic rocks. The dark tungsten minerals are recognized principally by their tabular crystalline form, color, and specific gravity. Scheelite in quartz is difficult to recognize without the mineral light. Panning streams for tungsten minerals with the aid of an ultra-violet light is an excellent way to search for both vein and contact deposits. The Thompson Creek deposit, northwest of Clayton, was discovered in this manner. Sand and gravel immediately below a tungsten deposit may actually be rich enough to mine; some of the surface material at the Yellow Pine mine, for instance, provided valuable mill feed and some scheelite has been recovered by sluicing hillside and creek gravels at the Thompson Creek property.

In contact deposits

Because the tungsten mineral in contact deposits is scheelite or powellite, the ultra-violet lamp or mineral light is an invaluable aid to prospecting for such deposits. A knowledge of the geology of contact tungsten deposits will serve to greatly narrow down areas favorable for prospecting. Contact tungsten deposits occur only in areas where limy sedimentary or metamorphic rocks are in contact with granitic rocks. The invaded rock may be limestone, marble, calcareous argillite, or calcareous shale; the granitic rock may be a batholith, a stock, or a dike. Almost all contact deposits are in tactite, a rock formed of distinctive green, red, white, and colorless minerals such as epidote, garnet, diopside, and quartz. Thus the search can be quickly narrowed to portions of limy beds which have been converted to tactite near granitic rock masses. Then the mineral light is brought into play, with the bottle of acid to foil the deceptively fluorescent calcite, if such be present.

South-central Idaho tungsten belt

As previously mentioned, there is a zonal distribution of most of the known Idaho tungsten deposits (Fig. 5), and it would seem logical to expect a greater chance of finding new tungsten deposits somewhere near the axis of this zone than elsewhere, especially in the headwaters area of the Middle Fork of the Salmon River, where no tungsten has yet been found.

HOW TO LOCATE A MINING CLAIM

WHO MAY LOCATE A CLAIM?

All citizens of the United States and those who have declared their intention to become citizens may locate mining claims on government land open to prospecting, and may occupy the land for the purpose of exploration and development, and may eventually secure patent for this land. Right to such lands is initiated by prospecting for minerals thereon and upon discovery of mineral, by location of such lands. A location is made by staking corners of the claim, posting notice of location thereon and complying with the state laws regarding the recording of the notice in the office of the county recorder of the county where the lands are located, after location work has been completed.

Women as well as men are allowed to locate and hold mining claims. It is not necessary to be a resident of the state.

FEDERAL LANDS OPEN TO PROSPECTING

Unoccupied, unappropriated vacant public lands of the United States, surveyed or unsurveyed, are open to prospecting, and upon discovery of mineral, to location and patent, as also are lands in national forest reserves (forest regulations must be observed), and lands entered or patented under the grazing homestead law (title to minerals only can be acquired). Under the grazing homestead law, mining locations may be made with the written consent of the owner of the surface rights, or upon agreement and payment of damages to surface rights, or upon giving bond to secure payment of damages; all minerals are reserved to the United States under this law and no mineral rights are acquired by grazing homestead patent. Mining claims may also be located within grazing districts under the Taylor Grazing Act.

Mining claims on the other hand may not be located on patented lands, except as above noted, nor on lands withdrawn from entry by the government. Except as to the grazing homestead act, mining claims may not be located on patented homesteads or other homestead entries. With but four exceptions, mining claims may not be located in National Parks or National Monuments.

PROCEDURE TO BE FOLLOWED IN LOCATING CLAIMS

Discovery of mineral

A mining location is not valid until an actual discovery of mineral is made within the limits of the claim. Assessment work will not take the place of a discovery. The mining laws do not limit the number of claims that can be located by an individual, association or corporation; however, no location notice shall claim more than one location, whether the location is made by one or several locators.

Dimensions of a claim

Lode locations, for minerals in lodes or veins, may not exceed in length 1500 feet along the vein and in width 300 feet on each side of the middle vein (if several are present), or a total width of 600 feet. The end lines of the claim must be parallel and straight; this is not true of the side lines, but if angles are contained in the side lines they must be staked at each angle.

