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METHODS OF BOTANICAL PROSPECTING FOR URANIUM DEPOSITS ON THE COLORADO PLATEAU*

By

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By Helen L. Cannon

ABSTRACT

A handbook has been prepared by the U. S. Geological Survey under the auspices of the Atomic Energy Commission as a guide to geologists and prospectors. Two botanical methods of prospecting for uranium ores on the Colorado Plateau are described. By one method, tree branch tips are sampled and analyzed for uranium content. Assay values of more than 1 ppm uranium in the ash are considered to indicate favorable ground for further geologic exploration.

A second method, that of mapping indicator plants, is also used in prospecting for uranium. Indicator plants are used in conjunction with detailed geologic studies of restricted areas as guides to chemical changes in the ore-bearing formation. Plants of the Astragalus genus are most useful in prospecting for uranium deposits with a high selenium/sulfur ratio; Allium and Eriogonum are most useful as indicators of ores with a low selenium/sulfur ratio. Forty descriptions and illustrations are given of selenium- and sulfur-indicator plants commonly associated with carnotite deposits and also of plants tolerant of highly mineralized ground.

INTRODUCTION

Two methods of botanical prospecting have been applied to the search for uranium deposits on the Colorado Plateau. One method is based on a chemical analysis for uranium content of deep-rooted plants that absorb uranium from the ore bodies; the other is based on distribution studies of indicator plants that are commonly associated with uranium deposits. A third possibility, that of morphological or physiologicial changes in plants located in ore deposits has been discarded as a method of prospecting on the Colorado Plateau. In dumps and in diggings where the ore has been oxidized plants become yellowed and are observed to flower and set fruit earlier; no growth changes, however, can be detected in plants rooted in undisturbed ore.

The general principles on which methods of prospecting were developed are described in earlier papers (Cannon, 1952; 1953). Prospecting by plant analysis is comparable to soil analysis but admits the possibility of detecting ore through a maximum of 75 ft of barren rock. The tree thus acts as a conduit for the upward migration of soluble salts to the ground surface. The method is applicable on broad flat benches where plant samples can be collected on a grid pattern to outline mineralized areas at depth and also along rim outcrops where the ore-bearing bed may be covered by talus or slump. The samples are shipped to a chemical laboratory for quantitative assay.

Prospecting by indicator plants is a less expensive method and consists of mapping the areal distribution of indicator plants or studying plant associations of less diagnostic species. Forty indicator plants which are controlled in distribution by the chemistry of the ore deposits and useful in botanical prospecting are described, illustrated, and their use in prospecting evaluated in the latter half of this handbook. The material has been compiled as a non-technical guide for the field man. It is not intended as a key for species identification nor as a collection of taxonomic descriptions of plants growing on the Colorado Plateau. Rather, the illustrations are intended as a sorting device to enable geologists and prospectors to set apart, in a preliminary way, the plants growing in their area which may be useful in prospecting. The data have been gathered during the course of botanical prospecting studies on the Colorado Plateau. The work was done by the Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission. The author wishes to acknowledge the help of Al Froelich of the Geological Survey who contributed to the section on the absorber plant method.

Plants collected in the course of this study were identified by specialists familiar with the plants of each state. T. H. Kearney, A. H. Holmgren, R. J. Davis, and E. F. Castetter have been particularly helpful in identifying specimens submitted to them. The plant descriptions are accompanied in most cases by a line drawing and a black and white photograph. The drawings were made by Maxine Heyl and Ann Pettigrew from pressed plant specimens. The photographs were taken with a Busch press camera by the author and assistant, Edward Clebsch. Further descriptions and pressed material are available for study in the Geological Survey office in Grand Junction, Colo.

COLORADO PLATEAU SOILS AND GROUND WATER CONDITIONS

The interpretation of plant distribution patterns on the Colorado Plateau is related closely to soil and ground water conditions. The climate of the Plateau is semiarid and little residual soil is formed except on the higher mesas. The sandy and clayey soils that are present bear a close relation to the alternating beds of sandstone and shales from which they are derived. Shreve (1951, p. 16) described similar desert soils as typically of low humus content, well-aerated, with a high content of readily soluble salts, and encrustations of hardpan. The most common soluble salts in a desert soil are carbonates, chlorides, and sulfates of calcium, magnesium, and sodium. Many desert plants are tolerant of large amounts of these elements.

In the semiarid Plateau the dependence of indicator plants either directly or indirectly on ground water conditions makes mandatory a study of water conditions in an area of plant study.

Water occurring beneath the ground surface is present in the zone of saturation and the zone of aeration (Meinzer, p. 29-95, 1923). Water occurring in the "zone of saturation", or zone of permeable rocks that are generally saturated with water under hydrostatic pressure, is called "ground water". The upper surface of the zone is called the "ground water table". Due to capillarity, however, the earth is invariably moist for a distance of several feet above the water table. The thickness of the "capillary fringe", varies inversely with the size of the interstices and may vary from 8 or 10 feet in fine silt or sand to 3 or 4 feet in coarse clean sand. The "zone of aeration" extends from the water table to the surface, and water in this zone is called "vadose water". In addition to the zones described, water falling on dry soil may be held in a "suspended capillary fringe", if there is

not enough water to fill the capillary system to a depth sufficient to cause downward percolation by gravity. Also, above impervious layers of clay or volcanic ash, temporary zones of saturation may alternate with zones of aeration, giving rise to "perched water tables".

The latter situation is common on the Colorado Plateau where, in general, the ore-bearing sandstones are perched aquifers underlain by layers of impervious under-clay (Phoenix, 1952, p. 25). Locally clay seams or splits in the sandstone occurring above the ore horizon may prevent oxidation of primary ores at a relatively shallow depth.

PLANTS IN RELATION TO GROUND WATER

Perennial plants, especially in arid regions, which obtain their water from near or below the water table, in contrast to most plants which utilize soil moisture above the water table are called phreatophytes (Meinzer, 1923, p. 95), (Meinzer, 1927, p. 1) (Robinson and Turner, in preparation). Plants which utilize soil moisture where it is available in the zone of aeration, but can withstand long periods of drought are called xerophytes. Many, like the cactus, have relatively short roots, but thickened stems or leaves, well protected from evaporation and designed for water storage. A third group which endures adverse periods as bulbs or as seeds beneath the soil, bursts into bloom suddenly, following a period of heavy rainfall, sets fruit and disappears, is called ephemeral. These are largely annuals or spring bulb plants. Plants of all three groups occur in uranium districts of the Colorado Plateau and are described in this report.

Phreatophytes such as Salix (willow), Tamarix (tamarisk), Cowania (cliffrose), Shepherdia (buffaloberry), Sarcobatus (greasewood), Chrysothamnus (rabbitbrush), and Hedysarum (sweetvetch) are typical indicators of ground water. Normally, on the Colorado Plateau, juniper and pinyon are also phreatophytes and, in areas where the ore-bearing bed is an aquifer, are the best plants for absorber plant prospecting. The use of a phreatophyte in absorber plant prospecting assures that the roots of the sampled plants penetrate the ground water horizon which is also commonly the ore horizon.

Generally xerophytes are also halophytes or plants that are very tolerant of soils of high salt content and are therefore tolerant of and in some cases indicative of shallow uranium deposits. Where the ground water table is below the ore zone, Atriplex confertifolia (shadscale), a xerophytic halophyte, may be sampled as an absorber plant.

In areas where soluble salts from sulfide ore bodies have migrated in considerable quantities to surface soils, indicator ephemerals may flourish and be useful in prospecting. For example, wild onions and other lilies, which are sulfur indicators, have been found to indicate ore at depths of 20 to 30 feet beneath the surface.

PLANT ASSOCIATIONS ON THE COLORADO PLATEAU

The distribution of major plant communities of the Colorado Plateau is controlled by many factors including slope, altitude, ground-water conditions, soil aeration, soil acidity, and soil salt content. In general, the plants described belong either to the sagebrush-juniper-pinyon or the greasewood-shadscale plant associations. The former association is common on sandstone benches where ground water of low alkali content is available, and the latter in alluvium and clay beds of high salt content.

On the higher benches where water of low alkali content is available in the sandstones, little change in the general appearance of the sagebrush-juniper-pinyon flora can be seen around carnotite deposits except that sagebrush flats predominate over forest cover. In poorly drained areas at lower altitude, however, the general appearance of the flora in the carnotite districts is frequently similar to the flora of a salt flat. Instead of an association in which sagebrush (Artemisia tridentata), hop sage (Grayia spinosa), or salt bush (Atriplex canescens) is dominant, it is largely a shadscale (Atriplex confertifolia), snakeweed (Gutierrezia), or greasewood (Sarcobatus) association capable of growing in soils of high salt content.

Patches of indicator plants, controlled in distribution by the availability of specific chemical elements, are found within the shadscale-snakeweed browse. These plants, which may indicate mineralized ground, are not controlled by any one factor and are usually common rather than unusual plants. The control of the species may be pH variations; a change in the availability of phosphorus, potash, calcium or other major constituent necessary for plant growth; or a true dependence on a particular element such as selenium or sulfur.

Selenium-indicator plants are the only group definitely known to be dependent on the presence or absence of a single element. The selenium indicators described by Trelease and Beath (1949) include a tribe of Astragalus species, Stanleya, Aster venusta, Oryzopsis, and several other plants. These indicators absorb large amounts of selenium, sufficient in some areas to poison sheep and cattle. Because selenium is present in many uranium ores, these plants are in some places useful guides to the location of uranium deposits.

The distribution of many sulfur-absorbing plants reflects the presence of large amounts of sulfur in the soil. Plants that require large amounts of sulfur for their growth include the lily and mustard families, at least a part of the buckwheat family, and various isolated genera. Because many uranium ores contain fairly large amounts of sulfur, the sulfur absorbers are also commonly found in the vicinity of uranium deposits.

Both selenium and sulfur are present in all sedimentary rocks, but the concentration varies greatly with stratigraphic units and areal distribution. For instance, the selenium content of western Cretaceous shales is high and remains relatively constant in particular beds or strata over distances of several hundreds of miles. Both elements may also be concentrated in tuffs, coals, or ore deposits. Their occurrence, however, in amounts less than 10 ppm in barren Triassic and Jurassic sandstones contrasts sharply with concentrations up to 1,000 ppm in ore deposits in the same formations. For this reason, the effect on the distribution patterns of indicator plants may be conspicuous if observed along the outcrop and combined with careful geologic study.

Many of the other plants found near uranium deposits probably reflect changes in acidity and in the availability of major plant nutrients. In addition to the direct control that the hydrogen-ion content may have on the plant, conditions prevailing in the vicinity of sulfide-rich ores may control plant distribution by increasing the availability of potassium, calcium, and phosphorus. The increase in potash availability around uranium deposits may be the controlling factor in the preservation of relict areas of tall prairie grasses.

Undoubtedly, the tendency for Astragalus to grow around carnotite deposits is increased by the presence of potassium phosphate and also vanadium. According to Russell (1937, p. 91) potash has a stimulating effect on the germination of legumes and frequently controls their distribution in competition with grasses and other plants. Legumes absorb large amounts of phosphate, and vanadium is also important as it can substitute for molybdenum in the nitrate fixation process (Bortels, 1933). Many legumes are able by means of a symbiotic relationship with certain bacteria to enrich the soil by addition of nitrogen compounds. Controlled plot experiments indicate that the presence of carnotite is of even greater importance in the early growth of Astragalus than selenium, although selenium is necessary for the establishment of second year perennial plants. At the same time Stanleya, favored by the presence of selenium and sulfur, grows poorly in experimental plots containing additions of carnotite ore. Thus the combination of elements in a carnotite-ore body creates a complex environment for plant growth, and the relative abundance of one element compared to another affects the combination of indicator plants. Probably seleniferous carnotite ore deposits are very favorable for the growth of Astragalus, but a high selenium content restricts the growth of the sulfur-indicator Allium, and Stanleya, a dependable selenium-indicator, is most useful in alluvial or down-stream prospecting for a carnotite deposit.

In addition to those plants which act as indicators of mineralized ground or can be used in alluvial prospecting, a large group of plants are tolerant of mineralized ground and many of these plants are described in this report. In general, plant adaptation to soils of high mineral content has proceeded in two diverse directions. For example, the shadscale absorbs enormous quantities of salts without harm to the plant growth, while plants of the rose and cactus families have an acid cell sap and a buffering system which exclude these salts.

HOW TO USE ABSORBER PLANTS IN PROSPECTING

Basic data on the absorption of uranium by plants must be established for control in the area to be prospected. Commonly a collection of samples from a variety of species in close proximity to one another is made in an area known to be mineralized but uncontaminated by surface workings. These are compared with similar collections in an unmineralized area. Several trees are also selected for periodic sampling to test the consistency of laboratory results and seasonal variation.

A study is made of the extent of mineralized outcrop, size and habits of the ore bodies, and the relation of the ore-bearing bed to the water table and to plant roots. From these observations the sampling medium and sampling interval are determined. Those trees and shrubs commonly sampled on the Colorado Plateau are shown in table 1.

Table 1—Absorber plants used in prospecting on the Colorado Plateau

Plant	Altitude
Pinus ponderosa Dougl. (Ponderosa Pine) Pseudotsuga taxifolia Britt (Douglas fir) Abies concolor Lindl. (White fir) Shepherdia rotundifolia Parry (Buffaloberry)	7,000-9,000 ft
Pinus edulis Englm. (Pinyon) Juniperus scopulorum Sarg. (Rocky Mtn. juniper)	6,000-7,000 ft
Juniperus utahensis Sarg. (Utah juniper) Juniperus monosperma Engelm. (Oneseed juniper) Cowania stansburiana Torr. (Cliffrose) Atriplex confertifolia (T. & F.) S. Wats (Shadscale)	4,000-6,000 ft

Branches on a given side of the tree are connected directly to roots on that side of the tree so that the uranium content may vary greatly from one side of the tree to the other. To obtain the best possible representative sample, therefore, it is recommended that branch tips composed mostly of needles be collected from all sides of the tree.

The sampling interval depends upon the objective of the project. On a broad flat bench grid pattern spacing adequate to detect either ore bodies or mineralized halos is desired. The resulting values may be contoured to show ares favorable for geologic exploration. An initial sampling program on a 200 to 250-foot spacing is usually adequate. Later fill-in samples on a 50-foot spacing may be collected in anomalous areas. A short interval of 15-30 feet is recommended for sampling traverses across talus-covered outcrop. The results will give maximum information in areas where the bedrock is under cover.

Under the present laboratory procedure it is necessary that quart samples (about 150 grams) of material be collected. Samples can be collected at a rate of about 300 a week and shipped to a well equipped uncontaminated laboratory for analysis. Two methods of analysis for small amounts of uranium in plant ash have been developed by the

Geological Survey laboratories (Grimaldi, et al., 1952, 1954). By the direct fluorimetric method the plant ash is mixed with a fluoride-carbonate flux and the amount of fluorescence of the bead or button is measured photoelectrically by a transmission fluorimeter. This method is satisfactory for samples that contain little or no manganese or other elements which may act as a quencher and reduce the amount of fluorescence of the uranium bead. As this is a more rapid analytical procedure than the extraction fluorimetric method, it is desirable to use it whenever possible. When quenching elements are present in quantity, the extraction-fluorimetric method is employed. By this method the uranium is separated chemically from interfering elements before the bead is made. The procedure is considerably longer and more expensive than the direct fluorimetric method. Research on chromographic field tests by which several hundred analyses may be made in a day is in progress. Analytical results are stated in terms of parts per million (ppm) uranium in the plant ash. The precision to be expected from the laboratory for values from 0.3 to 5.0 ppm U is a standard deviation of a 0.5 ppm.

Although the average amount of uranium absorbed by plants rooted in ore varies slightly depending on the type of ore and degree of oxidation and also on differences in the type of samples selected, an average figure of 1 ppm in the ash has been set as an arbitrary cutoff. This was recently shown by a statistical analysis of 5,000 tree samples to be a true cutoff value. Contents of uranium above this amount are considered to be anomalous and to indicate favorable and possibly mineralized ground.

