THE GEOLOGICAL SURVEY OF WYOMING
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POTENTIALLY SELENIFEROUS AREAS IN WYOMING

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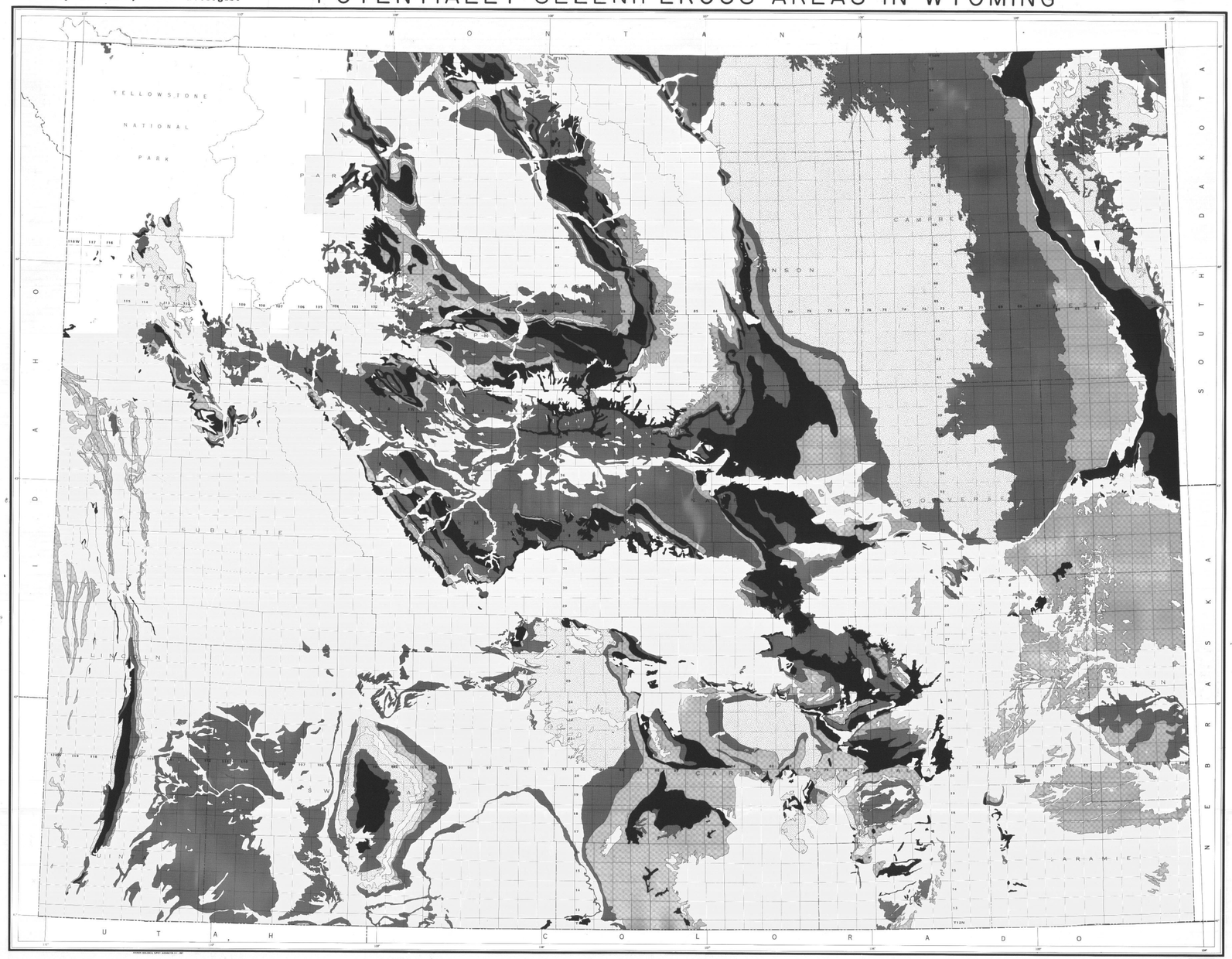

Cartography by Fred H. Porter

EXPLANATION

Geologic formations, equivalents of geologic formations, or locally derived soils that have the potential to support seleniferous vegetation that:

- May be highly toxic to animals in localized areas.
- May be moderately toxic to animals in localized areas.
- May be mildly toxic to animals in localized areas.