Location monument and notice

The locator, at the time of making the discovery of mineral, must erect a monument at the place of discovery, upon which he must place his name, the name of the claim, the date of discovery and distance claimed along the vein each way from such monument. <u>Within ten days from the date of discovery</u> he must mark the boundaries of his claim by establishing at each corner and at each angle in the side lines, a monument marked with the name of the claim and the corner or angle it represents; also, at the time of marking his boundaries, the locator must post at his discovery monument his notice of location in which must be stated:

(1) the name of the locator;

(2) the name of the claim;

(3) the date of discovery;

(4) The direction and distance claimed along the ledge or vein from the discovery;

(5) the distance claimed on each side of the middle of the ledge or vein;

(6) The distance and direction from the discovery monument to such natural object or permanent monument, if any such there be, as will fix and describe in the notice itself the location of the claim;

(7) the name of the mining district, county, and state.

When, from any cause, a monument cannot be safely planted at the true corner or angle, it may be placed as near thereto as practicable, and so marked as to indicate the place of such corner or angle.

Monuments may be made of any such material or form as will readily give notice, but when made of posts or trees, they must be hewn and marked upon the side facing the discovery, and must be at least four inches square or in diameter. Monuments must be at least four feet high above the ground, and trees must be so hewn as to readily attract attention.

Location work

Within sixty days after the location, the locator or his assigns must sink a shaft upon the lode to the depth of at least 10 feet from the lowest part of the rim of such shaft, and of not less than 16 square feet area. This requirement is necessary to secure a valid location and is distinct from the requirement as to annual labor under the federal law. The Idaho Supreme Court has held that there must be a substantial compliance with this provision as to location work and that it is required for the purpose of exacting good faith and preventing holding of mineral ground for the purpose of remote speculation without intent of development.

Recording the notice of location

Within 90 days after the location of the claim the locator or his assigns must file for record in the office of the county recorder of the county, or of the deputy recorder of the mining district in which the claim is situated, a substantial copy of his notice of location.

Location of an abandoned claim

The location of abandoned claims is done in the same manner as if the location were a new claim, except, that the locator may, instead of sinking a new discovery shaft, sink the original disdovery shaft ten feet deeper than it was at the time of his location, or he may drive an existing open cut or tunnel ten feet farther along the vein or lode. He must, however, erect new posts or monuments.

Security to surface owners

When the right to mine is in any case separate from the ownership or right of occupancy of the surface ground (as in the case of grazing homestead lands), the owners or rightful occupants of the surface ground may demand satisfactory security from the miners, and if it be refused or not given, may enjoin the miners from working the ground until such security is given. The court granting the writ of injunction shall fix the amount and nature of the security.

Location of placer claims

Placer claims may not exceed 20 acres in area and no location by one person or an association of persons shall exceed 160 acres. Placer claims must conform as near as practicable with the U. S. system of public-land surveys, and the rectangular subdivisions of such surveys. In general, the rules of location are similar to those for locating lode claims, except that:

(1) the notice of location is to be posted on one of the claim corner posts;

(2) within 15 days after making the location, the locator must make an excavation upon the claim of not less than 100 cubic feet, for the purpose of prospecting; and

(3) within 30 days after the location, the notice of location must be recorded in the office of the county recorder.

Affidavit of locators

At or before the time of presenting a location notice for record, whether it be for a lode or placer claim, one of the locators must make and subscribe an affidavit that he is a citizen of the United States or has declared his intentions to become such, that he is acquainted with the mining ground described in the location notice, that to the best of his knowledge the ground claimed has not previously been claimed or else has been abandoned, and that he has performed the required location work.

Annual Labor

The locator of a mining claim must do $100 worth of work annually in order to hold his claim. The annual period commences at noon on the first day of July following the date of location of the claim. What does count as annual labor and what will not count is set forth in the Mining Laws of the State of Idaho, available from the Office of the State Inspector of Mines, Boise.

