FIGURE 15.—View of Mitchell Mesa channel 1, Navajo County, Ariz., showing the Shinarump conglomerate (₸s), Moenkopi formation (₸m), Hoskinnini tongue of the Cutler formation (Pch), and De Chelly sandstone member of the Cutler formation (Pcd).

FIGURE 16.—Northeasterly view across the West Fork of Copper Canyon showing the broad deep Alfred Miles channel 1, Navajo County, Ariz., and the Shinarump conglomerate (Ꞧs), Moenkopi formation (Ꞧm), Hoskinnini tongue of the Cutler formation (Pch), De Chelly sandstone member of the Cutler formation (Pcd), and Organ rock member of the Cutler formation (Pco).

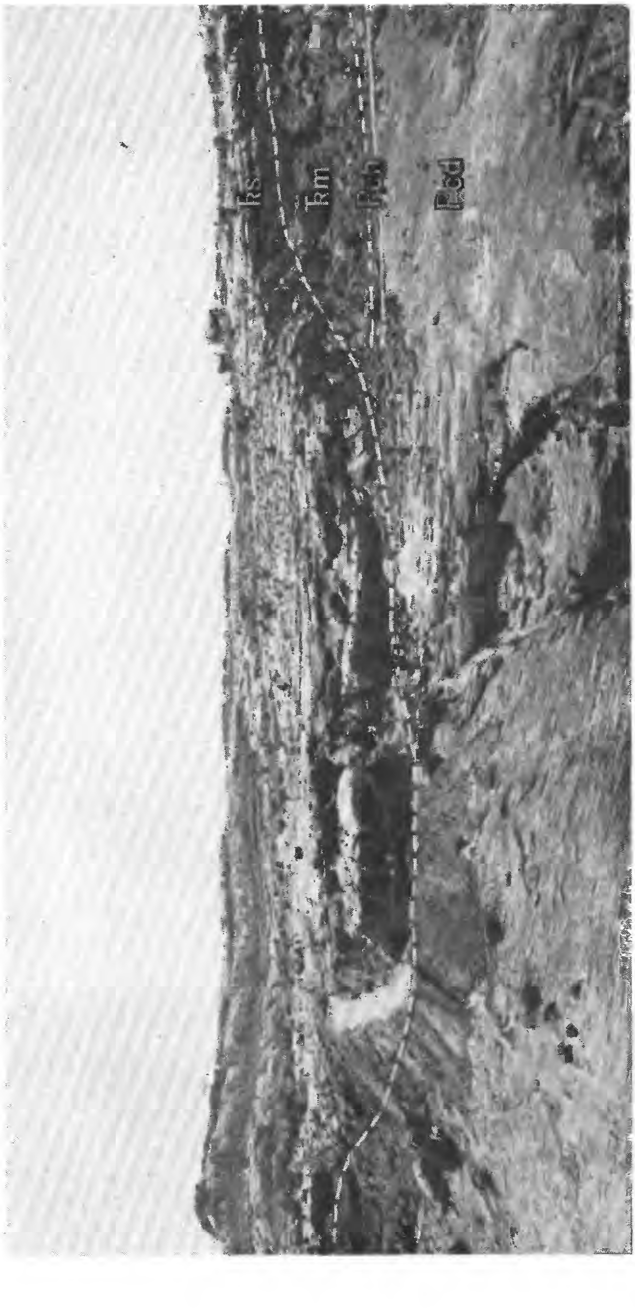


FIGURE 17.—Southeasterly view of South Ridge showing shape of Monument No. 2 channel, Apache County, Ariz., and the Shinarump conglomerate (Ꞧs), Moenkopi formation (Ꞧm), Hoskinnini tongue of the Cutler formation (Pch), and De Chelly sandstone member of the Cutler formation (Pcd).

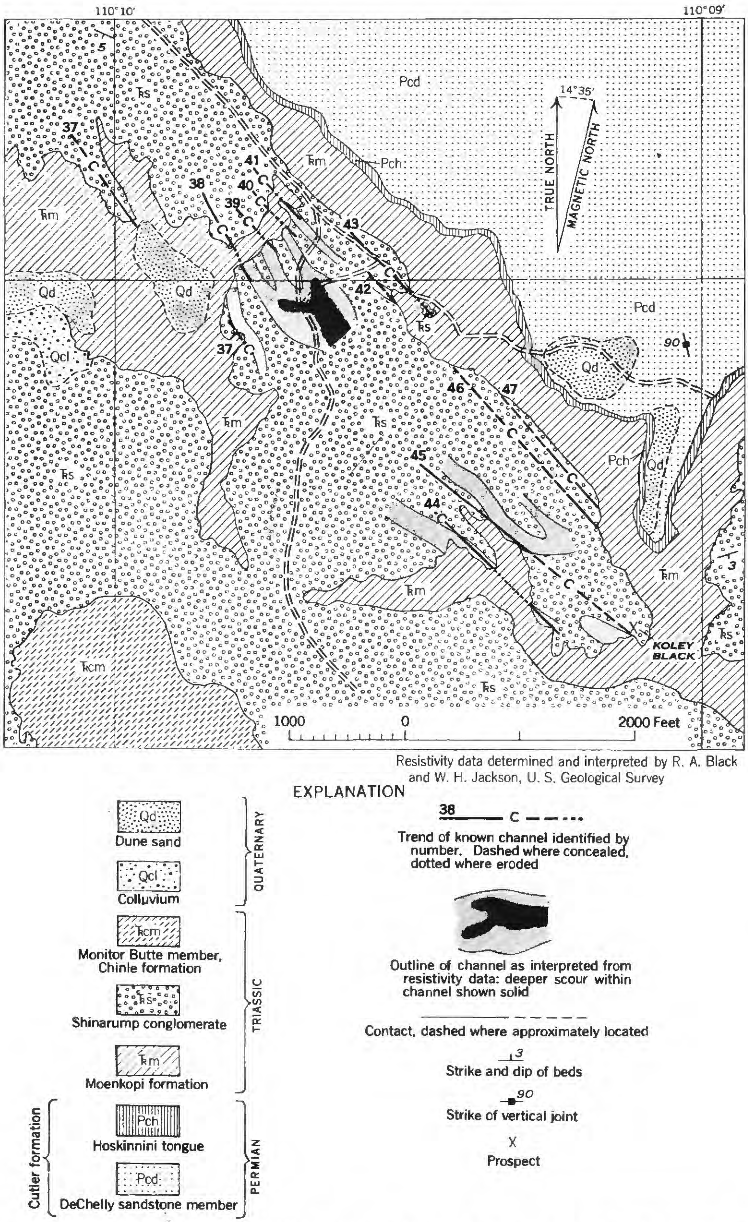


FIGURE 18.—Geologic and resistivity interpretations of channels in the Koley Black area, Navajo County, Ariz.

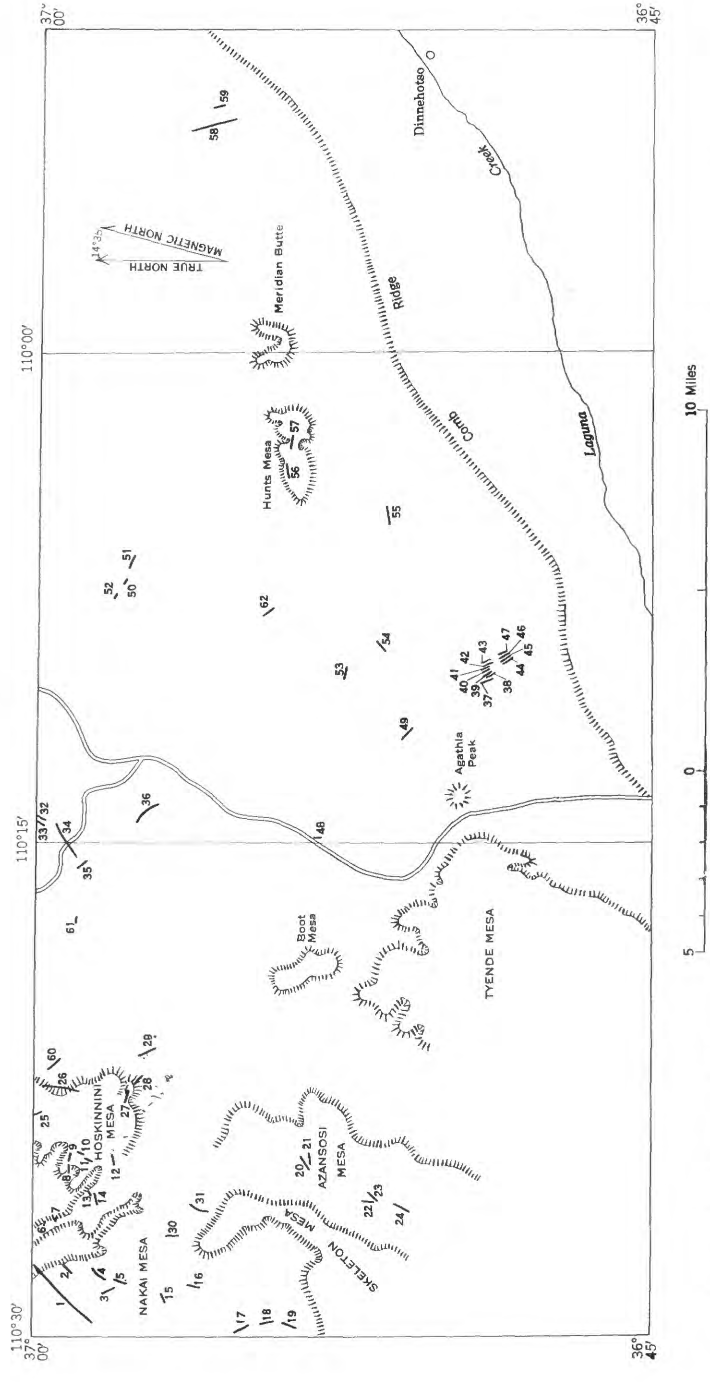


FIGURE 19.—Map showing distribution of channels in the Monument Valley area, Arizona. Channels are identified on page 114.

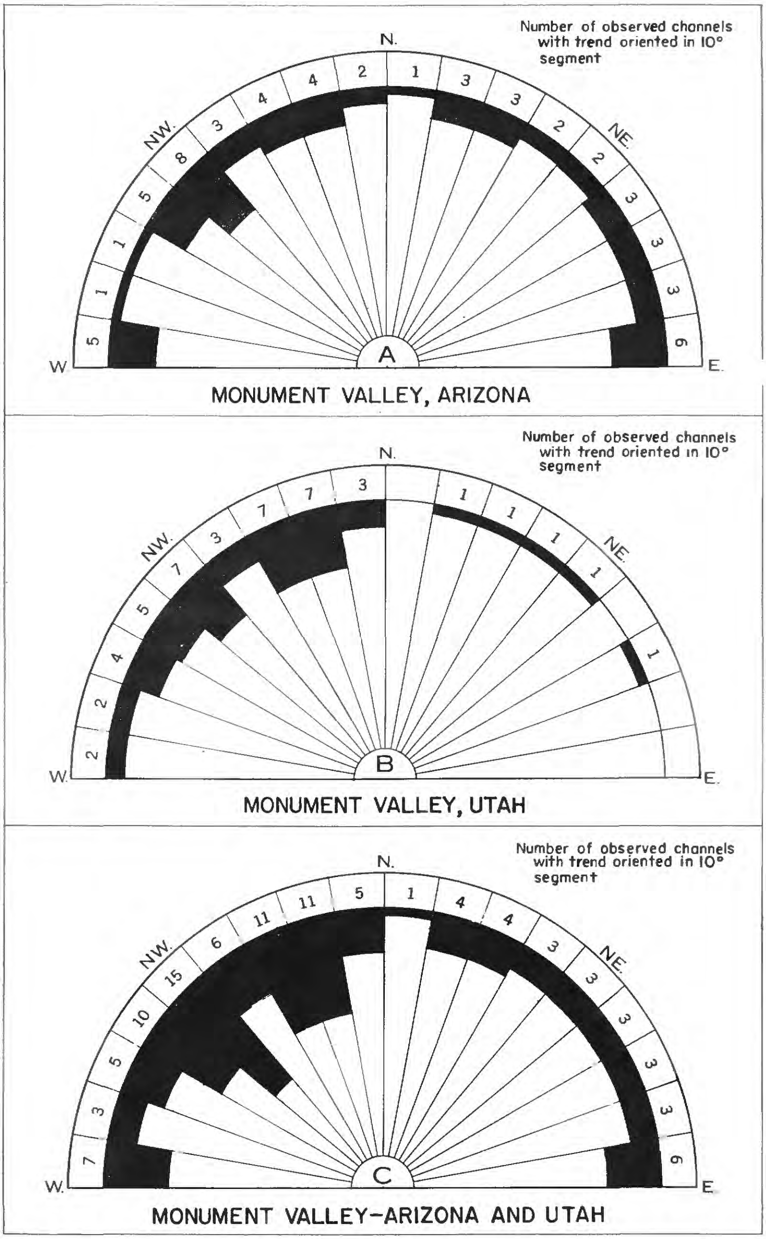


FIGURE 20.—Diagrams showing channel trends in the Monument Valley area, Arizona and Utah.

FIGURE 22.—View of large complex rod in Monument No. 2 mine, Apache County, Ariz., showing mixed limonite and tyuyamunite (ss) in sandstone center, surrounded by rings of tyuyamunite (ty) and limonite (lt).

FIGURE 23.—Oblique view of complex rod in Monument No. 2 mine, Apache County, Ariz., showing core of silicified wood (sw) surrounded by gray friable sandstone with mixed limonite and tyuyamunite (ss), which in turn is surrounded by rings of tyuyamunite (ty) and limonite (lt).

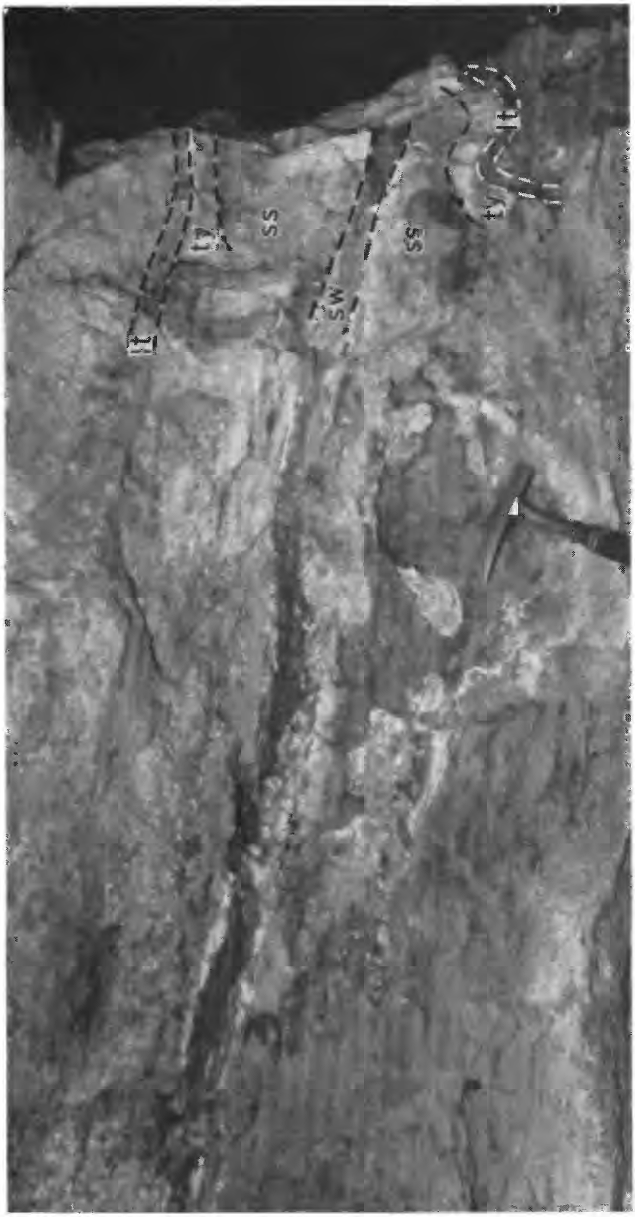


FIGURE 24.—Longitudinal view of complex rod in Monument No. 2 mine, Apache County, Ariz., showing thin core of silicified wood (sw), lying parallel to the trend of the rod and surrounded by rings of gray friable sandstone with mixed limonite and tyuyamunite (ss), tyuyamunite (ty), and limonite (lt).