Geologic formations that have selenium present in concentrations greater than 0.6 parts per million in localized areas.

Insufficient data for classification.

INTRODUCTION

Selenium is a naturally-occurring element that is present in varying concentrations in many of the geologic formations, soils, and vegetation of Wyoming. It is often associated with uranium, arsenic, molybdenum, and vanadium. Detailed and extensive geochemical surveys are needed to accurately determine the actual distribution in soil, rock, and vegetation. In order to design a geochemical survey, prospecting maps or maps of the "most probable areas of occurrence" are generated. These maps are based upon the extrapolation of whatever limited data are available. Once prospecting maps are generated, sampling schemes can be devised, sampling and analyses conducted, and element distributions defined.

A few areas in Wyoming have been sampled and analyzed for selenium in detail. Most areas of the State, however, have had spotty sampling from which broad generalizations have been made about the occurrence and distribution of selenium in geologic formations, soils, and vegetation. This *Guide to potentially seleniferous areas in Wyoming* represents the data and interpretations that are presently available. In many respects, this guide is similar to a prospecting map, in that limited data were extrapolated to cover the entire State. Two distinct types of data were utilized to generate the guide. The first set of data relates seleniferous vegetation to geologic formations and soils. The geochemistry of the bedrock and soil is in large part inferred from chemical analyses of the vegetation growing on the bedrock and soil. The other set of data is based on geochemical analyses of bedrock without analyses of vegetation. Both sets of data were combined on the guide by utilizing two classification schemes. In order to directly compare the two data sets, bedrock analyses will be required to supplement the former and vegetation analyses will be required to supplement the latter, respectively.

While the *Guide to potentially seleniferous areas in Wyoming* summarizes existing information, it is most useful in setting priorities for much needed sampling programs. The various categories now shown on the map reflect the potential for selenium to occur in specific zones or sites within outcrop boundaries of geologic formations or soils. Selenium may not occur in detectable amounts within all portions of the delineated areas. Similarly, selenium may occur in detectable amounts in areas outside those delimited on the guide map, although that probability is less or is unknown.

It has been known since the 1930s that different types of vegetation could concentrate selenium to varying degrees. In fact, certain plants called selenium indicators appear to require selenium for proper growth. Trelease and Beath, 1949, recognized the association of selenium indicator plants with seleniferous geologic formations and soils.

A discussion of selenium indicator plants is beyond the scope of this text, but there are a few types that are widely distributed in parts of Wyoming. For example, about twenty-four species and varieties of milk vetch (Leguminosae-*Astragalus*), woody aster (Compositae-*Xylorhiza*), goldenweed (Compositae-*Haplopappus*), and princes plume (Cruciferae-*Stanleya*) are all selenium indicators (Rosenfeld and Beath, 1964). Most cases of selenium poisoning in Wyoming have occurred as a result of grazing animals consuming selenium indicator plants.

CLASSIFICATION SCHEMES

Two classification schemes have been developed in order to rank areas of the State in regard to their localized potential for the occurrence of selenium. The first classification delineates specific geologic formations, equivalents of these geologic formations, or locally derived soils that have the potential to support seleniferous vegetation that may be toxic to grazing animals in localized areas. Most of the equivalents of these geologic formations that are delineated on the map have very little or no site-specific data to justify their inclusion in a category. They are included because they have similar depositional histories and are essentially the same age as geologic formations that do have a documented history of supporting toxic vegetation.

The first classification subdivides potential vegetation toxicity into highly toxic, moderately toxic, and mildly toxic categories. These categories were originated by Trelease and Beath (1949). Vegetation that is classified as highly toxic may be lethal to grazing animals. Many of the geologic formations or soils that can support this type of vegetation and are delineated on the map have had livestock deaths associated with the vegetation in specific localities. This is not to say that all the vegetation growing in the defined areas is lethal or even toxic. Within the defined areas, however, there is a greater probability of finding highly toxic seleniferous vegetation than outside of them.

