Description of Indicator Plants and Methods of Botanical Prospecting for Uranium Deposits on the Colorado Plateau

GEOLOGICAL SURVEY BULLETIN 1030-M

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By HELEN L. CANNON

A CONTRIBUTION TO THE GEOLOGY OF URANIUM

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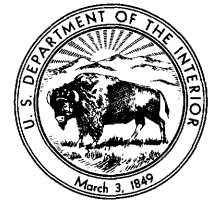

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By HELEN L. CANNON

ABSTRACT

Two methods of botanical prospecting for uraniferous deposits on the Colorado Plateau are useful in semiarid country in prospecting for ore-bearing beds at depths as much as 70 feet. By one method, tips of tree branches are sampled and analyzed for uranium content. Generally more than 1 part per million of uranium in the ash indicates favorable ground for further geologic exploration. The second method, that of mapping indicator plants, is used in semiarid parts of the Plateau at low altitude. The distribution of indicator plants is controlled by the availability of chemical constituents of the ore, such as selenium, sulfur, and calcium. Plants of the genus *Astragalus* are most useful in prospecting for uranium deposits of high selenium content; plants of the genera *Allium* and *Eriogonum* are most useful as indicators of deposits with a high sulfur content. Fifty indicator plants commonly associated with carnotite deposits and plants tolerant of mineralized ground are described and illustrated.

INTRODUCTION

Two methods of botanical prospecting for uranium deposits have been applied on the Colorado Plateau. One method is based on a chemical analysis for the 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 method, that of determining morphological or physiological changes in plants growing in ore deposits, has been discarded in this area. The general principles on which methods of prospecting were developed are described in earlier reports (Cannon, 1952; 1953).

The first method makes it possible to detect uranium-bearing material through a maximum of 70 feet of barren rock by means of tree root-systems, which act as conduits for the upward migration of soluble salts to the ground surface. The method is applicable where the mineralized bed crops out in a broad, flat bench so that plant samples can be collected on a grid pattern to outline mineralized zones at depth; and also where the mineralized bed crops out in a sharp cliff that is commonly obscured by talus or slump. Here a line traverse

parallel to the cliff may be desirable. The samples are either analyzed in the field by a quick test for uranium or are sent to a chemical laboratory for quantitative assay.

Prospecting by indicator plants is the less expensive of the two methods and consists of mapping the areal distribution of key indicator plant species. Indicator plants and also plants tolerant of mineralized ground, and therefore common in uranium districts, are described, illustrated, and evaluated in this report. The information has been compiled not as a key for species identification but as a sorting device that will enable geologists and prospectors to identify, in a preliminary way, the plants that may be useful in prospecting an area. The information was gathered while botanical prospecting studies were being made on the Colorado Plateau by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

A part of the section on the use of absorber plants was taken from unpublished reports by Albert J. Froelich of the Geological Survey. The plants collected during the study were identified by T. H. Kearney, formerly of the U. S. Department of Agriculture; A. H. Holmgren, Utah State Agricultural College; R. J. Davis, University of Idaho; and E. F. Castetter, University of New Mexico. The line drawings were made from pressed plant specimens by Maxine Heyl, Ann Pettigrew, and Catherine B. Hayes. The plants were photographed in the field by the writer, with the part-time assistance of Edward Clebsch.

COLORADO PLATEAU SOILS AND GROUND-WATER CONDITIONS

Plant associations on the Colorado Plateau depend on soil and ground-water conditions. Because the climate of the Plateau is semiarid, little residual soil forms except in the mountains and on the higher mesas. The sandy and clayey soils are commonly closely related to the alternating beds of sandstone and shale from which they are derived (Shreve, 1951, p. 16). The texture and salinity of the soil associated with the various stratigraphic units at lower altitudes largely determine the plants that grow in them. The most common soluble salts in a desert soil are carbonates, chlorides, and sulfates of calcium, magnesium, and sodium (Shreve, 1951, p. 16). Many desert plants tolerate large amounts of these compounds.

In the semiarid Colorado Plateau the dependence of plants either directly or indirectly on ground water requires a study of the ground water in areas where plants are studied. Water beneath the ground surface occurs in the zone of saturation and the zone of aeration (Meinzer, 1923, p. 29–95). The upper surface of the ground water occurring in the zone of saturation is called the water table. Owing to capillarity, however, the earth is moist for a distance of several

feet above the water table. The thickness of this capillary fringe may range from 8 or 10 feet in fine silt or sand to 3 or 4 feet in coarse clean sand. Roots of most phreatophytes terminate in the capillary fringe (White, 1932, p. 34). The zone of aeration extends from the water table to the surface. Other zones of saturation may occur above the main water table where lenses or layers of impermeable material prevent movement of water down to the main water table. Such zones are termed "perched water tables" and may be temporary or permanent.

Perched water tables are common on the Colorado Plateau where the ore-bearing sandstone beds are underlain by impervious clay (D. A. Phoenix, written communication, 1952). Locally, clay seams may prevent the downward movement of ground water and thus prevent the oxidation of primary ores even at relatively shallow depths.

PLANTS IN RELATION TO GROUND WATER

Perennial plants that obtain water from the water table, especially in arid regions, in contrast to plants that utilize soil moisture above the water table are called phreatophytes (Meinzer, 1923, p. 95; 1927, p. 1; Robinson, in preparation). Plants that 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 short roots and thickened stems or leaves that are well protected from evaporation and designed for water storage. A third group, called ephemeral, endures adverse periods as bulbs or as seeds beneath the soil, bursts into bloom suddenly after a period of heavy rainfall, sets fruit, and disappears. All three groups grow in uranium districts of the Colorado Plateau and are described in this report.

Such phreatophytes 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 contains water, are useful for uranium analysis.

Generally xerophytes are tolerant of soils that have a high salt content, and these are therefore tolerant of and in some cases indicative of shallow uranium deposits. Where the water table is below the ore zone, *Atriplex confertifolia* (shadscale), a xerophyte, may be used as the sampling medium.

In areas where the capilliary fringe extends nearly to the surface and soluble salts from sulfide ore bodies have migrated in large quantities to surface soils, ephemeral indicator plants may flourish and become useful in prospecting. For example, wild onions, which are

sulfur indicators, have indicated uranium at depths of 20 to 30 feet beneath the surface.

PLANT ASSOCIATIONS AND INDICATOR PLANTS ON THE COLORADO PLATEAU

The distribution of major plant associations on the Colorado Plateau is controlled by many factors including slope, altitude, ground-water conditions, and texture and salinity of the soil. Few uranium deposits occur at altitudes of more than 9,000 feet in the spruce-fir and alpine life zones. At altitudes of 7,400 to 9,500 feet ponderosa pine and Douglas-fir forests predominate. These include the following shrubs and trees:

Pinus ponderosa, ponderosa pine
Abies concolor, white fir
Pseudotsuga taxifolia, Douglas fir
Juniperus scopulorum, Rocky Mountain juniper
Populus tremuloides, quaking aspen
Quercus gambelli, Gambel's oak
Arctostaphylos pungens, manzanita
Ceanothus fendleri, buckbrush
Amelanchier alnifolia, shadbush
Symphoricarpos oreophilus, snowberry

Lack of sunlight causes a poor distribution of herbaceous plants and consequently of indicator plants in this association. Here tree sampling has been used successfully as a method of prospecting.

From 5,000 to 7,400 feet pinyon and juniper forests predominate on foothill pediments and on mesas capped with sandstone that contains sufficient water. The shrubs that occur in or near the fringes of these forests prefer a light sandy soil and water of low salt content. They include:

Cowania stansburiana, cliffrose
Cercocarpus montanus, mountain mahogany
Ephedra viridis, Mormon tea
Mahonia fremontii, hollygrape
Rhus trilobata, skunkbush

They also include low growth of Gambel's oak. The herbs in this altitude range include many of the plants described in this report. Pinyon and juniper have been used commonly in plant analysis prospecting.

From altitudes of 3,500 to 5,000 feet the plants are characteristic of the northern desert flora and are divided into two major groups; namely, those that are tolerant of alkali soils and those that are not. In loose soils of low-salt content, sagebrush predominates. Sagebrush is frequently associated with or replaced in drier areas by:

Atriplex canescens, saltbush
Grayia spinosa, hopsage
Coleogyne ramosissima, blackbrush
Chrysothamnus puberulus, little rabbitbrush

The sagebrush association is common on pediments and alluvial fans at the base of mountains and is the characteristic flora in areas underlain by the Dakota sandstone.

In low areas of drier soils and of higher salt content within this altitude range, the shadscale association is dominant. *Atriplex confertifolia*, or shadscale, is shallow rooted and depends upon moisture in the surface soils for its water supply. Woody plants belonging to the association include:

Tetradymia spinosa, horsebrush
Artemisia spinescens, budsage
Gutierrezia sarothrae, snakeweed
Eurotia lanata, winterfat.

The shadscale association is characteristic of sandstone exposures of the Summerville, Chinle, and Mancos formation at lower altitudes. In heavy saline soils of high moisture content, an association of *Sarcobatus vermiculatus*, or greasewood, prevails. The association is generally restricted to low, poorly drained salt flats, and the presence of greasewood indicates saline ground water at depths of not much more than 15 feet. In areas where the water table is at or near the surface, seepweed or pickleweed may be the only plants able to grow in the highly alkaline environment.

The importance of these associations in prospecting lies not in their normal association with a given geologic formation of the Colorado Plateau but in their abnormal occurrences as island communities indicative of greater or less soil salt or moisture content than the endemic association. On the higher benches where ground water of low alkali content is available in the sandstone, little change in the general appearance of the juniper-pinyon flora can be seen around carnotite deposits. In drier areas at lower altitude, however, the general appearance of the flora in the carnotite districts is commonly similar to the flora of a salt flat. Instead of an association in which sagebrush (*Artemisia tridentata*), hop sage (*Grayia spinosa*), or saltbush (*Atriplex canescens*) is dominant, it is largely a shadscale (*Atriplex confertifolia*) 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 commonly found within areas of shadescale and snakeweed. These plants that indicate mineralized ground are not all controlled by the same chemical element

and are usually common weeds rather than unusual plants. The control of the species may be pH variations; a change in the availability of phosphorus, calcium, or other major constituent necessary for plant growth; or a true dependence on a minor element, such as selenium or sulfur.

Selenium-indicator plants are the only group definitely known to be completely 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 venustus*, *Oryzopsis*, and several other plants. These indicators absorb large amounts of selenium, sufficient 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 and calcium-absorbing plants reflect the presence of gypsum in the soil. Plants that require large amounts of these elements for their growth include the lily and mustard families, at least a part of the buckwheat family, and various isolated genera. Because uranium ores commonly contain sulfides from which gypsum may be produced in the surface soils, gypsum-indicators may also be found in the vicinity of uranium deposits.

Both selenium and sulfur occur in all sedimentary rocks, but the concentration varies greatly between different stratigraphic units and in different regions. For instance, the selenium content of western shales of Cretaceous age is high and remains relatively constant in particular beds or strata for several hundred miles. Both elements may also be concentrated in tuff, coal, or sulfide ore deposits. The occurrence of selenium and sulfur, on the other hand, in amounts less than 10 ppm in barren sandstones of Triassic and Jurassic age contrasts sharply with concentrations of 100 to 1,000 ppm in ore deposits in the same formations. For this reason, the distribution of indicator plants along the outcrops of these sandstones forms conspicuous patterns.

Besides an increase in total selenium in carnotite ore, experimental-plot studies indicate that the proportion of water-soluble selenium is increased in the presence of carnotite. This results in a marked tendency for the *Astragalus* group to grow in the vicinity of ore deposits where it is possible for them to absorb selenium in concentrations of several hundreds or perhaps thousands of parts per million from ground containing only 2 ppm total selenium. *Stanleya*, however, appears to substitute selenium for sulfur in the plant metabolism and is capable of extracting and concentrating large quantities of selenium from gypsum containing only small amounts, but it is not

capable of extracting large amounts of selenium from a carnotite ore. For this reason *Stanleya* is not a primary indicator of seleniferous uranium ore but may be used in some areas as a secondary indicator of mineralized ground water.

Many of the other plants found near uranium deposits probably reflect changes in acidity and in the availability of major plant nutrients. Experimental studies show that larger amounts of calcium and phosphorus are available to plants in the vicinity of carnotite deposits than in barren ground. This favors an increase in the number of the calcium absorbers, *Mentzelia*, *Cryptantha*, and *Oenothera*, around ore deposits. The phosphorus absorbers, *Eriogonum*, *Allium*, *Calochortus*, and mustards, are encouraged by the increase in available phosphorus and sulfur as indicators of uranium ore.

In addition to those plants that act as indicators of mineralized ground or can be used in alluvial prospecting, many plants are tolerant of mineralized ground. Sixteen of these plants are described in this report. In general, the plants best adapted to soils of high mineral content are those having an acid cell sap that enables the plant to absorb and neutralize alkali elements. For example, shadscale absorbs large quantities of salts without harm to the plant growth. Plants of the goosefoot, rose, and cactus families are also tolerant of highly mineralized ground on the Colorado Plateau.

HOW TO PROSPECT BY PLANT ANALYSIS

Trees or shrubs of extensive root habit may be analyzed for uranium content to denote areas of mineralized ground. Basic information on the rate of absorption of uranium by plants must be gathered for control in the area to be prospected. Commonly a collection of samples from a variety of species in close proximity is made in an area that is known to be mineralized from drill-hole data or surface outcrop but is uncontaminated by surface workings. This collection is compared with similar collections in an area known by past exploration to be unmineralized.

In general, uranium is best absorbed by plants with a fairly acid cell sap and high cation exchange capacity in the root. Experimental work shows that plants belonging to this category absorb large amounts of calcium, selenium, and (or) sulfur along with uranium, but very little potassium. Conversely, potassium absorbers absorb only small amounts of uranium. Plants that have been used in sampling programs belong largely to the rose and pine families.

The trees and shrubs commonly sampled on the Colorado Plateau are as follows:

	Altitude (feet)
Pinus ponderosa Dougl. (ponderosa pine)	7,000–9,000
Pseudotsuga taxifolia Britt. (Douglas fir)	
Abies concolor Lindl. (white fir)	
Shepherdia rotundifolia Parry (buffaloberry)	
Pinus edulis Englm. (pinyon)	6,000–7,000
Juniperus scopulorum Sarg. (Rocky Mountain juniper)	
utahensis Sarg. (Utah juniper)	4,000–6,000
monosperma Engelm. (oneseed juniper)	
Cowania stansburiana Torr. (cliffrose)	
Atriplex confertifolia (T. & F.) S. Wats (shadscale)	

The sampling medium and sampling interval are determined after a study is made of the extent of mineralized outcrop, size, and habits of the known ore bodies, and the relation of the ore-bearing bed to the water table and to plant roots. A plant species that has an extensive root system which penetrates to the ore horizon is chosen as the sampling medium. If information concerning the absorption of uranium by that species is not available, preliminary samples are collected to determine the lowest value indicative of mineralized ground. Several trees are also selected for periodic sampling to test the consistency of laboratory results and seasonal variation. Branches on a given side of the tree are connected directly with roots on that side of the tree; thus the uranium content may vary greatly from one side of the tree to the other. To obtain the most representative sample, therefore, it is recommended that branch tips be collected from all sides of the tree. The method is applicable where the uranium-bearing bed is not more than 70 feet beneath the surface.

The sampling interval depends in part upon the objective of the project. On a broad flat bench a grid-pattern spacing adequate to detect either ore bodies or mineralized halos is desirable. The resulting values may be contoured to show areas 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 to 30 feet is recommended for sampling across talus-covered outcrop.

In the fluorimetric laboratory procedure, pint samples (about 75 grams) of material are required for an analysis. Samples are shipped to a well-equipped, uncontaminated laboratory for analysis. Two fluorimetric methods of analysis for small amounts of uranium in plant ash have been developed by the Geological Survey laboratories (Grimaldi and others, 1952 and 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 that may act as a quencher and reduce the amount of fluorescence of the uranium bead. 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 button is made. The procedure is considerably longer and more expensive than the direct fluorimetric method. Analytical results are stated in terms of parts per million of uranium in the plant ash. The precision to be expected from the laboratory for values from 0.3 to 5.0 ppm of uranium is a standard deviation of 0.5 ppm. A chromatographic field test by which many more analyses may be made in a day has also been developed in the Survey laboratory.

The detection of radioactivity in plant ash by alpha count has been used by Anderson and Kurtz (1955) in prospecting for pitchblende vein deposits. It is possible by this method to detect variations in uranium content above 10 ppm. Interferences from natural radioactivity due to other elements in the plant ash apparently mask radioactivity due to uranium below this amount. Therefore, the method is probably not applicable to prospecting for carnotite-type deposits.

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 the species collected, an average figure of 1 ppm in the ash has been used in many areas sampled as an arbitrary cutoff. Contents of uranium above this amount are considered anomalous and indicate favorable and possibly mineralized ground.

In places where grid sampling is used, isograms of the assay data can be drawn 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 vegetation 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 depends on the validity of the laboratory analysis, the size of sample interval, and the studies that are made of 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 use of a plant as an indicator in prospecting for uranium is based on the assumption that its distribution is affected by the avail-

ability of the chemical constituents of the ore. The first step, then, in a new area is to study the plants growing in ground known to be mineralized. The information on indicator plants included in this report was established by marking off 10- by 5-foot areas over known ore bodies in a number of districts, and similar areas over unmineralized parts of the same bed with similar exposure and slope. Complete lists of plants in each plot were made, and final lists of indicator and tolerant plants were derived from them. When any of the plants illustrated in this report are observed in a new area, a careful study of their distribution should be made to determine whether and how they can be used in prospecting.