In places where grid sampling is used the assay data can be contoured on base maps. Where rim-sampling is employed, areas of favorable rim can be indicated for back-from-rim drilling. The anomalies, however, delimit only areas of unusual uranium content in the vegetative cover. They do not show a positive correlation between the amount absorbed by the plants and the grade of the ore or the depth to ore. The interpretation of the data is dependent on the validity of the laboratory analysis, the size of sample interval, and the amount of work done on geologic and topographic field relations. Much depends on the comprehension by the prospector of the geologic environment. Plant analysis is an additional prospecting tool to be used with geologic interpretation in the search for ore.

HOW TO USE INDICATOR PLANTS IN PROSPECTING

The first step in using indicator plants in a new area is to study the plants growing in areas of known mineralized ground. The information on indicator plants included in this report was established by marking off 10 ft by 5 ft areas over known ore bodies in a number of districts and similar areas over unmineralized portions of the same bed with similar exposure and slope. In each plot complete plant lists were made from which final lists of indicator and tolerant plants were derived. When any of the illustrated plants are observed in a new area, a careful study of their distribution should be made to determine if and how they can be used in prospecting.

After such studies have been made, similar plant associations may be located along a given outcrop of ore-bearing bed through reconnaissance prospecting. A certain amount of caution must be exercised. The plants are, of course, all common roadside weeds and may be found in places where no uranium is present. Selenium plants, for example, may grow wherever there is a small amount of selenium in the soil. Sulfur plants may grow wherever gypsum is present. The plant species described in this book, however, have been noted repeatedly in close association with uranium ore deposits and have been used successfully in uranium prospecting.

Indicator plants are best studied and mapped when in bloom. For this reason, the approximate blooming date has been given for plants growing at an altitude of 4,500 feet and near the 39th parallel. The blooming time for a given plant would be somewhat earlier farther south or at lower altitudes, and later farther north or at higher altitudes. In general, ephemerals, like plants of the lily family, are available for study only in the spring or early summer. Many of the Astragalus species bloom in April, but as they can be recognized from the dead seed pods and stalks they can be used later in prospecting (figure 1). Stanleya and other mustards continue to bloom throughout much of the summer. Many composites, Plantago, and Mentzelia bloom in the late summer and fall.

Figure 1.--Dead plants of Astragalus pattersoni useful in setting drill sites in fall and winter.

Plants have been listed by families in relative order of their importance in prospecting. Those that have aided directly in the location of ore have been marked primary indicators; those that occur in plant associations known to indicate favorable ground are listed as secondary indicators; and common plants known to be very tolerant of mineralized ground are included last. For many genera, identification to species is not necessary, as all species may act as indicator plants. For these, species identification has not been given. English and Latin names of all species are spelled in accordance with Kelsey and Dayton (1942). Descriptions have been written simply with as few technical terms as possible, and these terms are listed in a glossary. All information of interest in the use of these plants has been compiled from the references listed. Finally, districts in which these plants have been observed are given as a general guide to their areal distribution. An index map showing the districts on the Colorado Plateau is shown as figure 2.

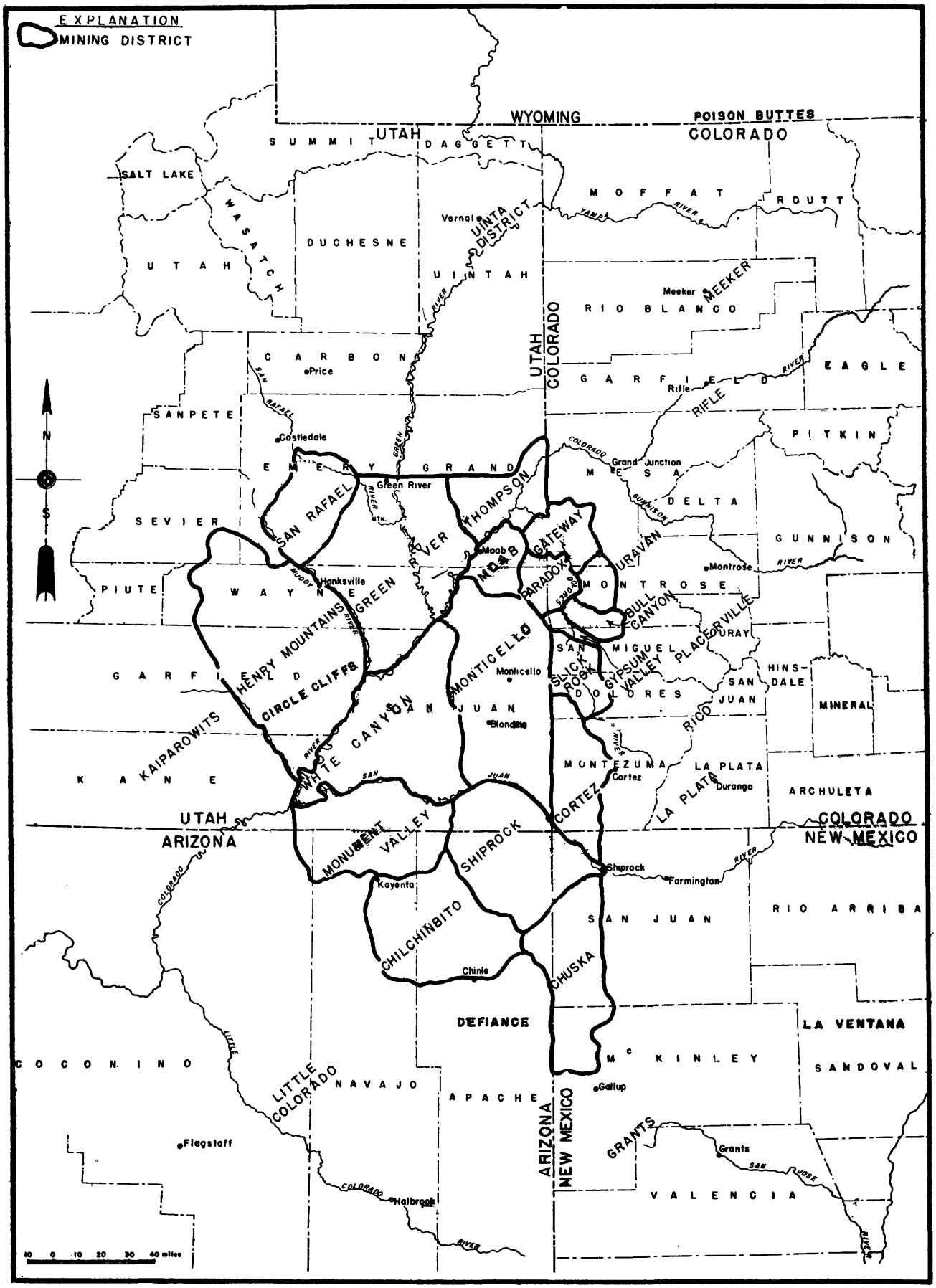

Figure 2. --Index map of part of the Colorado Plateau showing location of mining districts.

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PLANT DESCRIPTIONS

ASTRAGALUS PATTERSONI, A. Gray

Family: pea, Leguminosae

Flowers: Cream-colored irregular flowers with purple dot on keel, growing in tall clusters which extend beyond the foliage. Blooms in April and May.

Leaves: Pinnate with numerous oval leaflets.

Fruit: Fat pods mounted on short stem. Seeds rattle in pod when dry (then called rattle-weed).

Root: Very long taproot, commonly 30 ft or more in length.

Plant: Perennial, 1-4 ft high. Garlic-like odor common to foliage due to presence of selenium.

PRIMARY INDICATOR

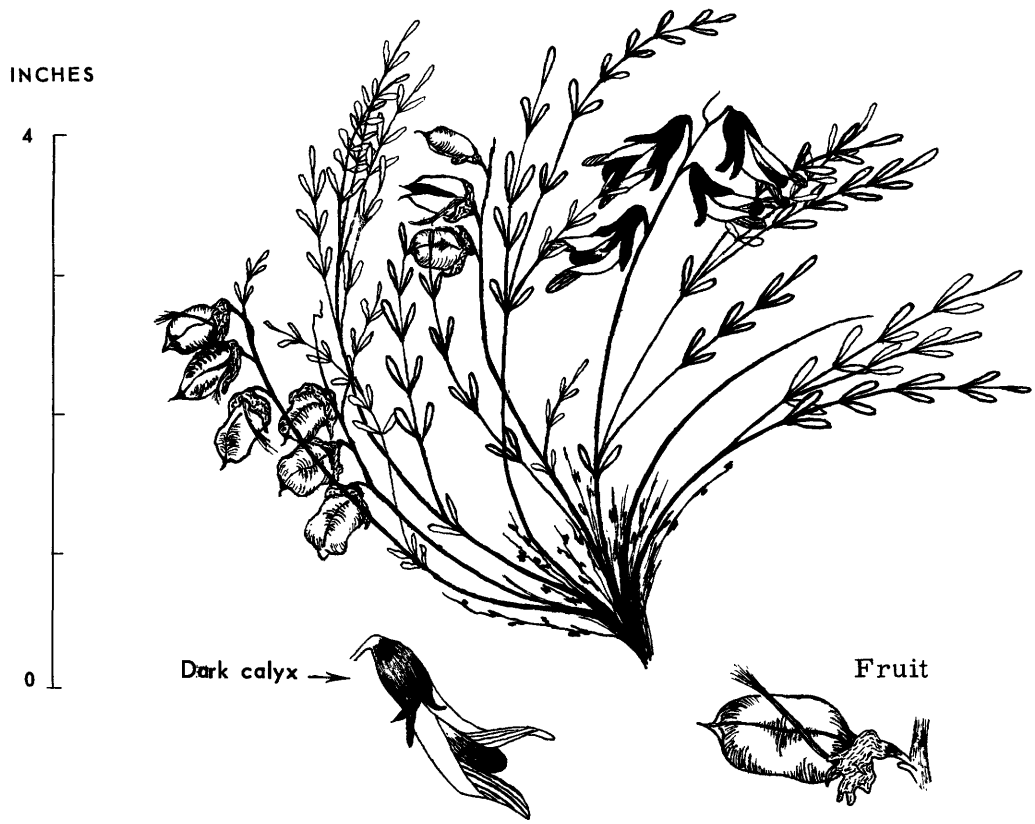
Control: Selenium

PATTERSON'S LOCO

Altitude: 4,000-6,500 ft

Occurrence: Common on flat sand-covered areas where roots can penetrate to water reservoir in underlying rock. Best selenium-indicator plant in uranium districts of the Colorado Plateau since requirements and absorption of selenium are very high. Commonly absorbs several thousand ppm selenium from ore bodies. Plot experiments suggest growth stimulated in vicinity of carnotite deposits by potassium, but inhibited by excesses of $CaSO_4$.

Districts observed: San Rafael, Thompsons, Green River, Monticello and Circle Cliffs, Utah;
Shiprock, Ariz.;
Slick Rock and Gypsum Valley, Colo.;
Grants, N. Mex.



ASTRAGALUS PREUSSI, A. Gray

Family: pea, Leguminosae

Flowers: Purple irregular flowers with darker calyx, arising from creeping root stalks. Blooms in April-May.

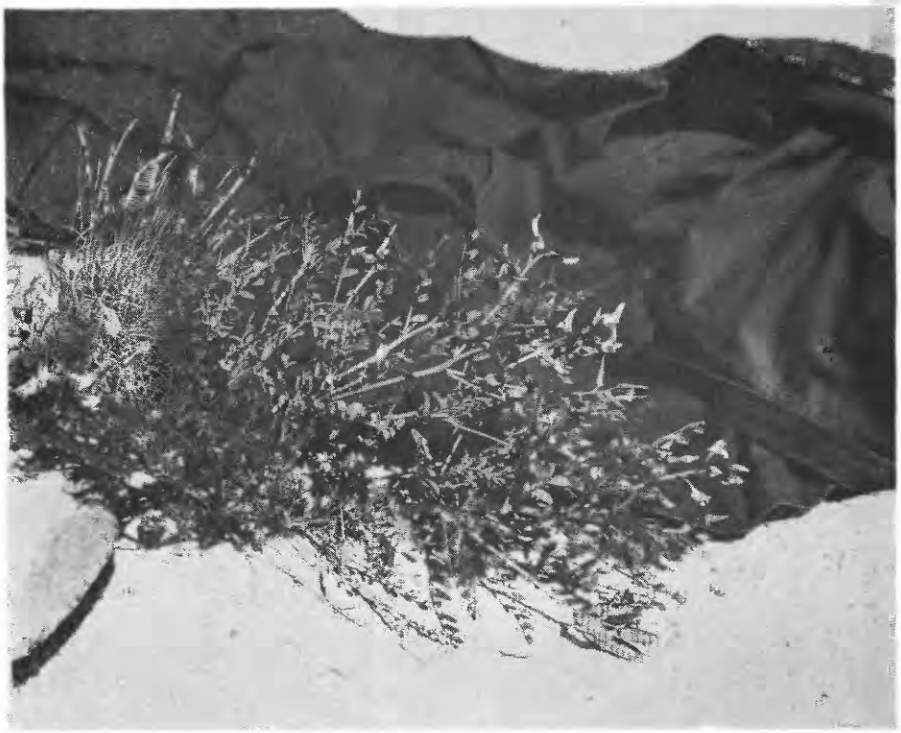
Leaves: Smooth pinnate with 11-15 elliptic leaflets.

Fruit: Fat smooth oblong slightly curved, with short stem.

Plant: Perennial. Many stems less than a foot high arising from a woody base. Garlic-like odor of foliage due to presence of selenium.

PRIMARY INDICATOR

Control: Selenium



PREUSS LOCO

Altitude: 3,300-6,000 ft

Occurrence: Common on mine dumps and along outcrops of ore-bearing beds where selenium is present. Mineralized ground under these plants in Yellow Cat area, Utah, at an average depth of 41 ft. This is one of the best selenium indicator plants in uranium districts on the Colorado Plateau. Commonly absorbs several thousand ppm Se from ores.

Districts observed: Shiprock, Ariz.

Slick Rock and Gypsum Valley, Colo.

Thompsons, San Rafael, Henry Mtns., Green River and Moab, Utah.

ASTRAGALUS THOMPSONAE, S. Wats.

Family: pea, Leguminosae

Flowers: Very showy, pinkish-lavender irregular flowers. Blooms in April-May.

Leaves: Leaves all basal, pinnate, with ovate leaflets. Hairy, but hairs not alined in any particular direction.

Fruit: Fat, two-celled, slightly curved, hairy pods with thick walls which become woody.

Plant: Rosette type, 6-12 in. across with all leaves basal. Plant and pods covered with soft silvery hairs.

