Uranium indicator plants of the Colorado Plateau

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Uranium indicator plants of the Colorado Plateau

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Introduction

Uranium occurrences have been reported in numerous localities and geologic formations throughout the Colorado Plateau, which includes parts of Colorado, Utah, Arizona, and New Mexico (fig. 1). Uranium prospecting techniques are many and varied, but a simple method that requires no special equipment is a botanical system utilizing indicator plants. Botanical prospecting by plotting and mapping the distribution of selenium indicator plants has been used effectively in this area for the past 80 years.

FIGURE 1—Index map showing location of Colorado Plateau.

Botanical prospecting based on the premise that concealed mineral deposits may be chemically reflected in surface vegetation has been used through the ages in the search for various metals. Certain plants growing in soils over metalliferous deposits absorb and accumulate metals and associated elements. A Russian geologist, Karpinsky, was one of the first to recognize that different plant associations thrive on varying geologic substrates (Brooks, 1972). The many uses of plants in interpreting geological phenomena are reviewed by Cannon (1971).

Two methods of botanical prospecting for uranium deposits have been applied on the Colorado Plateau. The first, based on a chemical analysis of deep-rooted plants that absorb uranium from ore bodies, detects small but measurable amounts of the element in plants rooted in ore. Fluorimetrically analyzed plant ash commonly indicates that these plants contain several ppm (parts per million) uranium, whereas ash from plants in unmineralized soil generally contains less than one ppm. In semiarid country, similar specimens collected from identical species of trees and deep-rooted shrubs show differences in uranium content. These variations reflect the presence of mineralized ground to a maximum depth of 75 ft (Cannon and Kleinhampl, 1956).

A second method involves mapping the distribution of indicator plants because these plants are dependent—either directly or indirectly—upon the presence of abnormally high levels of elements in the parent soil or rock. Indicator geobotany is concerned with the aspects of vegetation and its component species as indicators of the environmental condition. Prospecting by indicator plants is the quickest and least expensive of the two methods (Cannon, 1957).

A plant may be used as a valid indicator in prospecting for metalliferous deposits if its distribution is affected by the availability of chemical constituents present in the ore. The plants used in prospecting for a particular deposit may be controlled by other elements associated with the ore as well as the potentially economic element. Indicator plants for uraniferous sandstone deposits are seldom affected by in- ☞

TABLE 1—URANIUM-BEARING FORMATIONS OF THE COLORADO PLATEAU (after Cannon, 1960).

SYSTEM	GROUP, FORMATION OR MEMBER	MINING DISTRICTS AND OTHER AREAS IN WHICH PLANT RELATIONS HAVE BEEN EXAMINED
Tertiary and Quaternary (?)	Santa Fe Group	Santa Fe, NM
Tertiary	Uinta Formation	Uinta, UT
	Green River Formation	Poison Butte, WY
	Chuska Sandstone	Defiance, AZ
Cretaceous	Mesaverde Group	La Ventana, NM
	Dakota Sandstone	Grants, NM
Jurassic	Morrison Formation:	
	Brushy Basin Member	Grants, NM
	Westwater Canyon Member	Grants, NM
	Recapture Member	Chuska, AZ-NM
	Salt Wash Member	Thompson, UT; Green River, UT; Henry Mountains, UT; Monticello, UT; Gateway, CO-UT; Paradox, CO-UT; Gypsum Valley, CO-UT; Bull Canyon, CO; Slick Rock, CO; Ship Rock, NM-AZ-UT
Triassic	Todilto Limestone	Grants, NM
	Chinle Formation:	
	Moss Back Member	San Rafael, UT
	Shinarump Member	White Canyon, UT
Permian	Cutler Formation	Gallina, NM

creased amounts of uranium but rather by high concentrations of uranium-associated selenium. Sulfur, calcium, and phosphorous in water-soluble forms also influence the growth of the same plant communities (Cannon, 1960). A correlation between the distribution of selenium indicator plants and uranium deposits was first noted by Beath (1943) in conjunction with toxicity studies of range land. The U.S. Geological Survey has since established the use of selenium indicator plants in uranium prospecting (Cannon and Kleinhampl, 1956).