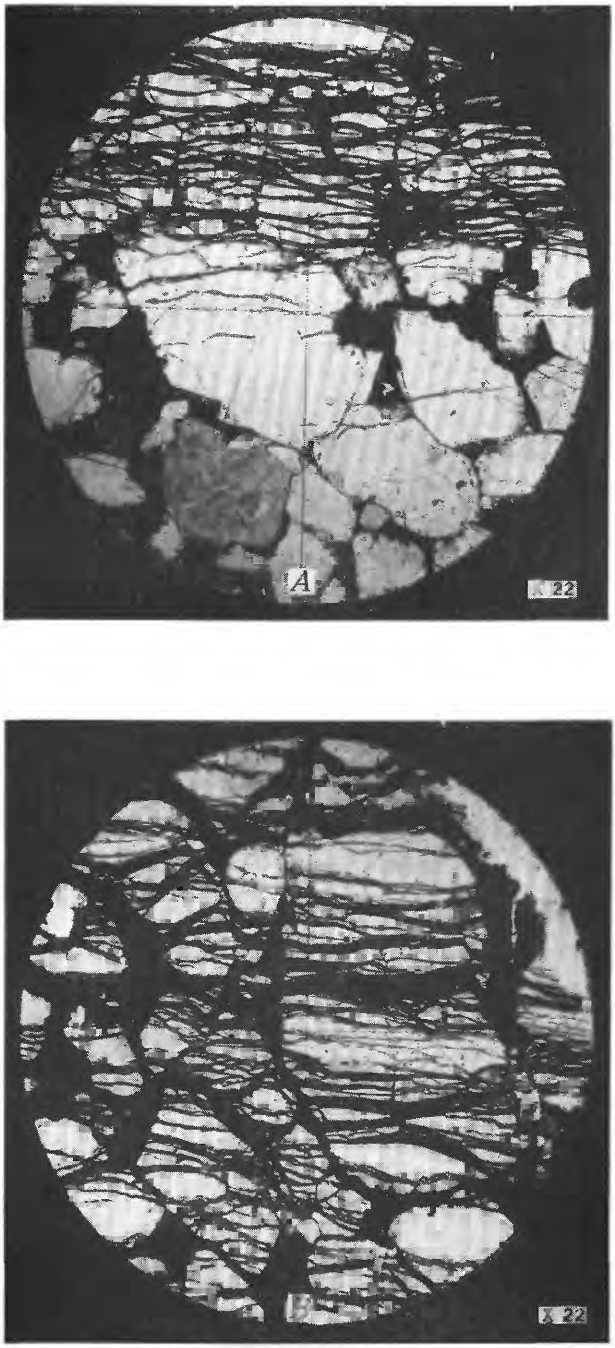


FIGURE 25.—Photomicrographs of thin sections of specimens collected in the Monument No. 2 mine; specimens contain secondary uranium and vanadium minerals in interstices and fractures. *A*, Rim of rod showing distinct boundary between fractured and unfractured grains. *B*, Rim of rod showing quartz grains broken by parallel set of fractures.

FIGURE 26.—Photomicrograph of thin section of specimen collected in the Monument No. 2 mine, showing irregular fractures of channel sediments about 1 foot away from rim of rod. Specimen contains secondary uranium and vanadium minerals in interstices and fractures.

the slide are whole (fig. 25). The separation between fractured and unfractured grains is a zone not more than 1 millimeter wide.

Two systems of fractures were noted: one consists of a set of parallel fractures (fig. 26) with a subsidiary set trending more or less at right angles; the other is a plexus of fractures that lacks orientation. Each fracture of the parallel set is as much as 1 millimeter away from adjacent fractures, and each fracture can be traced for as much as 10 to 15 millimeters in a relatively straight line as it continues uninterrupted through sand grains. In places this parallel set is cut by a subsidiary set that is at right angles to the main set. The subsidiary set offsets the main fractures slightly; but those fractures with no determinable pattern are less common. The fractures are jagged and end at the grain boundaries. The gross appearance of this fracture system is that of an interlacing network, devoid of orientation or system.

Filling the fractures, interstices, and other voids are secondary uranium and vanadium minerals, calcite, and authigenic quartz. The depositional sequence appears to be as follows: First, authigenic quartz; second, secondary uranium and vanadium minerals; and third, emplacement of calcite.

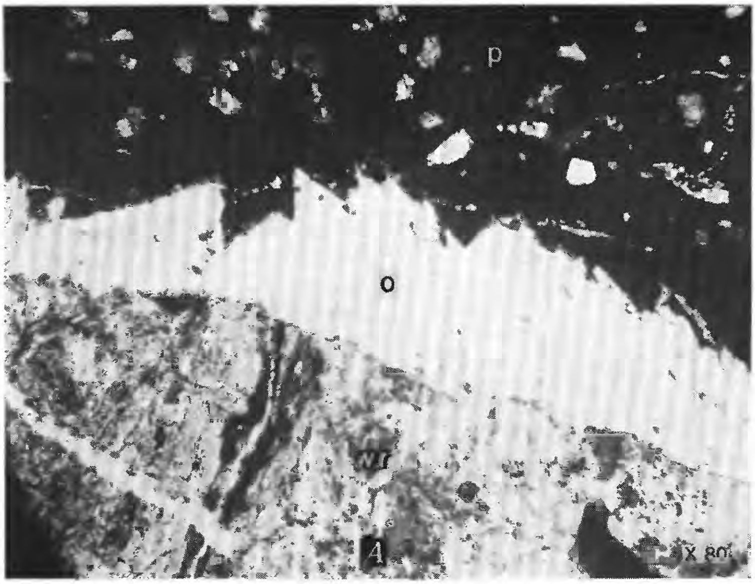
The circular pattern formed by the fractures as they outline the rods is distinctive and has been found only in the Monument No. 2 mine.

How these circular fracture patterns form and the reason why some grains are fractured whereas others only a few millimeters away are not fractured is unknown. One answer may involve factors of selective cementation. Perhaps those grains in the fractured zones were once tightly cemented. When stress was applied, possibly as a result of load, the cemented grains may have fractured, but the uncemented grains may have merely rolled and readjusted themselves to the forces applied.

Many of the rods were interpreted by me to represent replacement of coalified logs by silt, pyrite, and uraninite. Subsequent oxidation altered the pyrite to limonite, and the uraninite to becquerelite and carnotite. It was thought that the woody texture of these coalified logs is now reflected in the rims of the rods by these materials. To test this concept, six samples were sent to James M. Schopf of the Geological Survey. Five of the samples were collected from the rims of the rods, and the sixth was collected from silicified wood in the core of a rod. It was requested that he determine whether any of the samples represented replaced plant matter. In selecting the samples an effort was made to include a range from those that seemed to show woody texture to others that appeared to contain only rudimentary traces of former plant matter.

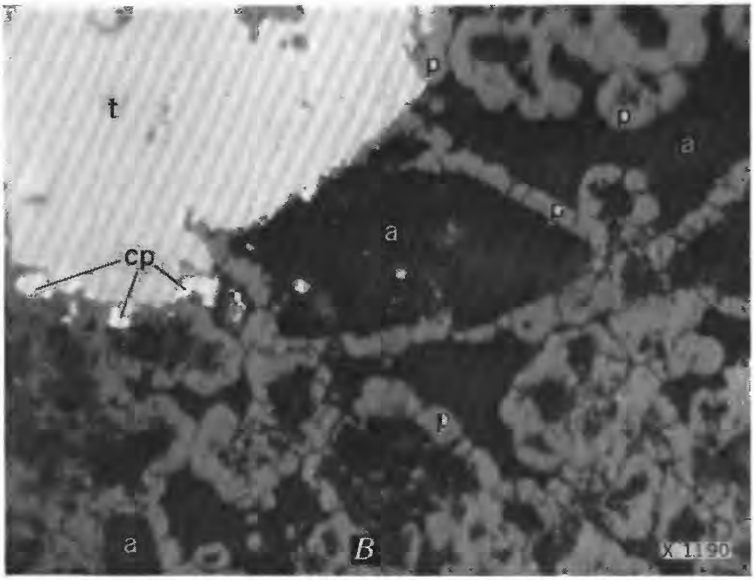
Of the six samples submitted, Schopf identified only one as replaced fossil wood, and that was the one collected from the core of the rod; the others contained no trace of organic matter. It appears, therefore, that although parts of some rods may represent replacement of some form of former plant matter, the mineralized rims of the rods do not show this phenomenon. The similar pattern between trends of rods and of silicified wood fragments (fig. 27), however, as well as the collinearity apparent between many of the rods and silicified remnants of logs, suggests that some relationship does exist between these former buried logs and the rods.

Possibly the shape, size, and distribution of the rods were determined by the buried logs. During or very shortly after burial the original organic matter of the buried logs may have been removed and other, more stable materials, such as sand, silt, and clay may have been deposited in the voids so formed. The removal of the organic matter and its subsequent replacement was probably a gradual process and affected only part of any log at any one time. It may have been during this episode that porosity and permeability conditions were changed; possibly this was sufficient to localize the ore solutions when they invaded the Shinarump conglomerate. Thus, those rods over which the bedding arches, as well as those that show abrupt changes in grain size between the confining strata and the rod boundaries, may merely represent the former presence of buried logs, which have since been replaced by sand, silt, and clay.



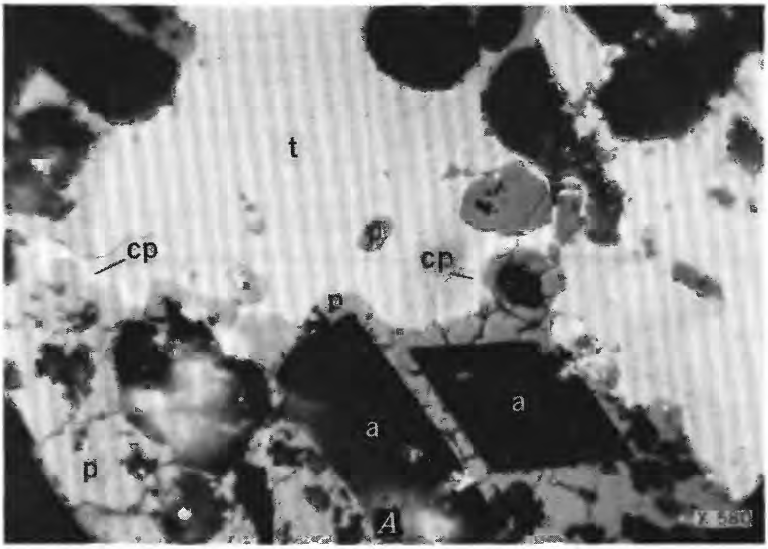
A. PHOTOMICROGRAPH OF THIN SECTION OF ORE FROM UNION PACIFIC DEPOSIT

Shows pitchblende (*p*) coating orthoclase (*o*) crystals formed on altered wall rock (*wr*). Plain light, × 80.

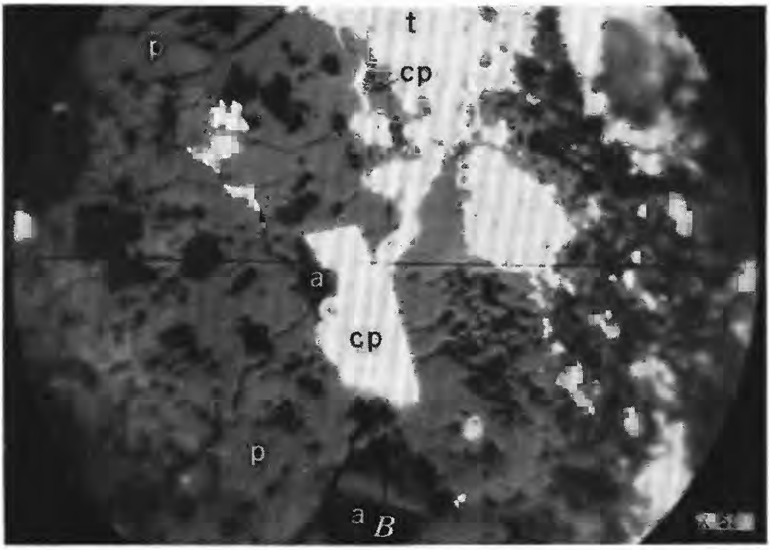


B. PHOTOMICROGRAPH OF POLISHED SECTION

Shows typical pitchblende (*p*) ankerite (*a*) intergrowth, containing tennantite (*t*) and chalcopyrite (*cp*). × 1190.



A. Shows pitchblende (*p*) coating ankerite (*a*), both replaced by tennantite (*t*) and chalcopyrite (*cp*). × 580.



B. Shows replacement of ankerite crystal (*a*) by chalcopyrite (*cp*) marginal to tennantite (*t*). Gray areas are pitchblende (*p*). × 580.

PHOTOMICROGRAPHS OF POLISHED SECTIONS

URANIUM DEPOSITS IN OOLITIC LIMESTONE NEAR MAYOWORTH, JOHNSON COUNTY, WYOMING

By R. R. GUILINGER and P. K. THEOBALD

ABSTRACT

The uranium deposits of the Mayoworth area, Johnson County, Wyo., are in oolitic limestone at the base of the Sundance formation of Late Jurassic age. The uranium mineral has been identified as metatyuyamunite, a hydrous calcium uranium vanadate that coats joints and fractures and replaces calcite in both the cement and the oolites. In the largest area of measured radioactivity, the deposits are coatings on joint surfaces, but in the other areas, replacement of oolites and cement is most common. Some of the uranium may be syngenetic. Secondary metatyuyamunite has been concentrated along groundwater channels. The uranium content ranges from 0.017 to 0.32 percent and the V_2O_5 content ranges from 0.06 to 0.17 percent. The known deposits of the area are of sub-ore grade and are not of economic importance at this time.

INTRODUCTION

The uranium deposits of the Mayoworth area are 2.2 miles south of the abandoned postoffice at Mayoworth, Johnson County, Wyo. The area is accessible by a dirt road from Mayoworth, which is reached by a paved secondary road from U. S. Highway 87 at Kaycee.

The stratigraphy and structure of the area surrounding the uranium deposits have been mapped and described by Richardson [1] and the general area to the north by Hose (1954). Love (1954) described the uranium deposits of the Mayoworth area.

To evaluate the economic potential and to study controls of deposition of the uranium, the writers examined the deposits in August 1954 and mapped the area by plane table methods in September 1954. This work was done by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

STRATIGRAPHY

Sedimentary rocks of Triassic and Jurassic age are exposed in the immediate vicinity of the Mayoworth uranium deposits. The Chugwater formation of Triassic age is composed of massive red sandstones

[1] Richardson, A. L., 1950, Geology of the Mayoworth region, Johnson County, Wyoming: Univ. of Wyoming, M. A. thesis, unpub.

and shales. The Sundance formation of Late Jurassic age unconformably overlies the Chugwater formation. In the mapped area (fig. 1), the Sundance formation is divided into three units. The basal unit, in which the uranium deposits occur, is a gray oolitic

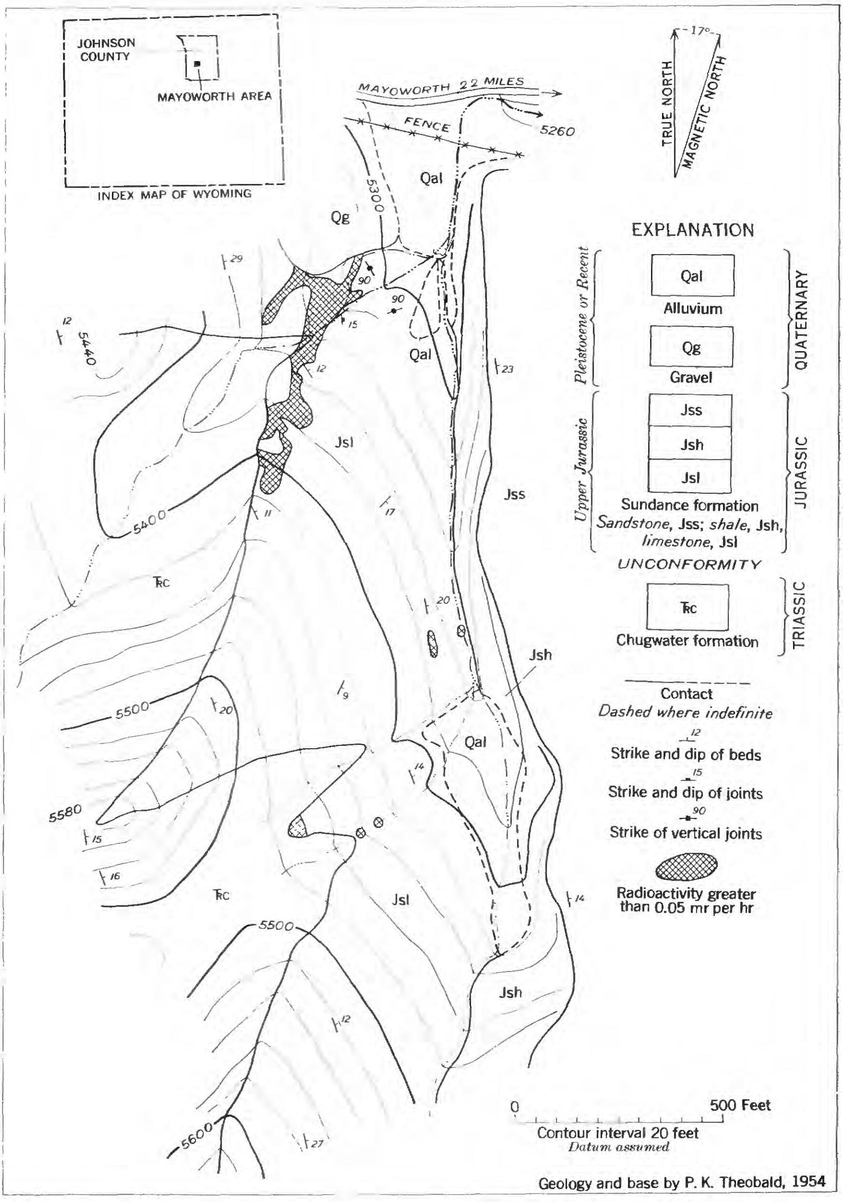


FIGURE 62.—Map showing distribution of radioactive localities in the Sundance formation near Mayoworth, Johnson County, Wyo.

limestone, 8 to 10 feet thick. Conformably overlying the limestone is 30 feet of soft gray fossiliferous shale, and directly overlying the shale is white to buff sandstone. Isolated patches of gravel of late Cenozoic age uncomformably overlie both the Triassic and Jurassic rocks.