PRIMARY INDICATOR

Control: Selenium

THOMPSON LOCO

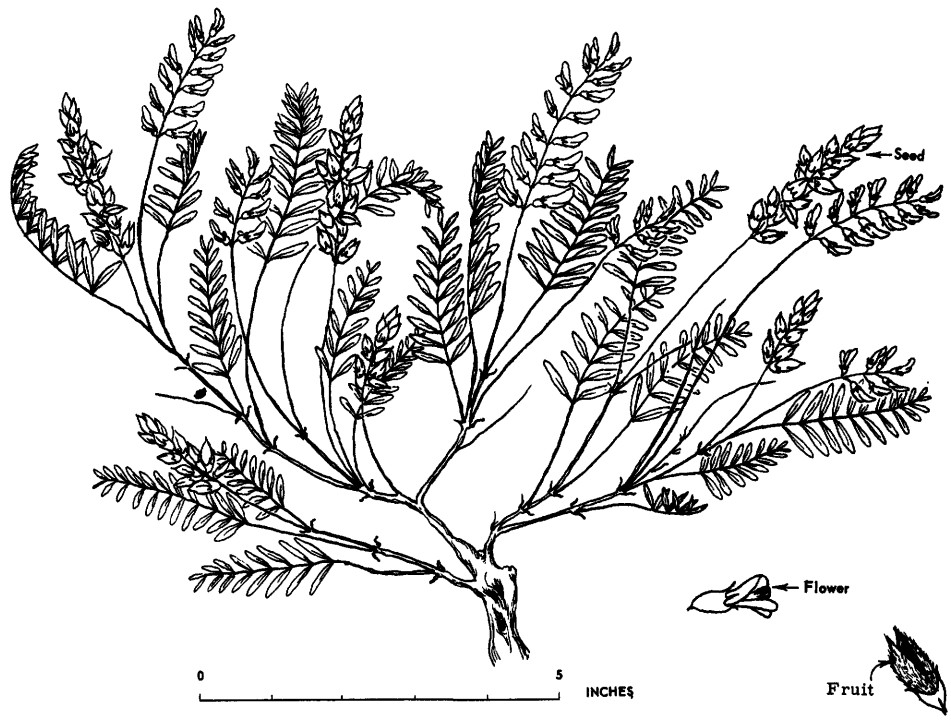
Altitude: 4,700-6,800 ft

Occurrence: On seleniferous sandy soils and rocks. Often grows directly on rock outcrop, but difficult to distinguish except in bloom.

Districts observed: Shiprock, Ariz.

Thompsons, San Rafael, White Canyon, Monticello, and Uinta Basin, Utah;

Gypsum Valley, Bull Canyon, and Paradox Valley, Colo.



ASTRAGALUS CONFERTIFLORUS, A. Gray

Family: pea, Leguminosae

Flowers:	Cream-colored, irregular flowers in dense inflorescence. Blooms in May.
Leaves:	Pinnate with linear leaflets.
Fruit:	Erect pod from stalk, not inflated, and with no individual stem.
Plant:	Perennial about 8 in. high with erect stems and bluish foliage.

SECONDARY INDICATOR

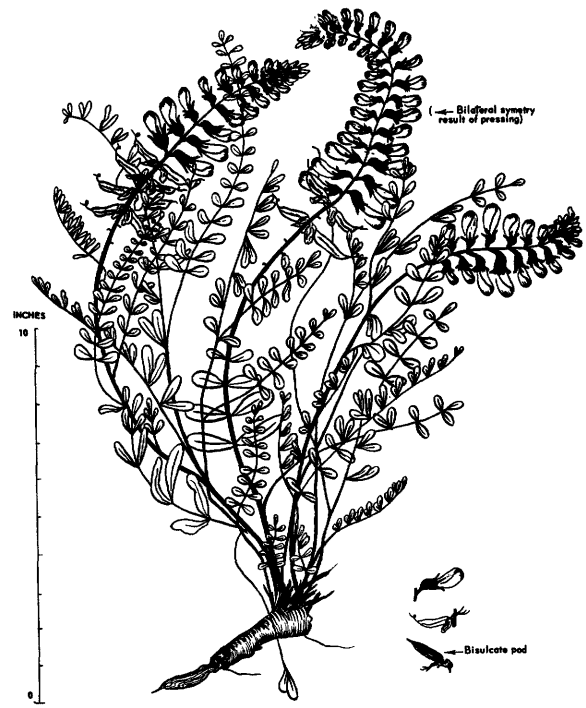
Control: Selenium

BLUE LOCO

Altitude: 5,000-6,000 ft

Occurrence: Restricted to seleniferous portions of under clays which are frequently associated with ore deposits.

Districts observed: Thompsons, and Henry Mtns., Utah; Grants, N. Mex.



ASTRAGALUS BISULCATUS (Hook) A.Gray

Family: pea, Leguminosae

Flowers:	Deep purple, irregular flowers in elongated inflorescence which extends above the foliage. Blooms in June-July.
Leaves:	Smooth pinnate with oval or oblong leaflets.
Fruit:	Linear 1-celled pod with 2 deep grooves on the upper side.
Plant:	Stout, erect.

PRIMARY INDICATOR

Control: Selenium

No photo available

TWO-GROOVED MILKVETCH

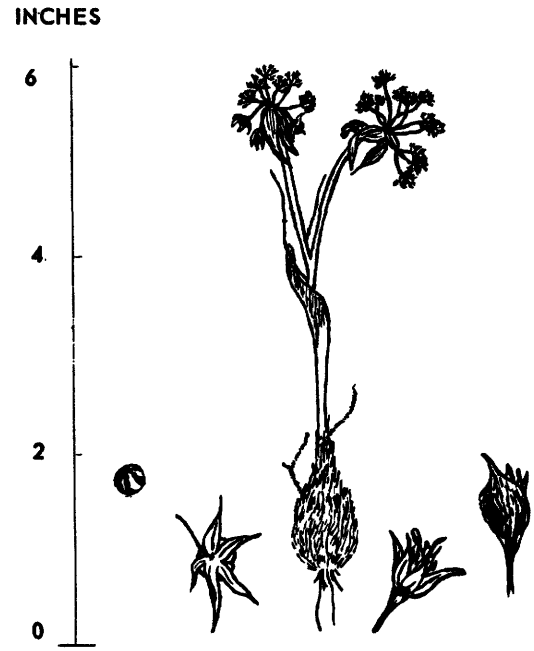
and other species listed below have been observed around uranium deposits and used in prospecting in some areas. A. bisulcatus occurs in Powder River Basin deposits and at Poison Buttes in Wyoming and is highly seleniferous. Although the species listed below are not described as Se indicators by Beath, it is believed that they can be used as indicators where association with known ore bodies has been established.

A. dodgeanus Jones

A. lentiginosus Dougl.

A. lonchocarpus Torr.

A. missouriensis Nutt.



ALLIUM ACUMINATUM Hook. and related species

Family: lily, Liliaceae

Flowers: Umbrella-like cluster of small pink flowers at end of lorg stalk. Each petal has a middle line of deep pink. Blooms in April-May.

Leaves: Two linear leaves about 6 in. long from bulb at base. Leaves are shorter than flower stem.

Fruit: 3-lobed capsule.

Plant: Spring ephemeral. Bulb with outer covering. Strong odor of crushed plant characteristic.

PRIMARY INDICATOR

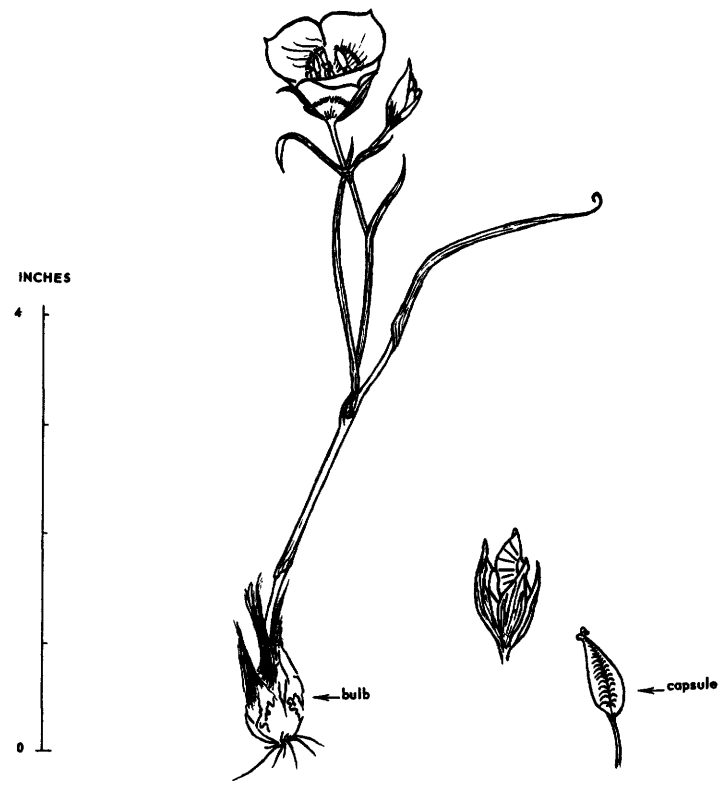
Control: sulfur

WILD ONION

Altitude: 4,000-7,500 ft

Occurrence: Grows in great patches around gypsiferous ore deposits and on sulfur-rich shales, but inhibited by highly seleniferous ores. Roots are shallow, but in Thompson district it is found growing over carnotite deposits lying as much as 25 feet below the surface.

Districts noted: Thompsons, Moab, and Green River, Utah.
Slick Rock, Colo., Jefferson Co., Colo.



CALACHORTUS NUTTALLI, Torr. & Gray

Family: lily, Liliaceae

Flowers: 3 large white petals marked with yellow and purple at base. Gland with hairs at base of petal. 1-5 flowers on stalk. Blooms in April-May.

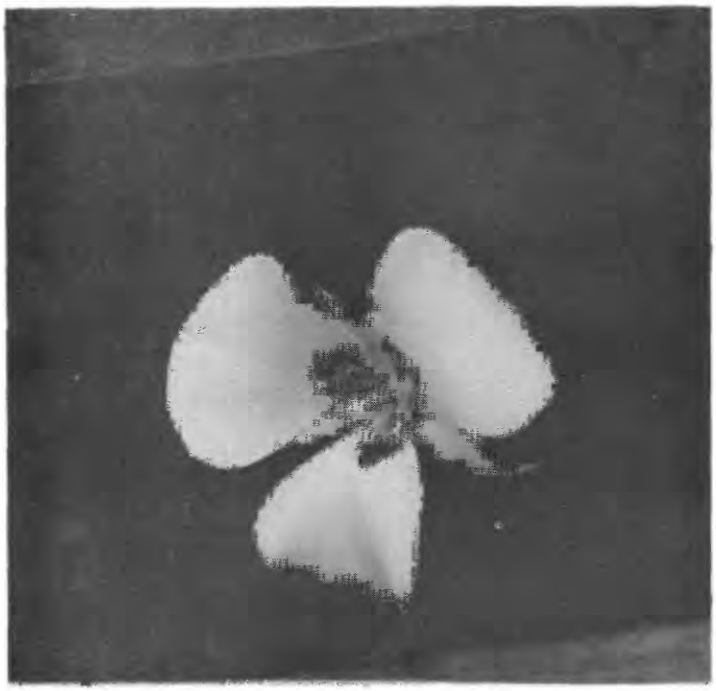
Leaves: Several alternate grass-like leaves about 6 in. long, trough-shaped in cross section. Onion-like bulb.

Fruit: Three-angled capsule.

Plant: Spring ephemeral. Grass-like leaves arising from bulb.

SECONDARY INDICATOR

Control: sulfur

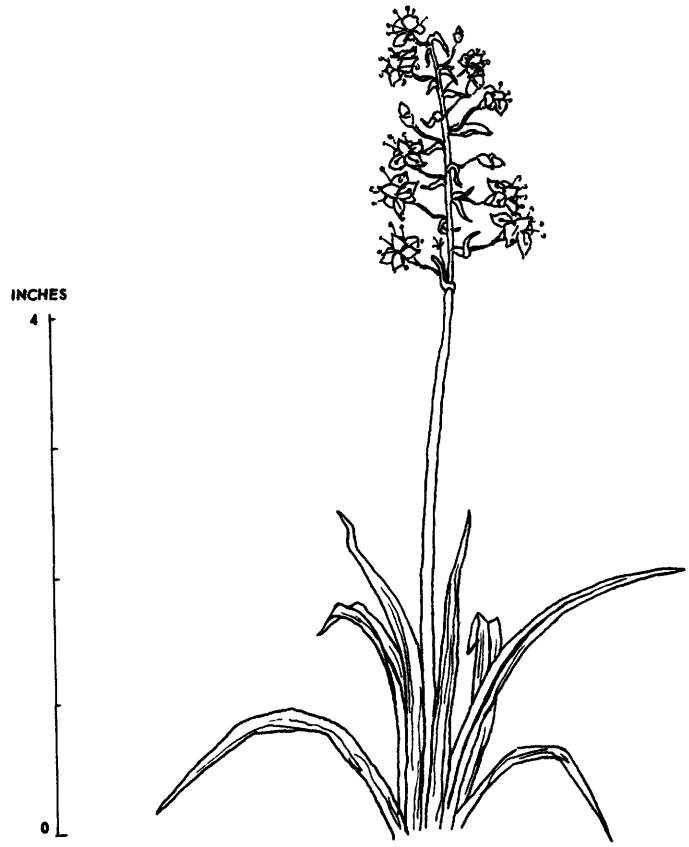


SEGO LILY, MARIPOSA

Altitude: 5,000-8,000 ft

Occurrence: Dry sandy soil. A good sulfur-indicator in the early spring.

Districts noted: Thompsons, Utah:
Slick Rock, Colo.;
Poison Buttes, Wyo.



ZIGADENUS GRAMINEUS, Rydb.

Family: lily, Liliaceae

Flowers: Inconspicuous greenish-white flowers with 6 "petals" which grow in a raceme on flower stalk about 8 in. high. Gland near the base of the petal. Blooms in April.

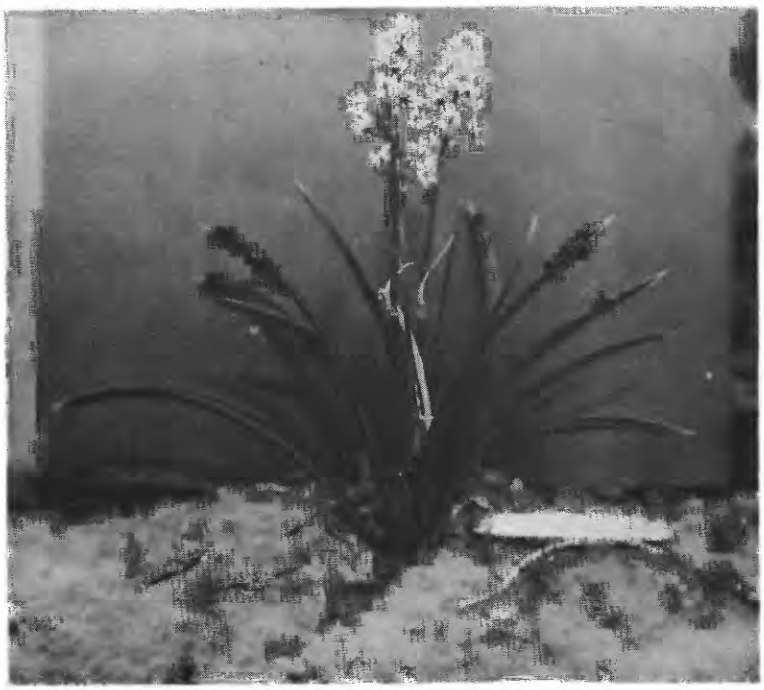
Leaves: Smooth, narrow, grass-like leaves arising from bulb.

Fruit: 3-celled capsule.

Plant: Spring ephemeral. Bulb with membranous covering.

SECONDARY INDICATOR

Control: sulfur

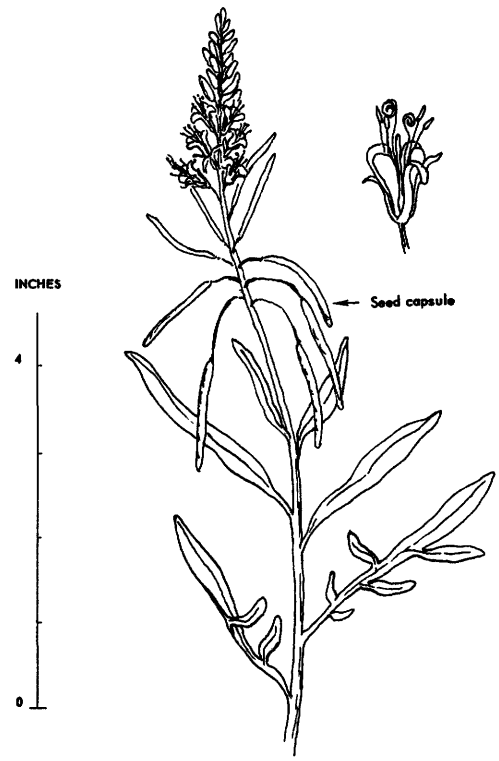


GRASSY DEATH CAMAS

Altitude: Up to 12,000 ft

Occurrence: In sulfur-rich soils, from wet sandy seashore to dry desert sandstones. Poisonous to sheep due to toxic alkaloids.