After such studies have been made, similar plant associations may be sought along the outcrop of an ore-bearing bed through reconnaissance prospecting. Caution must be exercised because the plants are, of course, all common weeds and may be found in places where no uranium occurs. Selenium plants, for example, 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 report, nevertheless, have been noted repeatedly in close association with uranium ore deposits on the Colorado Plateau 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, ephemeral plants such as the lily family are available for study only in the spring or early summer. Although many of the *Astragalus* species bloom in April, they can be recognized from the dead seed pods and stalks and can be used in prospecting throughout most of the year (fig. 74). *Stanleya* and other mustards bloom throughout most of the summer. Many Composites, *Plantago*, and *Mentzelia* bloom in the late summer and fall.

The plants shown in this report (figs. 76–175) are given in order of their importance in prospecting. Those that have aided directly in the location of uranium 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. It is not necessary to identify species of many genera because all species may act as indicator plants. Species identification of these genera has not been given. Common and scientific names of most species are spelled in accordance with Kelsey and Dayton (1942). Descriptions have

FIGURE 74.—Dead plants of *Astragalus pattersoni* useful in fall and winter in deciding where to drill.

been written as simply as possible; the technical terms are listed in a glossary. All information of interest in the use of these plants has been compiled from the references listed. Mining districts (fig. 75) in which these plants have been observed are given as a general guide to their areal distribution.

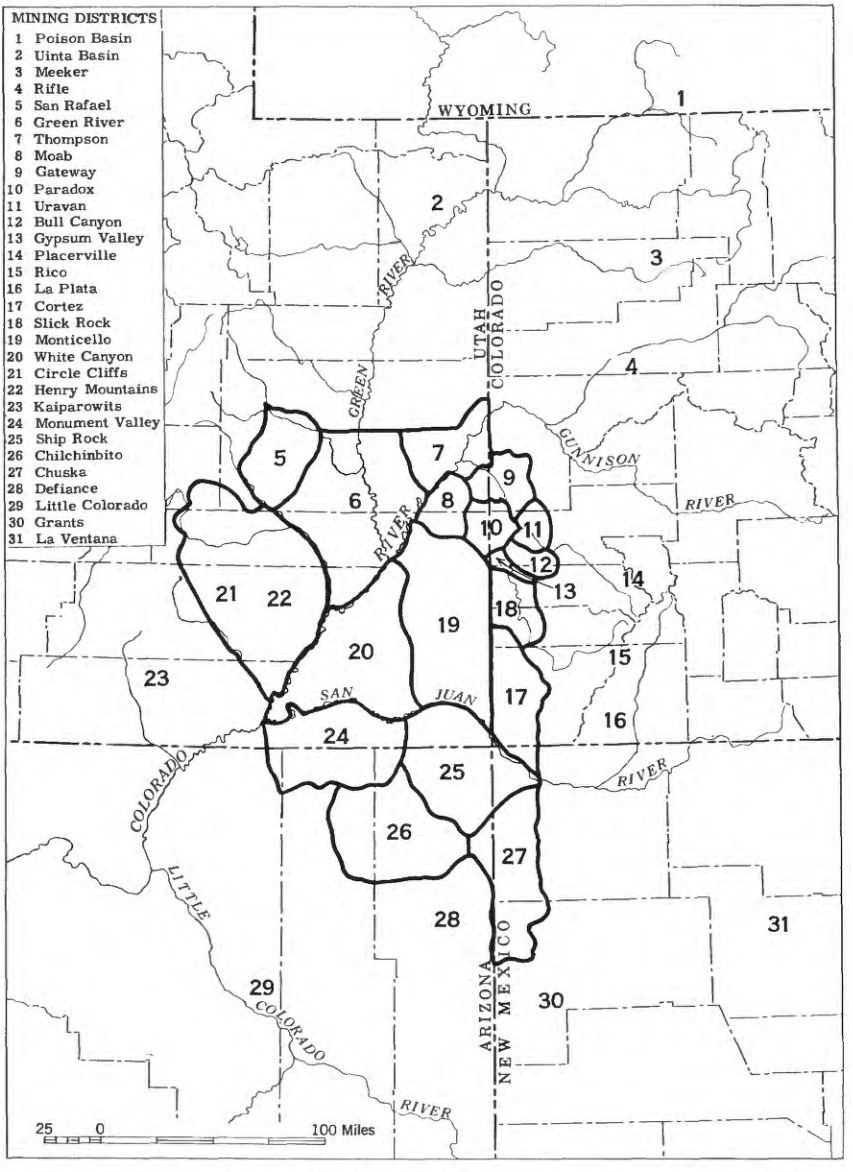

FIGURE 75.—Index map of part of the Colorado Plateau showing location of mining districts.

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ILLUSTRATIONS AND DESCRIPTIONS OF INDICATOR PLANTS

The plants shown on the facing pages that follow are the same species, the scientific name being given on the left-hand page and the common name on the right-hand page.

FIGURE 76.—*Astragalus pattersoni* A. Gray.

Family: Pea, Leguminosae.
Subgenus: *Jonesiella.*
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 rattleweed).
Root: Very long taproot, commonly 30 feet or more in length.
Plant: Perennial, 1–4 feet high. Garliclike odor common to foliage owing to presence of selenium.

Primary indicator Control: selenium

FIGURE 77.—Patterson poisonvetch.

Altitude: 4,500–7,500 feet.

Occurrence: Best selenium-indicator plant in uranium districts of the Colorado Plateau because requirements and absorption of selenium are very high. Commonly absorbs several thousand parts per million of selenium and several hundred parts per million of molybdenum from ore bodies. Plot experiments suggest growth stimulated in vicinity of carnotite deposits by increased solubility of selenium and molybdenum but inhibited by excesses of calcium sulfate.

Districts noted: San Rafael, Thompson, Green River, Monticello and Circle Cliffs, Utah; Ship Rock, in Arizona; Slick Rock and Gypsum Valley, Colo.; Grants and Pojoaque, N. Mex.

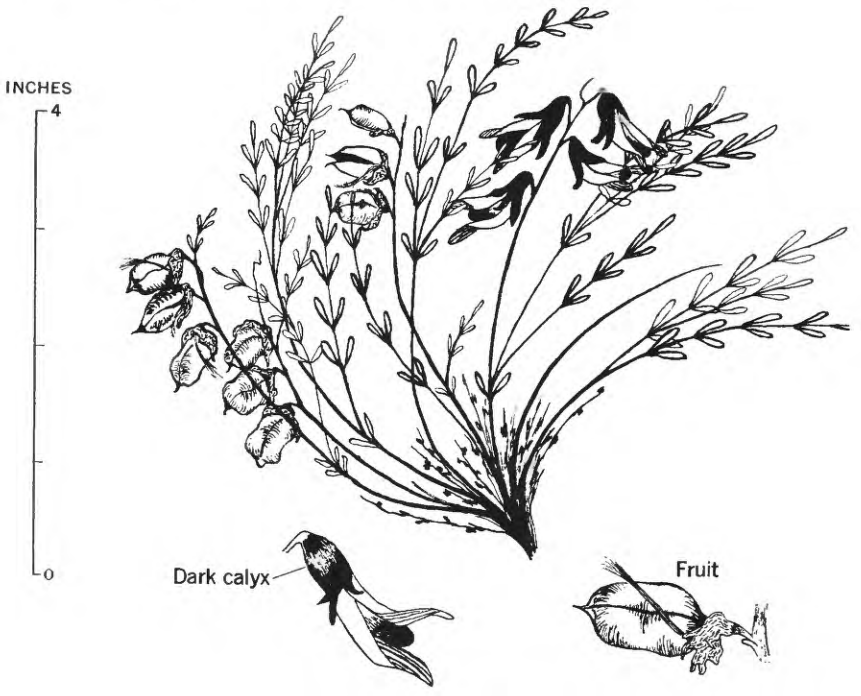

FIGURE 78.—*Astragalus preussi* A. Gray.

Family: Pea, Leguminosae.
Subgenus: *Jonesiella*.
Flowers: Purple irregular flowers with darker calyx, arising from creeping root stalks. Blooms in April and May.
Leaves: Smooth pinnate with 11–15 elliptic leaflets.
Fruit: Fat smooth oblong pod slightly curved, with short stem.
Plant: Perennial. Many stems less than a foot high arising from a woody base. Garliclike odor of foliage is due to presence of selenium.

Primary indicator Control: selenium

FIGURE 79.—Preuss poisonvetch.

Altitude: 3,300–6,000 feet.

Occurrence: Common on mine dumps and along outcrops of ore-bearing beds where selenium and vanadium are available. Mineralized ground under these plants in Yellow Cat area, Utah, at an average depth of 41 feet. One of the best selenium indicator plants in uranium districts on the Colorado Plateau. Commonly absorbs large amounts of selenium and vanadium from the ores.

Districts noted: Ship Rock, in Arizona; Slick Rock, Uravan, and Gypsum Valley, Colo.; Thompson, San Rafael, Henry Mountains, Green River, and Moab, Utah.

FIGURE 80.—*Astragalus thompsonae* S. Wats.

Family: Pea, Leguminosae.
Subgenus: *Euastragalus.*
Flowers: Very showy, pinkish-lavender irregular flowers in clusters on long stems. Blooms in April and May.
Leaves: Leaves all basal, pinnate, with 10 or more pairs of ovate leaflets which become progressively smaller toward apex. Hairy, but hairs not alined in any particular direction; spreading.
Fruit: Fat, erect, two-celled, slightly curved, hairy pods with thick walls which become woody. No stem.
Plant: Rosette type of perennial 6–12 inches across, with all leaves basal. Plant and pods covered with soft, silvery hairs.

Primary indicator

Control: selenium

FIGURE 81.—Thompson loco.

Altitude: 4,700–7,500 feet.

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

Districts noted: Ship Rock, in Arizona; Thompson, San Rafael, White Canyon, Monticello, and Uinta Basin, Utah; Gypsum Valley, Bull Canyon, and Paradox Valley, Colo.

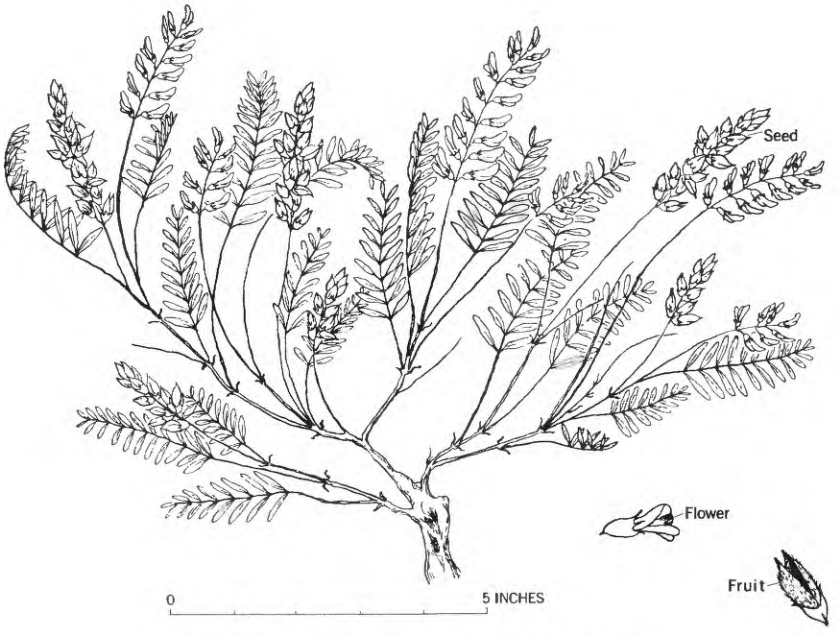

FIGURE 82.—*Astragalus confertiflorus* A. Gray.

Family: Pea, Leguminosae.
Subgenus: *Cnemidophacos.*
Flowers: Cream-colored, irregular flowers in dense inflorescence. Blooms in May.
Leaves: Pinnate, with 11 to 15 linear leaflets. Silvery hairs.
Fruit: Erect one-celled pod from stalk, not inflated, and with no individual stem. Woody.
Plant: Perennial; about 8 inches; has erect stems and bluish foilage.

Primary indicator — Control: selenium

FIGURE 83.—Blue poisonvetch.

Altitude: 5,000–6,000 feet.
Occurrence: Restricted to seleniferous clay which commonly underlies ore deposits.
Districts noted: Thompson, Henry Mountains, Monticello, and Uinta Basin, Utah, Grants, N. Mex.

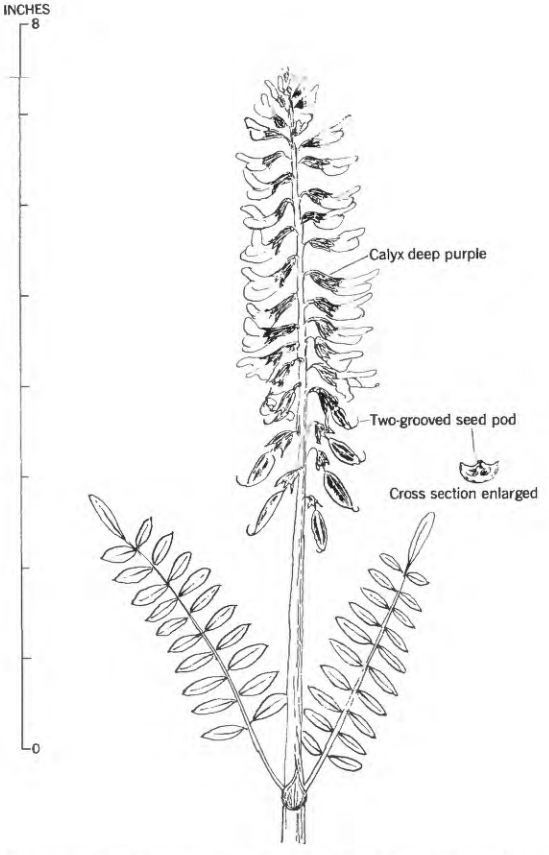

FIGURE 84.—*Astragalus bisulcatus* (Hook.) A. Gray.

Family: Pea, Leguminosae.
Subgenus: *Diholcos.*
Flowers: Deep purple, irregular flowers in dense elongated spikelike inflorescence which extends above the foilage. Blooms in June and July.
Leaves: Smooth pinnate with oval or oblong leaflets.
Fruit: Linear one-celled pod with two deep grooves on the upper side. Pod with stem extends from calyx.
Plant: Stout, erect. Perennial.

Primary indicator — Control: selenium

FIGURE 85.—Two-grooved poisonvetch.

Altitude: 3,500 to 8,000 feet.

Occurrence: Dry meadows and sandy soil. This species absorbs large amounts of selenium and molybdenum and is very poisonous to stock.

Districts noted: Powder River Basin, Wyo.; Huerfano, Colo.

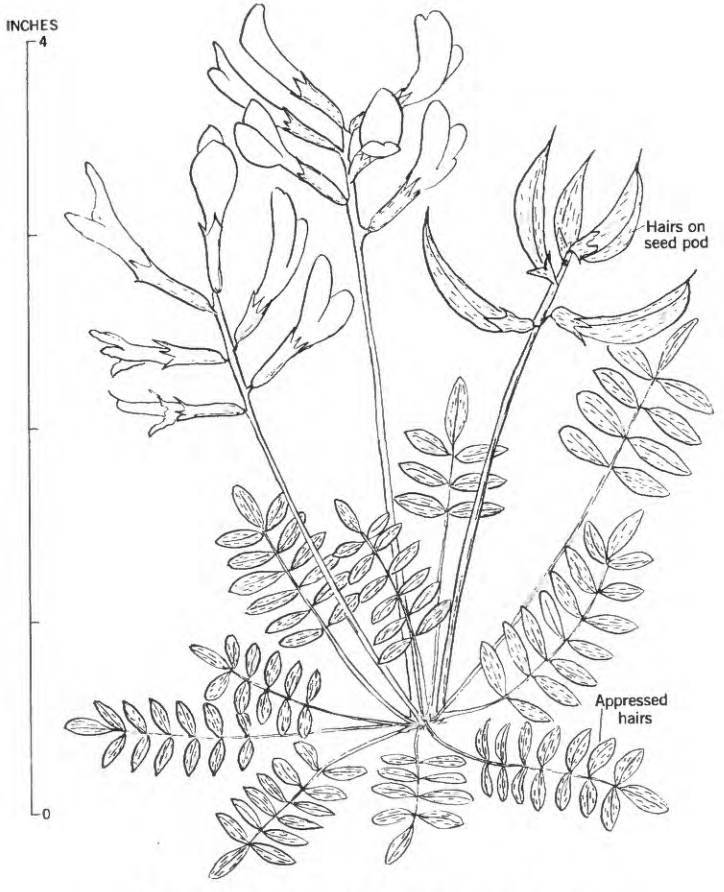

FIGURE 86.—*Astragalus missouriensis* Nutt.

Family: Pea, Leguminosae.
Subgenus: *Xylophacos.*
Flowers: Irregular, large, rose-purple pealike flowers in open cluster. Blooms in May.
Leaves: Pinnate, with 9–15 broad leaflets. Hairs oppressed, not spreading, some pick-shaped or attached below the middle.
Fruit: Pods 1 inch, 4-angled, 1-celled, beaked, curved slightly upward, and woody. No stem.
Plant: Low perennial, with basal rosetted leaves and large flowers on many erect flowering stems.

Secondary indicator — Control: selenium

FIGURE 87.—Missouri milkvetch.

Altitude: 3,500–8,000 feet.

Occurrence: Dry sandy soils. Replaced on mesas by closely related *A. shortianus* Nutt. with inflated seed pods and deep pink flowers.

Districts noted: Thompson and Monticello, Utah; Paradox, Colo.; Ship Rock, in Arizona.