Uranium minerals occur in virtually all formations exposed on the Colorado Plateau (Table 1). About 20 formations ranging in age from Pennsylvanian to Tertiary have yielded commercial ore. Mineable concentrations of uranium occur chiefly in beds of sandstone, but the deposits in the Todilto Limestone are an important exception. Geographic locations of most of these areas are shown in fig. 2 (Cannon, 1960).

FIGURE 2—Index map of part of the Colorado Plateau showing mining districts (after Cannon, 1960).

The ore deposits are generally tabular and lie roughly parallel to the bedding. Carnotite and tyuyamunite, composed of oxides of uranium and vanadium, are the principal ore minerals in the oxidized zone. Uraninite and coffinite associated with sulfides are common at depth (Finch, 1967). Uranium is fixed with vanadium, arsenic and phosphate in insoluble clay-like layer compounds (Cannon, 1960). Uranium ores of the Colorado Plateau often contain anomalous amounts of vanadium, sulfur, selenium, cobalt, molybdenum, lead, zinc, nickel, copper and silver (McKelvey and others, 1955). Several of these elements have been used as geochemical tracers in uranium prospecting. Because differences in the availability of these trace elements and of the major plant nutrients—potassium, phosphorous and calcium—in the environment of an ore deposit affect the vegetation, such effects form the basis for prospecting by botanical means (Cannon, 1960, 1971).

Selenium indicator plants

Twenty-four species and varieties of *Astragalus,* all species of *Xylorrhiza* (woody aster), all species of *Oonopsis* (goldenweed), and all species of *Stanleya* (prince's plume) are plants that require selenium. These plants invariably contain selenium during the greater part of their life cycle, and maximum tissue concentrations often approach 15,000 ppm (Beath and others, 1939b).

The most important group of selenium indicators are included in the genus *Astragalus,* a member of the vetch family. The genus includes some 300 American species; each varies considerably in selenium absorption. Only 24 species of *Astragalus* are known to be selenium absorbers; of these, four are associated with ore deposits of the Colorado Plateau. Other species are indicative, but not diagnostic. Possibly all species of *Astragalus* require selenium, but some require only minute amounts (Cannon, 1957).

FIGURE 3—*Astragalus pattersoni* A. Gray (after Cannon, 1957).

COMMON NAME: RATTLEWEED OR PATTERSON POISON VETCH. Perennial, 1-4 ft high, pinnate with oval leaflets, cream-colored flowers; fat pods on short stems. Seeds rattle in pod when dry.

Districts noted: San Rafael, Thompson, Green River, Monticello, Circle Cliffs, Ship Rock, Slick Rock, Gypsum Valley and Grants.

The two most important species of *Astragalus* are *A. pattersoni* (Patterson poison vetch, locoweed, or rattleweed) and *A. preussi* (Preuss' poison vetch). *Astragalus pattersoni* (fig. 3) grows 1 to 2 ft high with pea-like flowers and pods that rattle when dry—thus the name rattleweed. The plant requires considerable amounts of selenium and commonly absorbs several thousand ppm. Because *Astragalus pattersoni* absorbs selenium more effectively in the presence of uranium, it is an excellent indicator of uranium deposits containing as little as 1 ppm selenium. This widespread species has been useful in prospecting the area from the Henry Mountains, Utah, to

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- Red Rock talc deposit

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Grants, New Mexico in beds ranging in age from Triassic to Miocene (Cannon, 1960).

Astragalus preussi (fig. 4) has purple pea-like flowers in contrast to the cream-colored flowers of *A. pattersoni,* but otherwise is similar in appearance. The absorption of large amounts of vanadium by this species may be a significant factor in the geographic distribution of the plant. *Astragalus preussi* has been used in prospecting in the Thompson, Green River, and Henry Mountain districts of Utah's Morrison Formation. Other indicator species of *Astragalus* are *A. argillous* and *A. confertiflorus* (Cannon, 1960).