Districts noted: Thompsons, Utah;
Slick Rock and Paradox Valley, Colo.;
Monument Valley, Ariz.



STANLEYA sp., pinnata

Family: mustard, Cruciferae

Flowers: Golden yellow, with four clawed petals, on tall stalk; through the summer months the stalks show a progression from buds, to flowers, to seeds. Stamens unequal with anthers curled at maturity.

Leaves: Pale green, alternate; variable in shape and size, often lyre-shaped or entire.

Fruit: Long thin capsule containing many seeds.

Plant: Coarse phreatophyte perennial with thick erect stalk, 1-3 ft high, and woody root.

SECONDARY INDICATOR

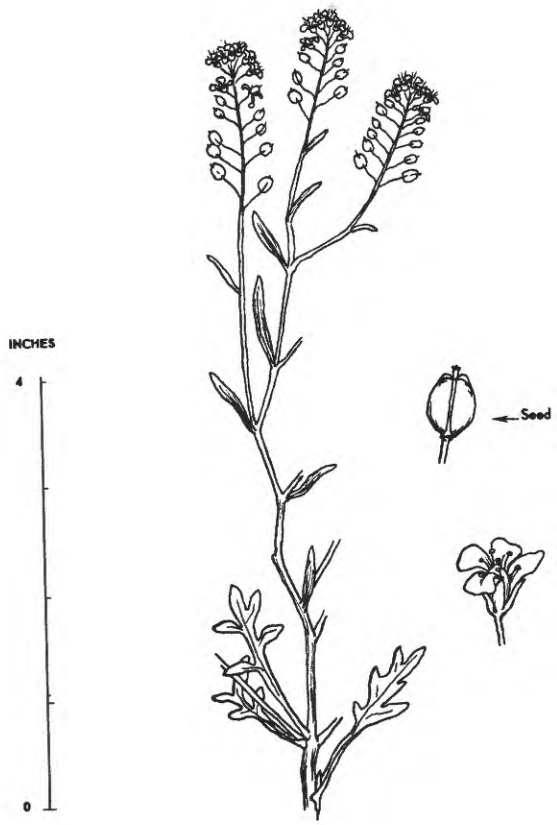
Control: selenium and sulfur

DESERT PRINCESPLUME

Altitude: 2,500-7,000 ft

Occurrence: Along rims and water courses draining gypsiferous areas. All species of this genus require both selenium and sulfur, but plot experiments indicate intolerance of highly mineralized ground. Therefore useful along drainage courses and in prospecting rims.

Districts noted: Shiprock, Chilchinbeto, Ariz.;
Slick Rock, Gypsum Valley, and Paradox Valley, Colo.;
Thompsons, San Rafael, Marysvale, White Canyon, Monticello, Green River, Henry Mtns., Moab, and Circle Cliffs, Utah;
La Ventana, N. Mex.



LEPIDIUM MONTANUM, Nutt.

Family: Mustard, Cruciferae

Flowers: Dense cluster of white flowers. Four clawed petals $\frac{1}{4}$ in. long which form a cross. Blooms from April to Sept.

Leaves: Basal leaves finely divided, several inches long. Upper leaves simple and smooth edged; do not clasp the stem.

Fruit: Small round disk-shaped capsules that are not inflated. Narrowly winged and obscurely notched at the apex.

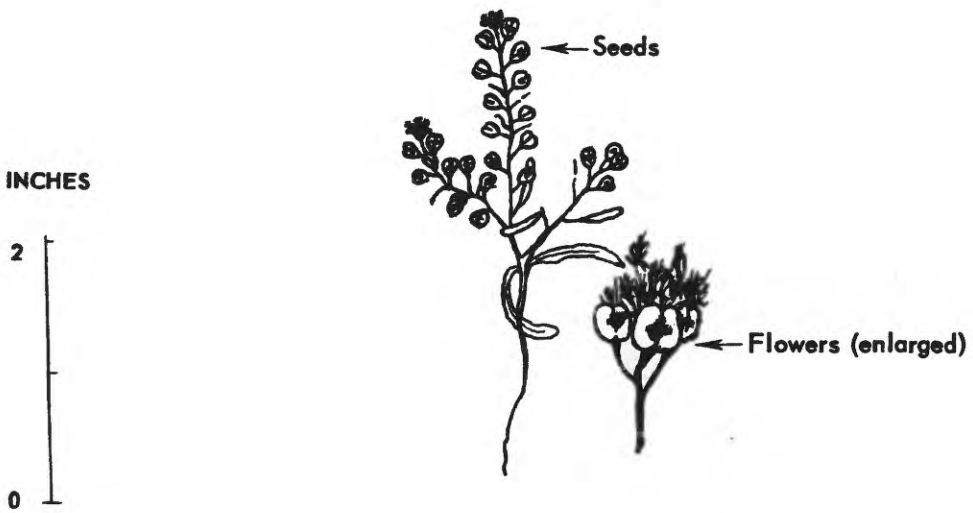
Plant: Bushy perennial 1-2 ft high. Stems not woody. Several stems from same root.

SECONDARY INDICATOR

Control: sulfur

MOUNTAIN PEPPERWEED

Altitude:	3,000-7,000 ft
Occurrence:	Common around shallow uranium deposits where sulfur available in surface soil. Common on gypsum dunes of White Sands, N. Mex.
Districts observed:	Thompsons, White Canyon, and Green River, and Uinta Basin, Utah; Fall River, S. D.



LEPIDIUM LASCIOCARPUM, Nutt.

Family: mustard, Cruciferae

Flowers: Not conspicuous, may be obsolete.
Blooms Jan. to April.

Leaves: Small simple rounded leaves. Basal leaves incised.

Fruit: Notched round disk-shaped capsules.

Plant: Tiny hairy annual, 2 in. high, branched from the base and not woody.

SECONDARY INDICATOR

Control: sulfur

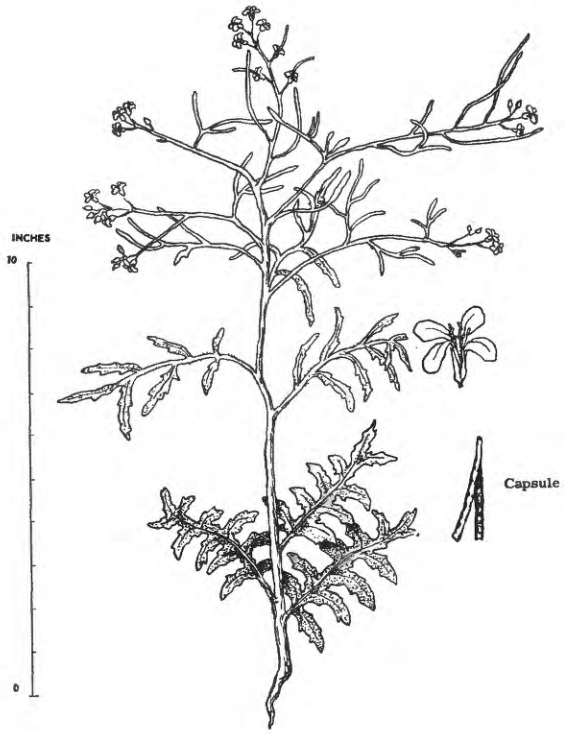
HAIRY-POD PEPPERWEED

Altitude: 3,000 to 4,500 ft.

Occurrence: Sandy soil where sulfates present at surface.

Districts noted: Thompsons and San Rafael, Utah;

Shiprock, Ariz.



SISYMBRIUM ALTISSIMUM, (L.) Britt.

Family: mustard, Cruciferae

Flowers: Four creamy, flat, ¼ in. petals which form a cross. Blooms from May to July.

Leaves: Upper leaves thread-like, lower leaves divided and not clasping the stem.

Fruit: Thin linear capsules, more than 2 in. long. Divergent.

Root: Tap root, but with fine long laterals so that root system extensive.

Plant: Coarse erect annual 2-4 ft high with smooth stems, freely branching. An introduced European adventive weed both tolerant and indicative of high sulfate soils.

SECONDARY INDICATOR

Control: sulfur

TUMBLE MUSTARD

Altitude: 5,000-7,000 ft

Occurrence: Noted around ore deposits on higher mesas.

Districts observed: Slick Rock, Gypsum Valley, and Paradox Valley, Colo.;

White Canyon and San Rafael, Utah.

CRYPTANTHA FLAVA, A. Nels, and related species

Family: borage, Boraginaceae

Flowers: Pale-yellow, tubular flowers $\frac{1}{4}$ in. long in small congested, densely hairy heads. Blooms in spring and summer.

Leaves: Rough, simple, linear, and mostly basal.

Fruit: Smooth oval nutlet.

Plant: Stout, pale-green, hairy perennial 4-12 in. high, growing from woody base.

SECONDARY INDICATOR

Control: calcium

CRYPTANTH

Altitude: 5,000-7,000 ft

Occurrence: Prefers dry sandy or limestone soil. Localized around gypsiferous uranium deposits in many districts. The controlling factor probably available calcium. Common on gypsum dunes at White Sands, N. Mex. and on limestones and Ca-rich vein deposits in Ariz.

Districts observed: Thompsons, Green River, White Canyon, and Circle Cliffs, Utah;

Grants, N. Mex.;

Shiprock, Defiance, Ariz.;

Gypsum Valley, Bull Canyon, and Paradox Valley, Colo.;

Poison Buttes, Wyo.

OENOTHERA CAESPITOSA, Nutt.

Family: primrose, Onagraceae

Flowers: Large fragrant white flower with 4 heart-shaped petals on a long slender calyx tube which rises directly from the ground for about 4-5 in. Flowers open in the evening and turn pink with age. Fragrant. Blooms in May and June.

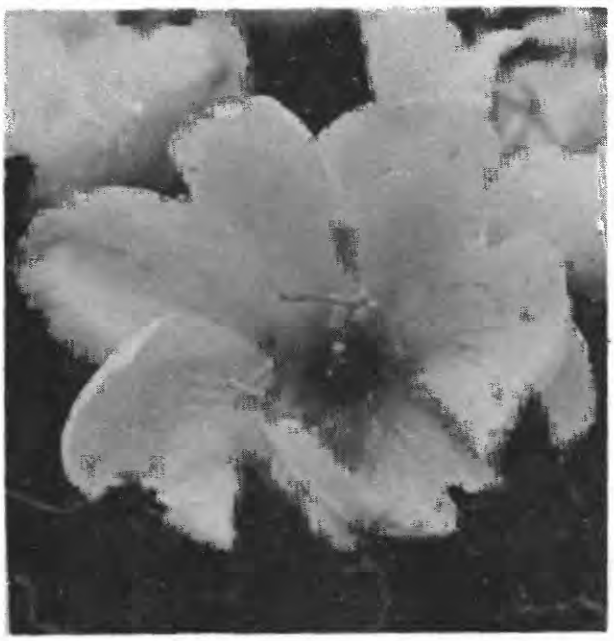
Leaves: Strap leaves in a basal rosette. Smooth margined or toothed, on winged stems.

Fruit: Oval capsule with rounded tubercles on the angles.

Plant: Perennial.

PRIMARY INDICATOR

Control: calcium



TUFTED EVENINGPRIMROSE

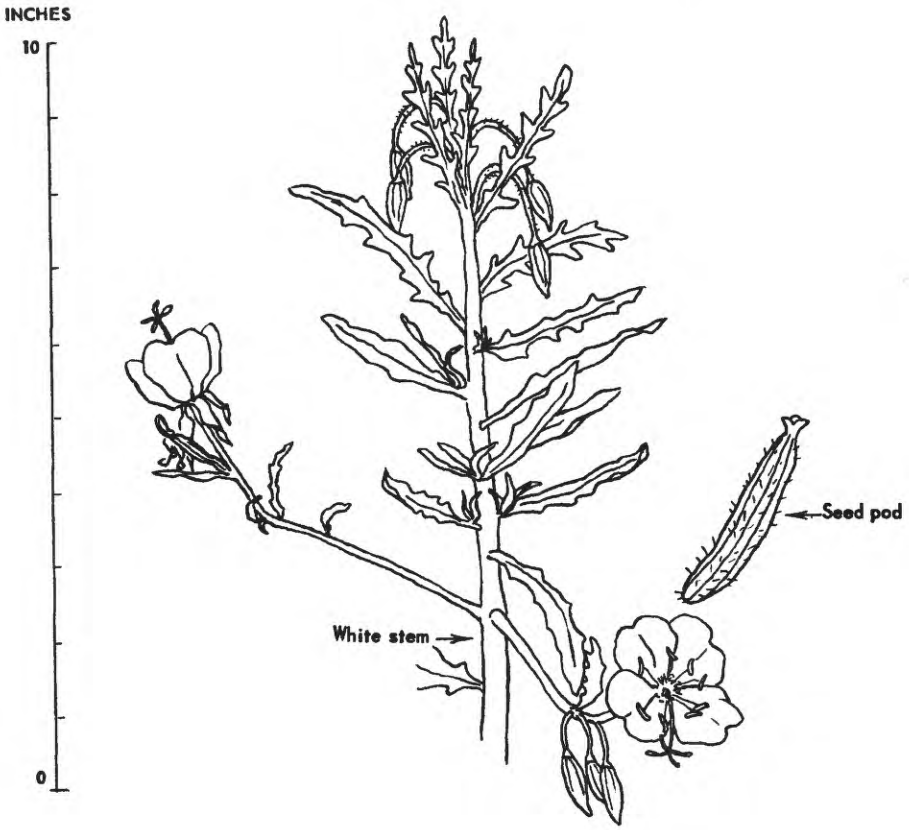
Altitude: 3,000-7,500 ft

Occurrence: Common associate of uranium-indicator plants. The distribution of this plant suggests that it is a calcium indicator. Listed in flora of White Sands, N. Mex. and common on volcanics of Arizona.

Districts noted: Grants, N. Mex.

Thompsons, San Rafael, Green River, and White Canyon, Utah;

Shiprock, Ariz.



OENOTHERA ALBICAULIS, Pursh.

Family: primrose, Onagraceae

Flowers: Four large white lobes resembling petals at end of tube 1 in. long. Blooms May to July.

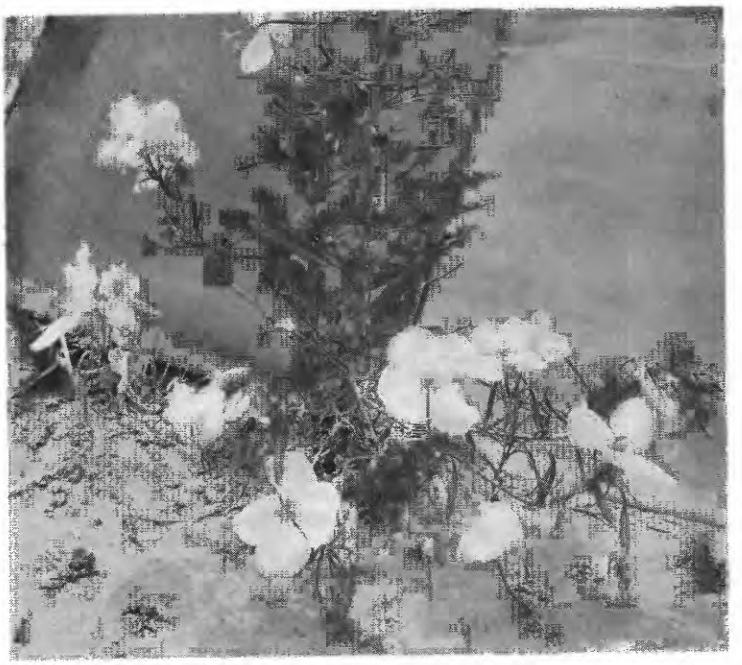
Leaves: Basal leaves, blunt, spatulate, toothed. Stem leaves, 2-5 in. long, deeply divided.