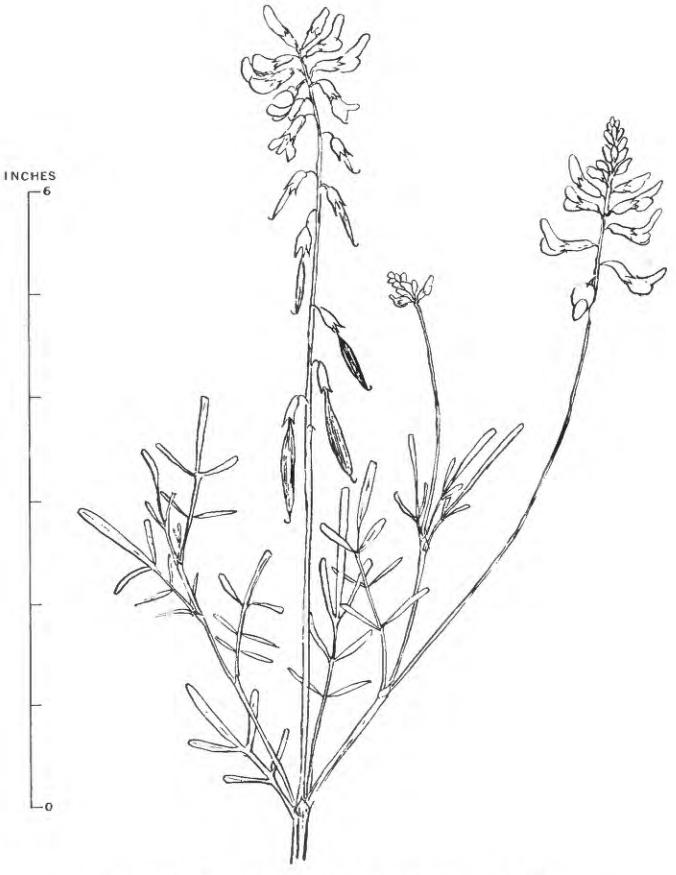

FIGURE 88.—*Astragalus lonchocarpus* Torr.

Family: Pea, Leguminosae.
Subgenus: *Lonchophaca.*
Flowers: Irregular creamy white, pea-shaped flowers, ½ to ¾ inch long, in elongate spreading clusters. Blooms in June.
Leaves: Pinnate with three to nine linear or threadlike leaflets. Terminal leaflet much longer than the others.
Fruit: Linear pod with long stem exceeding calyx, tapering at both ends, 1½ inches long. Thin, 1-celled, dorsally flattened, with prominent sutures. Pods pendulous.
Plant: Tall rushlike perennials with 1–2 foot stems arising from woody base.

Secondary indicator — Control: selenium

FIGURE 89.—Long-seeded milkvetch.

Altitude: 4,000–7,500 feet.
Occurrence: Dry, sandy, or clayey soil.
Districts noted: Paradox, Colo.; Cuba, N. Mex.

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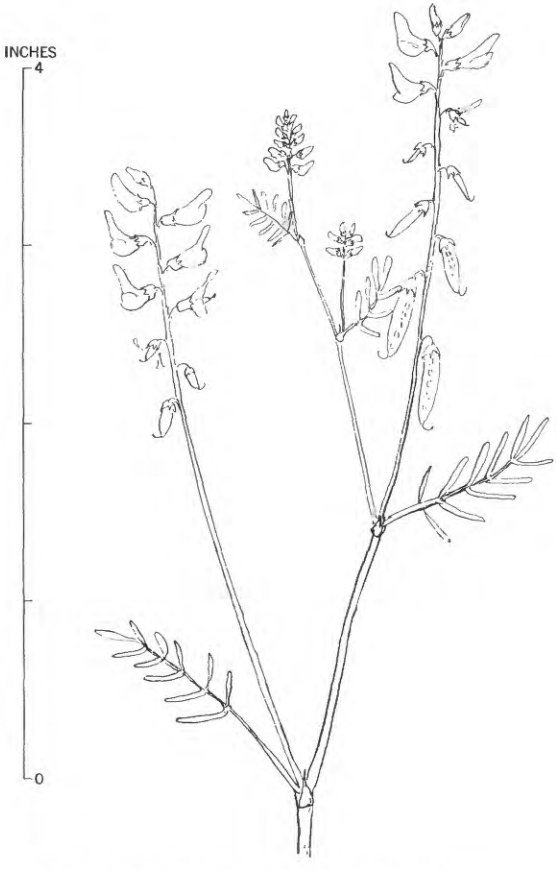

FIGURE 90.—*Astragalus* dodgianus Jones.

Family: Pea, Leguminosae.
Subgenus: *Homalobus.*
Flowers: Irregular, white, pealike flowers with purple-tipped keel. ⅓ inch. Black hairs on calyx which has triangular teeth. Blooms in May.
Leaves: Odd pinnate with 9 to 11 linear leaflets ⅓ inch long.
Fruit: Linear pod 1-celled with short stem. Flattened, with both sutures prominent and lower suture straight.
Plant: Sparingly hairy perennial with slender lax stems and woody root stalk.

Secondary indicator **Control: selenium**

FIGURE 91.—Dodge milkvetch.

Altitude: 4,000–7,500 feet.
Districts noted: Rocky slopes.
Occurrence: Paradox, Colo.

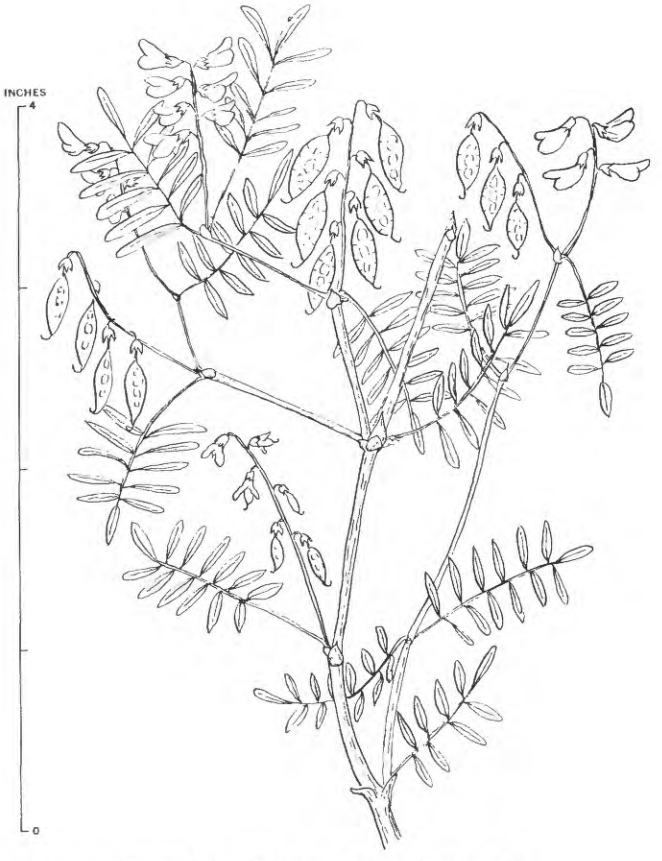

FIGURE 92.—*Astragalus tenellus* Pursh.

Family: Pea, Leguminosae.
Subgenus: *Homalobus.*
Flowers: Irregular, ¼-inch cream to pale-lavender flowers with purple tip on keel generally hidden in the foliage. Blooms in June.
Leaves: Pinnate with 7 to 21 linear smooth leaflets.
Fruit: Pods 1-celled, ½ inch long, laterally flattened with both sutures prominent. Pods pendulous with short stem exceeding calyx.
Plant: Perennial with woody root stalk. Stems 8 to 20 inches tall and leafy. Foliage blackens when dried.

Secondary indicator — Control: selenium

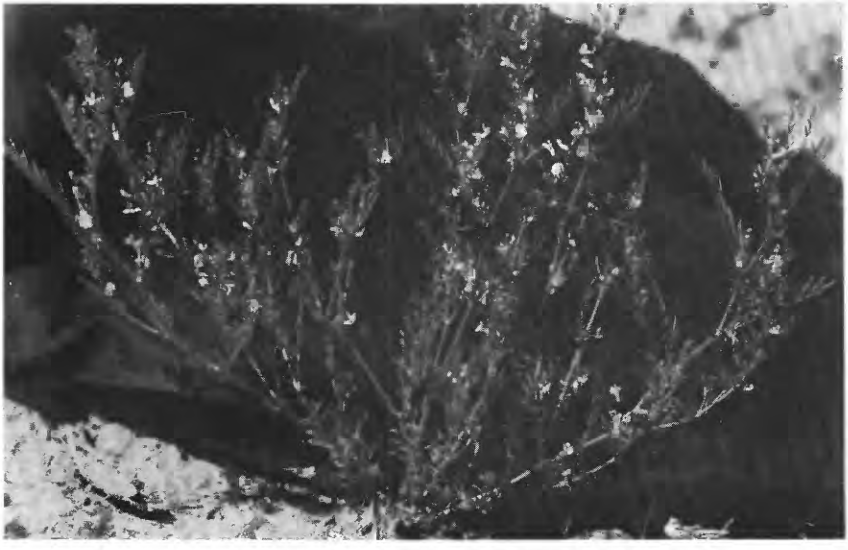

FIGURE 93.—Looseflower milkvetch.

Altitude: 5,000–11,000 feet.
Occurrence: Moist alkaline soils.
Districts noted: Poison Basin, Wyo.

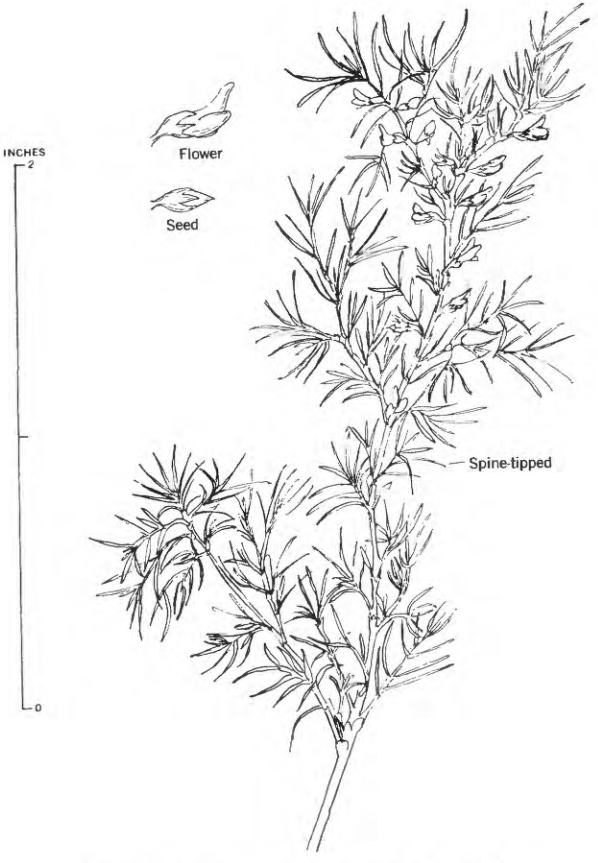

FIGURE 94.—*Astragalus aculeatus* A. Nels.

Family: Pea, Leguminosae.
Subgenus: *Kentrophyta.*
Flowers: Irregular, small purple pea-shaped flowers about 4 mm long, in axils of leaves. Blooms in July.
Leaves: Pinnate, with 5 stiff spine-tipped leaflets ½ inch long.
Fruit: Pods with 2 prominent sutures 1-celled, ovoid, ⅛ inch long.
Plant: Perennial, with strong taproot, branches sprawling or erect, so densely covered with prickly leaves as to appear clublike.

Secondary indicator

Control: selenium

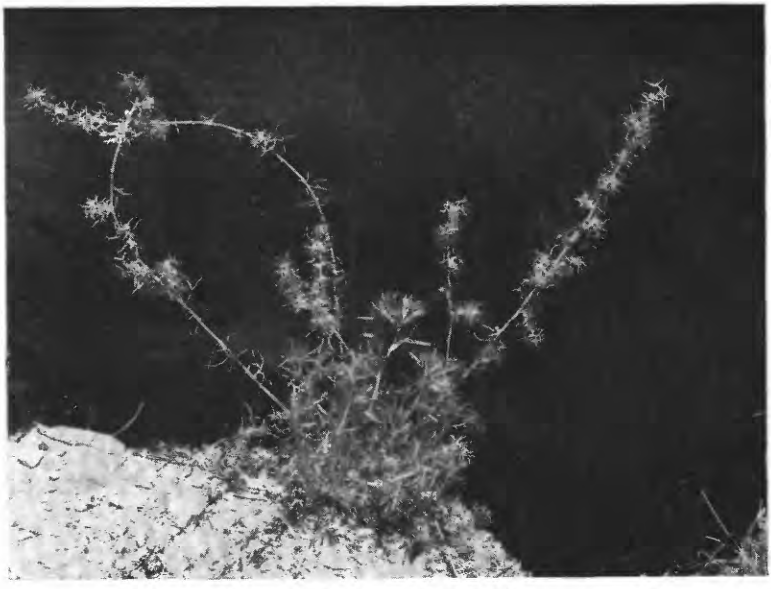

FIGURE 95.—Spiny milkvetch.

Altitude: 4,500–9,000 feet.
Occurrence: Dry mesas.
Districts noted: Pojoaque, and Grants, N. Mex.

FIGURE 96.—*Allium acuminatum* Hook. and related species.

Family: Lily, Liliaceae.
Flowers: Umbrellalike cluster of small pink flowers at end of long stalk. Each petal has a middle line of deep pink. Blooms in April and May.
Leaves: Two linear leaves about 6 inches long from bulb at base. Leaves are shorter than flower stem.
Fruit: Three-lobed capsule.
Plant: Spring ephemeral. Bulb with outer covering. Strong odor of crushed plant characteristic.

Primary indicator — Control: sulfur, phosphorus

FIGURE 97.—Tapertip onion.

Altitude: 4,000–7,500 feet.

Occurrence: Grows in large patches around gypsiferous ore deposits and on sulfur-rich shale, but inhibited by highly seleniferous ores. Encouraged by increased availability of phosphate in carnotite environment. 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: Thompson, Moab, and Green River, Utah; Slick Rock, Colo.; Chilchinbeto, Ariz.

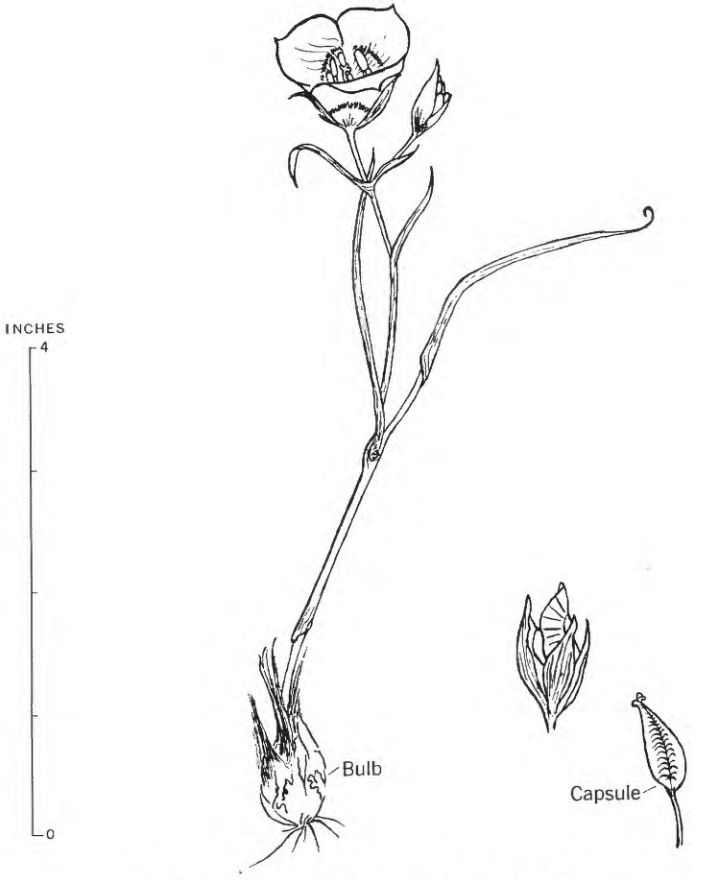

FIGURE 98.—*Calochortus nuttalli* Torr. & Gr.

Family: Lily, Liliaceae.
Flowers: Three large white petals marked yellow and purple at base. Gland with hairs at base of petal. One to five flowers on stalk. Blooms in April and May.
Leaves: Several alternate grasslike leaves about 6 inches long, trough-shaped in cross section. Onionlike bulb.
Fruit: Three-angled capsule.
Plant: Spring ephemeral. Grasslike leaves arising from bulb.

Secondary indicator — Control: sulfur, phosphorus

FIGURE 99.—Sego lily, mariposa.

Altitude: 5,000–8,000 feet.
Occurrence. Dry sandy soil. A good indicator in early spring.
Districts noted: Thompson, Utah; Slick Rock, Colo.; Poison Basin, Wyo.

FIGURE 100.—*Zigadenus gramineus* Rydb.

Family: Lily, Liliaceae.
Flowers: Inconspicuous greenish-white flowers with 6 "petals" which grow in a raceme on flower stalk about 8 inches high. Gland near the base of the petal. Blooms in April.
Leaves: Smooth, narrow, grasslike leaves arising from bulb.
Fruit: Three-celled capsule.
Plant: Spring ephemeral. Bulb with membranous covering.

Secondary indicator — Control: sulfur, phosphorus

FIGURE 101.—Grassy deathcamas.

Altitude: As high as 12,000 feet.