Vegetation that is classified as moderately toxic may result in observable toxic effects on animals that consume it. The records at the Geological Survey of Wyoming do not indicate that any deaths have been associated with the vegetation growing on bedrock or soils in this category. Most of the geologic formations and soils in this category were included as a direct result of vegetation or bedrock analyses reported by Trelease and Beath (1949).

Vegetation that is classified as mildly toxic has potential to cause observable toxic effects if the vegetation is consumed over long periods of time. There have been reports of toxicity in animals confined to pastures with an abundance of plants in this category (Beath, Eppson, and Gilbert, 1939). Most of the geologic formations and soils in this category were included as a direct result of bedrock analyses and descriptions reported by Trelease and Beath (1949) and Beath, Eppson, and Gilbert (1935).

Very few vegetation analyses are available for the geologic formations not included in the first classification, resulting in a need for a second classification scheme. The second classification delineates geologic formations that have a potentially significant selenium content. The average concentration of selenium in crustal shale is estimated at 0.6 parts per million (ppm) by Turekian and Wedepohl (1961). Because average concentrations of elements in shale are often used for geochemical comparisons, values above 0.6 ppm selenium in bedrock are considered significant in this study. As a result, the second classification delineates geologic formations where selenium has been reported in concentrations greater than 0.6 ppm. Most of the data used for this analysis was derived from the U.S. Geological Survey's Rock Analysis Storage System (RASS), Trelease and Beath (1949), Davidson (1963), Harlow et al. (1967), and Bendix (1983). The existing or potential selenium toxicity has not been determined for vegetation growing on the geologic formations in this category. Future work must determine the levels of selenium in plants growing on these formations.

All portions of the map not addressed by the above classifications have insufficient bedrock, soil, or vegetation data to put them in either classification. Although many of these areas have been described as being nonseleniferous by Trelease and Beath (1949), the limited data was found to be insufficient to justify those claims.

Classifications and comments on geologic formations

The areas delineated on the guide map to the left in large part outline various geologic formations. The formation boundaries were derived from the *Geological map of Wyoming* by Love and Christiansen (1985). Listed below are the formations that were incorporated into the guide map. Comments on the formations serve to justify their inclusion. Most comments and data were derived from Trelease and Beath (1949); Rosenfeld and Beath (1964); Beath, Eppson, and Gilbert (1935); Davidson (1963); Harlow, et al., (1967); U.S. Geological Survey Rock Analysis Storage System (1987); and Bendix (1983).

GEOLOGIC FORMATIONS THAT SUPPORT VEGETATION THAT MAY BE HIGHLY TOXIC TO GRAZING ANIMALS IN LOCALIZED AREAS. AVAILABLE BEDROCK DATA IS INCLUDED.

BROWNS PARK FORMATION (Miocene) - Supports the growth of highly seleniferous plants in southwestern Carbon County. Selenium levels in some sandstones in that vicinity have been as high as 112 ppm with 91 percent of that being water soluble (selenate). Uranium minerals in the sandstone contained 12-80 ppm selenium six miles west of Baggs, Wyoming.

WAGON BED FORMATION (Tertiary) - Near Lysite, highly seleniferous tuffaceous rocks and (or) alluvium derived from them support vegetation that is highly toxic to livestock. One sample of bedrock contained 187 ppm of selenium with selenate comprising 96 percent of the total selenium.

PIERRE SHALE (Upper Cretaceous) - Grains and grasses grown on soils derived from the Pierre Shale can produce alkali disease in grazing animals.

STEELE SHALE (Upper Cretaceous) - A variety of highly seleniferous plants are found growing on the basal portion of the Steele Shale.

CODY SHALE (Upper Cretaceous) - An approximate time equivalent with, and similar depositional environment to, the Niobrara Formation and Steele Shale.

NIOBRARA FORMATION (Upper Cretaceous) - Supports the growth of highly seleniferous vegetation. Livestock deaths have been associated with the formation.

HILLIARD SHALE (Upper Cretaceous) - In part equivalent to the Niobrara Formation. It supports a diversity of seleniferous plants.