The limestone of the Sundance formation is composed of oolites formed primarily around elongate cores of colorless calcite. The oolites are generally uniform in size, averaging about 0.5 mm in diameter but ranging from 0.1 mm to 2 mm in diameter. They tend to follow the form of the cores, with elongated shapes predominant. Radial and concentric growth is evident around the cores, and in many oolites both kinds occur (fig. 63). Where both forms of growth

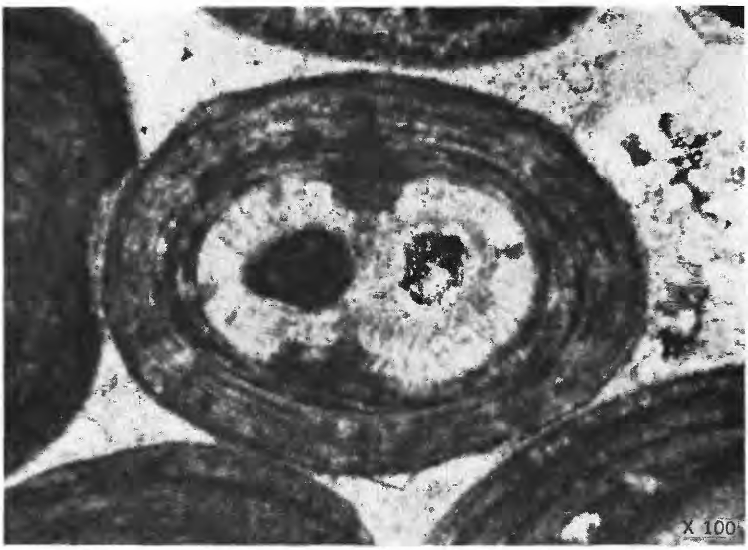


FIGURE 63.—Photomicrograph of limestone near Mayoworth, Wyo., showing radial and concentric oolite growth. Crossed nicols. ×100.

are present in a single oolite, the radial growth is on the inside, surrounded by the concentric rings and separated from the concentric rings by a thin layer of clay. This suggests two stages and two processes of oolite formation with a slight interruption between the stages. Another interruption in the oolite formation is suggested by some corrosion and clay accumulation on a concentric ring at about the same position in several oolites.

Though most of the cores consist of colorless calcite, there are other kinds. Of these, fossils are the most common. They include small pelecypod shells, Foraminifera(?), or shell fragments. Opaque black minerals form the cores of some oolites. Most of these black minerals are hematite or goethite, but some have not been positively identified. The cores of some oolites are quartz grains, but grains of this mineral are generally larger and occur as clastic grains free of oolite forming calcite.

The oolites are imbedded in a cement of colorless coarsely crystalline calcite. At the time of cementation some solution of the oolites occurred, and their outer edges appear corroded and partly replaced by the cementing calcite. Later solutions, apparently moving along the interfaces between the cement and the oolites, introduced iron oxide that replaced both the cement and oolites. In some places the cement is completely replaced by iron oxide, and an unidentified green mineral replaces the edges of some oolites. In places finely divided iron oxide gives a reddish color to the oolites and cement. Hematite and metatyuyamunite have filled fractures that cut both the cement and oolites (fig. 64).

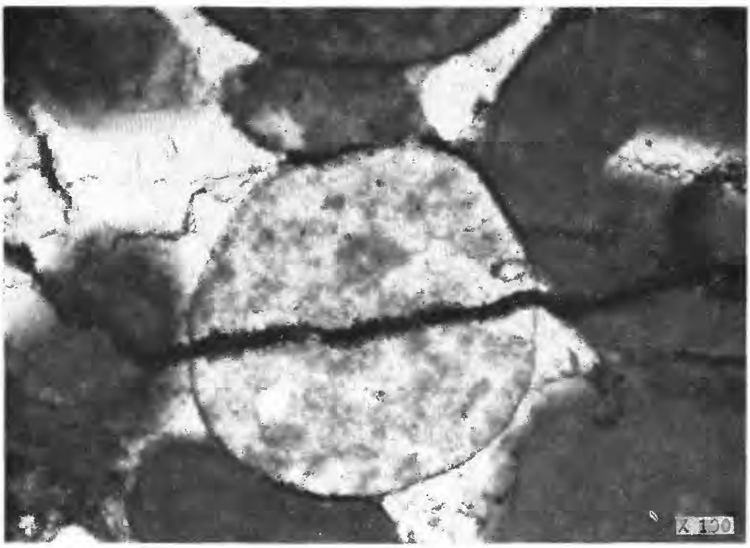


FIGURE 64.—Photomicrograph of limestone near Mayoworth, Wyo., showing a metatyuyamunite-filled fracture. ×100.

STRUCTURE

The Mayoworth area is on the southeast flank of the Bighorn arch. The sedimentary rocks in the Mayoworth area are separated from Precambrian crystalline rocks to the north by a northwest-trending thrust fault about 6 miles north of the mapped area. South of this thrust fault, the east limb of the major arch is warped into smaller anticlines and synclines. The uranium-bearing limestone is exposed on the east limb of an anticline that forms the eastern limit of exposure of the minor folds.

The structure in the vicinity of the uranium occurrences is shown on figure 65. The strike of the Chugwater formation and the sandstone of the Sundance formation is uniform. The Chugwater forma-

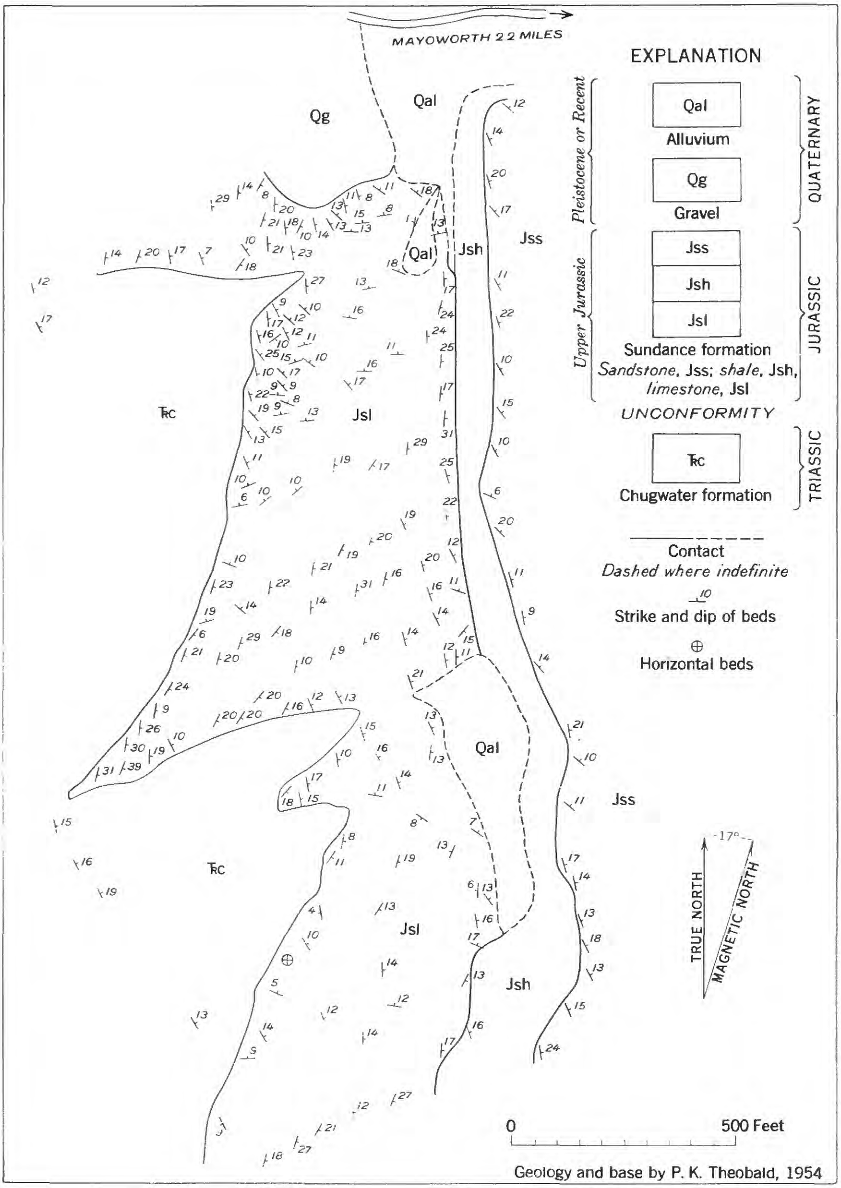


FIGURE 65.—Map showing lithologic units and structure of part of the Sundance formation near Mayoworth, Johnson County, Wyo.

tion has an average strike of N. 23° W., and an average dip of 15° NE.; the sandstone unit of the Sundance formation has an average strike of N. 28° W., and an average dip of 14° NE. The structure of the oolitic limestone is complex; bedding planes are warped, and there is some crossbedding. The erratic strike and dip symbols on figure 63 reflect these features.

Three sets of joints are conspicuous in the limestone; one is essentially parallel to bedding and strikes from N. 15 to 20° W., and two are vertical with strikes of N. 70° E. and N. 30° W. (fig. 62). The joints probably were formed during the Laramide orogeny. No faults were observed in the area mapped.

URANIUM DEPOSITS

MINERALOGY AND MODE OF EMPLACEMENT

Metatyuyamunite, a hydrous calcium uranium vanadate, was identified by W. F. Outerbridge of the Geological Survey by X-ray methods in a selected sample of oolitic limestone. It occurs as coatings on joints and small fractures and as replacements of calcite in the cement and oolites. In zones of highest radioactivity, metatyuyamunite is prominent as joint coatings, particularly in the north half of the mapped area. The coatings are most conspicuous along joints striking N. 70° E. and N. 15° W.

In the less radioactive rocks, replacement was the most common mode of emplacement. Uranium-bearing solutions entered the limestone along small fractures, and replaced cement or oolites adjacent to the fractures. Where fractures are absent the solutions appear to have moved along the interfaces between crystals of the cement or more commonly between cement and oolites. In the latter, both cement- and oolite-forming calcite were replaced, but the oolite-forming calcite seems to be more susceptible to replacement. In several thin sections only the oolites or oolite cores were replaced but there is no evidence of channels through which replacing solutions could have entered. In one polished section an unidentified black mineral formed the core of the oolite. This black mineral has a dark-gray or black streak in contrast to the red and brown streak of the iron minerals. Immediately surrounding this black mineral is an orange alteration product, which is surrounded in turn by a concentration of a yellow uranium mineral. The black mineral may be a syngenetic primary uranium mineral, but it is too small to be positively identified. An autoradiograph of this polished section gave inconclusive results. The same polished section also showed a black mineral, with orange and yellow alteration halos, veining an oolite (fig. 66).

Association of the radioactive rocks with present water courses is evident from figure 62, suggesting some geomorphic control of the deposits. The relations of the Quaternary gravel shown at the north end of the map and similar occurrences at about the same altitude north of the mapped area suggest that the present trunk stream, which parallels the road shown at the north edge of figure 62, developed its course after the gravel was deposited. The small streams shown

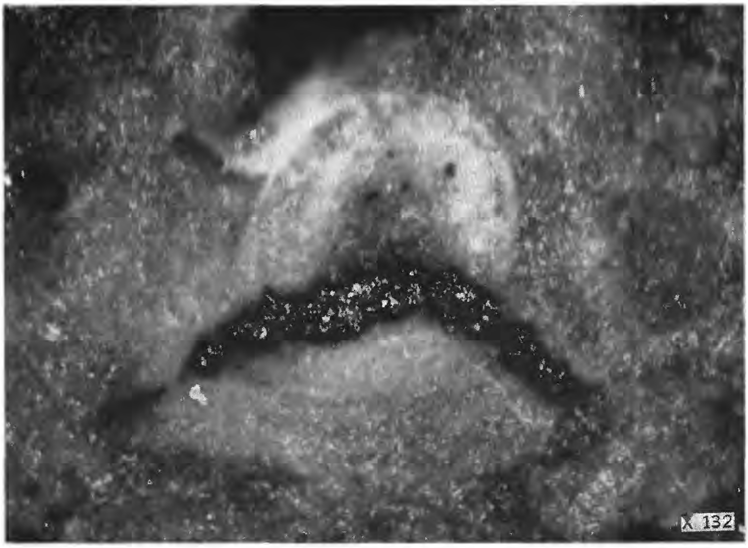


FIGURE 66.—Photomicrograph of limestone near Mayoworth showing opaque uranium(?) mineral veining an oolite. ×132.

on figure 62 are entrenched along their lower reaches. Along most of the stream that flows parallel to the strike along the contact of the limestone and shale there is no flood plain though there is a well-developed flood plain near its head in the south half of the map.

Anomalous radioactivity is confined to areas as high or higher than the Quaternary gravel and the patch of alluvium at the head of the strike valley. This suggests that at least some of the uranium concentration took place along the courses of mature streams as they entered the limestone at the two gaps in the flatirons shown on the west side of figure 62. Channels of flow would be northeast along the bedding-plane joints and the vertical joints parallel to the stream flow, and not along vertical northwest-striking joints perpendicular to the flow. Thus greater uranium concentrations should occur along the joints striking N. 70° E. and N. 15° W., as they do.

In the discussion of the uranium mineralogy it is suggested that some of the uranium minerals may be syngenetic. If this is true, syngenetic uranium could have been leached from the limestone up dip and reconcentrated as secondary metatyuyamunite along ground water channels such as joints and fractures in the limestone. Love (1954) suggests that solutions bearing uranium could have been derived from tuffaceous rock in the White River formation of Oligocene age, which may have covered this area. Also, streams entering the Mayoworth area could have derived uranium from known bodies of radioactive rocks higher in the Bighorn Mountains (Hose, 1954, and Jones, 1952).

ECONOMIC POTENTIAL

About 20,000 square feet within the area mapped is more radioactive than 0.05 milliroentgens per hour (mr per hr). Maximum radioactivity is 2 mrperhr in the large mineralized zone in the north half of the area (fig. 62) where the background is 0.1 mrperhr. There are several areas of high radioactivity in the south half of the mapped area where a maximum radioactivity of 0.25 mrperhr was noted. The average background for the southern area is 0.025 mrperhr. Radioactive localities also occur in the limestone north and south of the area mapped.

Analyses of samples from the Mayoworth deposits indicate that the radioactivity ranges from 0.04 to 0.16 percent equivalent uranium (see table below). The uranium content ranges from 0.017 to 0.32 percent. The V_2O_5 content ranges from 0.06 to 0.17 percent. The $CaCO_3$ content of sample 214833 is 96.3 percent.

Analyses of samples from the Mayoworth area

Laboratory sample No.	eU (percent)	U (percent)	V_2O_5 (percent)	Description of sample	Location
D-97107 [1]	0. 16	0. 21	0. 17	Selected sample of oolitic limestone.	Radioactive deposit 500 feet south of road.
D-97108 [1]	. 039	. 052	. 06	Grab sample of oolitic limestone.	Do.
RW-5132 [2]	--------	. 32	--------	Selected sample of oolitic limestone.	Do.
214833 [1]	. 040	. 017	. 10	Grab sample of oolitic limestone.	½ mile south of mapped area.

[1] Analysts: S. Furman, W. Mountjoy, J. Wilson, H. Lipp, J. Schuch, U. S. Geological Survey.
Analyst: J. J. Warr, U. S. Geological Survey.

The known uranium deposits of the Mayoworth area are of sub-ore grade, and of small size. Vanadium content of the deposits is too small to provide a by-product. From the available information it is unlikely that large, high-grade deposits occur in the oolitic limestone.

LITERATURE CITED

Hose, R. K., 1954, Geology of the Crazy Woman Creek area, Johnson County, Wyo.: U. S. Geol. Survey Oil and Gas Map OM 142.

Jones, E. E., 1952, Airborne radiometric survey of the east flank of the Big Horn Mountains, Wyoming and Montana: U. S. Atomic Energy Commission RME-4006, Tech. Inf. Service, Oak Ridge, Tenn.

Love, J. D., 1954, Uranium in the Mayoworth area, Johnson County, Wyo.—A preliminary report: U. S. Geol. Survey Circ. 358.

O

26[4]		do	.000X	0	.00X	0	0	.00X	0	0	0	.000X–	0	.0X–	.000X
14	G2	do	.000X	0	.00X	0	0	.00X	0	0	0	.000X–	0	.0X	.000X–
43	e5	Green coarse-grained arkosic sandstone with chalcocite	.00X–	0	0	0	0	.00X–	0	0	0	.000X	0	.0X	.000X–
21[4]		Fossiliferous limestone with chalcocite and malachite	Tr.	0	0	0	0	.00X	0	0	0	.000X–	0	.00X	0
Standard spectrographic sensitivity			.001	.05	.005	.001	.01	.001	.05	.005	.05	.0005	.05	.001	.001

[1] Example of notation, in percent: XX, > 10; 0.X+, 0.464 to 1.0; 0.X, 0.215 to 0.464; 0.X–, 0.100 to 0.215; Tr., near threshold amount.

[2] Colorimetric analyses by H. E. Crowe, R. R. Beins and C. E. Thompson show approximately 150 ppm As, 120 ppm Mo, 50 ppm Se, and 4 ppm Ge. Radiochemical analyses of uranium daughter elements by J. N. Rosholt, Jr., show 1.34 percent Th^{230} ionium), 1.22 percent Pa^{231}, 1.08 percent Ra^{226}, 0.92 percent Rn^{222}, and 0.94 percent Pb^{210}. The figures are the amounts of uranium required to produce the daughter elements present assuming equilibrium conditions and a normal uranium isotope abundance. The data indicate the disequilibrium is caused by leaching of uranium and that the original uranium content could have been as high as 1.34 percent.