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

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

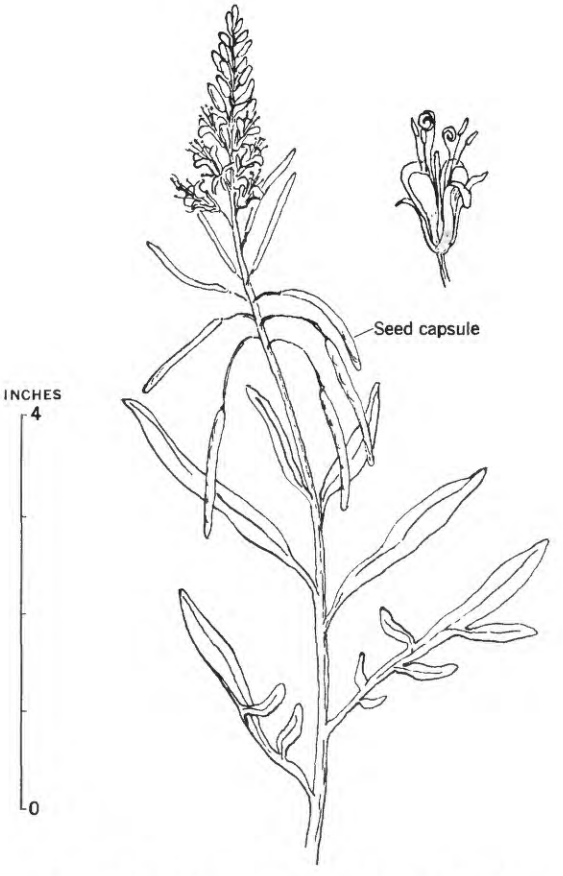

FIGURE 102.—*Stanleya pinnata* (Pursh) Britt.

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 perennial with thick erect stalk, 1–3 feet high, and woody root.

Secondary indicator — Control: selenium, sulfur

FIGURE 103.—Desert princesplume.

Altitude: 2,500–7,000 feet.

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: Ship Rock, Chilchinbeto, in Arizona; Slick Rock, Gypsum Valley, and Paradox Valley, Colo.; Thompson, San Rafael, Marysvale, White Canyon, Monticello, Green River, Henry Mountains, Moab, and Circle Cliffs, Utah; La Ventana, N. Mex.

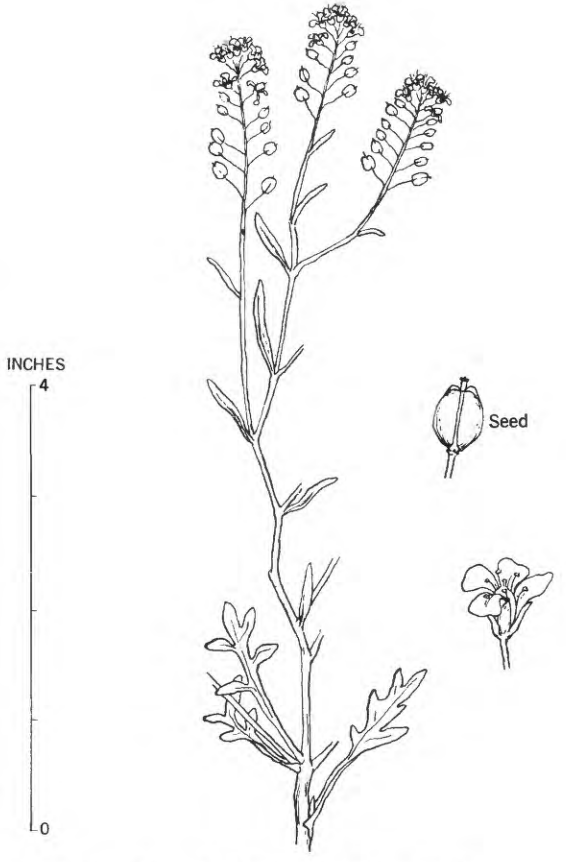

FIGURE 104.—*Lepidium montanum* Nutt.

Family: Mustard, Cruciferae.
Flowers: Dense cluster of white flowers. Four clawed petals one-fourth inch long which form a cross. Blooms from April to September.
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 to 2 feet high. Stems not woody. Several stems from same root.

Secondary indicator — Control: sulfur, phosphorus

FIGURE 105.—Mountain pepperweed.

Altitude: 3,000–7,000 feet.

Occurrence: Common around shallow uranium deposits where sulfur is available in surface soil. Very high absorption of uranium. Common on gypsum dunes of White Sands, N. Mex.

Districts noted: Thompson, White Canyon, and Green River, and Uinta Basin, Utah.

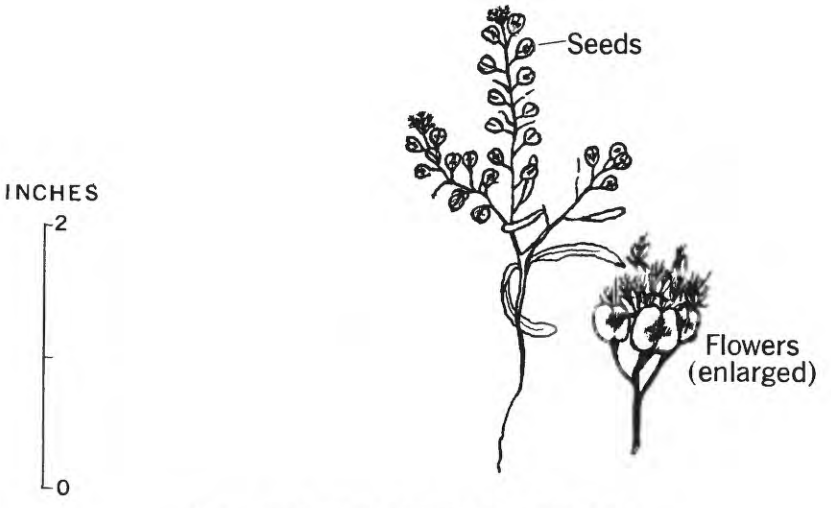

FIGURE 106.—*Lepidium lasiocarpum* Nutt.

Family: Mustard, Cruciferae.
Flowers: Not conspicuous, may be obsolete. Blooms from January to April.
Leaves: Small simple rounded leaves. Basal leaves incised.
Fruit: Notched round disk-shaped capsules.
Plant: Tiny hairy annual, 2 inches high, branched from the base and not woody.

Secondary indicator — Control: sulfur, phosphorus

FIGURE 107.—Hairy-pod pepperweed.

Altitude: 3,000–4,500 feet.
Occurrence: Sandy soil where sulfates are present in surface soil.
Districts noted: Thompson and San Rafael, Utah; Ship Rock, in Arizona.

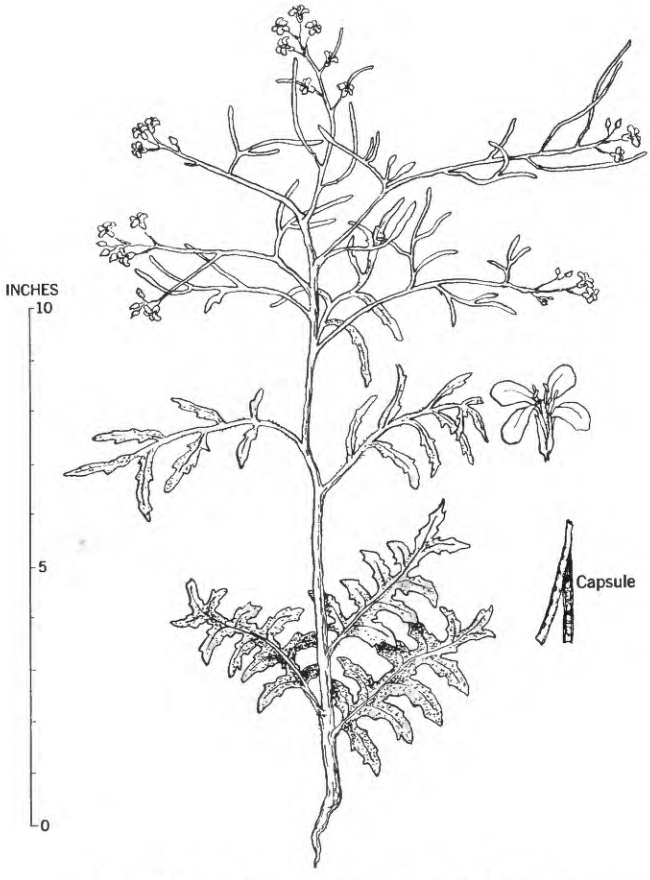

FIGURE 108.—*Sisymbrium altissimum* (L.) Britt.

Family: Mustard, Cruciferae.

Flowers: Four creamy, flat, one-fourth inch petals which form a cross. Blooms from May to July.

Leaves: Upper leaves threadlike, lower leaves divided and not clasping the stem.

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

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

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

Secondary indicator — Control: sulfur, phosphorus

FIGURE 109.—Tumblemustard.

Altitude: 5,000–7,000 feet.

Occurrence: Around ore deposits on higher mesas. High absorption of uranium.

Districts noted: Slick Rock, Gypsum Valley, Paradox Valley, and Rifle, Colo.; White Canyon and San Rafael, Utah.

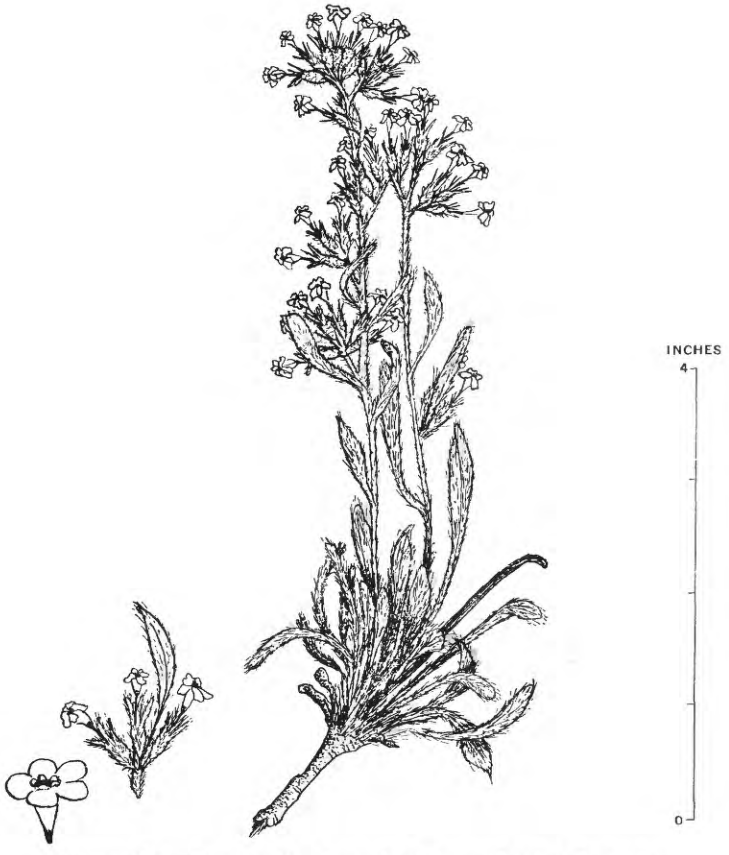

FIGURE 110.—*Cryptantha flava* A. Nels. and related species.

Family: Borage, Boraginaceae.
Flowers: Pale-yellow, tubular flowers one-fourth inch 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 to 12 inches high, growing from woody base.

Secondary indicator — Control: calcium

FIGURE 111.—Cryptanth.

Altitude: 5,000–7,000 feet.

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

Districts noted: Thompson, Green River, White Canyon, and Circle Cliffs, Utah; Grants, N. Mex.; Ship Rock, Defiance, in Arizona; Gypsum Valley, Bull Canyon, and Paradox Valley, Colo.; Poison Basin, Wyo.

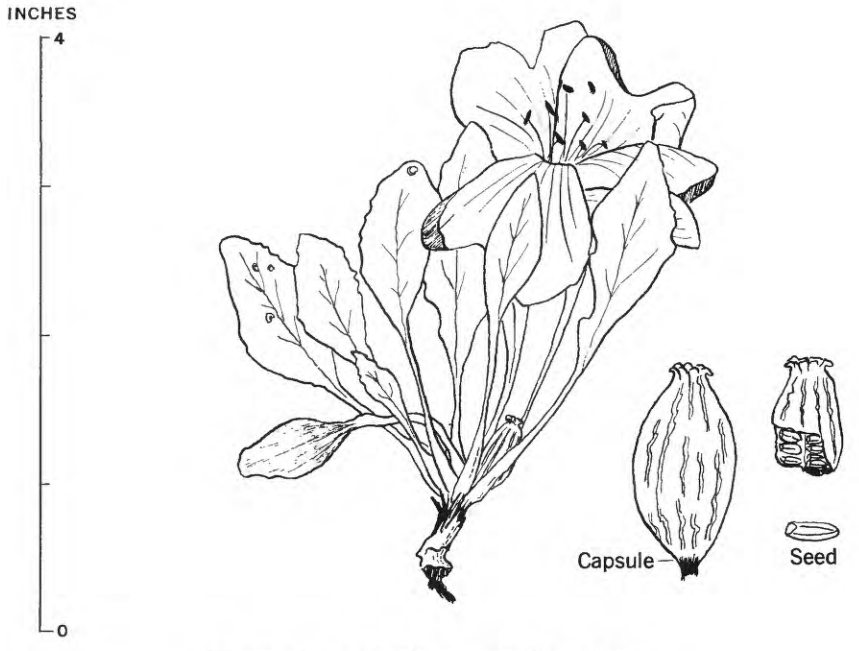

FIGURE 112.—*Oenothera caespitosa* Nutt.

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 to 5 inches. 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

FIGURE 113.—Tufted evening-primrose.

Altitude: 3,000–7,500 feet.

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

Districts noted: Grants, N. Mex; Thompson, San Rafael, Green River, and White Canyon, Utah; Ship Rock, in Arizona.

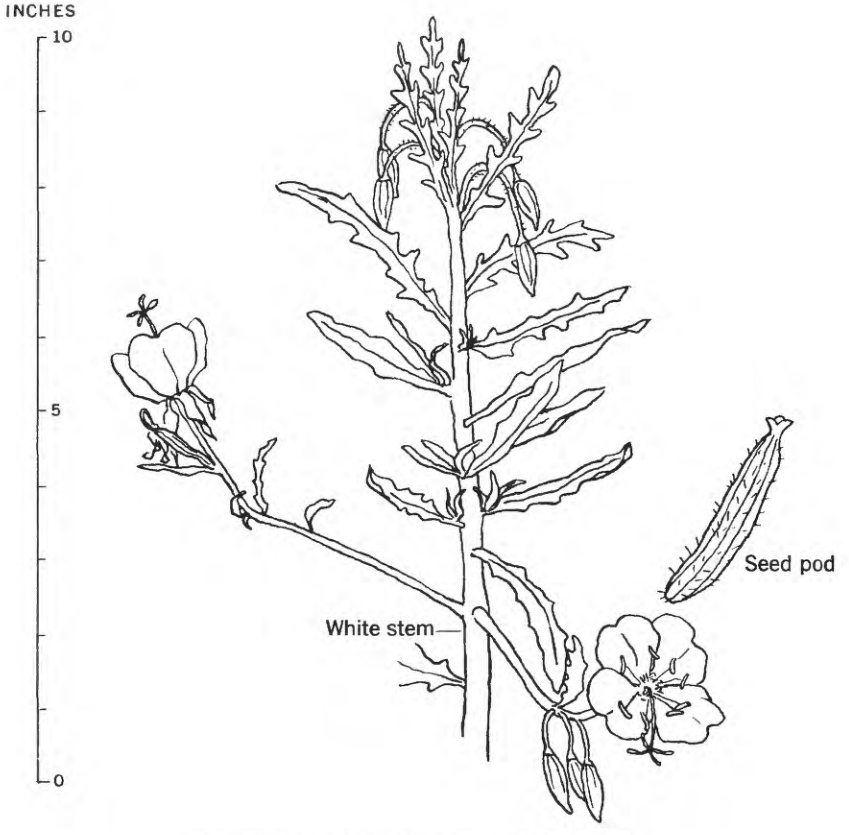

FIGURE 114.—*Oenothera albicaulis* Pursh.

Family: Primrose, Onagraceae.
Flowers: Four large white lobes resembling petals at end of tube 1 inch long. Blooms from May to July.
Leaves: Basal leaves, blunt, spatulate, toothed. Stem leaves, 2 to 5 inches long, deeply divided.
Fruit: Pod, ½ to 2 inches long, ½ inch thick.
Plant: Annual or biennial, 4 to 12 inches high, branched at the base.

Secondary indicator — Control: calcium

FIGURE 115.—Whitestemmed evening-primrose.

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

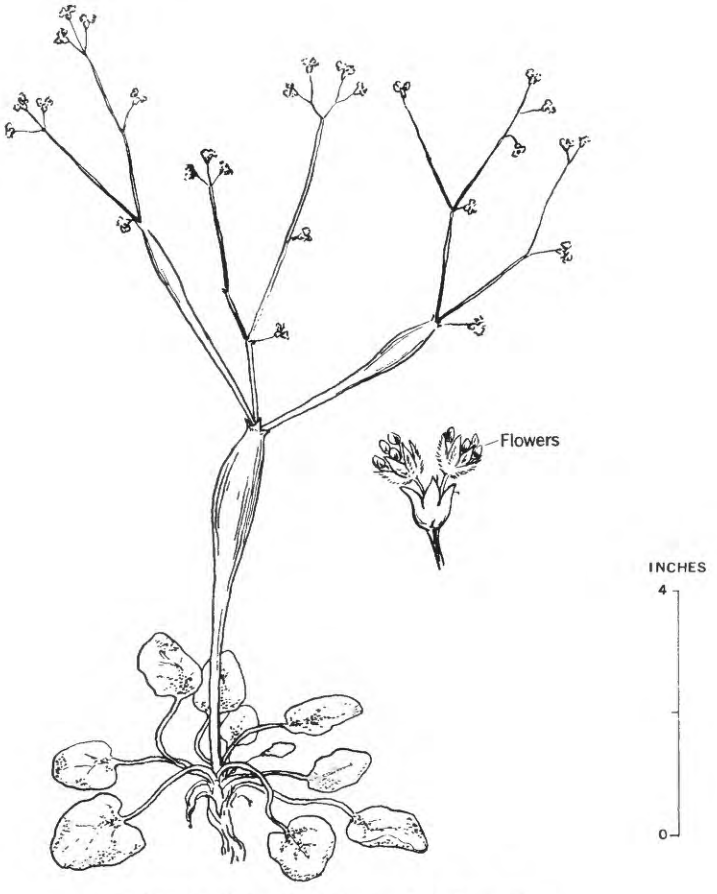

FIGURE 116.—*Eriogonum inflatum* Torr.