BAXTER SHALE (Upper Cretaceous) - An approximate equivalent to the Niobrara Formation.

MORRISON FORMATION (Upper Jurassic) - Supports the growth of selenium indicator plants wherever it crops out. Suitides are high in selenium. All vegetation in the Salt Wash Sandstone Member is potentially dangerous to grazing animals, due to the presence of large amounts of soluble selenium oxyanions (seleneates) in the soil. In fact, up to 1,000 ppm selenium has been found in some of the uranium-vanadium ores in that member. A portion of the selenium was soluble.

PHOSPHORIA FORMATION (Permian) - Several species of selenium indicator plants grow on the shales and on soils derived from the shales of this formation. In western Wyoming, high-grade phosphate rock contained from 1-95 ppm selenium, with lower grade phosphate rock containing a maximum of 212 ppm. Small amounts of selenium are in a water-soluble form (selenate). Some limestone beds contain up to 14 ppm selenium.

GEOLOGIC FORMATIONS THAT SUPPORT VEGETATION THAT MAY BE MODERATELY TOXIC TO GRAZING ANIMALS IN LOCALIZED AREAS. AVAILABLE BEDROCK DATA IS INCLUDED.

CHADRON MEMBER OF WHITE RIVER FORMATION (Oligocene) - Limited sampling indicates the member may support numerous indicator plants with moderate amounts of selenium.

BRIDGER FORMATION (Eocene) - Locally has highly seleniferous vegetation. Sampling has been limited. A partial equivalent of the Wagon Bed Formation.

BATTLE SPRINGS FORMATION (Eocene-Paleocene) - Available data indicates a selenium content locally ranging up to 768 ppm.

ATCROSS FORMATION (Eocene) - An approximate equivalent of the Bridger Formation.

WILKINS PEAK AND TIPTON SHALE MEMBERS OF GREEN RIVER FORMATION (Eocene) - Support a variety of plants with moderate to high amounts of selenium.

WIND RIVER FORMATION (Eocene) - Highly seleniferous in areas.

FORT UNION FORMATION (Paleocene) - Certain areas support dense growths of selenium indicator plants. High levels of selenium are associated with uraniferous areas. In parts of eastern Wyoming, this formation can pose a hazard to grazing animals. A coal from the Fort Union Formation in northeastern Wyoming had a 3 ppm selenium content.

MEDICINE BOW FORMATION (Upper Cretaceous) - In general, will support a few seleniferous plants. The carbonaceous shales along the east flank of the Medicine Bow Mountains, however, contain a high concentration of selenium. Some sandstones underlying the shales in that vicinity contain up to 112 ppm selenium. This selenium was probably leached from the overlying shales. A sample of weathered or impure coal in Albany County had 1-6 ppm selenium.

BLAIR FORMATION (Upper Cretaceous) - A partial equivalent of the Steele Shale. Limited data are available.

CARLILE SHALE (Upper Cretaceous) - Plants on this formation contain moderate amounts of selenium.

FRONTIER FORMATION (Upper Cretaceous) - Seleniferous and Beath (1949), the limited data was found to be plants are abundant. A limestone from the formation had 7 ppm selenium.

GREENHORN FORMATION (Upper Cretaceous) - A partial equivalent of the Frontier Formation.

BELLE FOURCHE SHALE (Upper Cretaceous) - A partial equivalent of the Frontier Formation.

MOWRY SHALE (Lower Cretaceous) - Supports seleniferous vegetation of moderate toxicity.

MUDDY SANDSTONE MEMBER OF THERMOPOLIS SHALE (Lower Cretaceous) - Supports considerable growth of moderately seleniferous plants.

CLOVERLY FORMATION (Lower Cretaceous) - Statewide, the Cloverly Formation supports mildly seleniferous plants in localized areas. However, portions of the formation contain up to 21 ppm selenium in Albany County.

SUNDANCE FORMATION (Upper-Middle Jurassic) - Supports the growth of moderately seleniferous plants.