THE APEX RULE

There has probably been more mining litigation based upon the application and interpretation of the so-called apex rule than there has over any other single mining law. This apex rule provides that locators "shall have the exclusive right of possession and enjoyment of all the surface included within the lines of their locations, and all veins, lodes, and ledges throughout their entire depth, the top or apex of which lies inside of such surface lines extended downward vertically, although such veins, lodes or ledges may so far depart from a perpendicular in their course downward as to extend outside the vertical side lines of such surface locations. Such rights are limited to such portions which lie between vertical planes drawn downward through the end lines". Nothing in this rule authorizes the locator or possessor of a vein which extends in its downward course beyond the vertical side lines of his claim to enter upon the surface of a claim owned or possessed by another.

This simply means that a locator may follow any vein which outcrops on his claim downward as far as he wishes, even if it passes outside the side lines of his claim, as long as he stays within the end lines of his claim or claims. The rule is relatively simple to apply in the case of a single fissure vein or definite shear zone, but it becomes difficult to apply to a complex system of faulted veins and stringers, many of which may not even outcrop on the surface.

FEDERAL LANDS ON WHICH PROSPECTING IS RESTRICTED OR PROHIBITED

Lands containing coal, phosphate, sodium, nitrate, potash, oil, oil shale, or gas

Until 1954 deposits of coal, phosphate, sodium, nitrate, potash, oil, or gas, and lands containing such deposits owned by the United States were withdrawn from the provisions of the general mining laws and only under dertain conditions could a person secure from the United States the right to enter such lands with a view to prospecting for deposits of these minerals. Such lands came under the provisions of the mineral leasing laws and could, under certain conditions, be leased from the Federal government for mining pusposes.

On August 13, 1954, the President signed Public Law 585, 83rd Congress, amending the mineral laws to provide for multiple mineral development of the same tracts of the public lands. Mining claims may now be located under the mining laws of the United States upon lands subject to the mineral leasing laws, even on such lands which at the time of location are included in a permit or lease issued under the mineral leasing laws. All Leasing Act minerals (coal, phosphate, etc.) are reserved to the United States. The Federal government and its lessees and permittees may enter upon the land covered by a mining claim to prospect for and mine Leasing Act minerals. Public Law 585 provides that, where the same lands are being utilized for mining operations and Leasing Act operations, each of such operations shall be conducted, so far as reasonably practicable, in a manner compatible with such miltiple use.

Other federal lands on which prospecting is restricted

At present no mineral location may be made in any of the National Parks or National Monuments which are in or near Idaho. Neither may claims be staked in a military reservation.

In order to prospect on an Indian reservation, a permit must be obtained from the superintendent of the reservation. Different reservations have different regulations about location of mineral claims, and the local superintendent should be asked about them.

The Atomic Energy Commission temporarily withdraws lands from entry during its prospecting program. Information about such lands may be obtained from district offices of the Atomic Energy Commission.

MINERAL CLAIMS ON STATE LANDS

Location of mineral claims, either lode or placer, may be made upon lands belonging to the State of Idaho in which the mineral rights are reserved or belong to the state. No location may be made on any lands for which a mineral lease application has been made or is pending. A mining location on state land must conform to legal subdivisions if made upon surveyed land. A claim on state land shall not exceed 20 acres. A notice declaring discovery of mineral or the intent of prospecting for mineral shall be conspicuously posted on each 20-acre tract, claim, or fraction. The locator is then allowed 20 days to file a certificate of location with the State Board of Land Commissioners. Within 90 days the locator must do location work in conformity with location work required on Federal land. The locator may hold the claim for two years by performing $100 worth of assessment work each year; he is then required to take a lease on the land or give up the claim.

The State Board of Land Commissioners may lease tracts of state lands not exceeding 640 acres in one lease for prospecting and mining purposes for an annual rental of not less than 25 cents per acre plus a royalty such as the board may deem fair and in the interest of the state. All mineral leases, except for oil and gas, shall be for a term of ten years.

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