Family: Buckwheat, Polygonaceae.
Flowers: Clusters of 10 to 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: Three-angled dry seed.
Plant: Bluish-green tubular stems with hollow, inflated, trumpetlike parts before divisions. Stem divides in threes, 1 to 2 feet high perennial, with woody base.

Primary indicator — Control: sulfur, phosphorus

FIGURE 117.—Deserttrumpet eriogonum.

Altitude: As high as 4,500 feet.

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

Districts noted: Ship Rock, in Arizona; Thompson, San Rafael, Henry Mountains, Green River, Monticello, and Circle Cliffs, Utah.

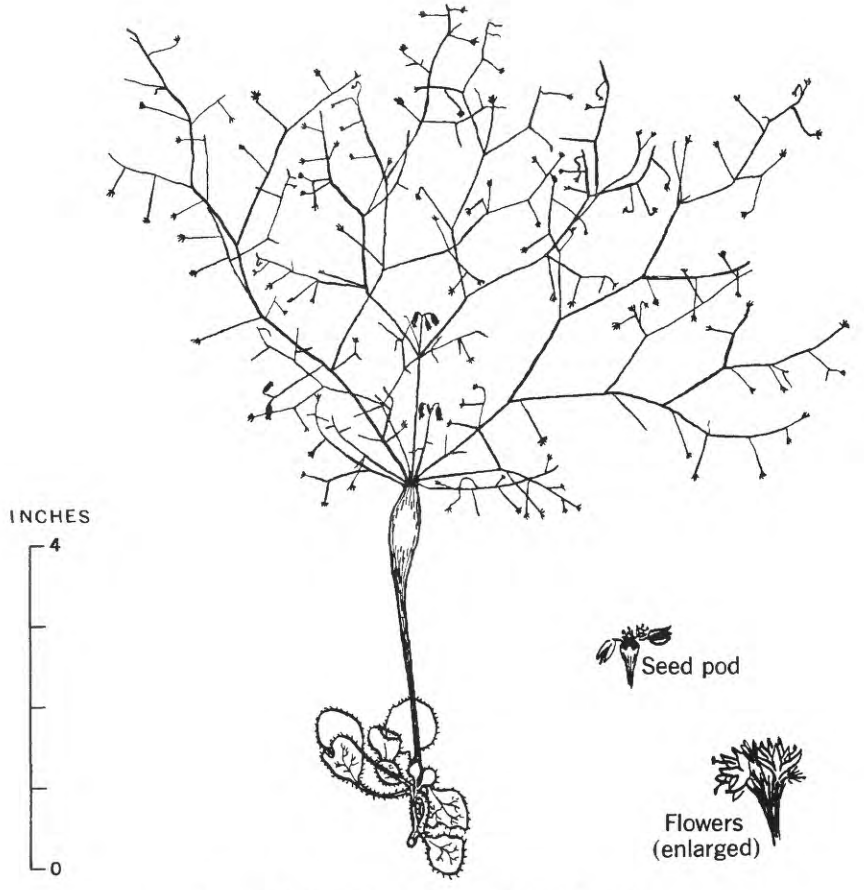

FIGURE 118.—*Eriogonum fusiforme* Small.

Family:	Buckwheat, Polygonaceae.
Flowers:	Tiny white or yellowish flowers in diffusely branching inflorescence. Blooms in June and July.
Leaves:	Basal, rounded or kidney-shaped in outline, scattered hairs.
Stem:	Inflated part above the middle of stem.
Fruit:	Dry, small, smooth.
Plant:	Annual, with flower stalk extending from basal rosette.

Secondary indicator — Control: sulfur, phosphorus

FIGURE 119.—Deserttrumpet.

Altitude: 4,000–6,000 feet.
Occurrence: Dry sandy alluvial soil.
Districts noted: Yellow Cat and Green River, Utah.

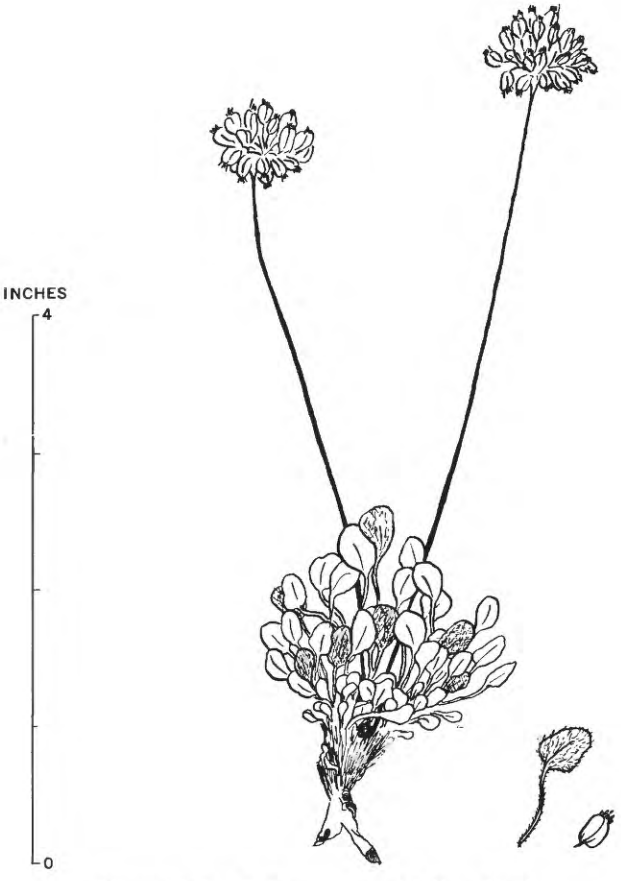

FIGURE 120.—*Eriogonum ovalifolium* Nutt.

Family: Buckwheat, Polygonaceae.
Flowers: Pale-yellow to pink; in headlike cluster on 4- to 6-inch stalk. Calyx yellowish with pinkish veins. Blooms from April to June.
Leaves: Densely white-woolly; oval leaves at base of plant about one-half inch in size.
Fruit: Dry, small.
Plant: Hairy perennial with basal cushion of leaves and 10-inch flower stalks. Woody base.

Secondary indicator — Control: sulfur, phosphorus

FIGURE 121.—Silver plant or cushion eriogonum.

Altitude: 5,000–7,000 feet.
Occurrence: Commonly on sandstone outcrops rooted in cracks and joints. Phosphate absorber.
Districts noted: Thompson, Utah; Ship Rock, in Arizona.

FIGURE 122.—*Eriogonum umbellatum* Torr.

Family: Buckwheat, Polygonaceae.

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

Leaves: Thick, oval-to-spatulate, ½ to 1 inch long, tapering to a stem. Green above, white-woolly underneath.

Seeds: Sharply three-angled, dry seeds.

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

Secondary indicator — Control: sulfur, phosphorus

FIGURE 123.—Sulfur eriogonum.

Altitude: 5,000–9,000 feet.
Occurrence: Dry slopes. Phosphate absorber.
Districts noted: Jefferson County, Colo.; White Canyon, Utah; Phosphoria formation, Wyoming.

FIGURE 124.—*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 phosphorus

FIGURE 125.—Salina wildrye.

Altitude: 3,000–7,000 feet.

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

Districts noted: Ship Rock, in Arizona; Slick Rock, Paradox Valley, and Gypsum Valley, Colo.; Thompson, Green River, and Circle Cliffs, Utah.

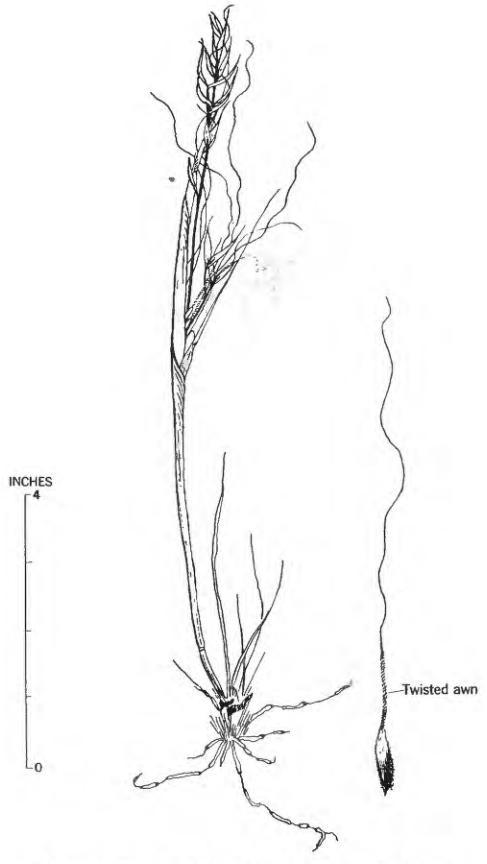

FIGURE 126.—*Stipa comata* Trin. & Rupr.

Family: Grass, Gramineae.
Flowers: Loose head 5 to 10 inches long with tightly twisted threadlike awns 4 to 5 inches long resembling tails attached to the seeds. Tight twist in lower third only. Blooms in June and July.
Leaves: Harsh, flat, inrolled.
Plant: Deep-rooted perennial 1 to 2 feet high.

Secondary indicator — Control: probably phosphorus

FIGURE 127.—Needleandthread.

Altitude: 4,500–8,000 feet.

Occurrence: Restriction to mineralized ground in many areas probably owing to increased availability of phosphorus.

Districts noted: Thompson, Utah; Gypsum Valley, Colo.; Grants, N. Mex. Closely related species in Ship Rock, in Arizona.

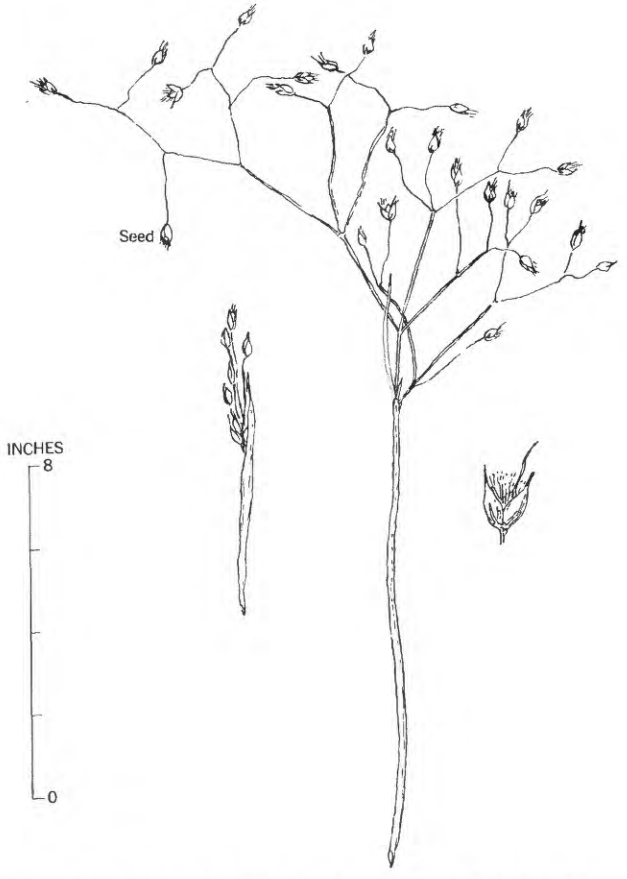

FIGURE 128.—*Oryzopsis hymenoides* (Roem. & Schult.) Rick.

Family: Grass Gramineae.
Flowers: Small dry flowers in open panicle with branches at right angles in zigzag pairs. Individual spikelets one-flowered. Blooms in June and July.
Leaves: Inrolled, narrow.
Seeds: Small, ricelike; edible.
Plant: Extensive perennial grass 1 to 2 feet high, with deep fibrous roots.

Secondary indicator Control: selenium

FIGURE 129.—Indian ricegrass.

Altitude: As high as 10,000 feet.

Occurrence: Drought-resistant and alkali-tolerant grass common in any western soil which contains a small amount of selenium. Capable of absorbing large amounts of selenium and uranium although the selenium requirements are very low. Useful only in districts where selenium 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, Thompson, San Rafael, Henry Mountains, Green River, Moab, Monticello, Uinta Basin, and Circle Cliffs, Utah; La Ventana and Grants, N. Mex.; Wamsutter and Poison Basin, Wyo.; Ship Rock, in Arizona.

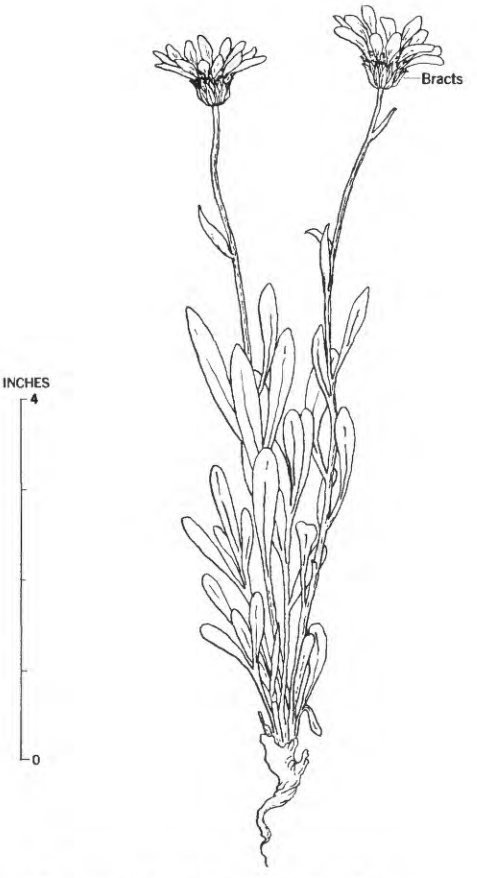

FIGURE 130.—*Aster venustus* Jones.

Family: Sunflower, Compositae.

Flowers: Composite flowers in 1-inch heads with long white ray flowers resembling daisies. Heads solitary on 8–20-inch flower stalks. Bracts nearly equal in length. White "petals" turn lavender on aging. Blooms in May and June.

Leaves: Spatula-shaped, with callous point, hairy and alternate. One to two inches long.

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

Plant: Woody perennial base and naked flower stalks; long taproot. Plant 6 to 18 inches high.

Secondary indicator — Control: selenium

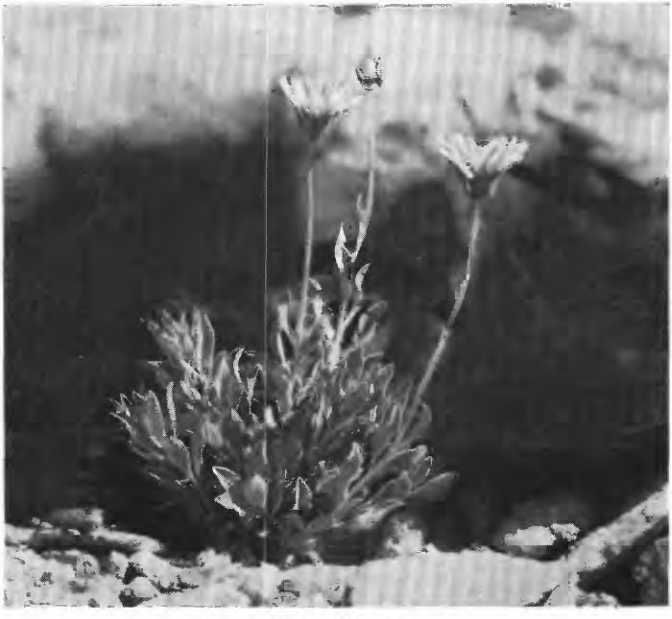

FIGURE 131.—Woody aster.

Altitude: 3,000–5,000 feet.

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 drainage prospecting.

Districts noted: Thompson, Moab, Henry Mountains, and Green River, Utah.