[3] Assay figures are for bulk sample.

[4] Locations shown on plate 24.

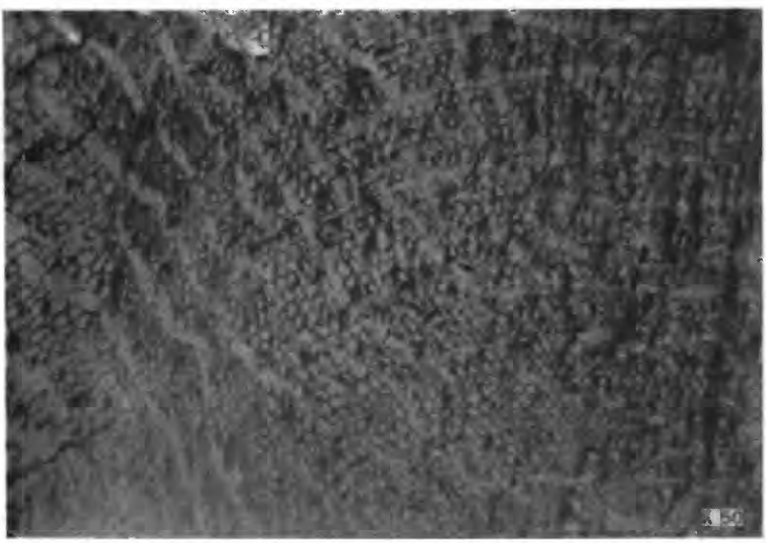
Area F, Arturo Le Deux property.—Massive pink medium-grained limy micaceous arkosic sandstone contains uranium and vanadium between pits f9 and f12 (pl. 29). The sandstone ranges in thickness from a featheredge to 4 feet and crops out sporadically at the surface. This sandstone is about 770 feet above the base of the formation and is enclosed in copper-bearing gray shale containing thin seams of black shale. Metatyuyamunite is concentrated in micaceous seams at the contact of the sandstone and the shale in pit f11 and disseminated through the sandstone in pit f9. A high-grade ore pocket found 2 feet below the surface in the featheredge of the sandstone in pit f11 probably extends to the north end of pit f12. The ore between depths of 2 and 4 feet is less than 2 feet thick. The radioactivity is not above background count south of pit f12 and north of pit f8, and no other uranium deposits were found in this zone. The analyses in table 7 indicate that uranium has been leached from the uraniferous shale and redeposited in the adjacent sandstone. The lack of control by sedimentary structures within the sandstone and the close association with copper-bearing shale are exceptional.

Three nearly vertical fluviatile sandstone beds between 1,920 and 1,960 feet above the base of the Sangre de Cristo formation contain uranium or vanadium deposits in the eastern part of area *F*. The middle or main uranium-bearing sandstone is a gray-brown poorly sorted, massive limy sandstone about 6 or 8 feet thick. This sandstone contains isolated concentrations of uranium in each pit between f19 and f26. Pockets of uranium ore occur chiefly in poorly defined lenses of coarse, pink, limy sandstone that contains carbonized wood and gray or black clay and limestone fragments. The pink color is distinctive and becomes more intense as the radioactivity increases. Black micaceous vanadium minerals impregnate the sandstone along bedding planes and partly surround the uranium pockets. The black color of clay fragments in ore of high vanadium content probably is the result of adsorbed vanadium, but at least part of the vanadium is in the clay mineral structure. The ore-grade material is less than a foot thick except in pits f23 and f26 where metatyuyamunite is abundant.

Several vertical slickensided joints cut the sandstone between pits f23 and f26. One joint contains nonradioactive caliche and iron oxides. A narrow zone of sandstone adjacent to this joint is barren; beyond this a zone impregnated with black vanadium minerals is parallel to the joint and partly envelops a small uranium pocket.

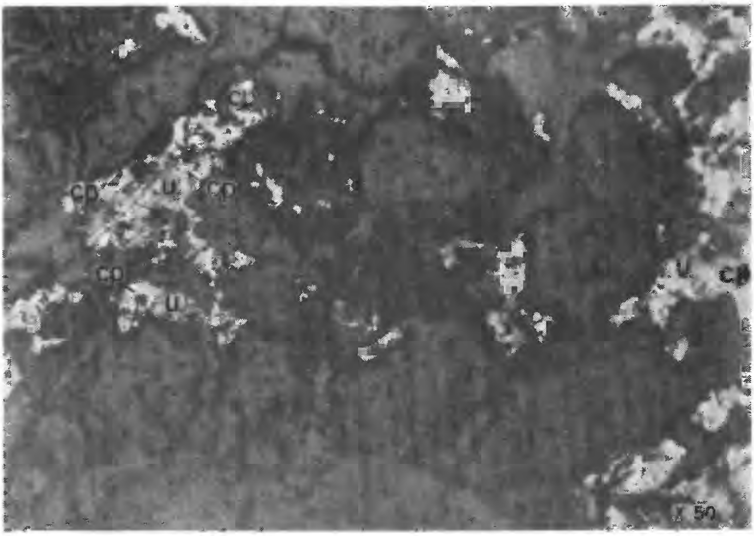
The lowest of the three sandstone beds contains small vanadium deposits, but the uranium content is low. The highest of the three sandstone beds is represented by a group of small isolated hard white massive fine-grained limy sandstone lenses at about the same stratigraphic position above the main ore-bearing sandstone. Several of

A. Polished longitudinal section of carbonized wood (dark gray) replaced by blue chalcocite (gray) containing residual grains of pyrite and bornite (not visible). X 50.

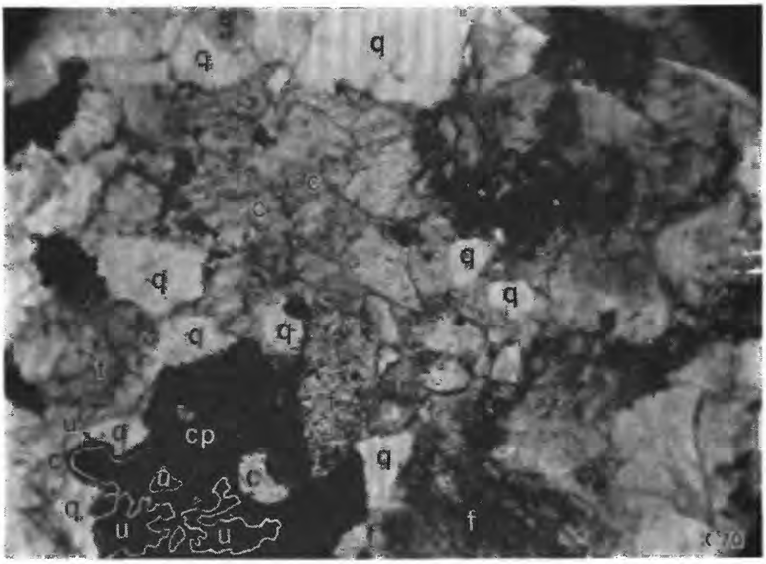


B. Polished cross section of carbonized wood (dark gray) replaced by gray chalcocite (gray) and minor covellite (not visible). Shows cell structure and growth rings. X 50.

PHOTOMICROGRAPHS OF COPPER ORES, COYOTE DISTRICT, MORA COUNTY, N. MEX.



A. Polished section of uraniferous sandstone, Blas Medina property, pit b-4. Quartz and feldspar (high relief) and calcite (low relief) replaced by chalcopyrite (*cp*) and black uraniferous substance (*u*). X 50.



B. Thin section of hematitic uraniferous sandstone, Blas Medina property, pit b-4. Quartz (*q*), hematite-impregnated feldspar (*f*), and calcite (*c*), replaced by chalcopyrite and black uraniferous substance. X 70.

PHOTOMICROGRAPHS OF URANIFEROUS SANDSTONE, COYOTE DISTRICT, MORA COUNTY, N. MEX.

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.

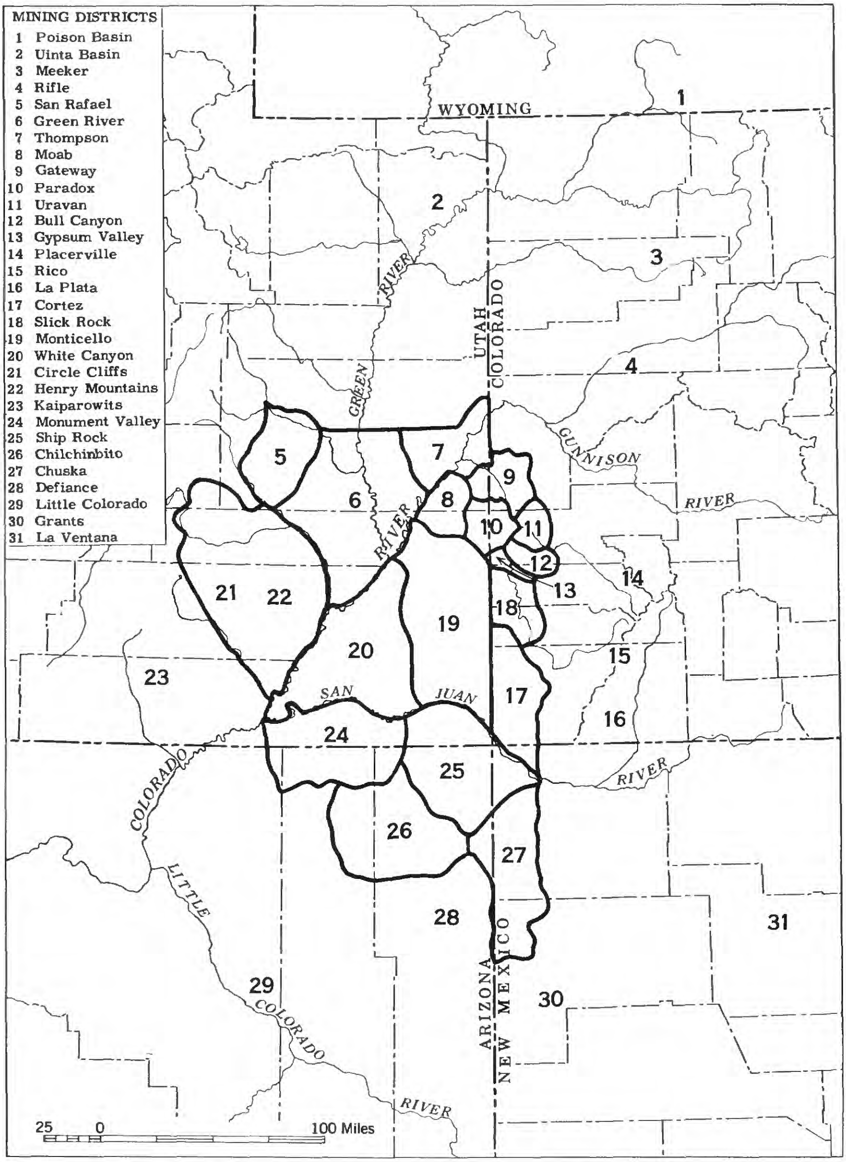


FIGURE 75.—Index map of part of the Colorado Plateau showing location of mining districts.

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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.

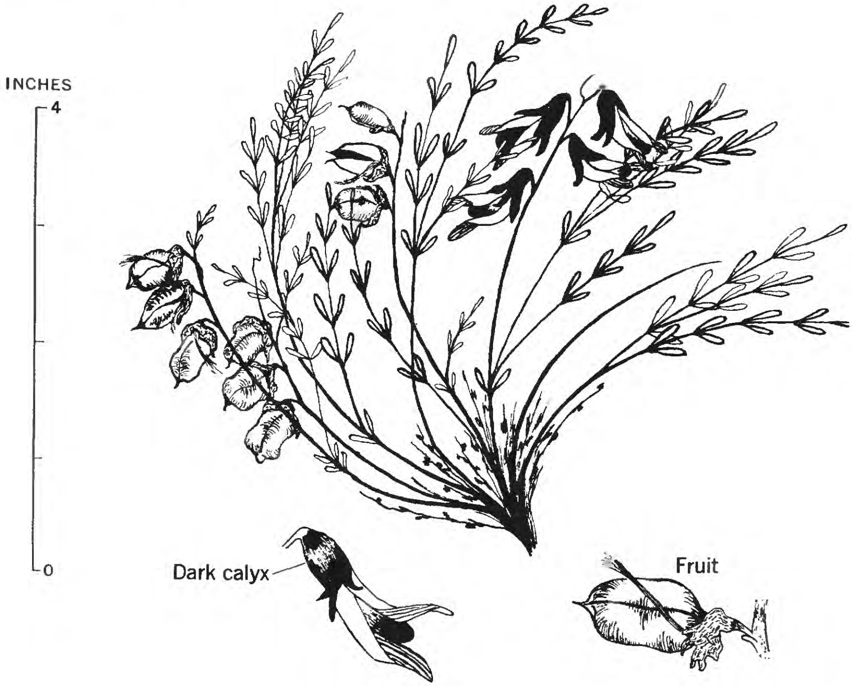

FIGURE 78.—*Astragalus preussi* A. Gray.

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

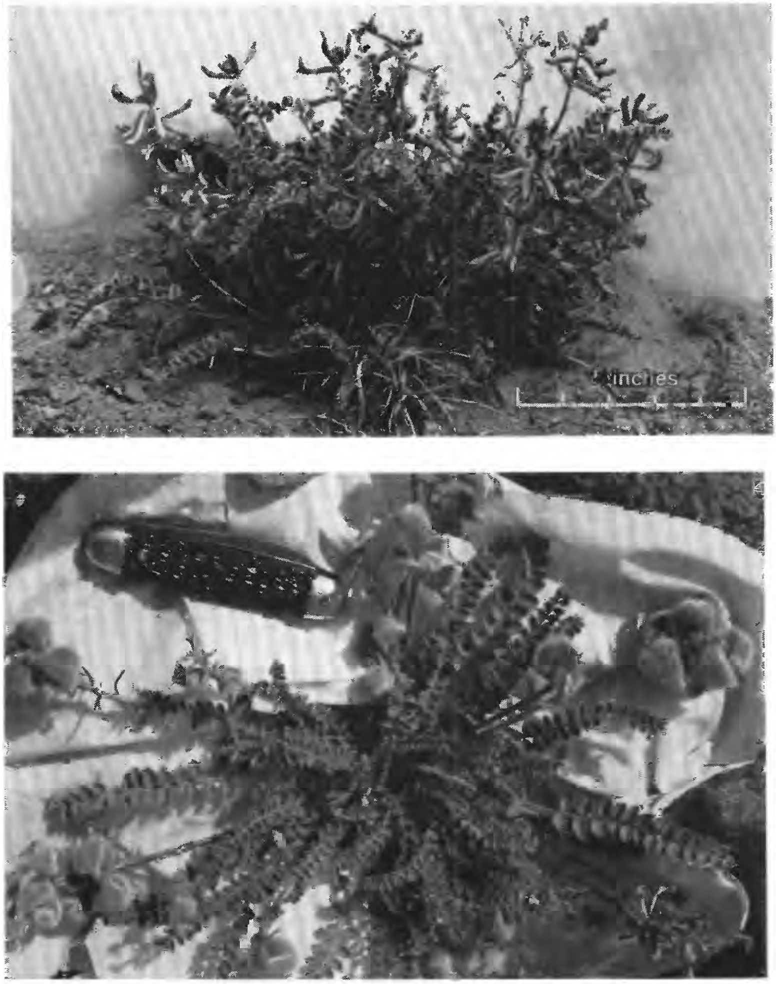

FIGURE 81.—Thompson loco.

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.

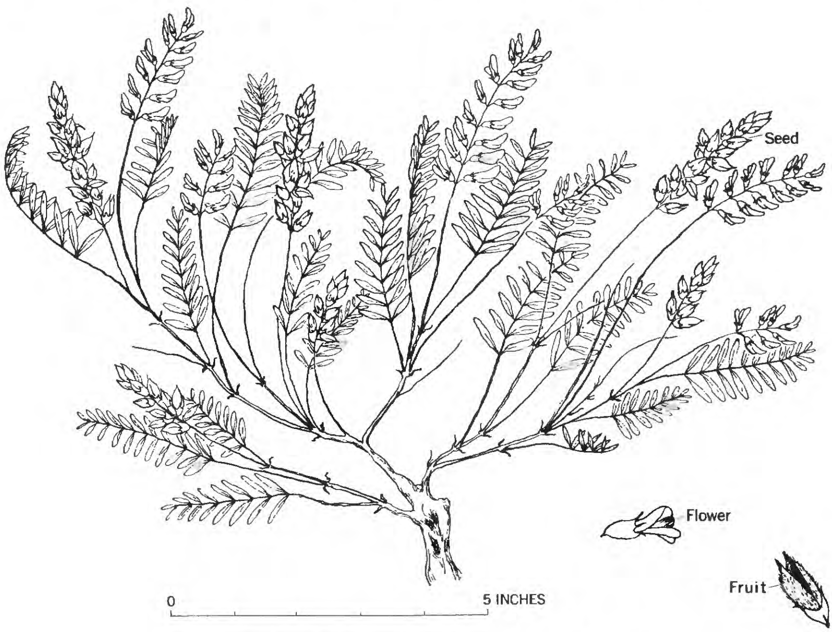

FIGURE 82.—*Astragalus confertiflorus* A. Gray.

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.