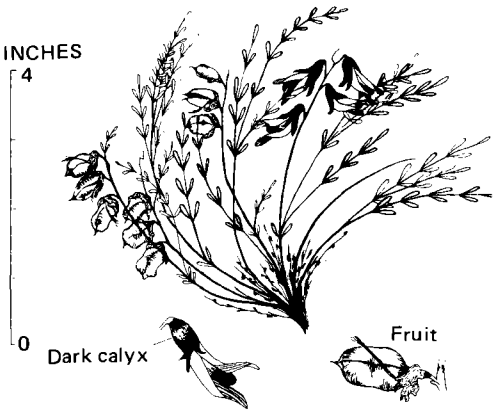

FIGURE 4—*Astragalus preussi* A. Gray (after Cannon, 1957).
COMMON NAME: PREUSS POISON VETCH. Perennial, many stems less than a foot high rise from a woody base, purple flowers with darker calyx, smooth pinnate with 11 to 15 elliptic leaflets; fat, smooth, oblong pod slightly curved, with short stem.
Districts noted: Ship Rock, Slick Rock, Uravan, Gypsum Valley, Thompson, San Rafael, Henry Mountains, Green River, and Moab.

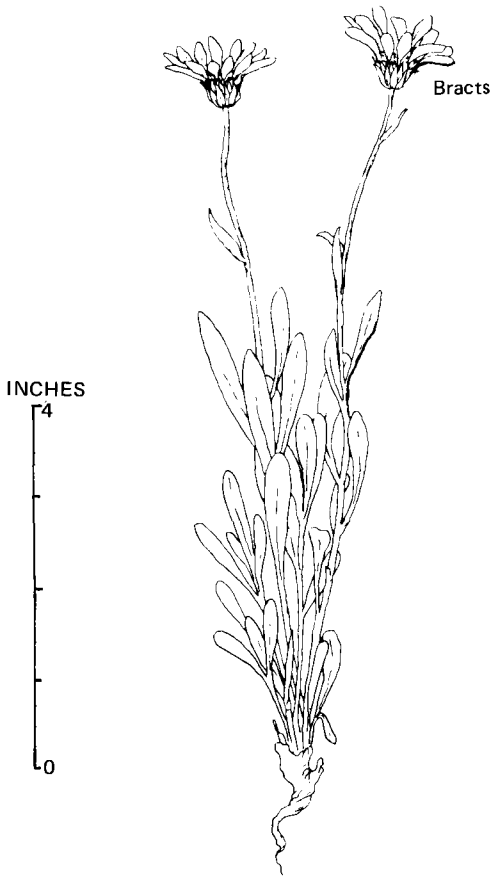

FIGURE 5—*Aster venustus* Jones (after Cannon, 1957).
COMMON NAME: WOODY ASTER. Woody perennial, naked flower stalks, long taproot, 6 to 8 inches tall, composite daisy-like white to lavender flowers, spatula-shaped hairy leaves and small silky seeds.
Districts noted: Thompson, Moab, Henry Mountains and Green River.

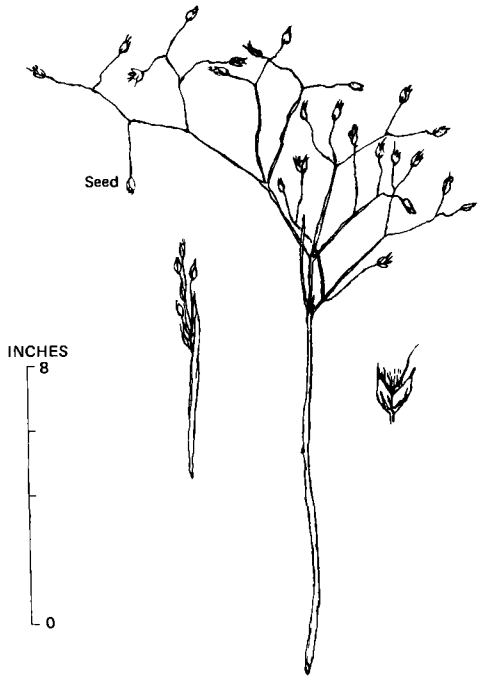

FIGURE 6—*Oryzopsis hymenoides* (Roem and Schult.) Rick (after Cannon, 1957).
COMMON NAME: INDIAN RICEGRASS. Perennial grass 1 to 2 ft high, with deep fibrous roots, small dry flowers, inrolled narrow flowers and small rice-like seeds.
Districts noted: Gypsum Valley, Rifle, Slick Rock, Bull Canyon, Paradox Valley, White Canyon, Thompson, San Rafael, Henry Mountains, Green River, Moab, Monticello, Grants, Poison Basin, and Ship Rock.