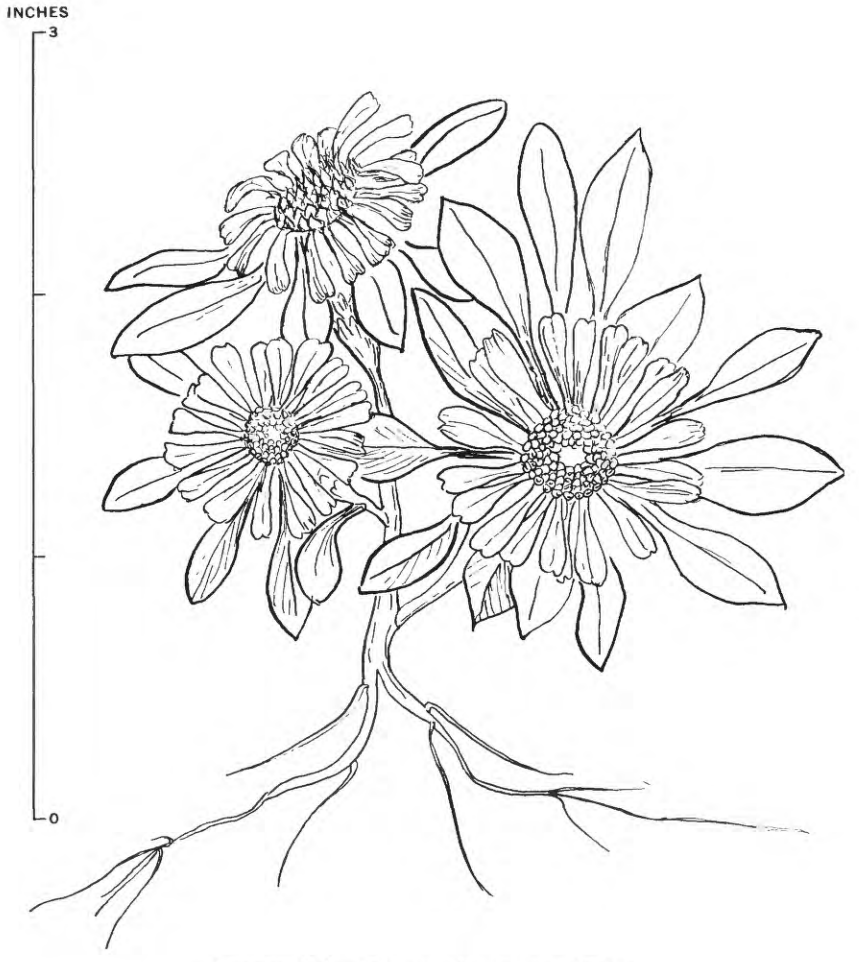

FIGURE 132.—*Townsendia incana* Nutt.

Family: Sunflower, Compositae.
Flowers: Daisy-like composite with yellow disk flowers and one-half-inch white to pink ray flowers. Blooms in April and May.
Leaves: Spatula-shaped, blunt hairy leaves 1 inch long arising from basal woody crown.
Seeds: Small flattened dry seeds.
Plant: Hairy perennial with woody crown and flower stems less than 4 inches high. Taproot.

Secondary indicator Control: selenium

FIGURE 133.—Hoary townsendia.

Altitude: 5,000–6,500 feet.
Occurrence: On selenium-bearing sands. Conspicuous only when in bloom.
Districts noted: Thompsons, Green River, Monticello and White Canyon, Utah.

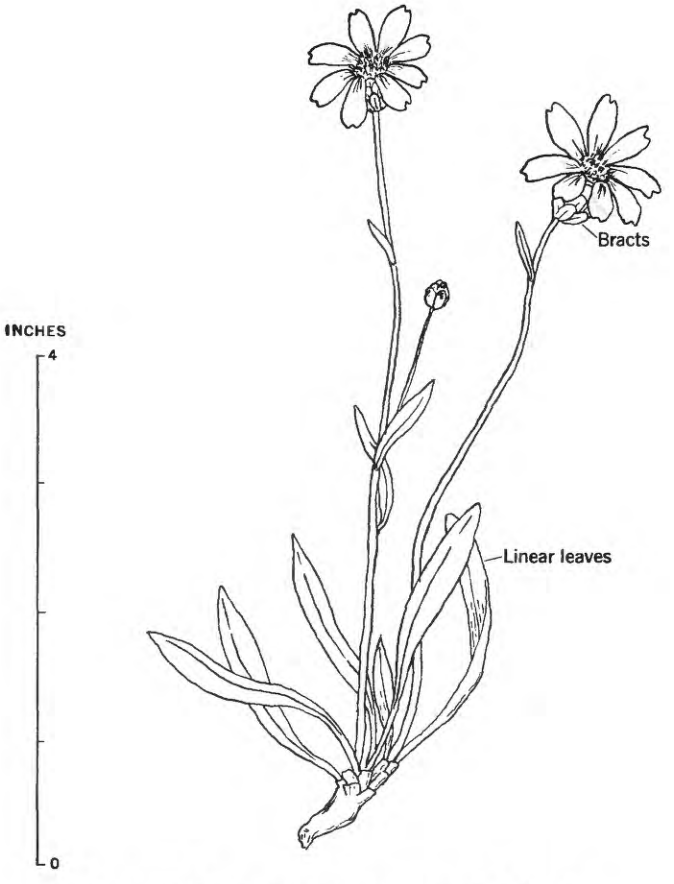

FIGURE 134.—*Aplopappus armeriodes* A. Gray.

Family: Sunflower, Compositae.
Flowers: Heads clustered at top of stem with yellow tubular disk and one-half-inch long ray flowers. Blooms in June and July.
Leaves: Smooth, 3-nerved, linear leaves, 1 to 3 inches long.
Plant: Perennial herb with leafless flower stems 2 to 6 inches long arising from bunched leaves at woody base.

Secondary indicator

Control: selenium (?)

FIGURE 135.—Goldenweed.

Altitude: 4,000–6,000 feet.
Occurrence: Dry sandstone mesas.
Districts noted: Thompson, San Rafael, Henry Mountains, Green River, and White Canyon, Utah; Bull Canyon, Colo.; Ship Rock, Defiance uplift, Ariz.

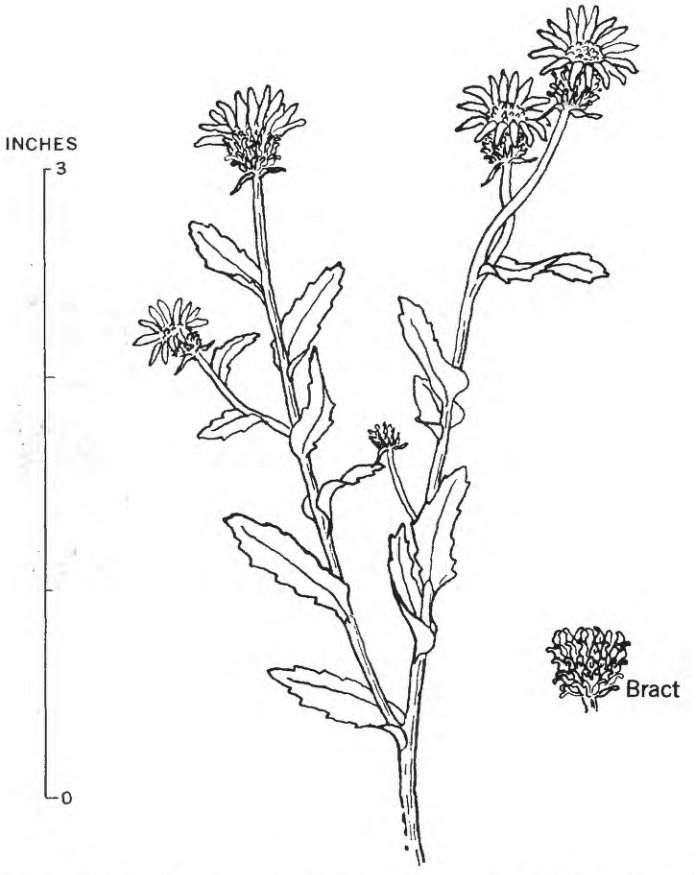

FIGURE 136.—*Grindelia squarrosa* (Pursh) Dunal, and closely related species.

Family: Sunflower, Compositae.
Flowers: Yellow radiate heads in flat-topped clusters. Green bracts of heads strongly graduated in 4 to 8 rows with recurved tips and mucilaginous. Blooms in fall.
Leaves: Undivided, alternate leaves clasping the stem; resinous and stiff.
Seeds: Dry, small, and short.
Plant: Biennial or perennial, 8 to 40 inches high; mucilaginous plant with long taproot. Balsamlike odor from exuded gum.

Secondary indicator Control: unknown

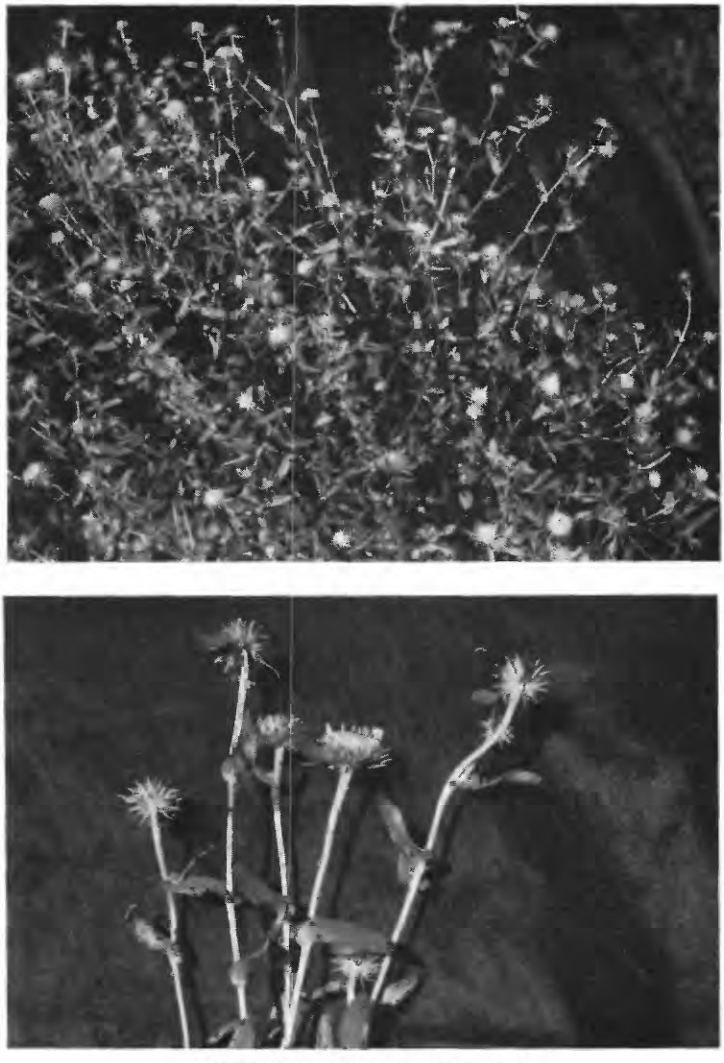

FIGURE 137.—Curlycup gumweed.

Altitude: As high as 9,000 feet.

Occurrence: Common in drainage and seeps from mines of high selenium content or rooted in ore deposits of low content. Plot studies indicate very high absorption of uranium and a marked increase in absorption in carnotite environment with development of anomalous growth habits. Intolerant of highly seleniferous soils. Calcium absorber.

Districts noted: Thompson, Utah; and others.

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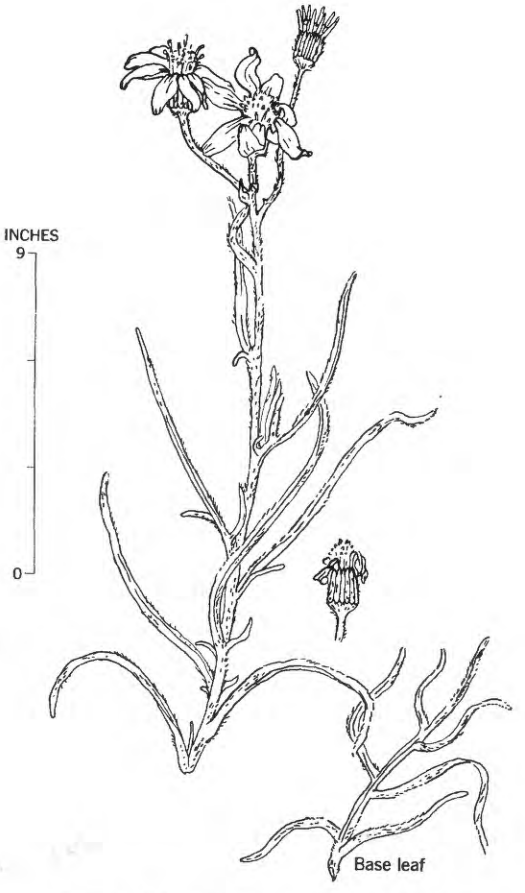

FIGURE 138.—*Senecio longilobus* Benth.

Family: Sunflower, Compositae.
Flowers: Yellow composite with ½-inch disk and long yellow ray flowers. Heads in flat-topped clusters. Blooms through summer months.
Leaves: Pinnate leaves with linear, threadlike, hairy leaflets.
Seeds: Small dry seeds.
Plant: Ill-scented perennial 1 to 2 feet high covered with white-woolly hairs and having a long taproot. The plant is very poisonous to cattle. Poison, alkaloid.

Secondary indicator Control: calcium

FIGURE 139.—Threadleaf groundsel.

Altitude: 4,000–7,500 feet.

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

Districts noted: Thompson, Utah, Ship Rock, Defiance uplift, Ariz.; Slick Rock and Gypsum Valley, Colo.

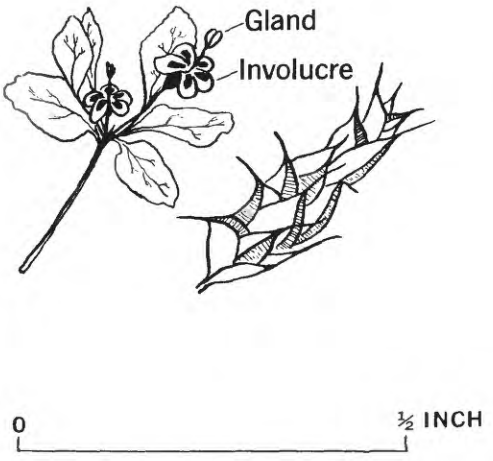

FIGURE 140.—*Euphorbia fendleri* Torr. & Gr., and related prostrate species.

Family: Spurge, Euphorbiaceae.
Flowers: Minute flowers in peculiar "petaled" involucre from which stalked glands extend. Flowers occur in axils of leaves. Bloom from April to October.
Leaves: Oval, opposite, entire, pale-green leaves ⅛ inch 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 or sulfur

FIGURE 141.—Sandmat or Fendler euphorbia.

Altitude: 4,000–7,000 feet.

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: Thompson, San Rafael, and Henry Mountains, Uinta Basin, Utah; Grants, N. Mex.; Ship Rock, in Arizona.

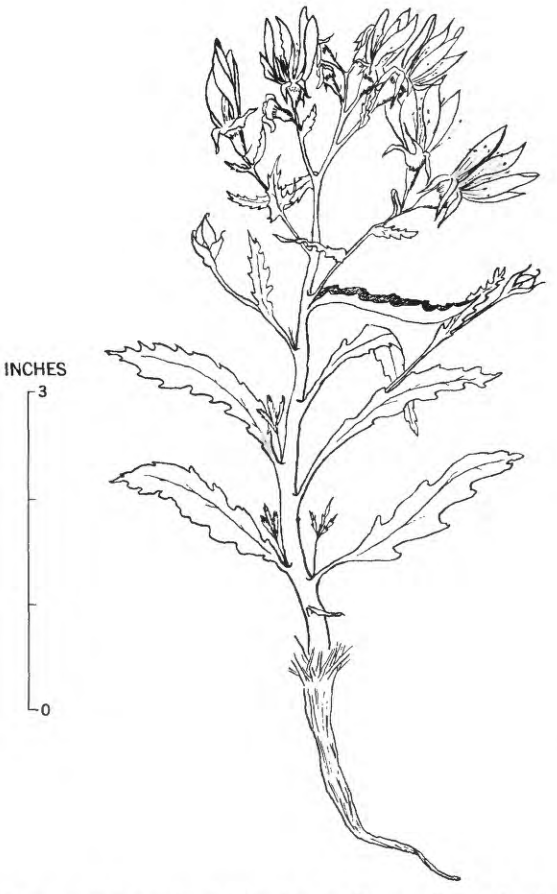

FIGURE 142.—*Mentzelia multiflora* (Nutt.) A. Gray. Several other species are similar in appearance.

Family: Loasa, Loasaceae.
Flowers: Light-yellow, star-shaped flowers with 10 petals and many stamens. Stamens in outer row are petallike. Opens in afternoon. Blooms from May to August.
Leaves: Light green, sticky, alternate, and toothed.
Fruit: Three- to five-valved capsule.
Plant: Stems freely branching; plant 1 to 3 feet high. Barbed stinging hairs. Perennial. Stout taproot.

Secondary indicator

Control : calcium

FIGURE 143.—Desert blazingstar.

Altitude : As high as 7,000 feet.

Occurrence : A common weed of roadsides and disturbed ground. This genus is found around many uranium deposits and on the pure gypsum sands of White Sands, N. Mex. It absorbs large amounts of calcium. As the growth is favored by the presence of carnotite ore, several species may be used under certain circumstances as an ore indicator.

Districts noted : Lost Creek, Wyo.; La Ventana and Penasco Hot Springs, Grants, N. Mex.; Gypsum Valley, Colo.; Ship Rock, in Arizona; and San Rafael, Utah.

FIGURE 144.—*Solidago petradoria* Blake.

Family: Sunflower, Compositae.
Flowers: Five to eight small yellow flowers in heads in dense flat-topped clusters. Blooms in July and August.
Leaves: Linear-oblong, three-nerved, rigid alternate leaves, 2 to 4 inches long and resinous.
Seeds: Dry, flat, five-nerved.
Plant: Low, tufted, perrenial herbs with short branched woody base. Smooth, 4 to 6 inches long, erect flower stems from cushion of basal leaves. Extensive root system.