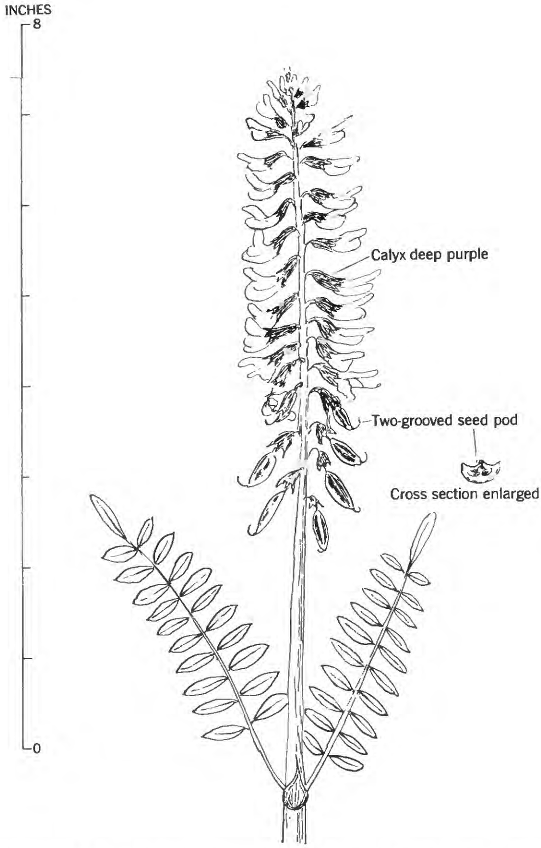

FIGURE 84.—*Astragalus bisulcatus* (Hook.) A. Gray.

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.

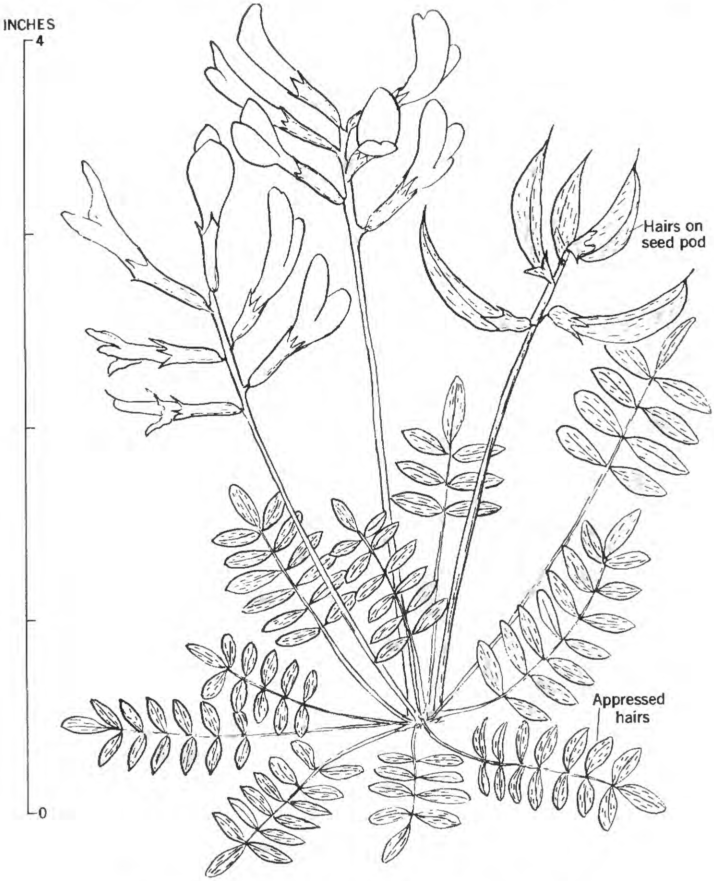

FIGURE 86.—*Astragalus missouriensis* Nutt.

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.

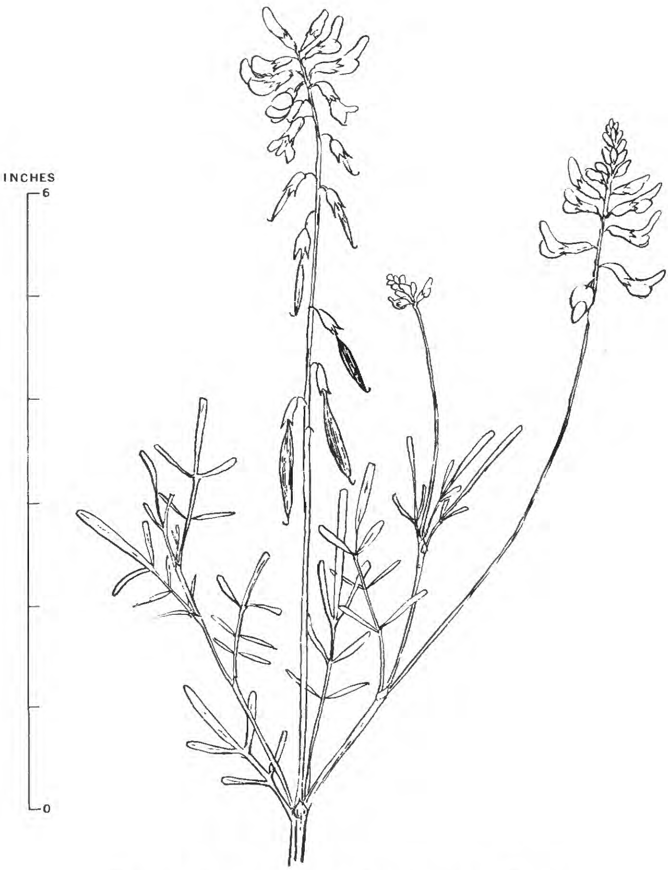

FIGURE 88.—*Astragalus lonchocarpus* Torr.

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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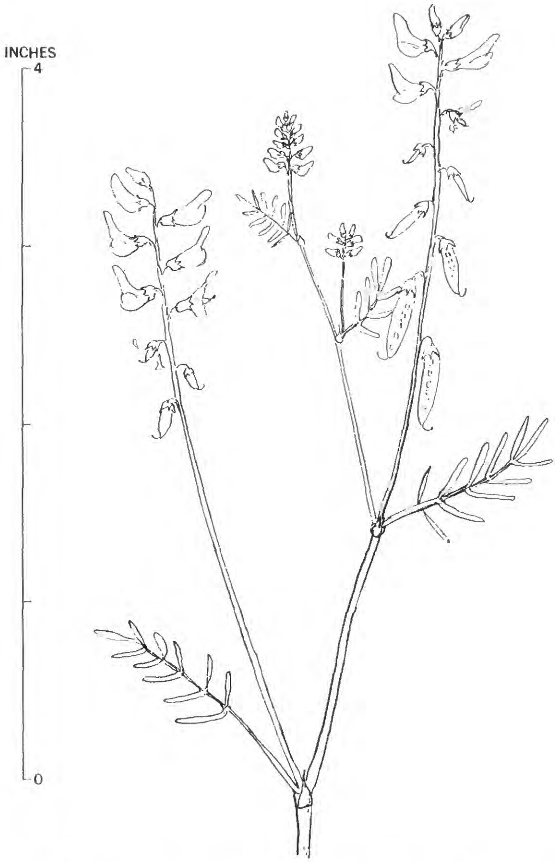

FIGURE 90.—*Astragalus* dodgianus Jones.

Family: Pea, Leguminosae.
Subgenus: *Homalobus.*
Flowers: Irregular, white, pealike flowers with purple-tipped keel. 1/3 inch. Black hairs on calyx which has triangular teeth. Blooms in May.
Leaves: Odd pinnate with 9 to 11 linear leaflets 1/3 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.

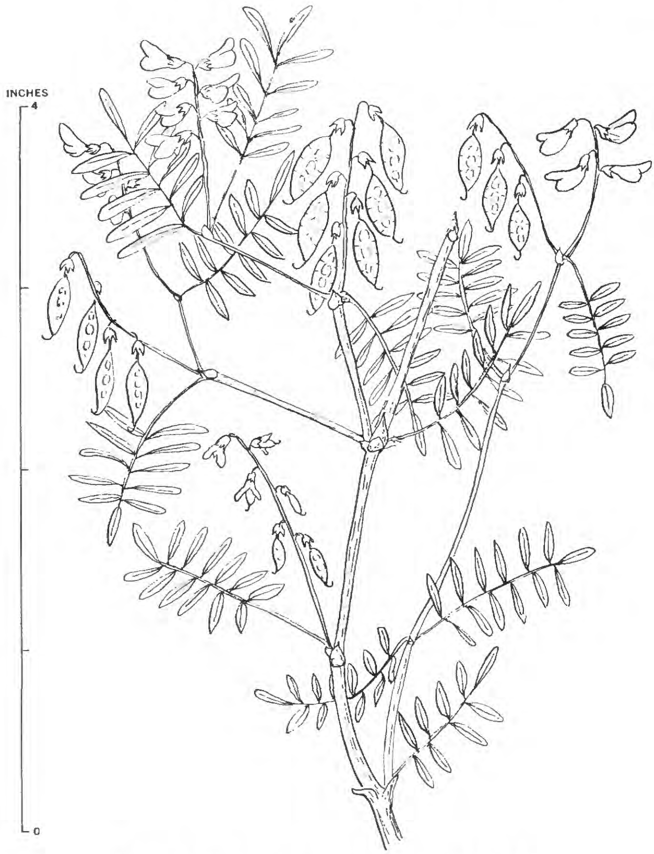

FIGURE 92.—*Astragalus tenellus* Pursh.

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.

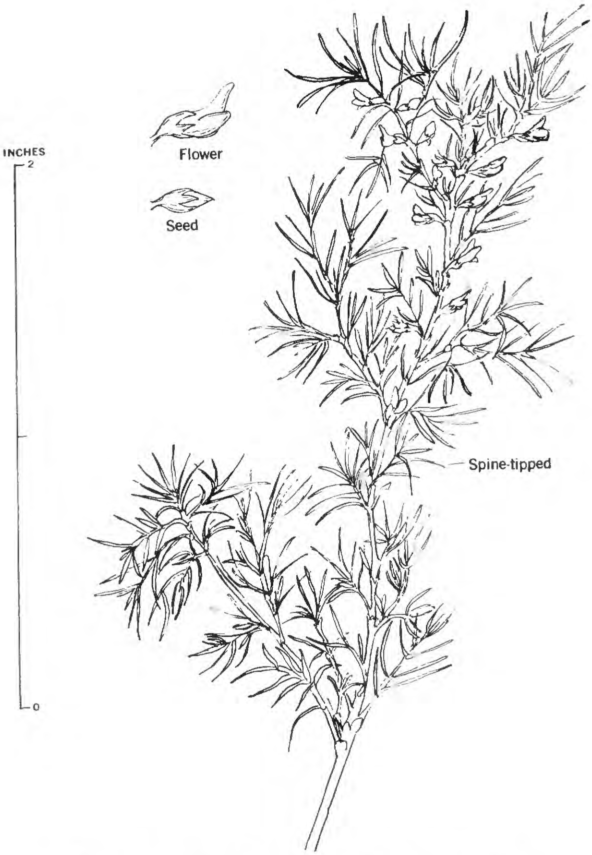

FIGURE 94.—*Astragalus aculeatus* A. Nels.

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

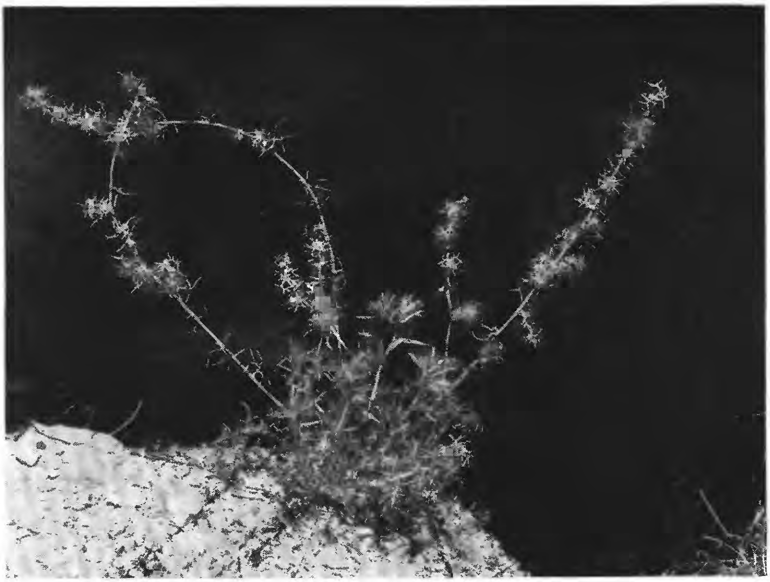

FIGURE 95.—Spiny milkvetch.

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.

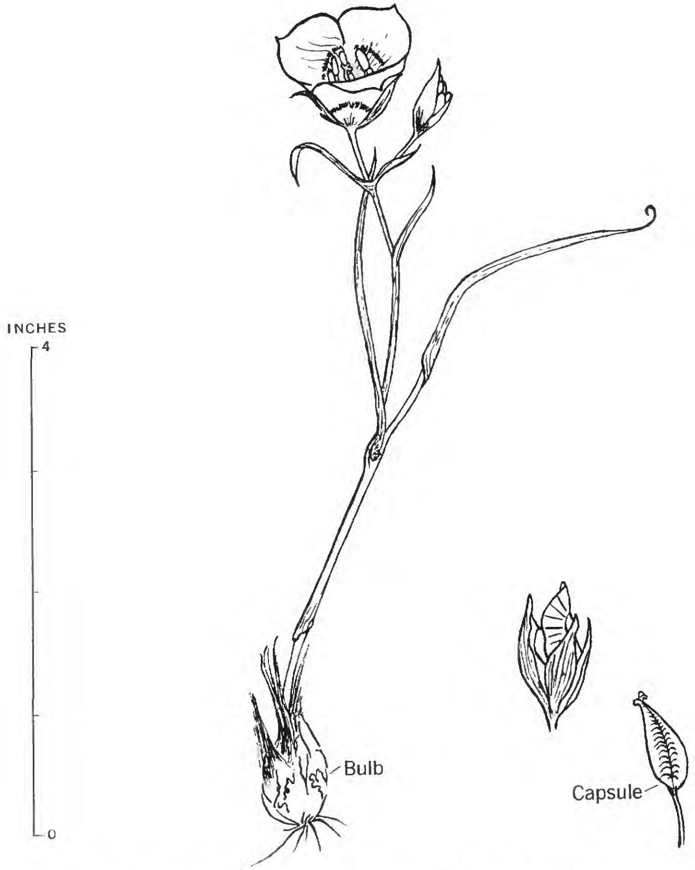

FIGURE 98.—*Calochortus nuttalli* Torr. & Gr.

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.

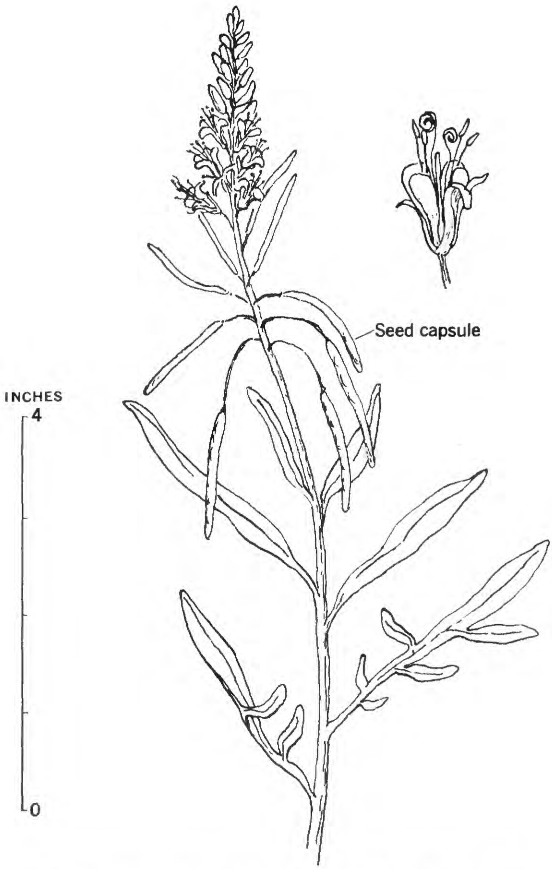

FIGURE 102.—*Stanleya pinnata* (Pursh) Britt.

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.

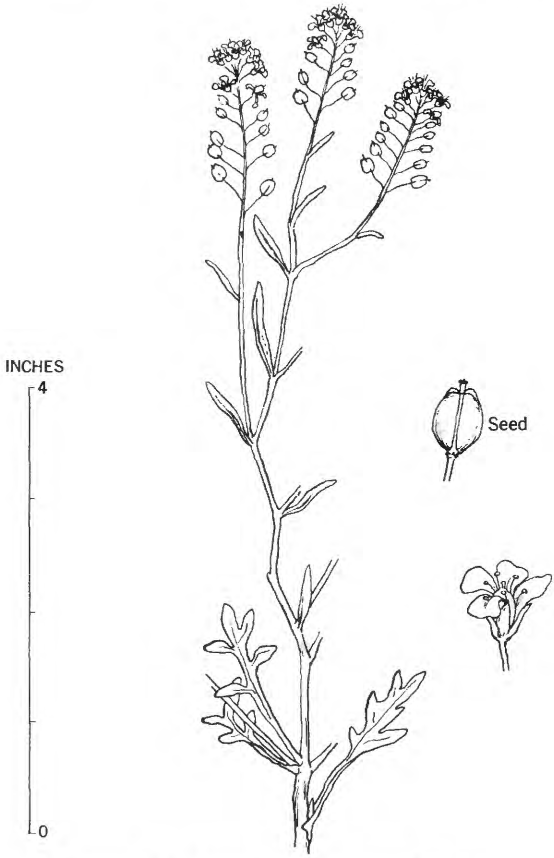

FIGURE 104.—*Lepidium montanum* Nutt.