Additional plants that require selenium and may act as indicators of uranium ore are *Aster venustus* (woody aster), *Oryzopsis hymenoides* (Indian ricegrass) and *Stanleya* sp. (desert prince's plume). Commonly found on clay soils and alluvium, *Aster venustus* (fig. 5) has white to pink daisy-like heads and hairy leaves growing from a woody base. *Oryzopsis hymenoides* (fig. 6), a perennial grass with small rice-like seeds, is prevalent throughout the western United States in soils containing small amounts of selenium. *Stanleya* sp. (fig. 7) is a weedy perennial of the mustard family with long flower spikes and thin seed capsules extending from the spikes. Although the plant, common to the Colorado Plateau, requires both sulfur and selenium, its use as an indicator is limited (Cannon, 1960). Other marginal indicator plants are *Descurainia* (tansy mustard), *Lepidium* (pepperweed), and *Grindelia* (gumweed). Calcium or sulfur indicator plants should not be considered indicative of mineralized ground, as many of these plants are common roadside weeds. These species, on the other hand, may abound in mineralized areas because the calcium or sulfur is more readily available in uranium deposits than in the surrounding country rock (Cannon, 1960).

Plant chemistry

The selenium content of a given plant is not a simple function of the soil. The major factor influencing selenium uptake from soils is solubility. Although selenium in acid soils is insoluble and unavailable to plants, alkaline soils host soluble selenium—up to half the total amount present. The degree to which soluble selenium will be absorbed is in turn dependent (although in ways not understood) on factors such as chemical form and quantities of other soil constituents, especially sulfur. These factors are more significant in the root-bearing soil horizon than at the soil surface proper (Cannon, 1952).

Although most plants are nonaccumulators, any plant may passively take up selenium dissolved in the soil—the amount will be determined in large part by the form of the selenium and the concentration in the soil. In summary, the concentration of selenium in a given plant is determined by its selenium-accumulating power and the soil's selenium-supply power. The former is determined by the species of the plant, its stage of growth, and its vigor. The latter is determined by the form of selenium, its concentration in the root zone, soil pH, and the amounts and kinds of other elements present (Cannon, 1952).

Toxicity of selenium-rich plants

Selenium has long been known for its toxicity to animals. Two types of poisoning have been recognized: "Blind staggers," usually found in cattle, manifests itself in poisoned animals by the tendency to wander aimlessly, running into fences or other fixed objects. The effects appear after a week or more of ingesting native

range plants of moderate (less than 200 ppm) selenium content. Termination is abrupt in acute cases, ending in death by respiratory paralysis (Gibbons and others, 1970; Merck and Co., 1967).

The chronic form, "alkali disease," usually appears in animals on forage or grain crops grown in seleniferous soils. This misleading term stems from the outdated belief that the disease was associated with alkaline soils or water. Corn, wheat, barley, oats, grass and hay containing 5 to 40 ppm ingested over a period of weeks produce dullness, emaciation and lameness. Split hooves and hair loss result from anemia—a consequence of the inability to graze normally and obtain adequate nourishment. Death from starvation or thirst is not infrequent (Gibbons and others, 1970; Merck and Co., 1967).

Selenium-bearing plants are not a problem to animals under adequate range conditions because the animals will not consume plants with high selenium content unless driven to it. The most troublesome selenium plants are *Astragalus bisulcatus, A. racemosus, A. pectinatus* and *A. pattersoni* (Beath, 1943).

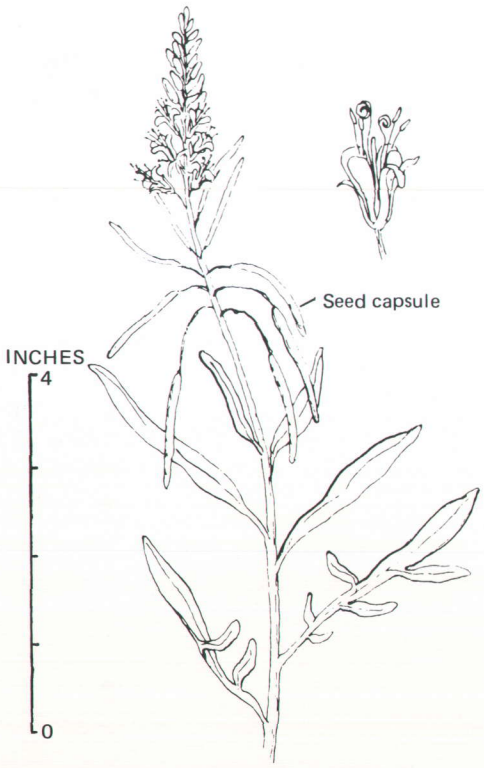

FIGURE 7—*Stanleya pinnata* (Pursh) Bitt (after Cannon, 1957).