Tolerant

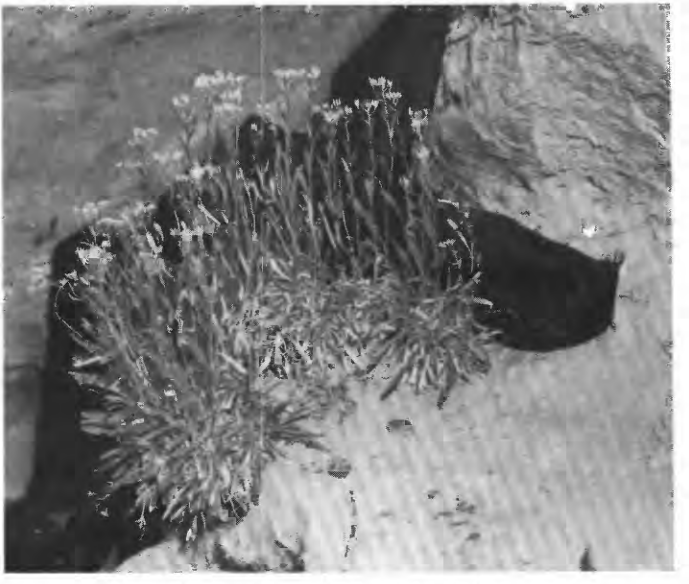

FIGURE 145.—Rock goldenrod.

Altitude: 5,500–7,500 feet.
Occurrence: Rock ledges and dry sandy soils.
Districts noted: Thompson and White Canyon, Utah; Paradox Valley and Bull Canyon, Colo; Defiance uplift, Ariz.

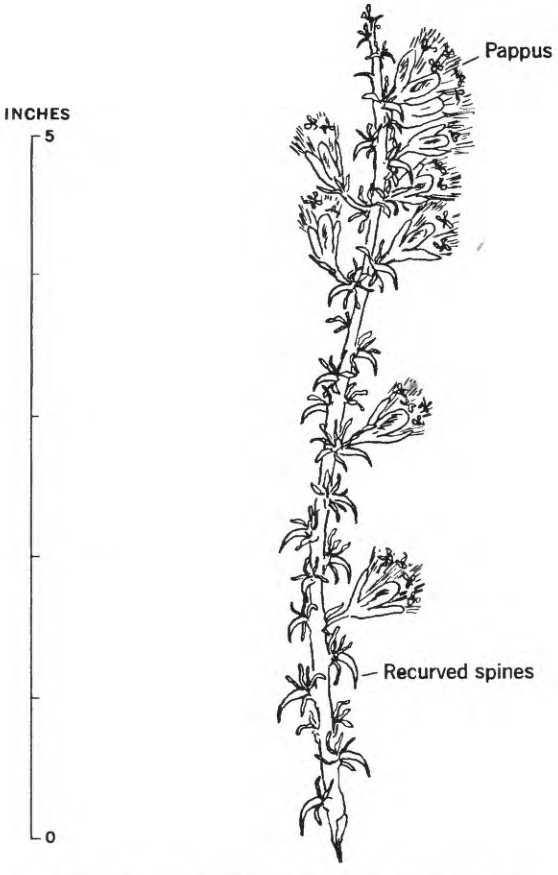

FIGURE 146.—*Tetradymia spinosa* Hook. & Arn.

Family: Sunflower, Compositae.

Flowers: Fleshy smooth heads of four yellow flowers ½ to ¾ inch long arising from axils of the leaves. Bracts at base of heads woolly. Blooms from May to July.

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

Plant: Divaricately branched xerophytic shrub 2 to 4 feet high with white woolly branches and characteristic recurved woolly spines which are soft and pliant when first produced. High potassium content in leaves and buds. Organic compound in plant poisonous to sheep.

Tolerant

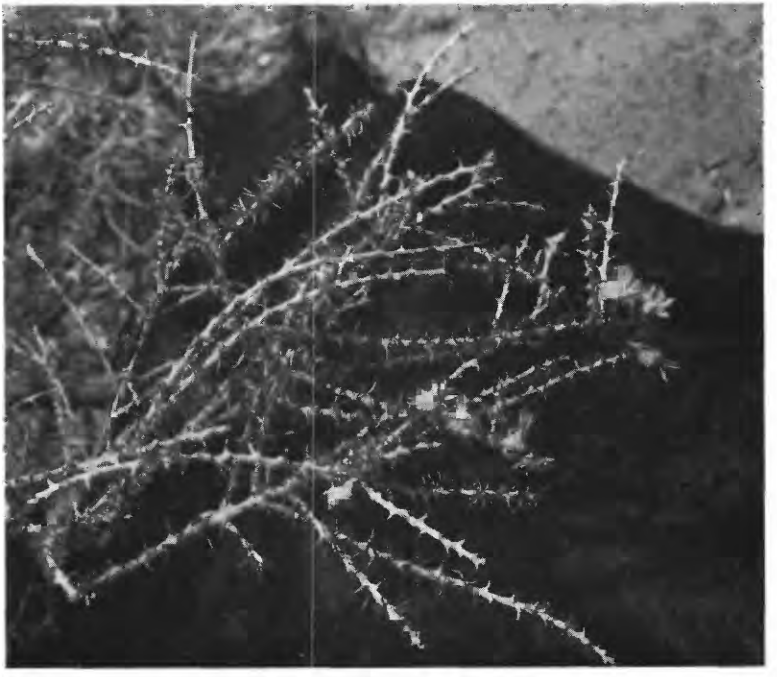

FIGURE 147.—Cottonthorn horsebrush.

Altitude: 4,000–7,000 feet.
Occurrence: Dry sandy plains and sandstone mesas.
Districts noted: Thompson, San Rafael Swell, Unita Basin, Utah, Gypsum Valley, Colo.

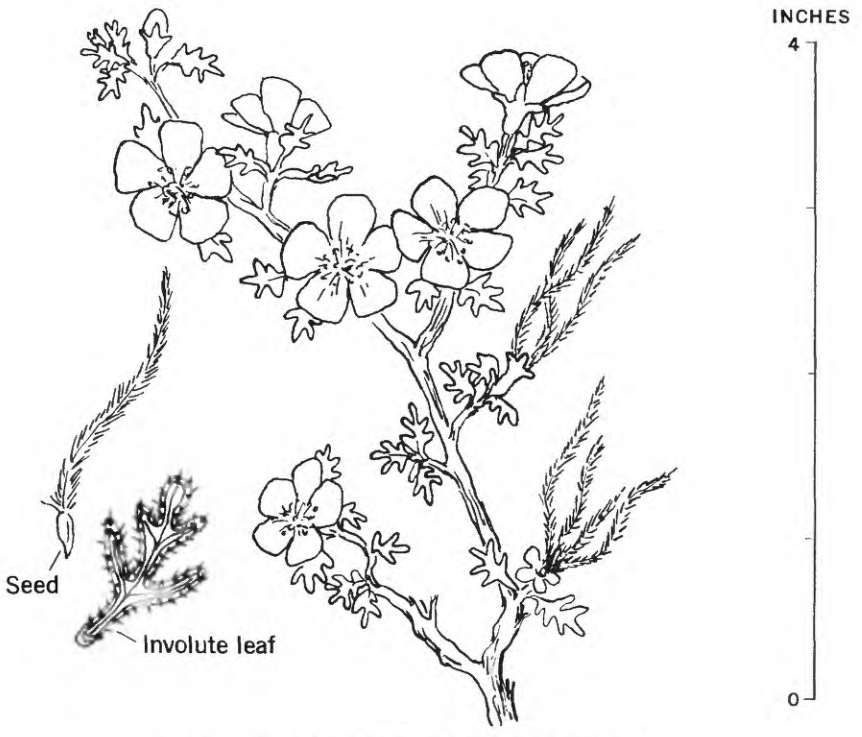

FIGURE 148.—*Cowania stansburiana* Torr.

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 to 12 feet high with shaggy gray bark and reddish twigs. Plant has a bitter taste and very acid cell sap.

Tolerant

FIGURE 149.—Stansbury cliffrose.

Altitude: 3,500–8,000 feet.

Occurrence: Phreatophyte, occurring with juniper and pinyon 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 noted: Ship Rock, Chilchinbeto, Chuska, and Defiance uplift, in Arizona; Thompson, San Rafael, White Canyon, Henry Mountains, and Circle Cliffs, La Ventana, and Grants, N. Mex.

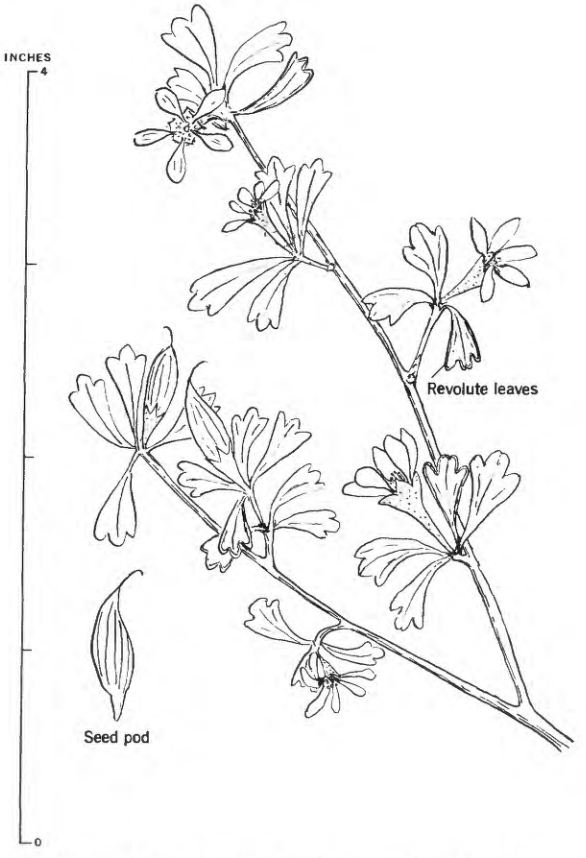

FIGURE 150.—*Purshia tridentata* (Pursh) DC.

Family: Rose, Rosaceae.

Flowers: Solitary at the ends of branches. Tube-shaped, hairy, five-lobed calyx, five yellow petals. Many stamens in single series. Blooms from April to July.

Leaves: Alternate but crowded into fascicles. Three-cleft, 0.2 to 1 inch long, wedge-shaped with rolled margins. White fuzz beneath.

Seeds: Spindle-shaped, ½ inch long, exserted from calyx tube with persistent break.

Plant: Intricately branched shrubs 1½ to 9 feet high with brown to gray bark. Drought resistant. Foliage has bitter taste.

Tolerant

FIGURE 151.—Antelope bitterbrush.

Altitude: 4,000–9,000 feet.
Occurrence: Arid plains and foothills. Common on volcanic flows.
Districts noted: Monticello, Utah; Slick Rock, Colo.; Henry Mountains, Utah.

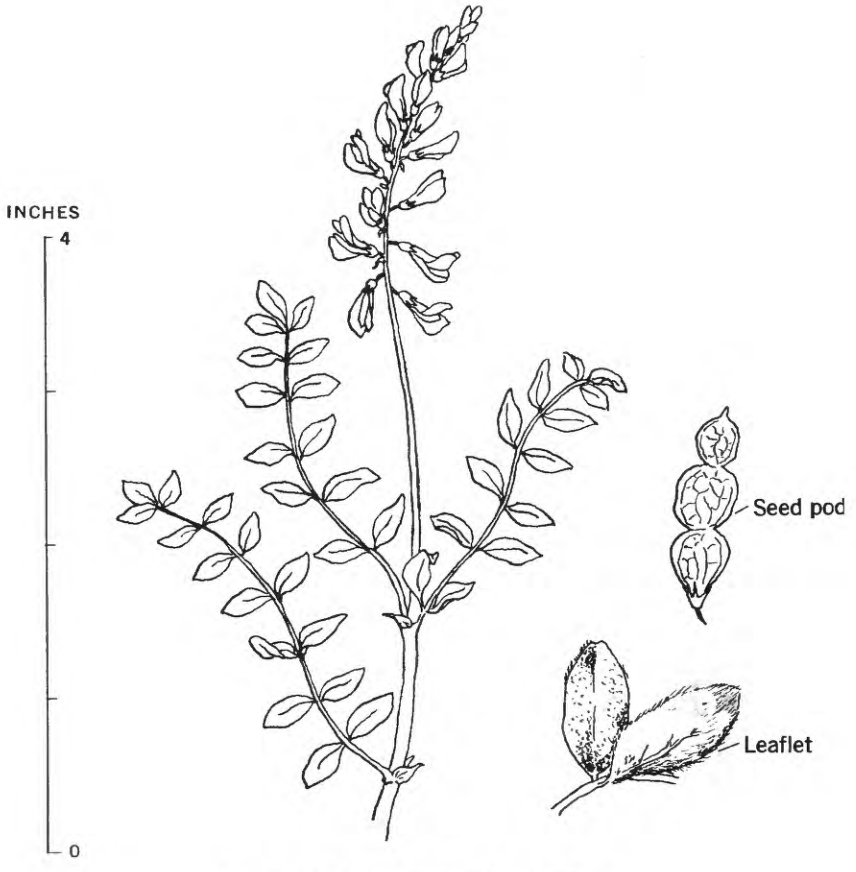

FIGURE 152.—*Hedysarum boreale* Nutt.

Family: Pea, Leguminosae.

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

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

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

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

Tolerant

FIGURE 153.—Northern sweetvetch.

Altitude: 4,000–7,000 feet.
Occurrence: Phreatophyte, tolerant of mineralized ground.
Districts noted: Thompson, White Canyon, Circle Cliffs and San Rafael, Utah; Paradox Valley, Colo.; Defiance uplift and Chuska, Ariz.

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FIGURE 154.—*Castilleja integra* Gray.

Family: Figwort, Scrophulariaceae.
Flowers: Spikes of flowers consisting of three-cleft, brilliant scarlet bracts surrounding yellowish fused calyx and narrow yellow petals. Four stamens. Blooms throughout summer.
Leaves: Alternate, sessile, linear leaves, 2 to 4 inches long.
Fruit: Two-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

FIGURE 155.—Indian paintbrush or paintedcup.

Altitude: 3,000–7,500 feet.

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

Districts noted: Thompson and White Canyon, Utah; Grants, N. Mex.; Chilchinbeto and Chuska, Ariz.

FIGURE 156.—*Plantago purshi* Roem. & Schult.

Family: Plantain, Plantaginaceae.

Flowers: Tiny dry flowers in dense cylindrical spike resembling wheat. Spike ½ to 1½ inches long on 2-inch woolly stem. Individual flower parts in fours. Blooms throughout summer.

Leaves: Woolly, linear, 3-ribbed leaves 1 to 2 inches 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 taproot; 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.

Tolerant

FIGURE 157.—Woolly indianwheat.

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

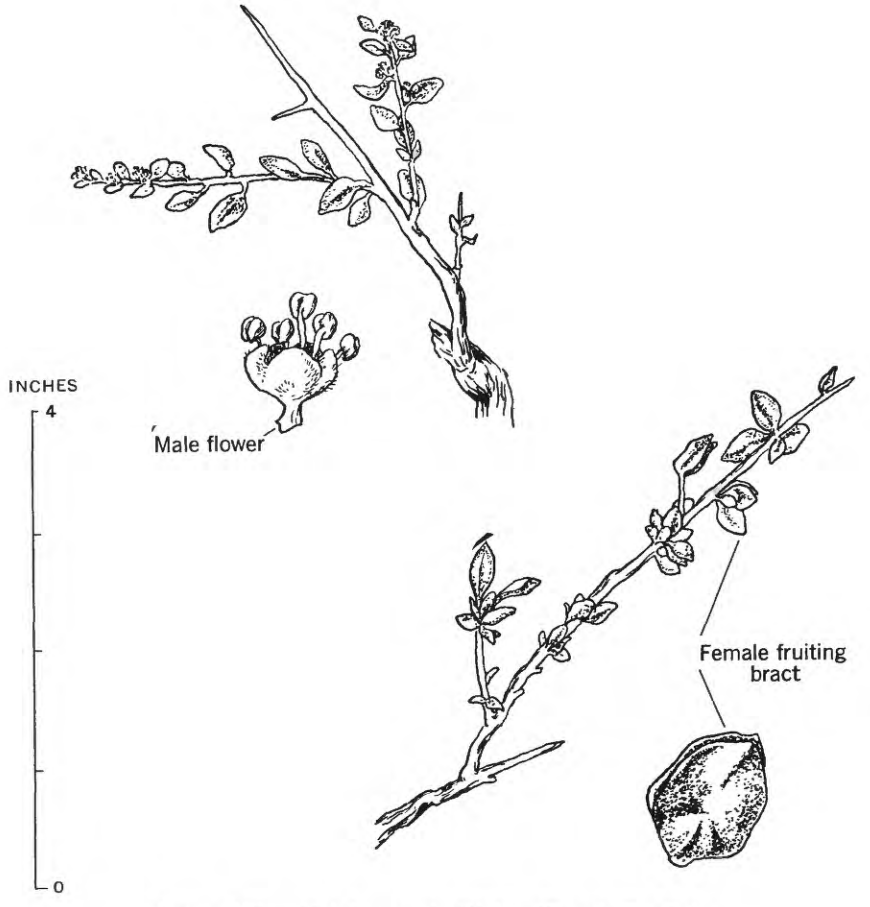

FIGURE 158.—*Atriplex confertifolia* (Torr.) S. Wats.

Family: Goosefoot, Chenopodiaceae.
Flowers: Small dense clusters. Blooms in late summer.
Leaves: Thickened, ovate, scurfy leaves; resembling a shad scale. Leaves have short stem.
Fruit: Fruit in large conspicuous yellowish-green to pinkish bracts at ends of the branches. Bracts never with wings.
Plant: Grayish-green xerophyte shrub 1–4 feet high; woody and branched. Branches ending in spines. Seeds not produced on same plants with pollen.

FIGURE 159.—Shadscale saltbush.

Altitude: 4,200–6,000 feet.

Occurrence: 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 Basin, and Lost Creek, Wyo.; La Ventana, N. Mex.; Slick Rock, Colo.; Thompson, San Rafael, White Canyon, Moab, and Uinta Basin, Utah.