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.

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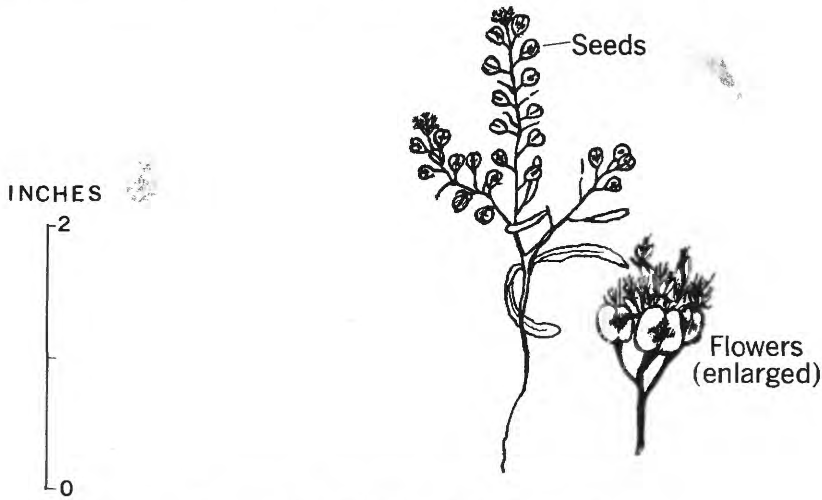

FIGURE 106.—*Lepidium lasiocarpum* Nutt.

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.

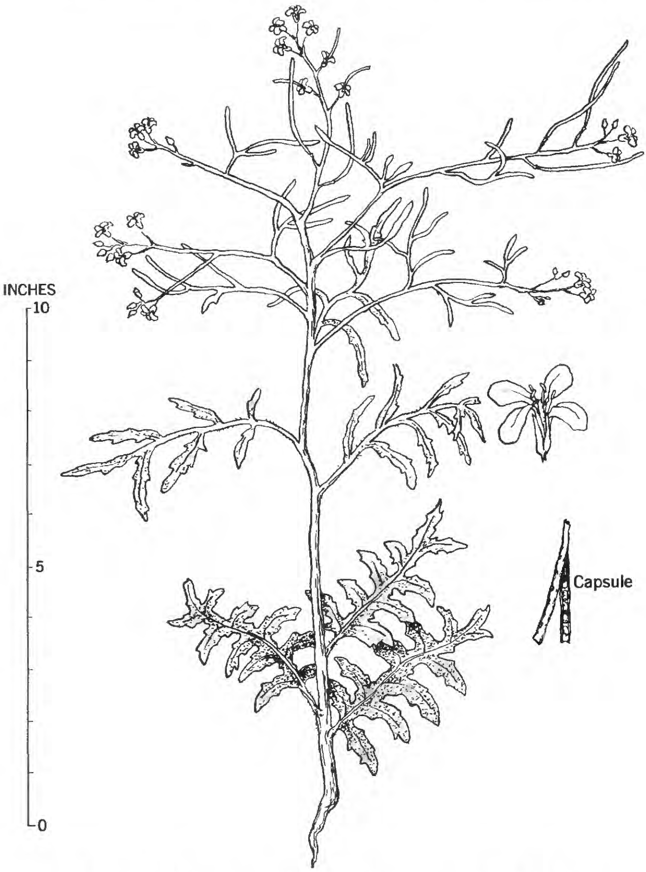

FIGURE 108.—*Sisymbrium altissimum* (L.) Britt.

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.

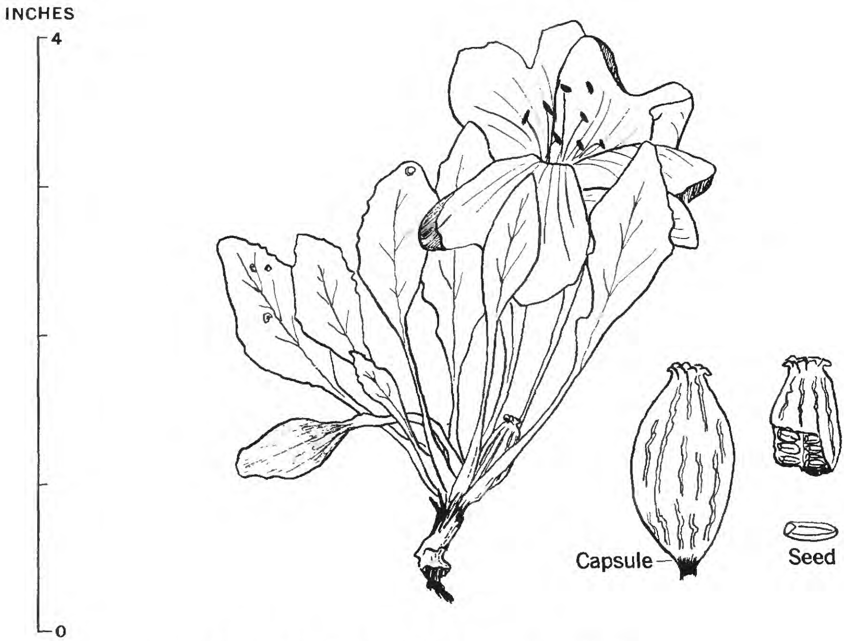

FIGURE 112.—*Oenothera caespitosa* Nutt.

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.

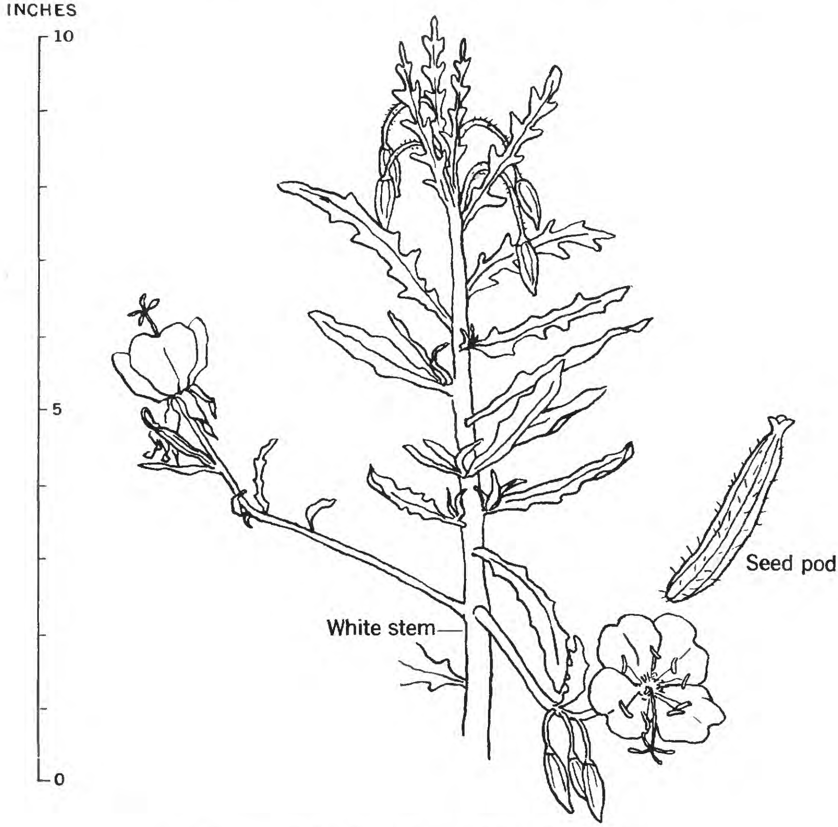

FIGURE 114.—*Oenothera albicaulis* Pursh.

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.

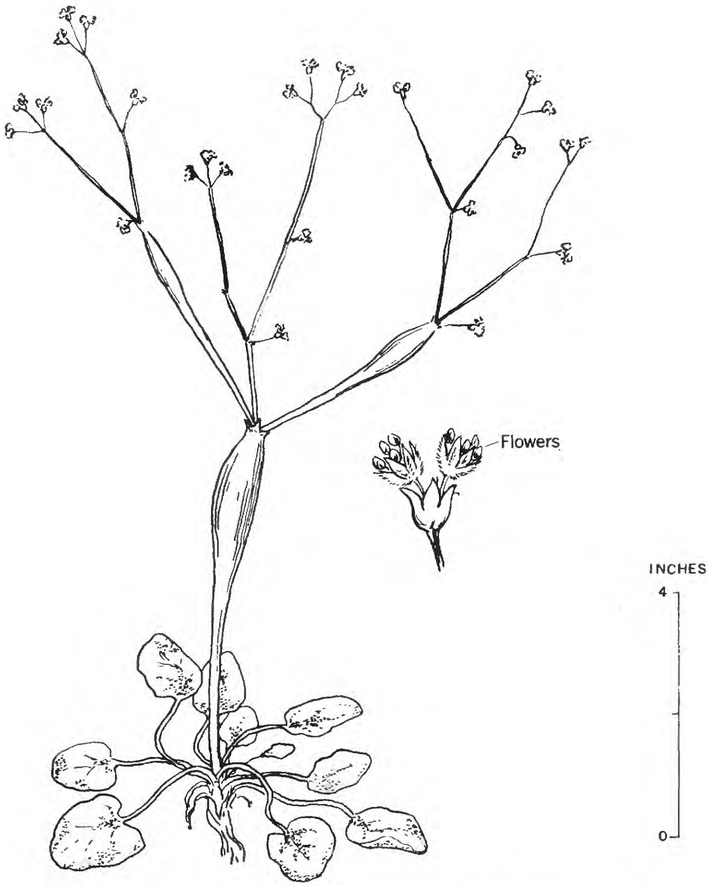

FIGURE 116.—*Eriogonum inflatum* Torr.

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.

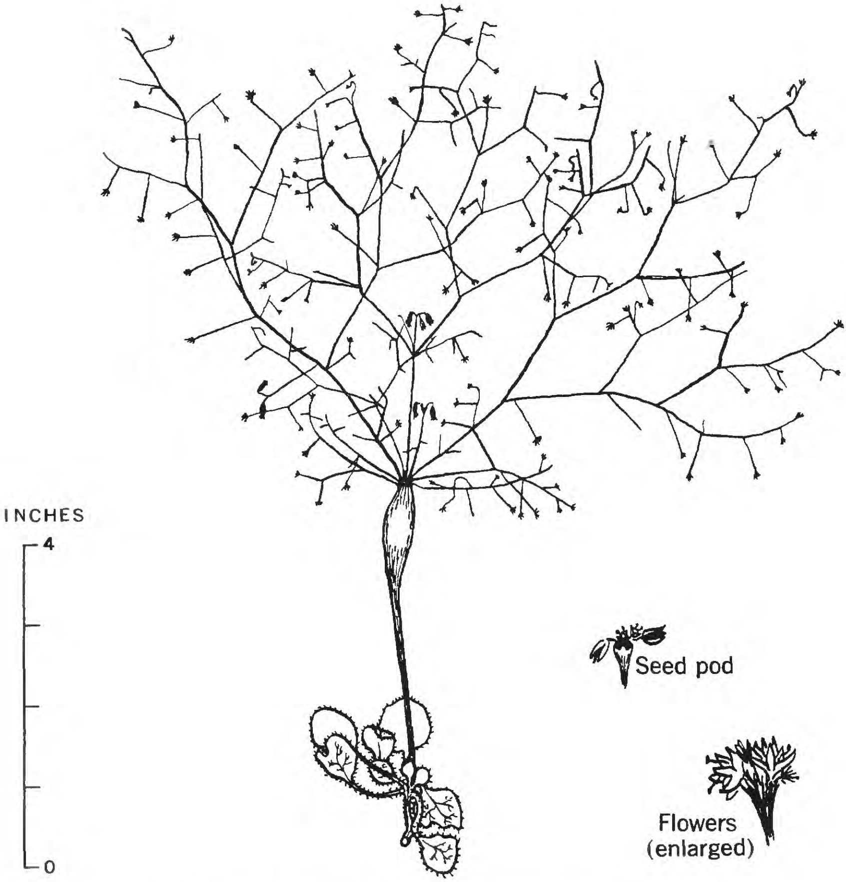

FIGURE 118.—*Eriogonum fusiforme* Small.

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.

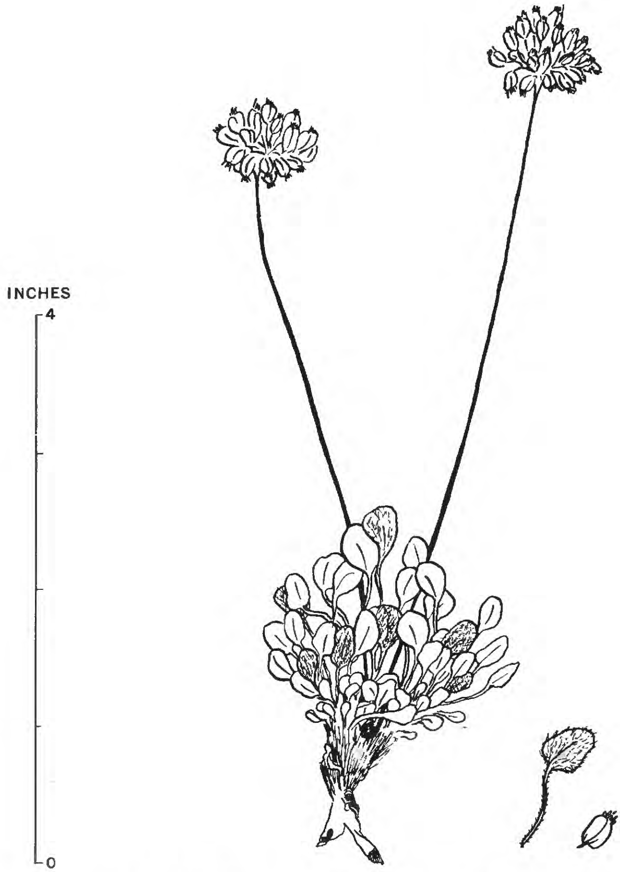

FIGURE 120.—*Eriogonum ovalifolium* Nutt.

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.

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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.

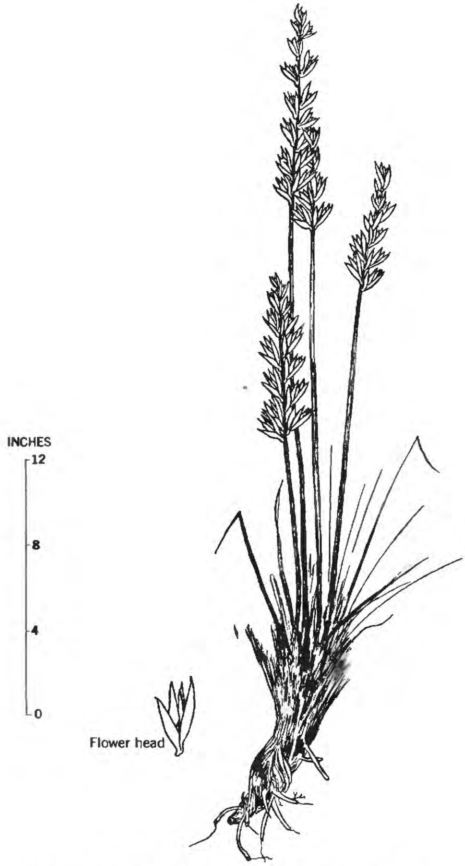

FIGURE 124.—*Elymus salina* Jones.

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.

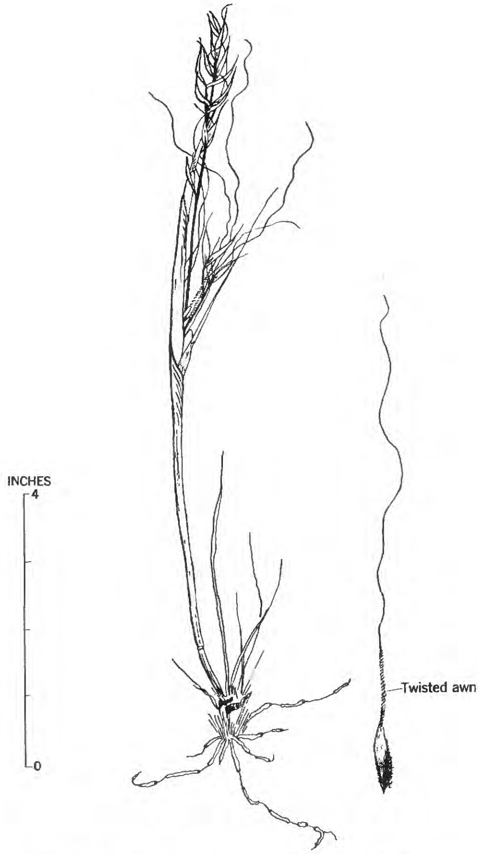

FIGURE 126.—*Stipa comata* Trin. & Rupr.

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.