Fruit: Pod $\frac{1}{2}$-2 in. long, $\frac{1}{2}$ in. thick.

Plant: Annual or biennial, 4-12 in. high, branched at the base.

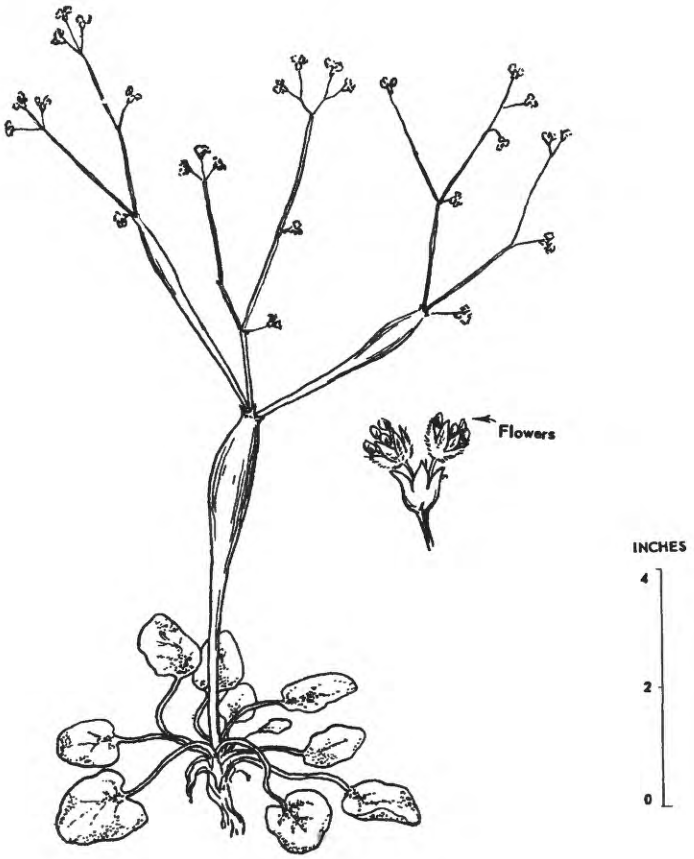
SECONDARY INDICATOR

Control: calcium



WHITESTEMMED EVENINGPRIMROSE

Altitude:	2,400-7,500 ft
Occurrence:	Gypsum-bearing sandy soil.
Districts noted:	Thompsons and San Rafael, Utah.



ERIOGONUM INFLATUM, Torr

Family: buckwheat, Polygonaceae

Flowers: Clusters of 10-20 tiny yellow flowers on much-branched mass of fine stems. Blooms from March to July.

Leaves: Rounded leaves in rosette at base of plant.

Seeds: 3-angled dry seed.

Plant: Bluish-green tubular stems with hollow, inflated, trumpet-like portions before divisions. Stem divides in threes. 1-2 ft high perennial with woody base.

PRIMARY INDICATOR

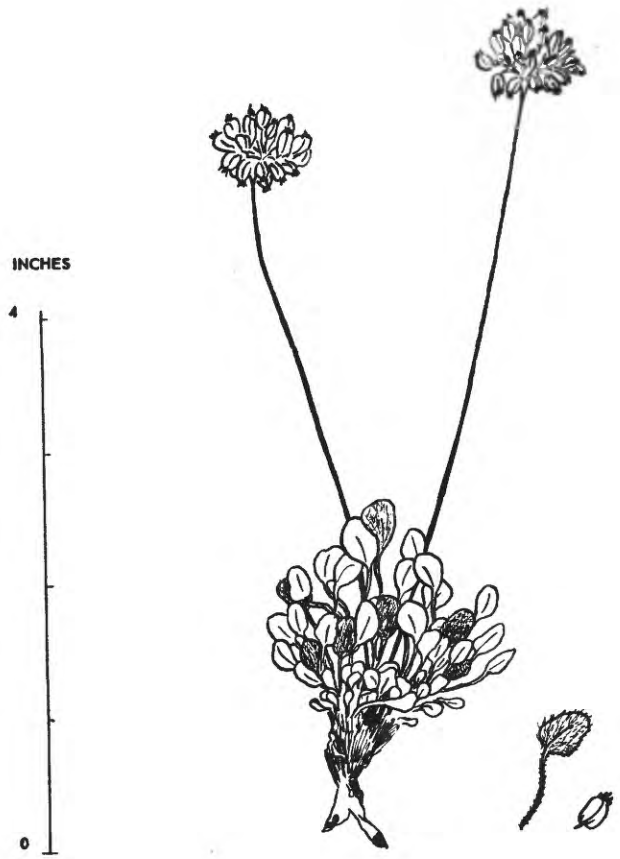
Control: sulfur and phosphate

DESERT TRUMPET

Altitude: Up to 4,500 ft

Occurrence: Common on sulfur-rich soils and gypsiferous ore deposits. Turns Mancos shales yellow when in bloom. High P content.

Districts noted: Shiprock, Ariz.;
Thompsons, San Rafael, Henry Mtns., Green River, Monticello, and Circle Cliffs, Utah;



ERIOGONUM OVALIFOLIUM, Nutt.

Family: buckwheat, Polygonaceae

Flowers: Pale yellow to pink; in head-like cluster on 4-6 in. stalk. Calyx yellowish with pink veins. Blooms April-June.

Leaves: Densely white-woolly; oval leaves at base of plant about $\frac{1}{2}$ in. in size.

Fruit: Dry, small.

Plant: Hairy perennial with basal cushion of leaves and 10 in. high flower stalks. Woody base.

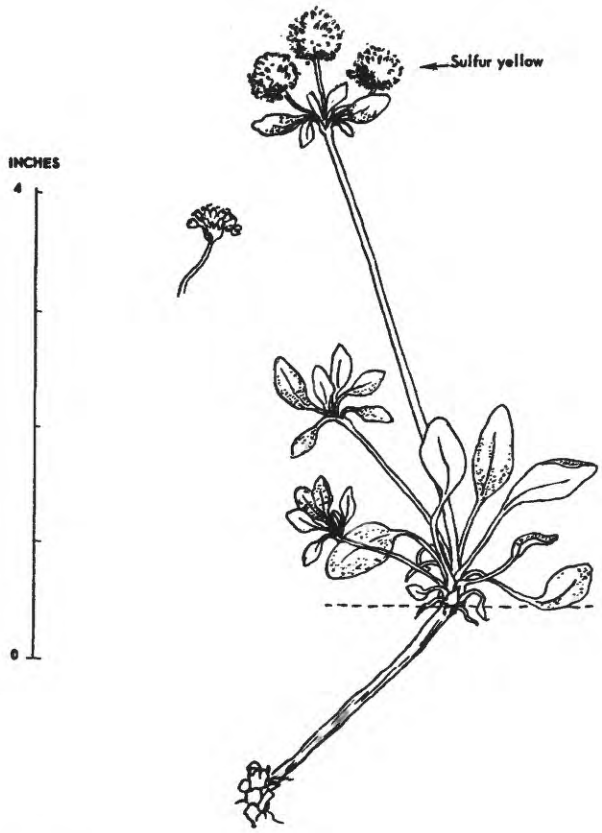
SECONDARY INDICATOR

Control: sulfur and phosphate

SILVER PLANT or

CUSHION ERIOGONUM

Altitude:	5,000-7,000 ft
Occurrence:	Commonly on sandstone outcrops rooted in cracks and joints.
Districts noted:	Thompsons, Utah; Shiprock, Ariz.



ERIOGONUM UMBELLATUM, Torr.

Family: buckwheat, Polygonaceae

Flowers: 20-30, sulfur-yellow flowers in heads held in simple umbrella-like cluster with leafy tracts at base. Individual flowers tubular with reflexed lobes and 9 stamens. Flower stalks stout, woolly, and 4-12 in. long. Blooms through summer.

Leaves: Thick, oval-to-spatulate, $\frac{1}{2}$-1 in. long, tapering to a stem. Green above, white woolly underneath.

Seeds: Sharply 3-angled, dry seeds.

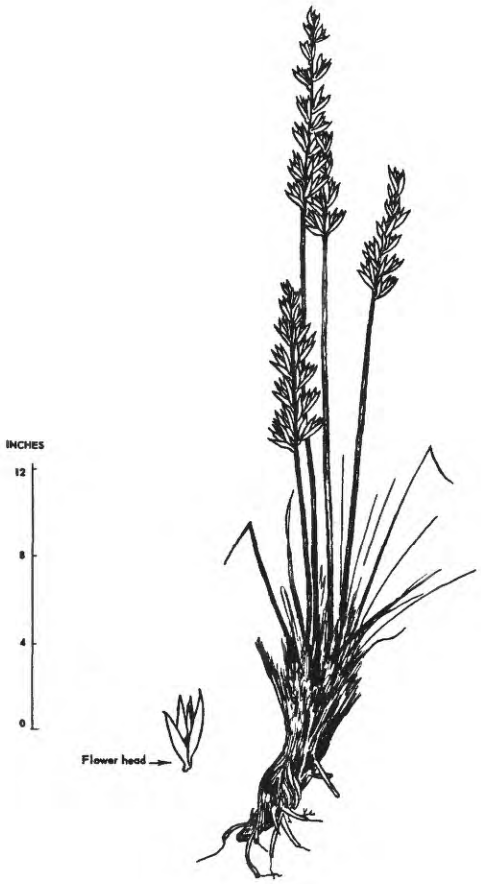
Plant: Perennial with thick tap root. Branched woody base tufted with leaves at the nodes from which erect leafless flower stalks extend.

SECONDARY INDICATOR

Control: sulfur and phosphate

SULFUR-ERIOGONUM

Altitude:	5,000-9,000 ft
Occurrence:	Dry slopes.
Districts noted:	Jefferson Co., Colo.;
	White Canyon, Utah;
	Phosphoria formation, Wyo.



ELYMUS SALINA, Jones

Family: grass, Gramineae

Flowers: Dense spikes. Spikelets coming off in pairs from jointed axis. No awns. Blooms through summer.

Leaves: Broad blades, rolled inward.

Plant: Perennial grass with harsh foliage. Grows in thick clumps several feet high.

PRIMARY INDICATOR

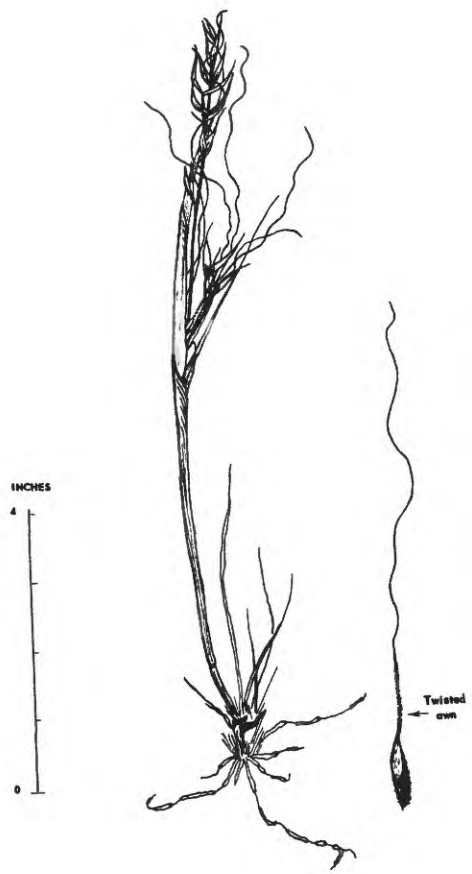
Control: Probably potash

SALINA WILD RYE

Altitude: 3,000-7,000 ft

Occurrence: A grass that formerly covered large areas of the west, now present only in relic areas. Common on mine dumps and along canyon rims, in the vicinity of uranium ore. Also known to occur around base metal sulfide deposits, probably due to increased availability of potash.

Districts noted: Shiprock, Ariz.; Slick Rock, Paradox Valley, and Gypsum Valley, Colo.; Thompsons, Green River, and Circle Cliffs, Utah.



STIPA COMATA, Trin. & Rupr.

Family: grass, Gramineae

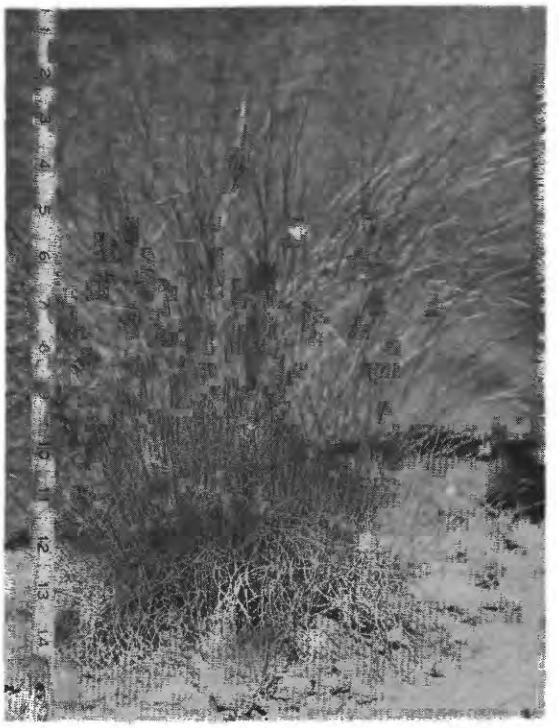
Flowers: Loose head 5-10 in. long with tightly twisted thread-like awns 4-5 in. long resembling tails attached to the seeds. Tight twist in lower third only. Blooms June-July.

Leaves: Harsh, flat, inrolled.

Plant: Deep-rooted perennial 1-2 ft high.

SECONDARY INDICATOR

Control: probably potash



NEEDLEANDTHREAD

Altitude: 4,500-8,000 ft

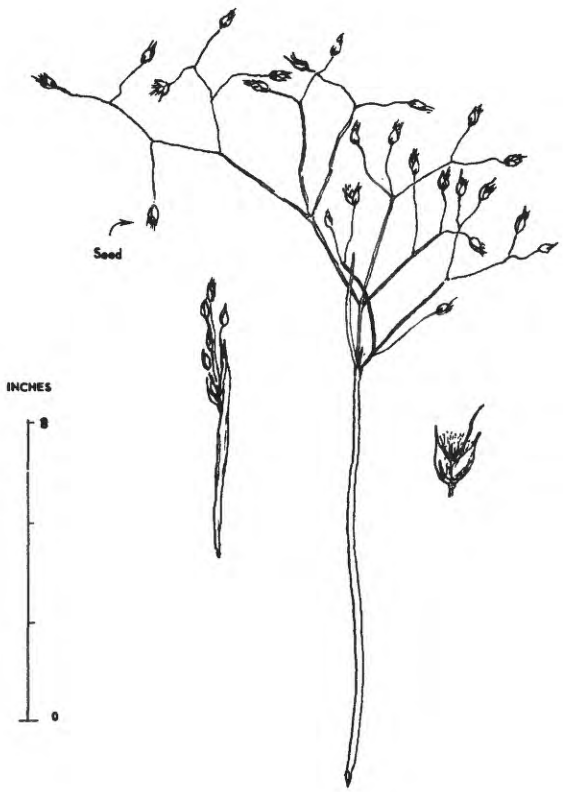
Occurrence: Restriction to the vicinity of uranium deposits in many areas probably due to increased availability of potash.

Districts noted: Thompsons, Utah.