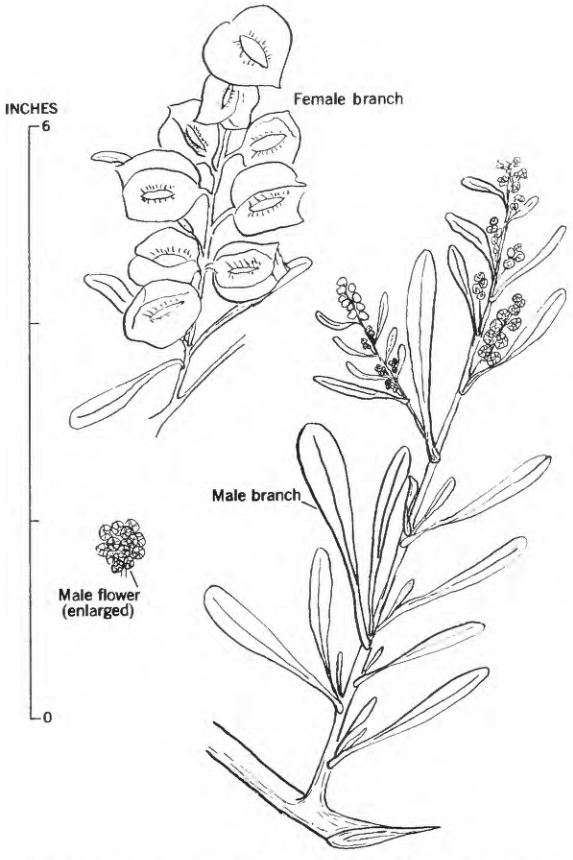

FIGURE 160.—*Atriplex canescens* (Pursh) Nutt.

Family: Goosefoot, Chenopodiaceae.

Flowers: Staminate flowers small glomerules in dense spikes. Pistillate flowers enclosed in bracts with no calyx or petals. Blooms in June and August.

Leaves: Linear, thick, grayish, scurfy. 2 inches long. No leaf stem.

Fruits: Fruits one seeded with four prominent wings. Fruiting bracts stalked, thick, fleshy and ovoid.

Plant: Woody perennial 2–8 feet with male and female flowers on separate plants. Branches circular in cross sections, white scurfy. Bark peels from old stems in thin layers. Roots reach 20 feet in length.

Tolerant

FIGURE 161.—Fourwing saltbush.

Altitude: 4,000–8,000 feet.

Occurrence: Dry sandy plains and hills. Alkaline soil. High ash content largely sodium. Replaced by *A. confertifolia* in extremely saline areas.

Districts noted: Yellow Cat and Green River, Utah; Ship Rock, Grants, and Nambé, N. Mex.; Uravan, Colo.

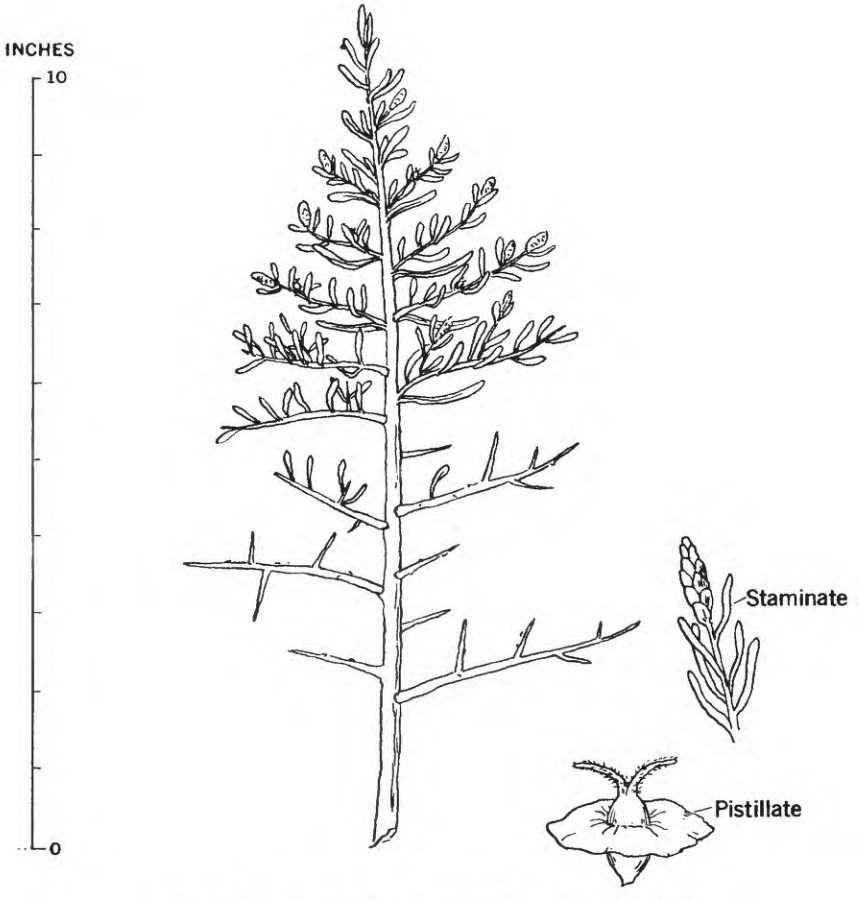

FIGURE 162.—*Sarcobatus vermiculatus* (Hook.) Torr.

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 from June to September.

Leaves: Alternate, linear, and fleshy leaves, ½–1½ inches long. Sessile.

Seed: Nutlet attached to expanded, membranous calyx.

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

Tolerant

FIGURE 163.—Black greasewood.

Altitude: 1,000–7,000 feet.

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, owing to salate of sodium and potassium in sap. Absorption of uranium very high.

Districts noted: Thompson and Henry Mountains, Utah; Lost Creek, and Poison Basin, Wyo.

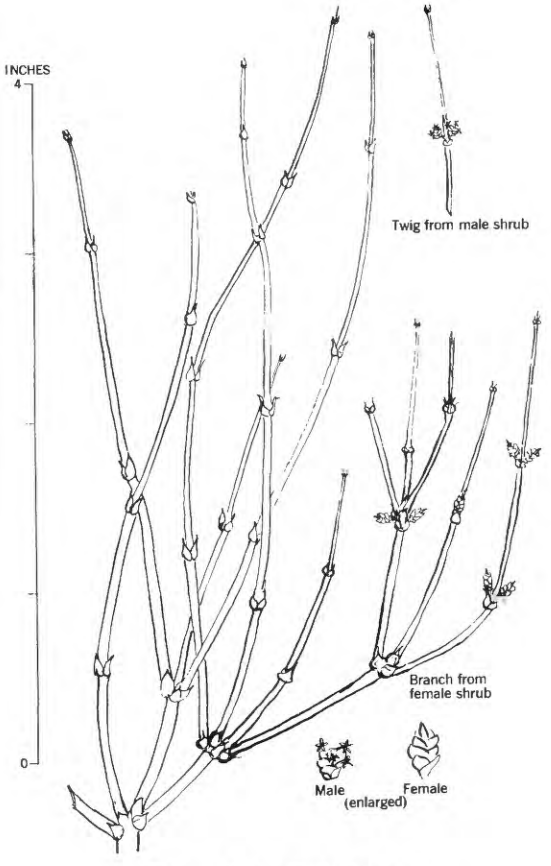

FIGURE 164.—*Ephedra* sp.

Family: Jointfir, Gnetaceae.

Flowers: Small male and female yellow flowers in short catkins with persistent bracts. Stamens united, 2-lobed flower tube. Blooms in spring.

Leaves: Scalelike in pairs or threes at stem joints.

Seeds: Hard nutlets.

Plant: Shrubs 6–25 inches high with rigid jointed striated branches resembling *Equisetum* and reduced leaves. Twigs opposite or clustered at stem joints.

Tolerant

FIGURE 165.—Jointfir, or mormon tea.

Altitude: 4,500–9,000 feet.
Occurrence: Dry desert areas.
Districts noted: Yellow Cat and Henry Mountains, Utah; Ship Rock, N. Mex.

FIGURE 166.—*Opuntia engelmanni* Salm–Dyck 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 in May and June.

Leaves: Small, awl-shaped deciduous, as much as ½ inch long.

Roots: Extensive fibrous roots.

Fruit: Fleshy edible berry as much as 2 inches long with many bony seeds.

Plant: Succulent shrubs as much as 5 feet 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

FIGURE 167.—Engelmann pricklypear.

Altitude: 1,000–8,000 feet.
Occurrence: Sandy plains and sandstone mesas.
Districts noted: Thompson, Henry Mountains, and Green River, Utah; Defiance uplift, and Ship Rock, in Arizona.

FIGURE 168.—*Mirabilis multiflora* A. Gray.

Family: Four o'clock, Nyctaginaceae.

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

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

Tolerant

FIGURE 169.—Colorado four-o'clock.

Altitude: 2,500–7,500 feet.
Occurrence: Hillsides and rocky mesas.
Districts noted: Thompson and White Canyon, Utah; Ship Rock and Grants, N. Mex.; Uravan, Colo.

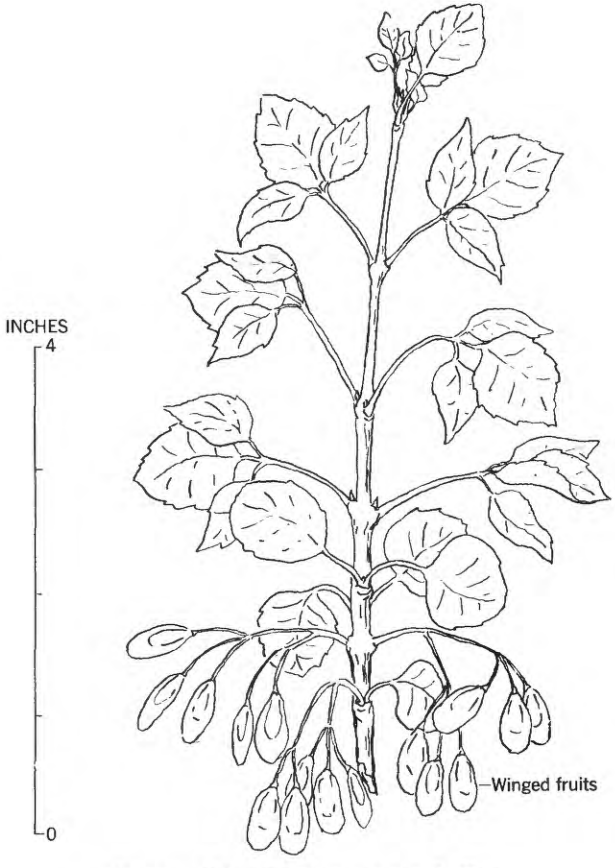

FIGURE 170.—*Fraxinus anomala* Torr.

Family: Olive, Oleaceae.
Flowers: Four-toothed, bell-shaped flowers. Blooms in April and May.
Leaves: Simple, smooth, rounded leaves 1–2 inches long occurring in threes.
Fruits: Dry, winged, oblong one-seeded fruits ½ to 1 inch long.
Plant: Small tree 5 to 15 feet high, with 4-angled twigs and thick simple leaves. Extensive root system.

Tolerant

FIGURE 171.—Singleleaf ash.

Altitude: 2,000–7,000 feet.
Occurrence: Dry sandstone mesas and sandy washes in full sun.
Districts noted: Ship Rock, N. Mex.; Thompson, San Rafael, and Green River, Utah.

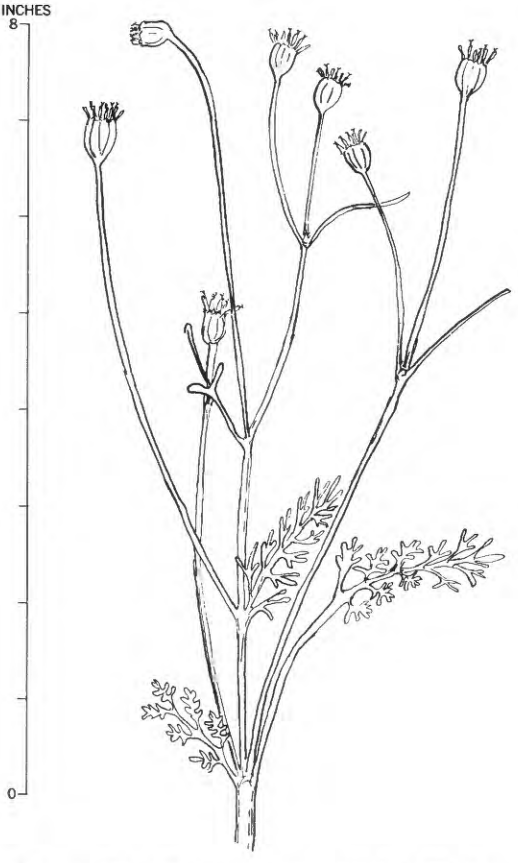

FIGURE 172.—*Hymenopappus filifolius* Hook.

Family: Sunflower, Compositae.
Flowers: Several heads of tubular yellow flowers with tubes longer than lobes. No ray flowers. Blooms in July and August. Bracts at base of head with yellowish tips.
Leaves: Woolly basal leaves twice-divided into threadlike segments.
Seeds: Small dry seeds with long silky hairs.
Plant: Woolly perennial plants with leaves crowded at branching woody base and 10 to 20-inch stalks.

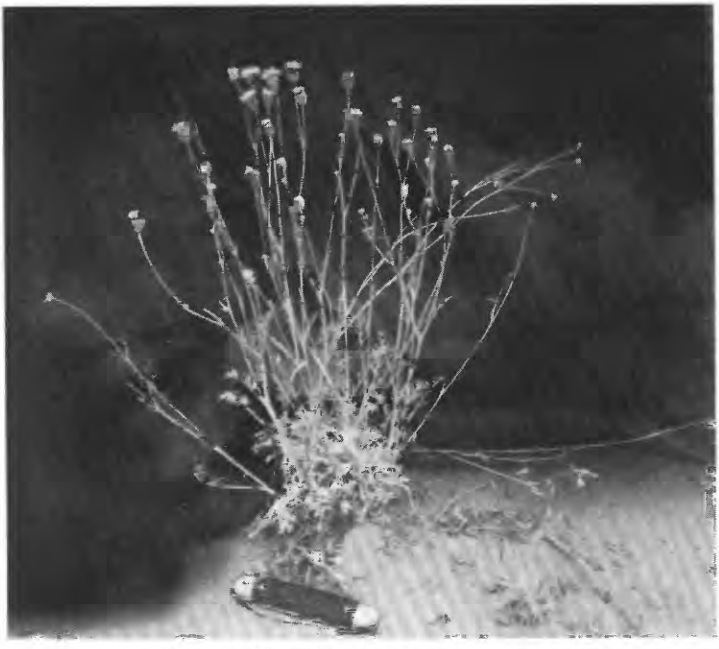

FIGURE 173.—Fineleaf hymenopappus.

Altitude: 3,500–8,000 feet.
Occurrence: Semiarid hills and mesas, commonly on sandstone.
Districts noted: Thompson, Utah; Pojoaque, N. Mex.

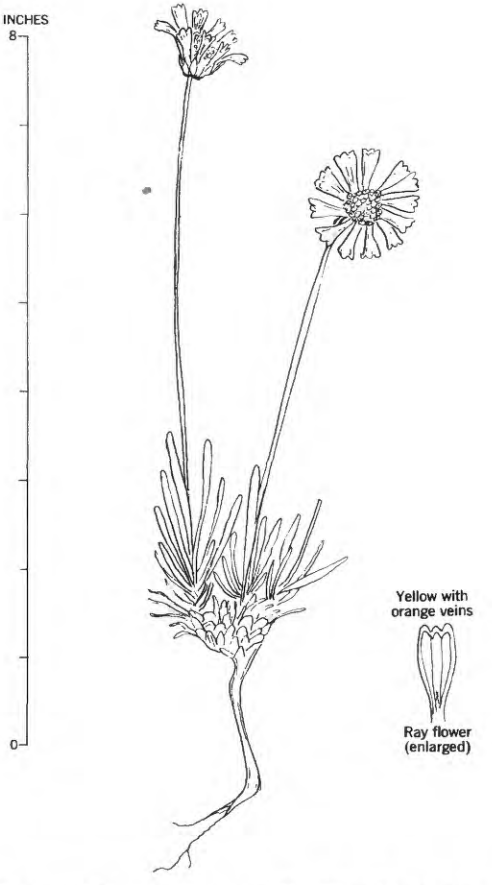

FIGURE 174.—*Actinea acaulis* (Pursh) Spreng.

Family: Sunflower, Compositae.

Flowers: Single composite head of yellow flowers on 8-inch leafless scape or flower stalk. Single series of ray flowers, 3-toothed, with orange veins. Bracts at base of flower in 2 or 3 rows, not united and densely hairy. Blooms from June to September.

Leaves: Basal rosette of linear leaves, ½ to 2 inches with entire margins, silky. Glands prominent.

Seeds: Dry, angled, hairy seeds crowned with 6 papery scales.

Plant: Perennials with woody base and strong taproot. Single leafless flower stalk with leaf rosette. Bitter, aromatic taste.

Tolerant

FIGURE 175.—Stemless actinea.

Altitude: 3,500–12,000 feet.
Occurrence: Dry rocky slopes.
Districts noted: Thompson and San Rafael, Utah; Grants, N. Mex.

GLOSSARY

Awn.—A slender bristlelike appendage on 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 petallike 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.—Tubular 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 in such a way as to resemble the keel of a boat.
Pinnate.—Compound (leaf) with leaflets arranged on each side of a common stem. Featherlike.
Punctate.—Dotted with depressions or with translucent glands.
Raceme.—A simple cluster of stalked flowers upon a common elongated stem.
Ray-flowers.—Straplike 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.

PLANT INDEX