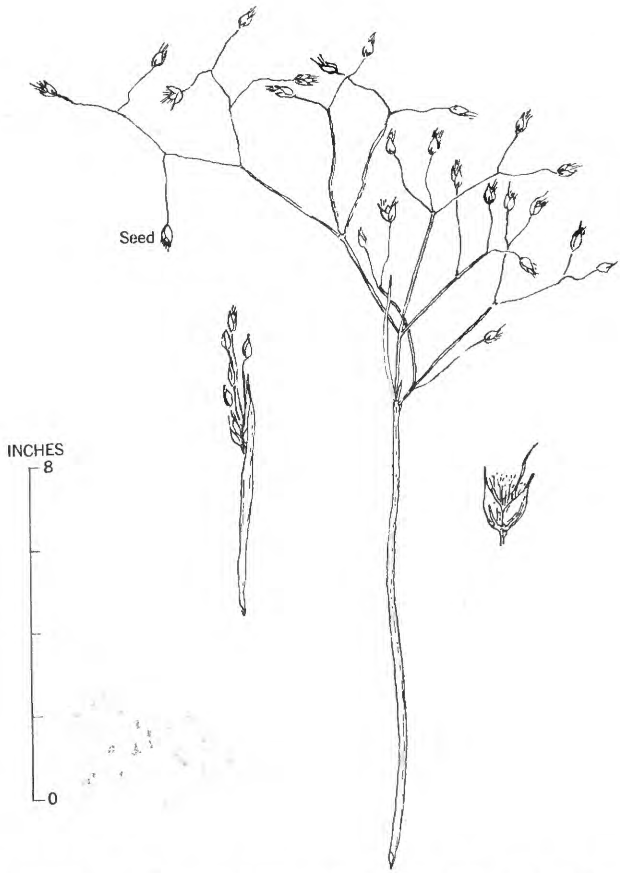

FIGURE 128.—*Oryzopsis hymenoides* (Roem. & Schult.) Rick.

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.

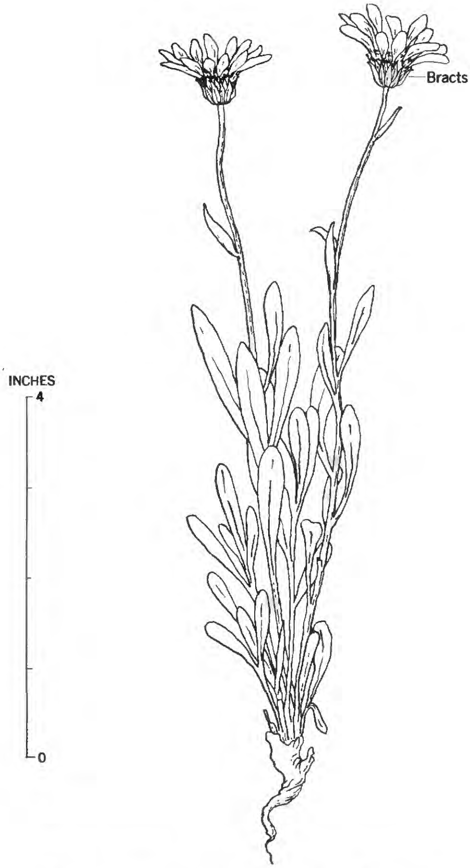

FIGURE 130.—*Aster venustus* Jones.

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.

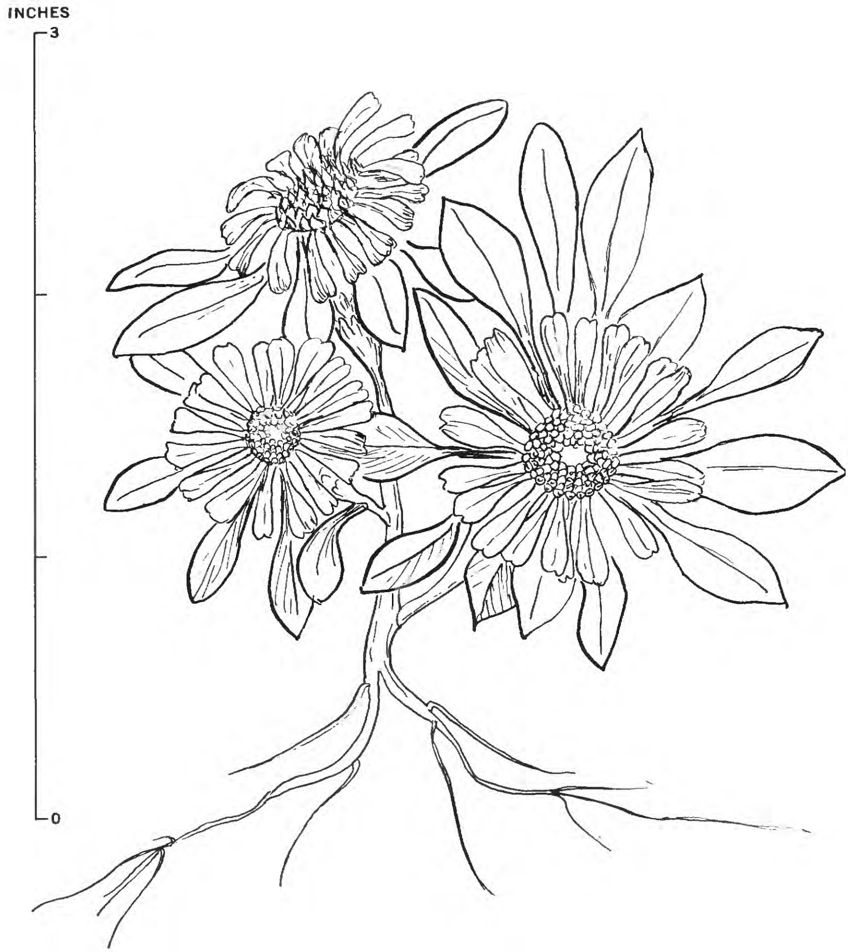

FIGURE 132.—*Townsendia incana* Nutt.

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.

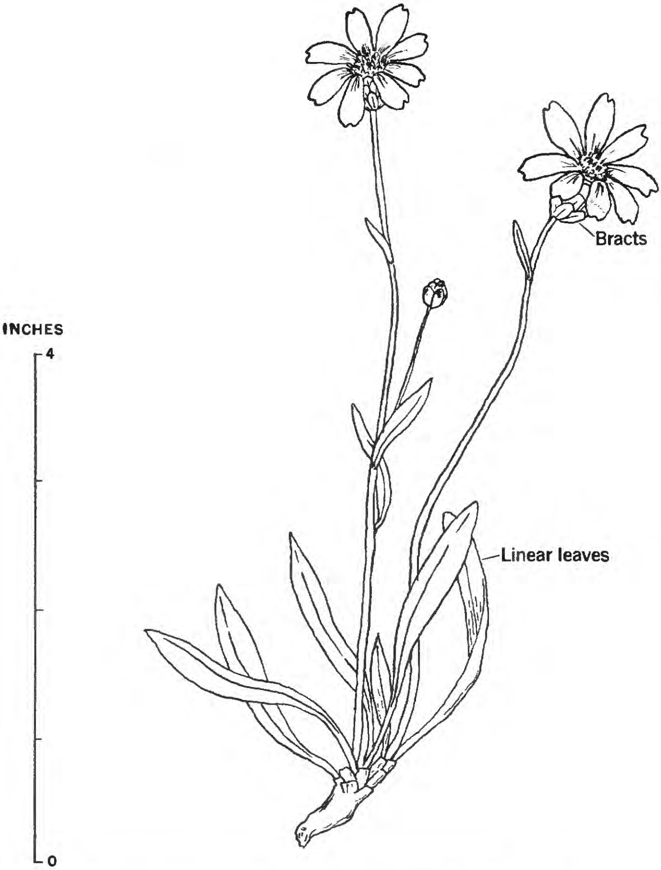

FIGURE 134.—*Aplopappus armeriodes* A. Gray.

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.

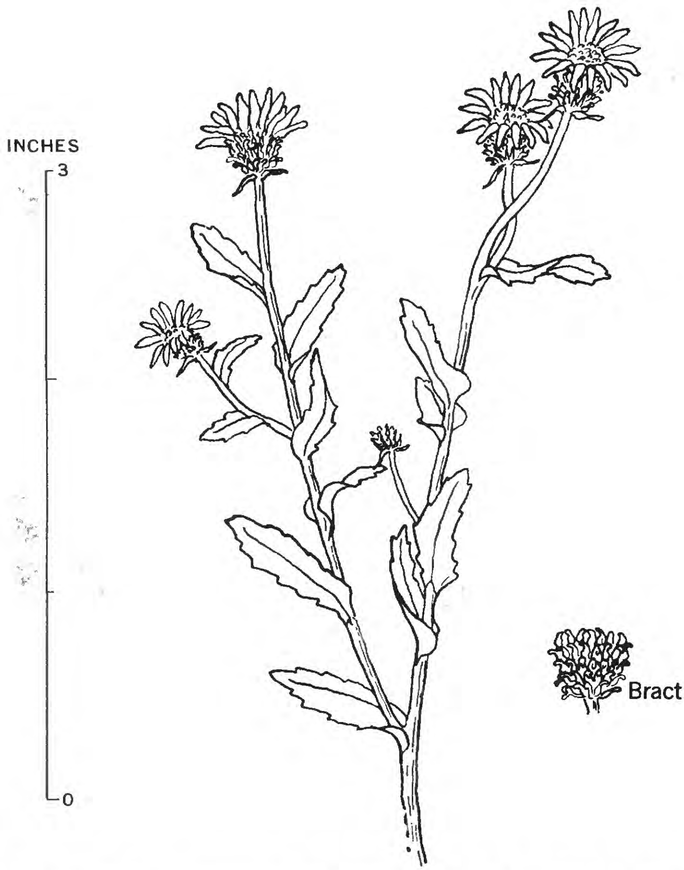

FIGURE 136.—*Grindelia squarrosa* (Pursh) Dunal, and closely related species.

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.

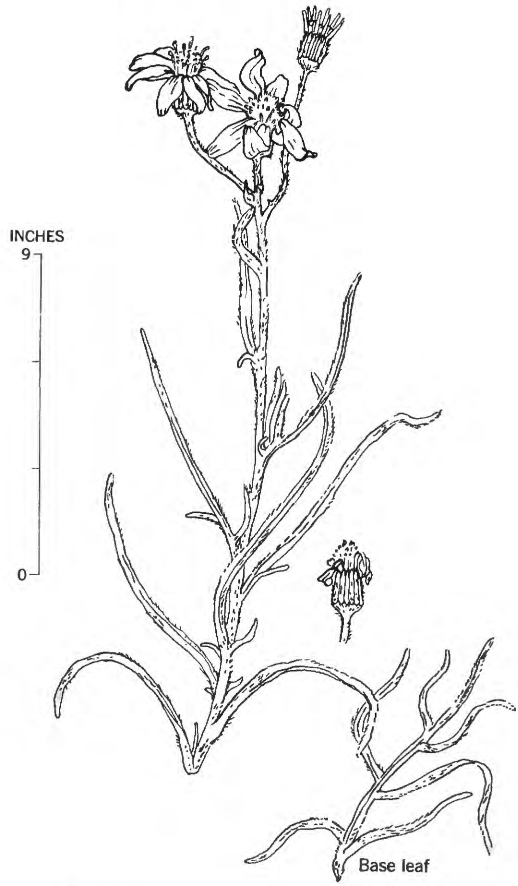

FIGURE 138.—*Senecio longilobus* Benth.

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.

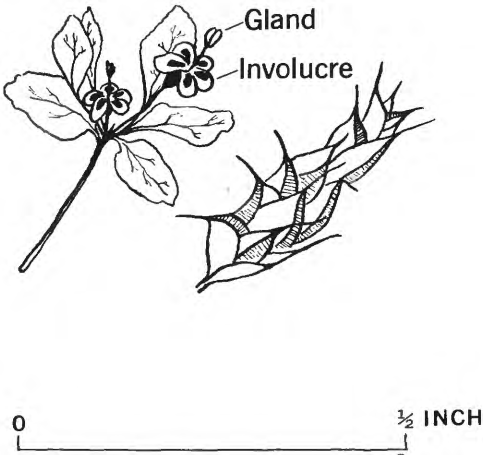

FIGURE 140.—*Euphorbia fendleri* Torr. & Gr., and related prostrate species.

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.

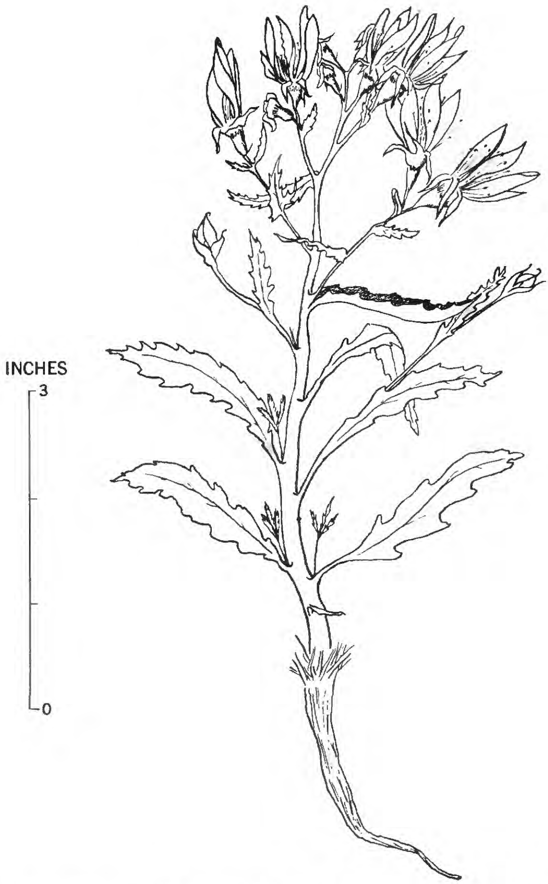

FIGURE 142.—*Mentzelia multiflora* (Nutt.) A. Gray. Several other species are similar in appearance.

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.

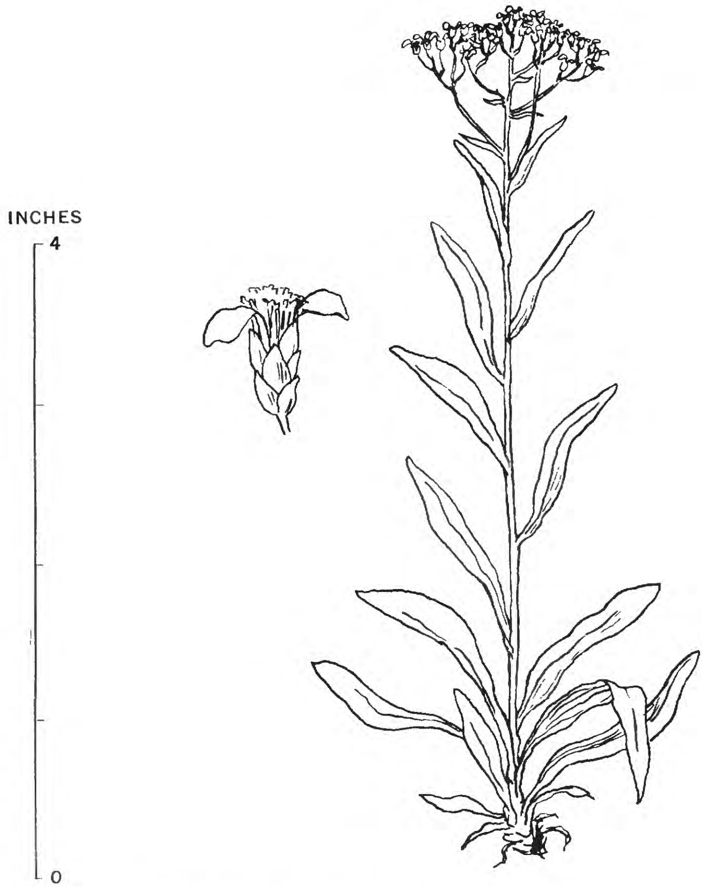

FIGURE 144.—*Solidago petradoria* Blake.

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.

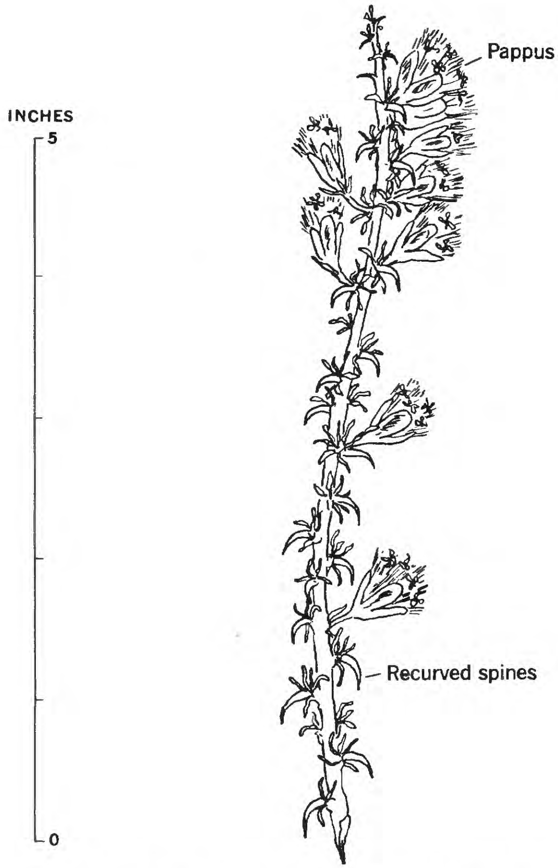

FIGURE 146.—*Tetradymia spinosa* Hook. & Arn.