Gypsum Valley, Colo.;

Grants, N. Mex. Closely related species in

Shiprock, N. Mex.



ORYZOPSIS HYMENOIDES, (R. & S.) Rick.

Family: grass, Gramineae

Flowers: Small dry flowers in open panicle with branches at right angles in zigzag pairs. Individual spikelets 1-flowered. Blooms in June-July.

Leaves: Inrolled, narrow.

Seeds: Small, rice-like; edible.

Plant: Extensive perennial grass 1-2 ft high, with deep fibrous roots.

SECONDARY INDICATOR

Control: selenium

INDIAN RICEGRASS

Altitude: Up to 10,000 ft

Occurrence: Drought-resistant and alkali-tolerant grass common in any western soil which contains a small amount of selenium and sulfur. Capable of absorbing large amounts of Se and U although the Se requirements are very low. Useful only in districts where Se content of the ore is low; there the plant may be restricted to ore.

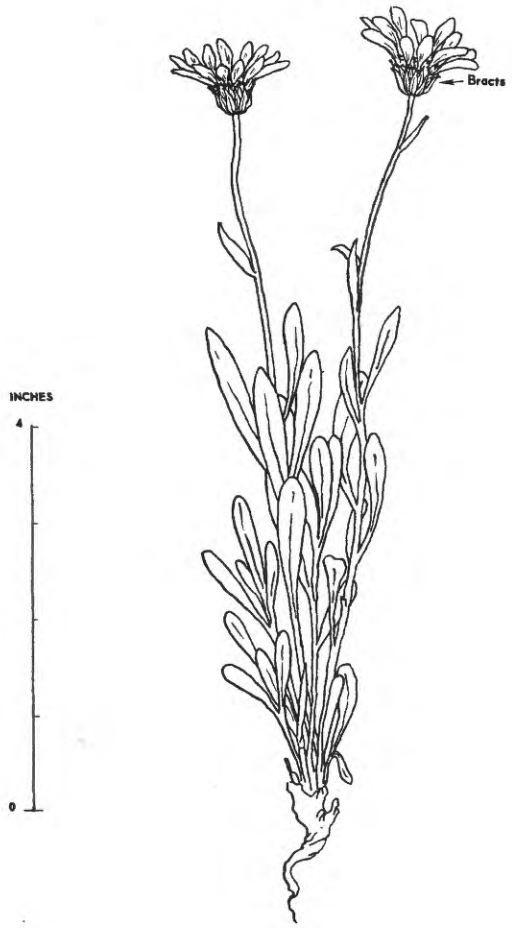
Districts noted: Gypsum Valley, Rifle, Slick Rock, Bull Canyon, and Paradox Valley, Colo.

White Canyon, Marysvale, Thompsons, San Rafael, Henry Mtns., Green River, Moab, Monticello, Uinta Basin and Circle Cliffs, Utah.

La Ventana and Grants, N. Mex.

Wamsutter, and Poison Butte, Wyo.

Shiprock, Ariz.



ASTER VENUSTA, Rydb.

Family: sunflower, Compositae

Flowers: Composite flowers in 1-in. heads with long white ray flowers resembling daisies; 4-6 in. flower stalks. White "petals" turn lavender on aging. Blooms in May and June.

Leaves: Spatula-shaped, hairy and alternate. 1-2 in. long.

Seeds: Small seeds; remain in dried heads through summer months.

Plant: Woody perennial base with long tap root. Plant 6-18 in. high.

SECONDARY INDICATOR

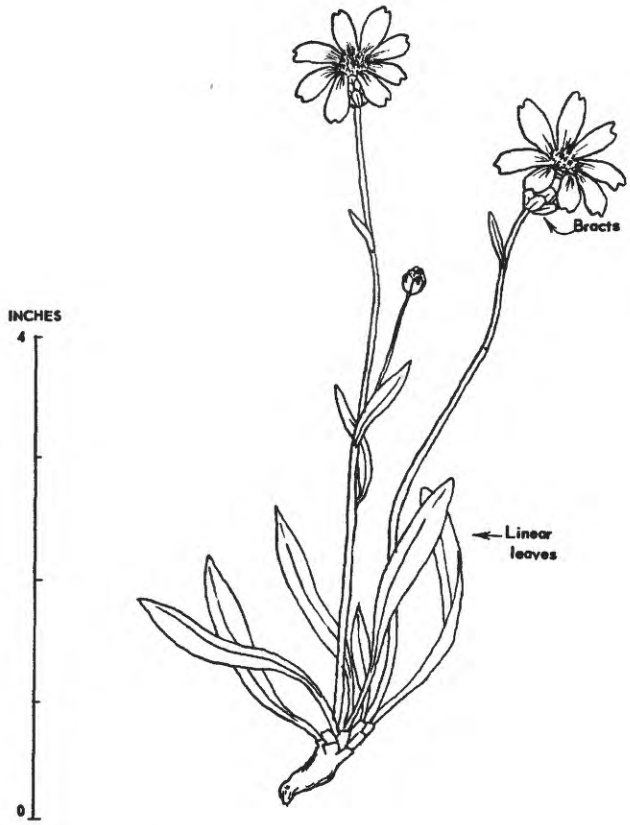
Control: selenium

WOODY ASTER

Altitude: 3,000-5,000 ft

Occurrence: Restricted to low altitudes. Common on clay soils of Mancos shale and alluvium of uranium districts in Utah. Although species absorbs large amounts of selenium when available, restriction to clay soils limits its usefulness to alluvium and wash prospecting.

Districts noted: Thompsons, Moab, Henry Mtns., and Green River, Utah.



APLOPAPPUS ARMERIODES, A. Gray

Family: sunflower, Compositae

Flowers: Heads clustered at top of stem with yellow tubular disk and ½ in. long ray flowers. Blooms June-July.

Leaves: Smooth, 3-nerved, linear leaves, 1-3 in. long.

Plant: Perennial herb with leafless flower stems 2-6 in. long arising from bunched leaves at woody base.

SECONDARY INDICATOR

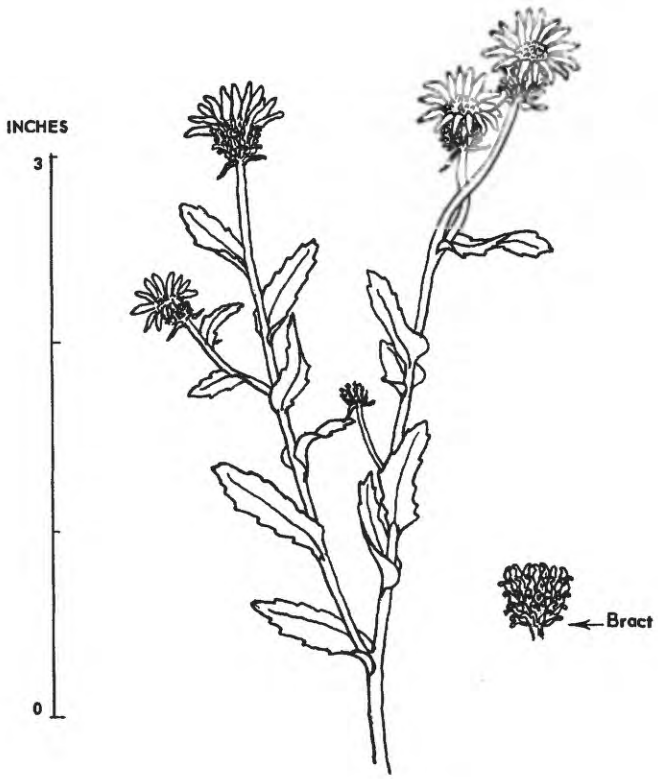
Control: selenium

GOLDENWEED

Altitude: 4,000-6,000 ft

Occurrence: Dry sandstone mesas.

Districts noted: Thompsons, San Rafael, Henry Mtns., Green River, and White Canyon, Utah;
Bull Canyon, Colo.;
Shiprock, Defiance Uplift, Ariz.



GRINDELIA SQUARROSA, (Pursh) Dunal.

and closely related species

Family: sunflower, Compositae

Flowers: Yellow radiate heads in flat-topped clusters. Green bracts of heads strongly graduated in 4-8 rows with recurved tips and very gummy. Blooms in fall.

Leaves: Undivided, alternate leaves clasping the stem; very resinous and stiff.

Seeds: Dry, small, and short.

Plant: Biennial or perennial, 8-40 in. high; very gummy plant with long tap root. Balsam-like odor from exuded gum.

SECONDARY INDICATOR

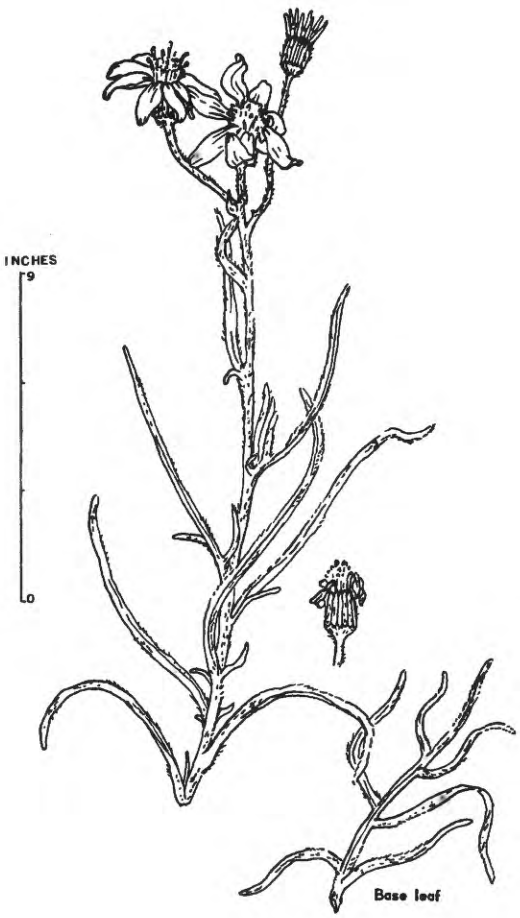
Control: Selenium and sulfur

CURLYCUP GUMWEED

Altitude: Up to 9,000 ft

Occurrence: Common in drainage and seeps from mines in desert country, but grows over hillside ore deposits at higher altitudes. Common along roadcuts in Mancos shale. Distribution in some districts seems closely related to that of ore. Analyses show no absorption of Se but a marked concentration of U.

Districts observed: Thompsons, Utah; and others.



SENECIO LONGILOBUS, Benth.

Family: sunflower, Compositae

Flowers: Yellow composite with $\frac{1}{2}$ in. disk and long yellow ray flowers. Heads in flat-topped clusters. Blooms through summer months.

Leaves: Pinnate leaves with linear, thread-like, hairy leaflets.

Seeds: Small dry seeds.

Plant: Ill-scented perennial 1-2 ft high covered with white woolly hairs and having a long tap root. The plant is very poisonous to cattle. Poison, alkaloid.

SECONDARY INDICATOR

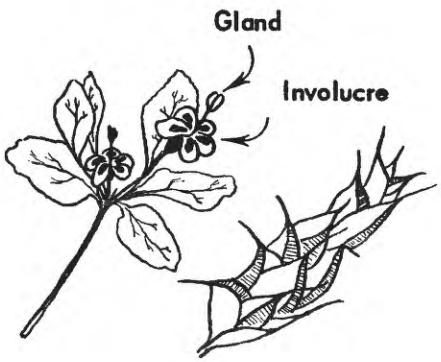
Control: unknown

THREADLEAF GROUNDSEL

Altitude: 4,000-5,500 ft

Occurrence: Along roadsides and in dry, alkaline country. Various species of Senecio are known to act as indicators around many types of heavy metal ore deposits. The control may be sulfur. Useful secondary indicator.

Districts observed: Thompsons, Utah;
Shiprock, Defiance Uplift, Ariz.;
Slick Rock and Gypsum Valley, Colo.



EUPHORBIA FENDLERI T. & G., and related prostrate species

Family: spurge, Euphorbiaceae

Flowers: Minute flowers in peculiar "petaled" involucre from which stalked glands extend. Flowers occur in axils of leaves. Bloom in April-October.

Leaves: Oval, opposite, entire, pale green leaves 1/8 in. long.

Fruit: Quadrangular seeds in lobed smooth capsule.

Plant: Prostrate, pale green annual with forking stems radially branched at the base. Milky acrid sap which is poisonous and may cause dermatitis upon contact.

SECONDARY INDICATOR

Control: calcium

SANDMAT or

FENDLER EUPHORBIA

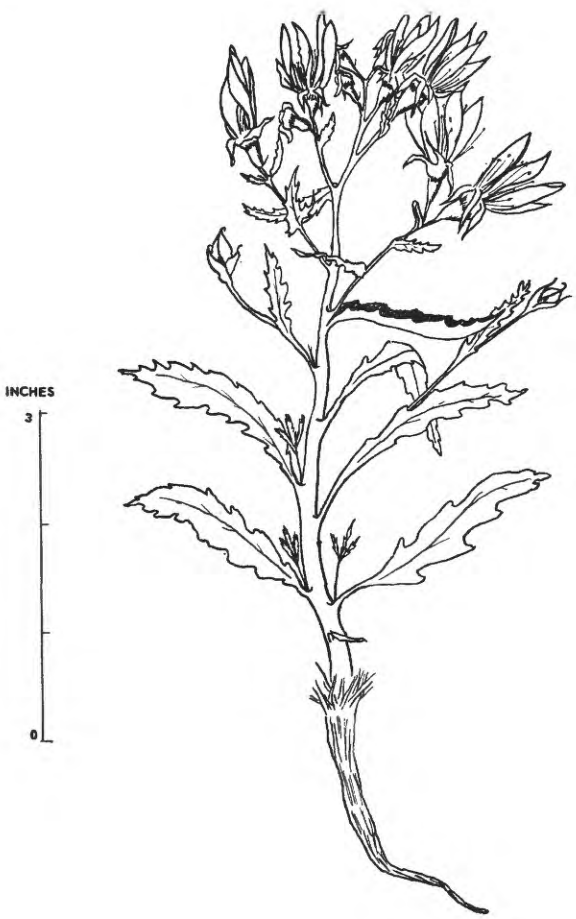
Altitude: 4,000-7,000 ft

Occurrence: Common on gypsum-bearing soils. Of importance only where soluble salts from ore deposits have migrated into the surface soils. Experimental plot studies show stems of this plant tend to be erect on high-sulfate soils, and completely prostrate on low-sulfate soils.

Districts noted: Thompsons, San Rafael, and Henry Mtns., Uinta Basin, Utah;

Grants, N. Mex.;

Shiprock, Ariz.



MENTZELIA MULTIFLORA (Nutt.) A. Gray

Family: loasa, Loasaceae

Flowers: Light-yellow, star-shaped flowers with 10 petals and many stamens. The outer row of stamens are petal-like. Opens in afternoon. Blooms from May to August.

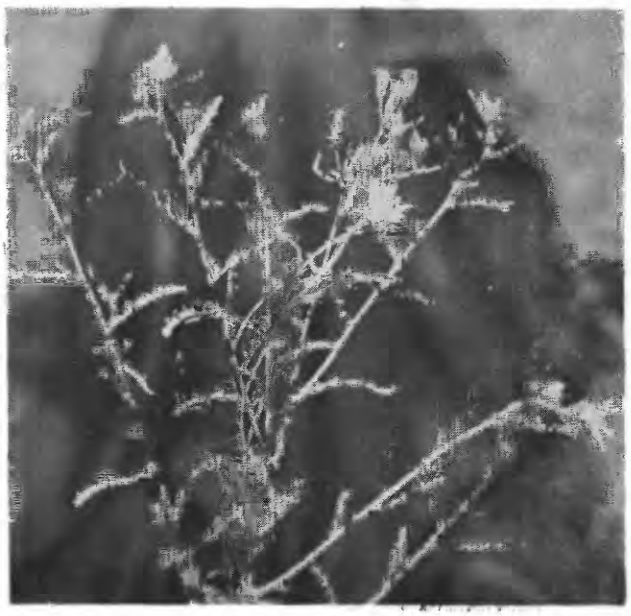
Leaves: Light green, sticky, alternate, and toothed.