COMMON NAME: DESERT PRINCE'S PLUME. Coarse perennial, thick erect stalk, 1-3 ft high, woody root, golden-yellow flowers, pale-green variable-shaped leaves, and long thin capsules containing many seeds.

Districts noted: Ship Rock, Chilchinbito, Slick Rock, Gypsum Valley, Paradox Valley, Thompson, San Rafael, White Canyon, Monticello, Green River, Henry Mountains, Moab, Circle Cliffs, and La Ventana.

Some species of *Astragalus* are not toxic under any circumstances and many of these are desirable forage or soil-building plants. Another group of *Astragalus,* in addition to the four above and the non-toxic varieties, are true locoweeds. Plants in this group produce loco poisoning. This disease, recognized long before 1873 and called "loco" from the Spanish word for crazy, is vividly descriptive of the characteristic symptoms (Beath, 1943).

Summation

The occurrence of indicator plants in the vicinity of ore deposits has been reported for the last 80 years, and it is now recognized that certain varieties truly designate the presence of high selenium levels, and in turn, uranium concentrations. The most reliable indicator plants are *Astragalus pattersoni* and *A. preussi,* found to reflect mineralized ground to an average depth of 70 ft (Cannon, 1960).

Through the increased availability of selenium in the presence of uranium, the most effective indicator plant, *Astragalus pattersoni,* can concentrate enormous amounts of selenium from uraniferous rocks that contain only traces of uranium. Prospecting by indicator plants is most effective in lower ecologic plant zones where the cover is open and herbaceous plant societies grow freely. The indicator plants develop best where the ore contains more than 0.001 percent selenium and lies at an average depth of less than 70 ft beneath the surface (Cannon, 1960).

Botanical prospecting studies made in ten districts of the Colorado Plateau have been remarkably productive. In the Thompson district, Grand County, Utah, five ore bodies were found solely on the basis of indicator plant data. Two ore bodies located in the Poison Canyon area of the Grants district were identified through *Astragalus pattersoni* (Cannon, 1960). A definite correlation between *A. pattersoni* and uranium ores is shown in a belt from the Thompson district through the Green River district to the Henry Mountains district of Utah; the Chuska district of Arizona and New Mexico; and in the Grants and Ship Rock districts of New Mexico (Cannon and Kleinhampl, 1956).

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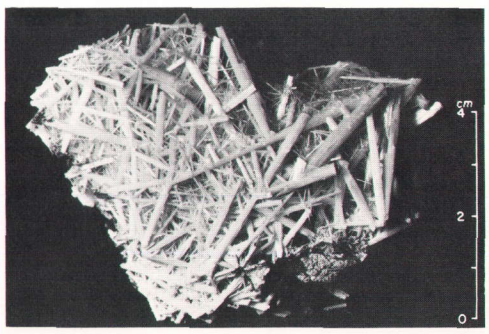
New Mexico's minerals



CERUSSITE, $PbCO_3$. KELLY MINE, KELLY, NEW MEXICO

Crystal system: orthorhombic. Hardness: 3-3½ Specific gravity: 6.55; Cleavage: {110}, good; {021}, fair.

Cerussite is a secondary lead mineral commonly found in the oxidized zone of ore deposits formed by the action of carbonate waters on galena (PbS). In the past, cerussite was an important lead ore in the Magdalena mining district, where it occurs associated with smithsonite ($ZnCO_3$), azurite [$Cu_2Co_3(OH)_2$], and minor oxidized minerals as replacement deposits in the Kelly Limestone (Mississippian). The specimen pictured was donated to the New Mexico Bureau of Mines Mineral Museum by C. T. Brown, geologist and mine operator in the Magdalena district in the early 1900's.