GYPSUM SPRING FORMATION (Middle Jurassic) - Selenium indicator plants grow in dense stands on the gypsum beds.

ALCOVA LIMESTONE MEMBER OF CHUGWATER FORMATION (Upper and Lower Triassic) - Supports a dense growth of selenium indicator plants.

GEOLOGIC FORMATIONS THAT SUPPORT VEGETATION THAT MAY BE MILDLY TOXIC TO GRAZING ANIMALS IN LOCALIZED AREAS. AVAILABLE BEDROCK DATA IS INCLUDED.

MIOCENE ROCKS - With the exception of the Browns Park Formation in southwestern Carbon County, the bulk of the Miocene rocks in the south and south-central portions of the State are suspected of supporting vegetation with low levels of selenium. Sampling has been very limited.

ARIKAREE FORMATION (Miocene and Upper Oligocene) - In localized areas, supports plants with a low selenium content.

LANCE FORMATION (Upper Cretaceous) - Supports indicator plants of low selenium content in some areas.

LEWIS SHALE (Upper Cretaceous) - Supports scattered growths of mildly seleniferous vegetation.

MESAVERDE FORMATION (Upper Cretaceous) - The lower marine portion supports seleniferous plants.

ASPEN SHALE (Lower Cretaceous) - Supports a diversity of seleniferous plants. Sampling is limited.

THERMOPOLIS SHALE (Lower Cretaceous) - Supports mildly seleniferous plants in localized areas.

GANNETT GROUP (Lower Cretaceous) - Supports several species of seleniferous plants with low selenium content.

CHUGWATER FORMATION (Triassic) - The basal Chugwater Formation supports the growth of numerous selenium indicator plants in areas.

DINWOODY FORMATION (Lower Triassic) - Supports an abundant growth of indicator plants with a low selenium content.

GOOSE EGG FORMATION (Lower Triassic and Permian) - Selenium indicator plants of low selenium content grow in abundance on this formation, especially the Little Medicine and the Freezeout Tongues.

AMSDEN FORMATION (Pennsylvanian-Mississippian) - Supports the growth of indicator plants with a low selenium content.

GEOLOGIC FORMATIONS WHERE SELENIUM IS LOCALLY PRESENT AT CONCENTRATIONS EXCEEDING 0.6 PARTS PER MILLION. TOXICITY OF VEGETATION HAS NOT BEEN DETERMINED.

WASATCH FORMATION (Eocene) - Available data indicates that the Wasatch Formation in the Powder River Basin and the Niland Tongue in the Rock Springs uplift have selenium contents locally ranging up to 1,900 ppm.

HANNA FORMATION (Paleocene) - Available data indicates a selenium content that locally ranges up to 5.16 ppm.

FERRIS FORMATION (Paleocene-Upper Cretaceous) - Available data indicates a selenium content locally ranging up to 2.19 ppm.

HAREBELL FORMATION (Upper Cretaceous) - Available data indicates a selenium content locally ranging up to 1.78 ppm.

MEETETSE FORMATION (Upper Cretaceous) - Available data indicates a selenium content locally ranging up to 1.4 ppm.

ALMOND FORMATION (Upper Cretaceous) - Available data indicates a selenium content locally ranging up to 2.45 ppm.

ROCK SPRINGS FORMATION (Upper Cretaceous) - Available data indicates a selenium content locally ranging up to 2.7 ppm.

ADAVILLE FORMATION (Upper Cretaceous) - Available data indicates a selenium content locally ranging up to 1.19 ppm.

BACON RIDGE SANDSTONE (Upper Cretaceous) - Available data indicates a selenium content locally ranging up to 7.46 ppm.

BEAR RIVER FORMATION (Lower Cretaceous) - Available data indicates a selenium content locally ranging up to 7.0 ppm.

INYAN KARA GROUP (Lower Cretaceous) - Available data indicates a selenium content locally ranging up to 900 ppm. This group is equivalent to the Cloverly Formation.

THAYNES LIMESTONE (Triassic) - Available data indicates a selenium content locally ranging up to 1.5 ppm.

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GUIDE TO POTENTIALLY SELENIFEROUS AREAS IN WYOMING

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