Fruit: 3-5 valved capsule.

Plant: Stems white and freely branching; plant 1-3 ft high. Barbed stinging hairs. Perennial. Stout tap root.

SECONDARY INDICATOR

Control: calcium

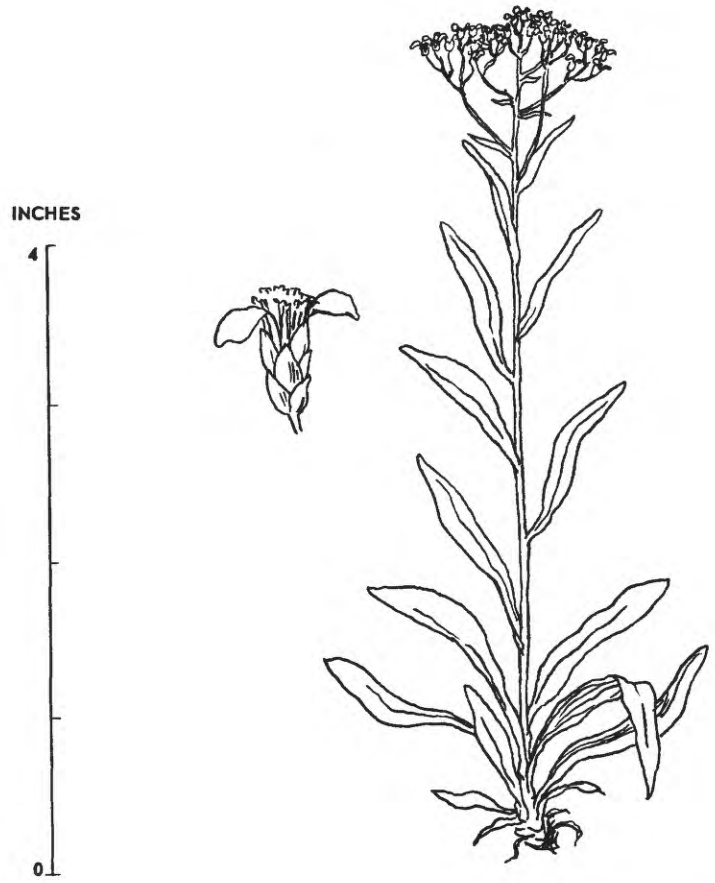


DESERT BLAZINGSTAR

Altitude: Up to 7,000 ft

Occurrence: A common weed of roadsides and disturbed ground. This plant is found around a great number of uranium deposits as well as on the pure gypsum sands of White Sands, N. Mex. It is probably an indicator of white alkali. It is tolerant of large amounts of selenium and uranium and under certain circumstances may be used as an ore indicator.

Districts noted: Lost Creek, Wyo.;
La Ventana and Grants, N. Mex.;
Gypsum Valley, Colo.;
Shiprock, Ariz.;
San Rafael, Utah



SOLIDAGO PETRADORIA, Blake

Family: sunflower, Compositae

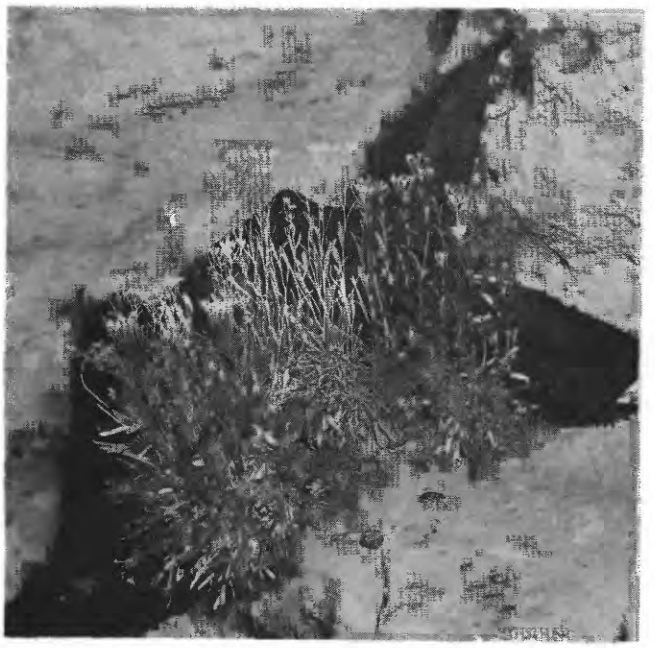
Flowers: 5-8 small yellow flowers in heads in dense flat-topped clusters. Blooms in July-August.

Leaves: Linear-oblong, 3-nerved, rigid alternate leaves, 2-4 in. long and resinous.

Seeds: Dry, flat, 5-nerved.

Plant: Low, tufted, perennial herbs with short branched woody base. Smooth, 4-6 in. long, erect flower stems from cushion of basal leaves. Extensive root system.

TOLERANT

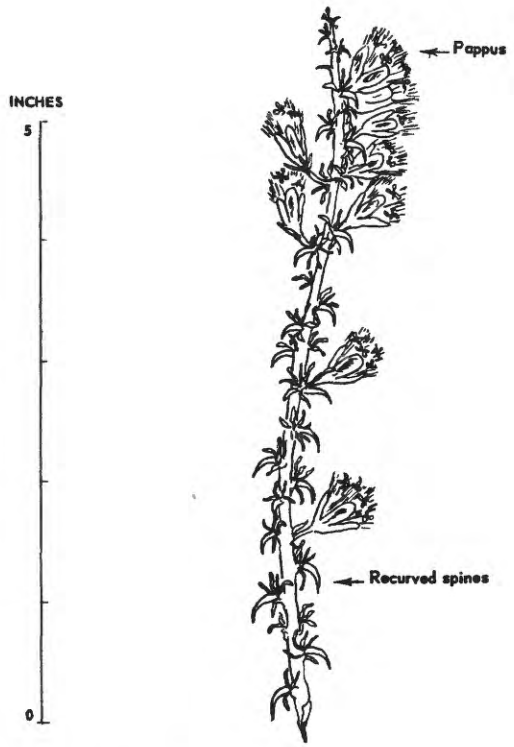


ROCK GOLDENROD

Altitude: 5,500-7,500 ft

Occurrence: Rock ledges and dry sandy soils.

Districts noted: Thompsons and White Canyon, Utah;
Paradox Valley and Bull Canyon, Colo.
Defiance Uplift, Ariz.



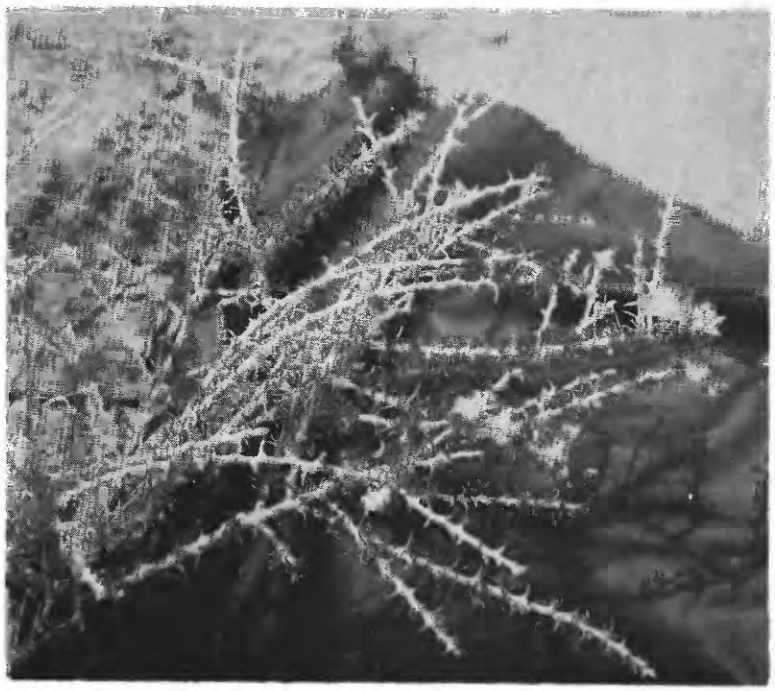
TETRADYMIA SPINOSA, Hook. & Arn.

Family: sunflower, Compositae

Flowers: Fleshy smooth heads of 4 yellow flowers ½ - 3/4 in. long arising from axils of the leaves. Bracts at base of heads woolly. Blooms in May-July.

Leaves: Primary leaves converted to woolly recurved spines ¼-½ in. long. Secondary leaves linear, ¼-½ in. long, fleshy and in clusters.

Plant: Divaricately branched xerophyte shrub 2-4 ft high with white woolly branches and characteristic recurved woolly spines which are soft and pliant when first produced. Plant contains high potassium content in leaves and buds. Organic poison makes plant poisonous to sheep.



COTTONTHORN HORSEBRUSH

Altitude:	4,000-7,000 ft
Occurrence:	Dry sandy plains and sandstone mesas.
Districts observed:	Thompsons, Utah;
	Gypsum Valley, Colo.

COWANIA STANSBURIANA, Torr.

Family: rose, Rosaceae

Flowers: Creamy yellow solitary flowers with 5 oval petals, 5 sepals, and many stamens. Fragrant; resembles the wild rose. Flowers through spring and summer whenever water is plentiful.

Leaves: Alternate gland-dotted, evergreen leaves with 3 to 5 lobes and curled-under margins. White fuzz underneath.

Seeds: Dry, attached to several long plumes which appear from each flower before the petals have dropped.

Plant: Twisted shrub, 3-12 ft high with shaggy gray bark and reddish twigs. Plant has a bitter taste, and very acid cell sap.

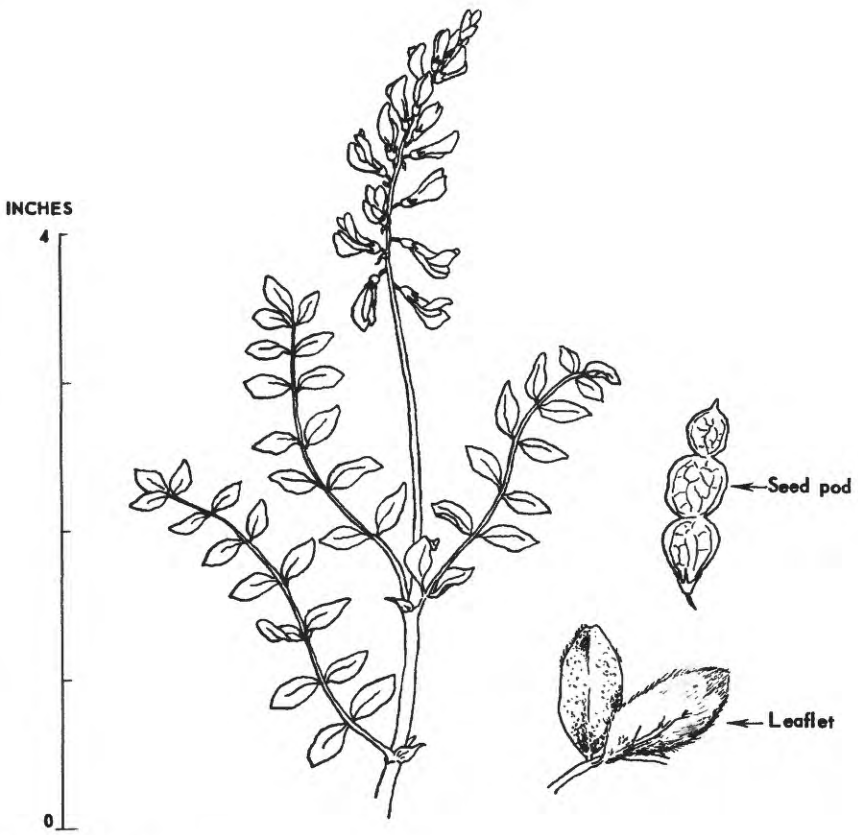
TOLERANT

STANSBURY CLIFFROSE

Altitude: 3,500-8,000 ft

Occurrence: Phreatophyte, occurring with juniper and pinyons on rock mesas and along sandy washes. Called "vanadium-bush" and used as indicator by early prospectors although probably indicating water commonly trapped in ore rolls. Able to grow in highly mineralized ground and to absorb large amounts of uranium. Type locality: Stansbury Island, Great Salt Lake.

Districts observed: Shiprock, Chilchinbeto, Chuska and Defiance Uplift, Ariz.;
Thompsons, San Rafael, White Canyon, Henry Mtns., and Circle Cliffs, Utah;
La Ventana, and Grants, N. Mex.



HEDYSARUM BOREALE Nutt.

Family: pea, Leguminosae

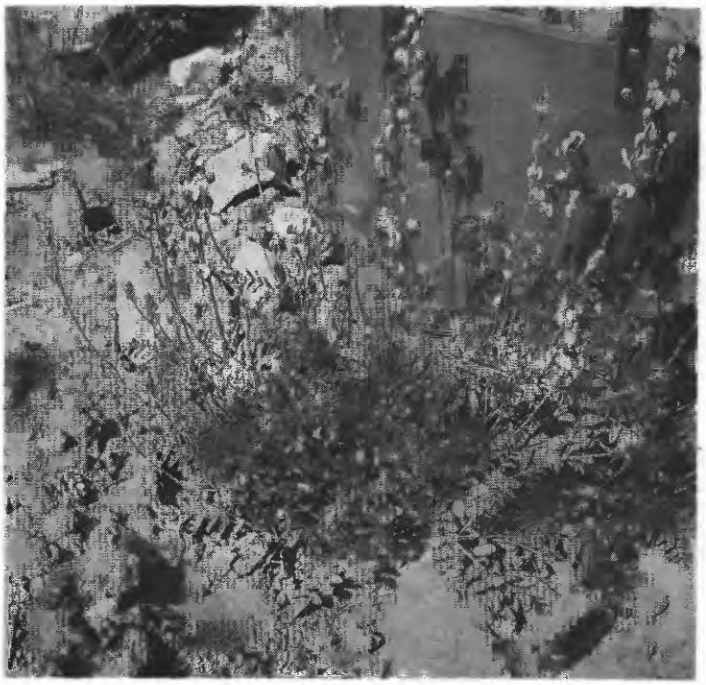
Flowers: Showy rose-purple irregular flowers in loose racemes which grow from the axils of leaves. Stamens 9 and 1. Blooms June-July.

Leaves: Odd-pinnate with numerous oblong leaflets. Finely punctate, smooth on upper surface and sparingly hairy beneath.

Fruit: Compressed, several-jointed pod divided into 2-4 separable rounded segments.

Plant: Perennial herb with 1-3 ft erect, leafy stems with scattered hairs. Resembles the Astragalus genus closely in general appearance except for seeds and hairy roughness.

TOLERANT



NORTHERN SWEETVETCH

Altitude: 4,000-7,000 ft

Occurrence: Phreatophyte, tolerant of mineralized ground.
Washes.

Districts observed: Thompsons, White Canyor, Circle Cliffs and San Rafael, Utah;
Paradox Valley, Colo.
Defiance Uplift, and Chuska, Ariz.

CASTILLEJA integra

Family: figwort, Scrophulariaceae

Flowers: Spikes of flowers consisting of three-cleft, brilliant scarlet bracts surrounding yellowish fused calyx and narrow yellow petals. 4 stamens. Bloors throughout summer.

Leaves: Alternate, sessile, linear leaves, 2-4 in. long.

Fruit: 2-celled capsule containing many seeds.

Plant: Erect perennial herb with simple leafy stem and spike of red or yellow bracted flowers. Roots fibrous, partly parasitic on other plants.

TOLERANT

INDIAN PAINTBRUSH or

PAINTEDCUP

Altitude: 3,000-7,500 ft

Occurrence: In sandy soils. Capable of absorbing considerable Se although not believed to be an indicator plant.

Districts noted: Thompsons and White Canyon, Utah.

Grants, N. Mex.

Chilchinbeto, and Chuska, Ariz.

PLANTAGO PURSHI, R. & S.

Family: plantain, Plantaginaceae

Flowers: Tiny dry flowers in dense cylindrical spike resembling wheat. Spike $\frac{1}{2}$-$1\frac{1}{2}$ in. long on 2 in. woolly stem. Individual flower parts in 4's. Blooms throughout summer.

Leaves: Woolly, linear, 3-ribbed leaves 1-2 in. long on a short stem from the base of the plant.

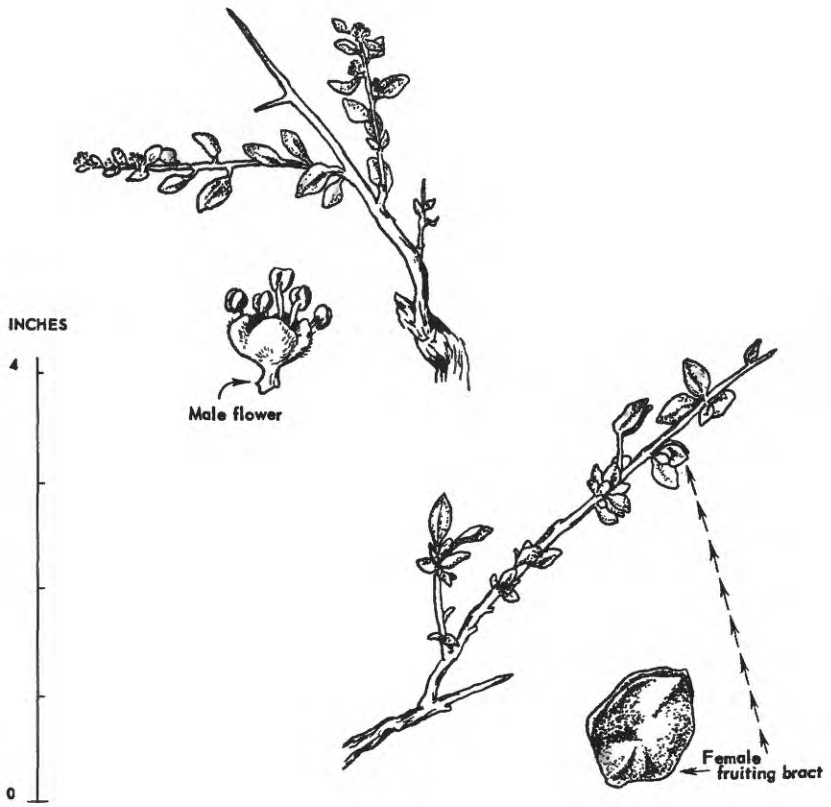
Fruit: Oblong, 2-seeded pod which divides in middle so that top half falls off like a lid.

Root: Long tap root; most deeply placed roots of any annual.

Plant: Tiny, drought-resistant, winter annual consisting of several leaves and single flower spike which arise from the base. Seeds become mucilaginous when wet.

WOOLLY INDIANWHEAT

Altitude:	1,000-7,000 ft
Occurrence:	Full sunlight and dry sandy soil. Commonly associated with sulfur-indicator plants.
Districts noted:	Thompsons, Utah. Grants, N. Mex.



ATRIPLEX CONFERTIFOLIA, (Torr.) S. Wats.

Family: goosefoot, Chenopodiaceae

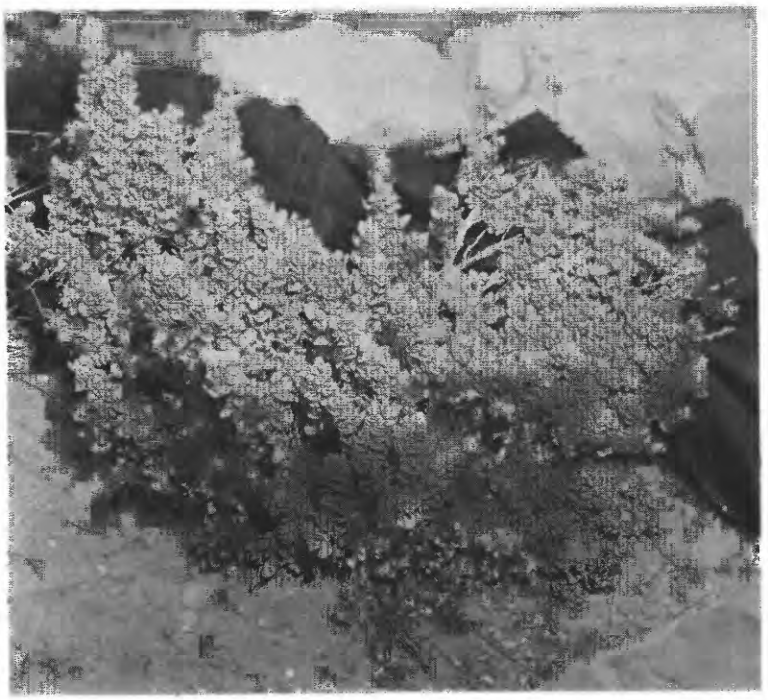
Flowers: Small dense clusters. Blooms in late summer.

Leaves: Thickened, ovate, scurfy leaves; resembling a shadscale.

Fruit: Fruit in large conspicuous yellowish-green to pinkish bracts at ends of the branches.

Plant: Grayish-green xerophyte shrub 1-4 ft high; woody and branched. Branches ending in spines. Seeds not produced on same plants with pollen.

TOLERANT



SHADSCALE SALTBUSH

Altitude: 4,200 to 6,000 ft

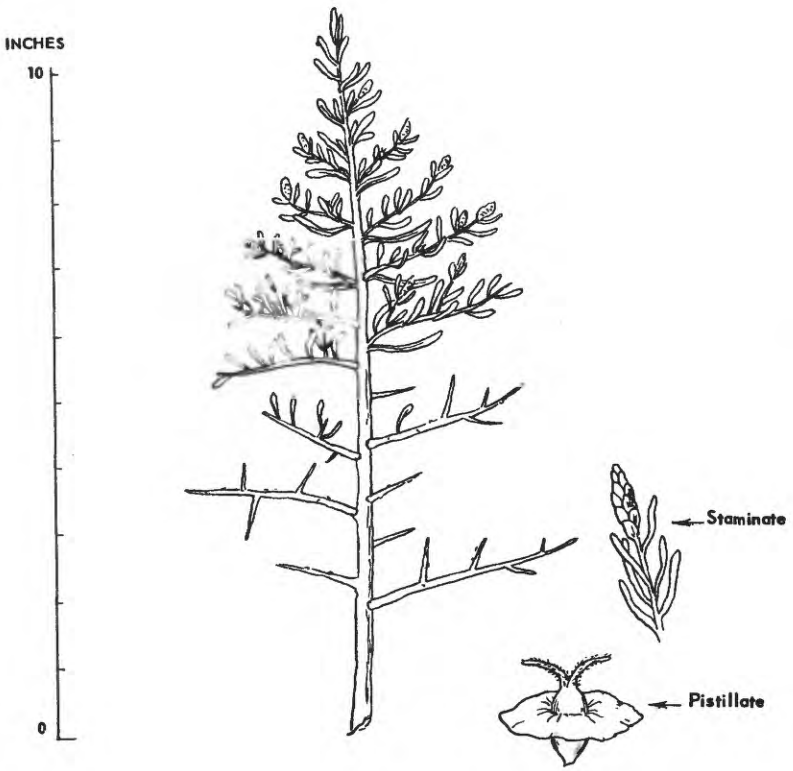
Occurrences: Drought-resistant and alkali-tolerant plant commonly the dominant species of uranium districts. Plant has ash content of about 25 percent consisting mostly of sodium. Absorbs uranium and selenium readily although not restricted in distribution to mineralized ground. Type locality: Great Salt Lake.

Districts noted: Wamsutter, Poison Buttes and Lost Creek, Wyo.

La Ventana, N. Mex.;

Slick Rock, Colo.;

Thompsons, San Rafael, White Canyon, Moab, and Uirta Basin, Utah.



SARCOBATUS VERMICULATUS (Hook.) Torr.

Family: goosefoot, Chenopodiaceae

Flowers: Pollen and seeds not produced on same plant. Seed-producing flowers axillary and with cup-shaped enlarged calyx. Pollen-producing flowers small, in terminal spikes. Blooms June-Sept.

Leaves: Alternate, linear, and fleshy leaves, $\frac{1}{2}$-$1\frac{1}{2}$ in. long. Sessile.

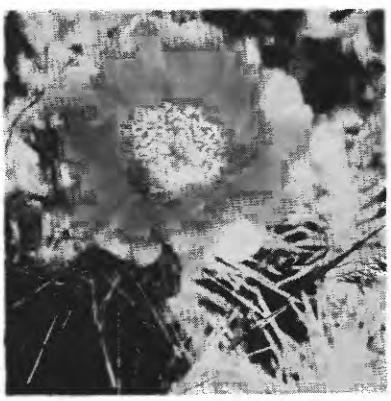
Seed: Nutlet attached to expanded, membranous calyx.

Plant: Erect shrub 4-8 ft high, much branched and thorny with gray bark and fleshy linear leaves.

TOLERANT

GREASEWOOD

Altitude:	1,000-7,000 ft
Occurrence:	A phreatophyte or ground-water plant tolerant of alkaline and saline soils. An indicator of "black alkali", or sodium carbonate. Poisonous to sheep in spring, due to salate of sodium and potassium in sap. Absorption of uranium very high.
Districts noted:	Thompsons, Utah: Lost Creek, and Poison Buttes, Wyo.



OPUNTIA ENGELMANNI and other species

Family: cactus, Cactaceae

Flowers: Many, waxy, colored petals, numerous sensitive stamens, and short green calyx supported on cup-shaped tube. Diurnal flowers normally several inches across arise from same growing centers as spines. Blooms May-June.

Leaves: Small, awl-shaped, deciduous, up to ½ in. long.

Roots: Extensive fibrous roots.

Fruit: Fleshy edible berry up to 2 in. long with many bony seeds.

Plant: Succulent shrubs up to 5 ft high with fleshy, jointed, flattened stems. Areoles, or growing centers, bear minute leaves, spines, and bristles. Water content 80 percent in stems. Acid cell sap.

TOLERANT

PRICKLY PEAR

Altitude:	1,000-8,000 ft
Occurrence:	Sandy plains and sandstone mesas.
Districts noted:	Thompsons and Green River, Utah

MIRABILIS MULTIFLORA A. Gray

Family: four o'clock, Nyctaginaceae

Flowers: Clusters of 6 rose-colored, funnel-shaped flowers 2 in. across enclosed in a large tunnel-shaped bract. 3-5 unequal stamens. Flowers open toward sunset. Blooms July- August.

Leaves: Thick, opposite, entire leaves, oval or heart-shaped and 2-3 in. long.

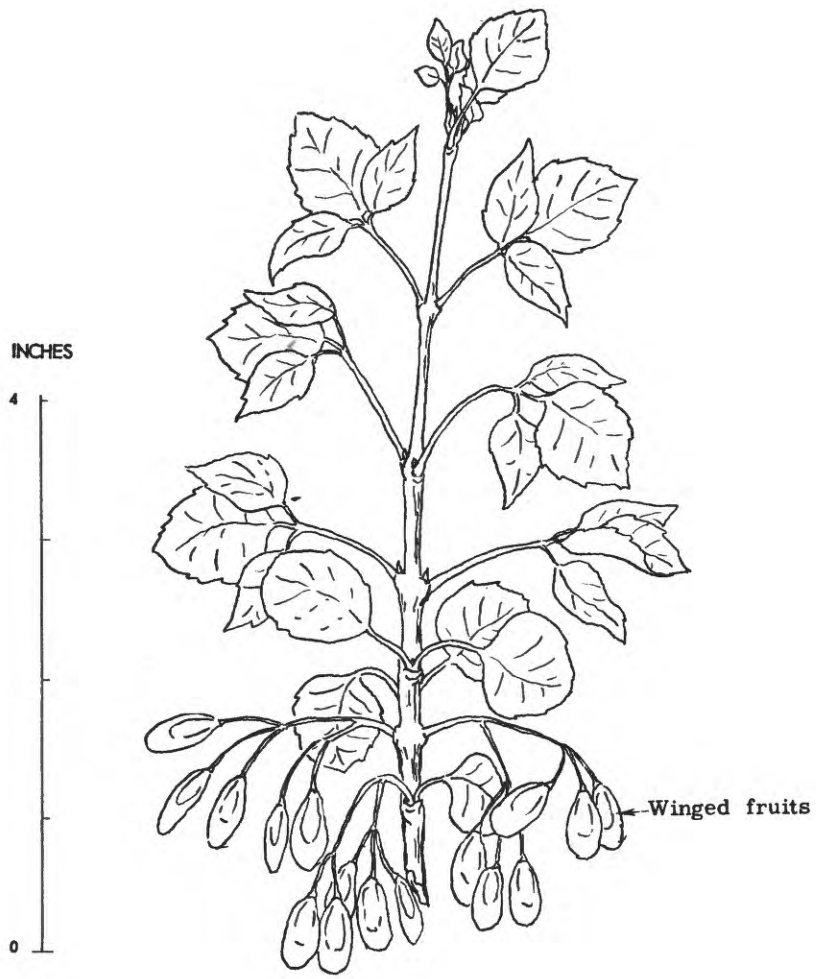
Seeds: Oval black seeds, 10-furrowed toward base.

Roots: Large and fleshy.

Plant: Perennial herbs with thick root stalk and stout stems, spreading or ascending, 2-3 ft long.

COLORADO FOUR-O'CLOCK

Altitude:	2,500-7,500 ft
Occurrence:	Hillsides and rocky mesas.
Districts noted:	Thompsons and White Canyon, Utah;
	Shiprock, N. Mex.;
	Uravan, Colo.



FRAXINUS ANOMALA Torr.

Family: olive, Oleaceae

Flowers: 4-toothed, bell-shaped flowers. Blooms April-May.

Leaves: Simple, smooth, rounded leaves 1-2 in. long occurring in 3's.

Fruits: Dry, winged, oblong 1-seeded fruits $\frac{1}{2}$-1 in. long.

Plant: Small tree 5-15 ft high, with 4-angled twigs and thick simple leaves. Extensive root system.

TOLERANT

SINGLELEAF ASH

Altitude:	2,000-7,000 ft
Occurrence:	Dry sandstone mesas and sandy washes in full sun.
Districts noted:	Shiprock, N. Mex.; Thompsons, San Rafael and Green River, Utah.

GLOSSARY

Awn - a slender bristle-like appendage of grasses.

Axil - the angle formed by a leaf or branch with the stem.

Bract - a modified leaf subtending a flower or flower cluster.

Calyx - the outer series of parts in a flower immediately surrounding the petals.

Corolla - the inner series of parts in a flower. Composed of petal-like parts which may be brightly colored.

Deciduous - falling away at the end of the growing period; not persistent. Commonly said of plants with such leaves.

Disk-flowers - tabular flowers of a composite head as distinct from the peripheral ray flowers.

Diurnal - daily; new flowers opening each day.

Irregular - a flower in which one or more of the petals are unlike the rest.

Keel - the two anterior petals of a legume flower joined as to resemble the keel of a boat.

Pinnate - compound (leaf) with the leaflets arranged on each side of a common stem. Feather-like.

Punctate - dotted with depressions or with translucent glands.

Raceme - a simple cluster of stalked flowers upon a common elongated stem.

Ray-flowers - strap-like marginal flowers of a composite.

Sepal - division of the calyx corresponding to petals in the corolla.

Sessile - attached directly at the base; without a stalk.

Stamen - one of the pollen-bearing organs of a flower.

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