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

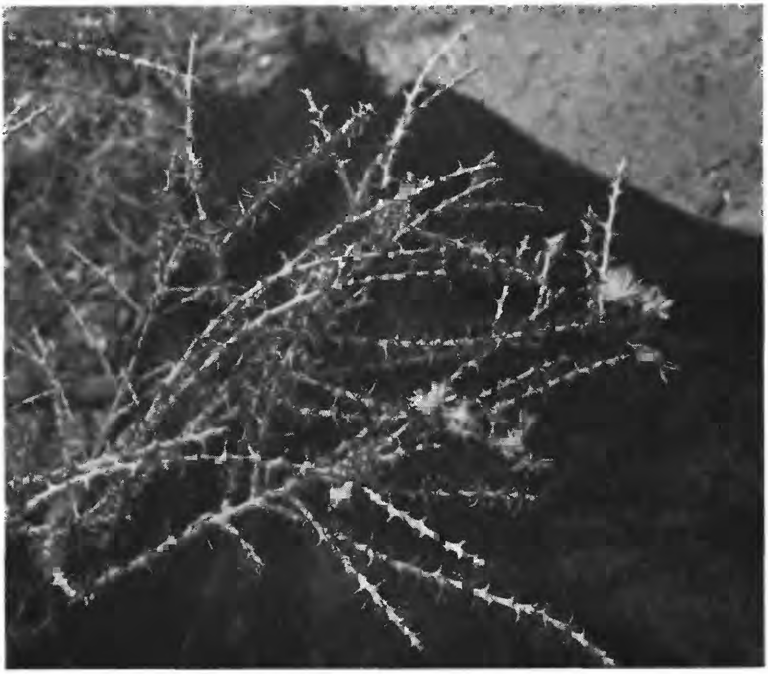

FIGURE 147.—Cottonthorn horsebrush.

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.

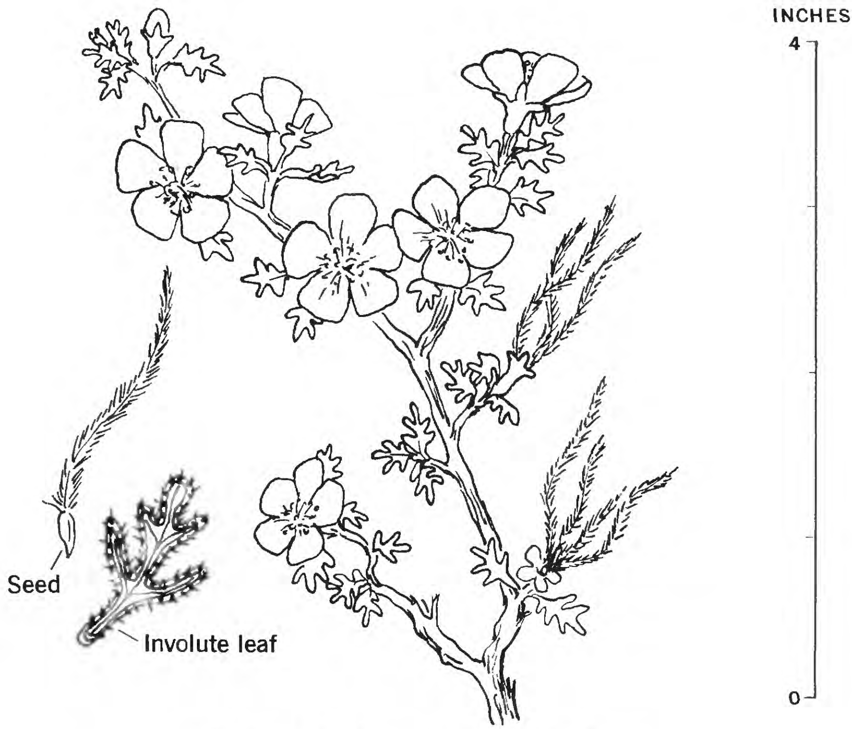

FIGURE 148.—*Cowania stansburiana* Torr.

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.

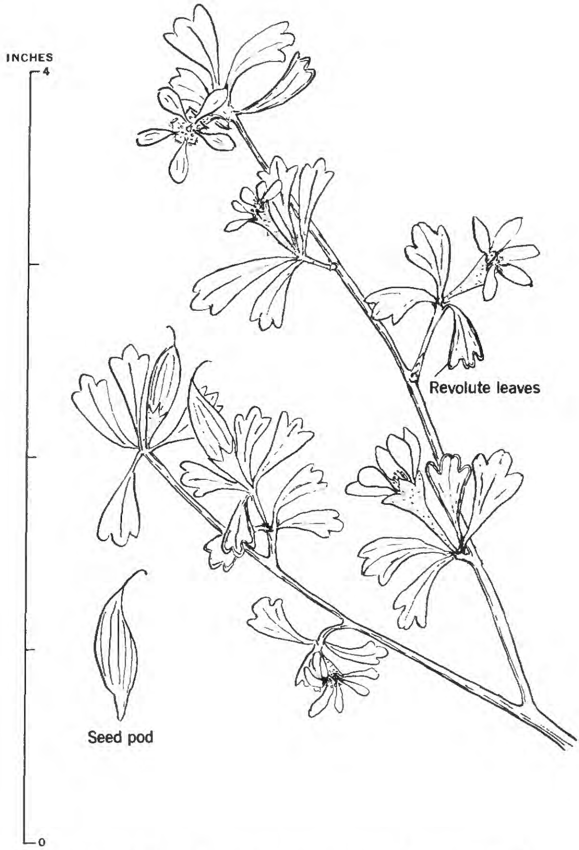

FIGURE 150.—*Purshia tridentata* (Pursh) DC.

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.

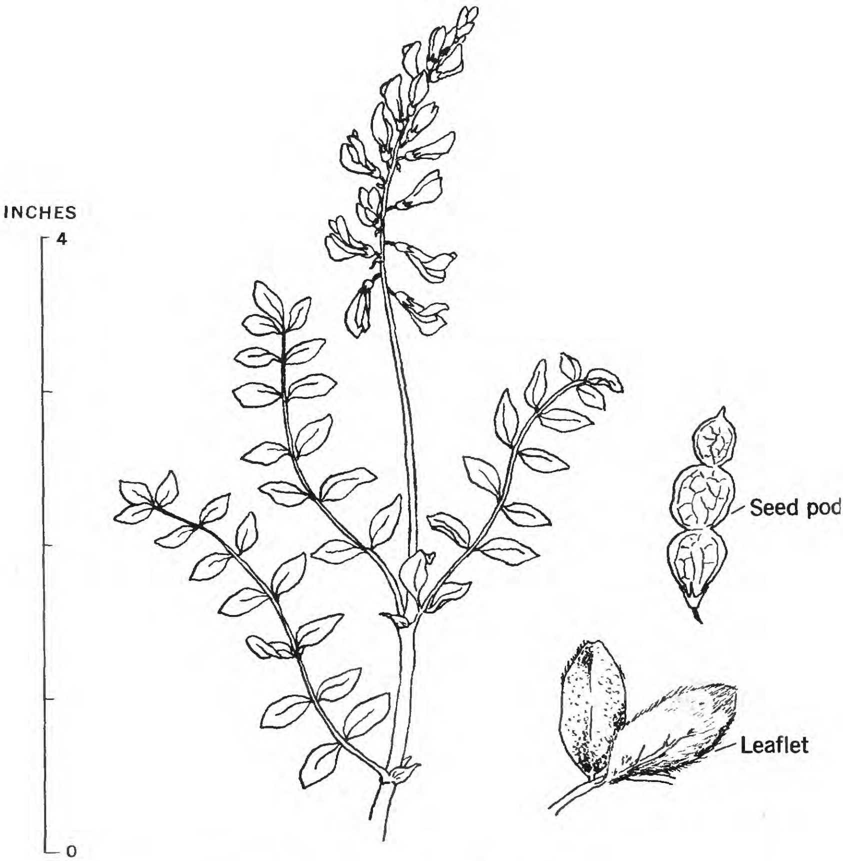

FIGURE 152.—*Hedysarum boreale* Nutt.

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.

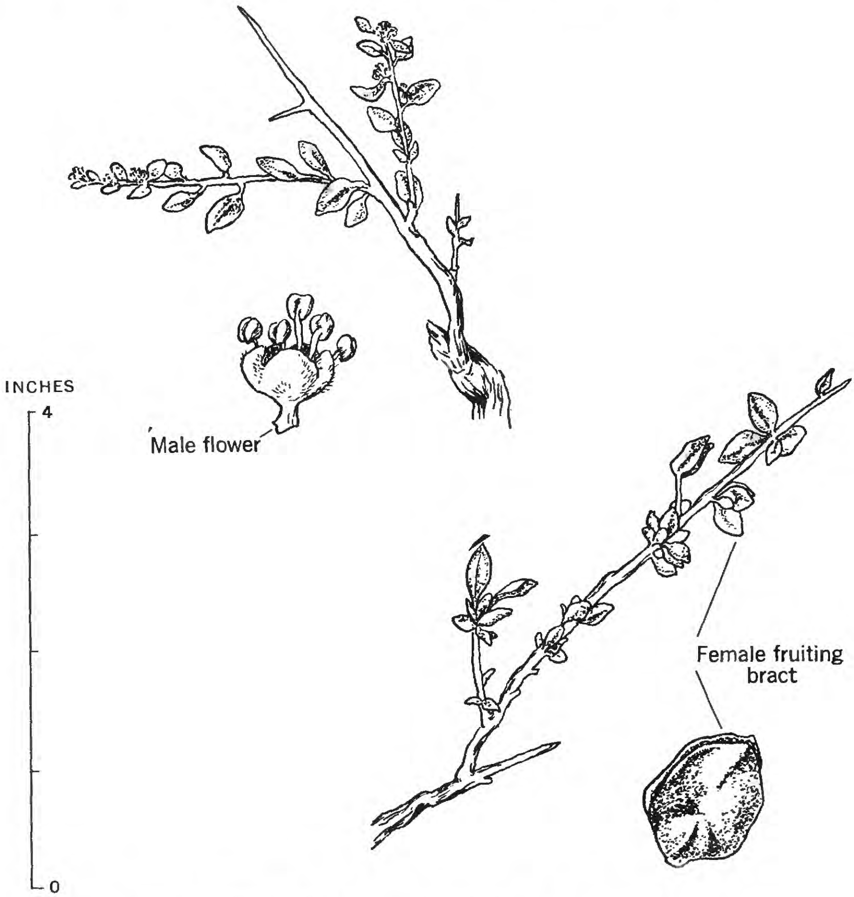

FIGURE 158.—*Atriplex confertifolia* (Torr.) S. Wats.

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.

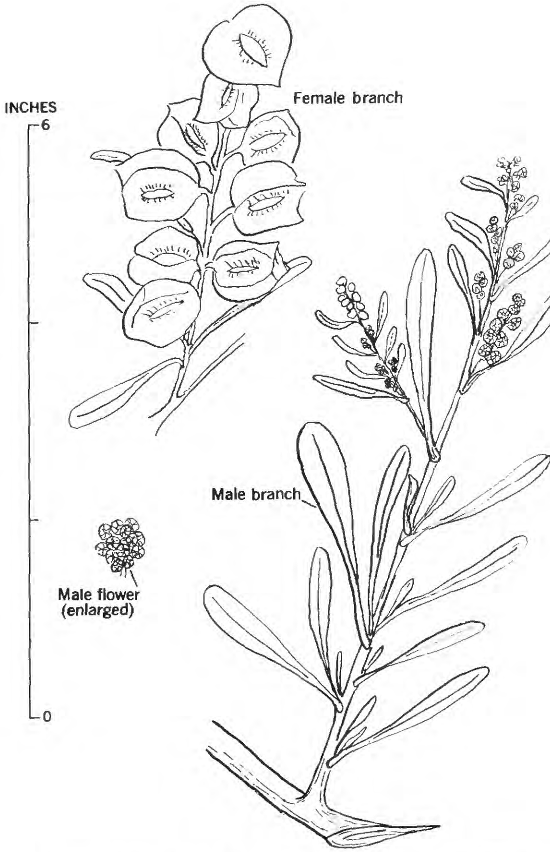

FIGURE 160.—*Atriplex canescens* (Pursh) Nutt.

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.

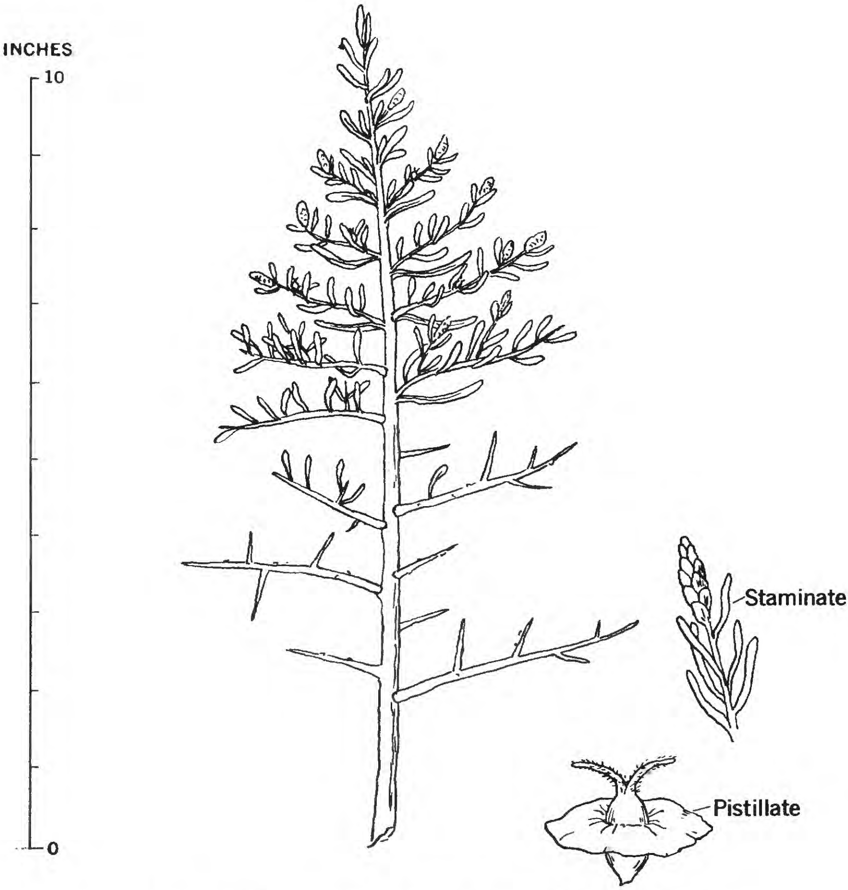

FIGURE 162.—*Sarcobatus vermiculatus* (Hook.) Torr.

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.

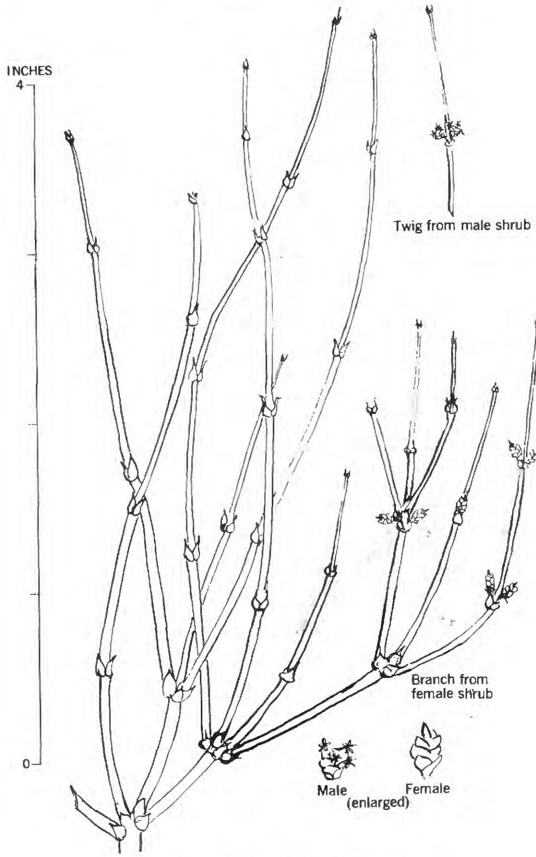

FIGURE 164.—*Ephedra* sp.

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.

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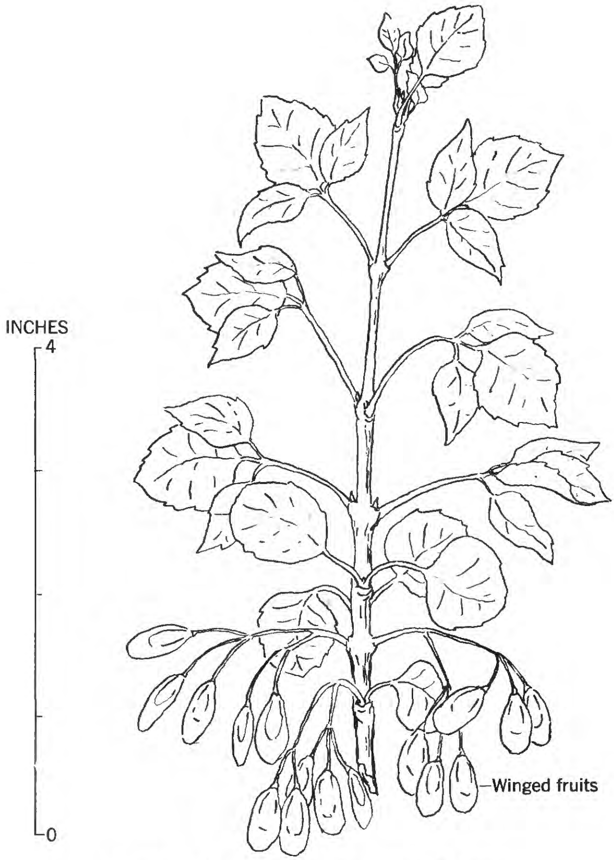

FIGURE 170.—*Fraxinus anomala* Torr.

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.

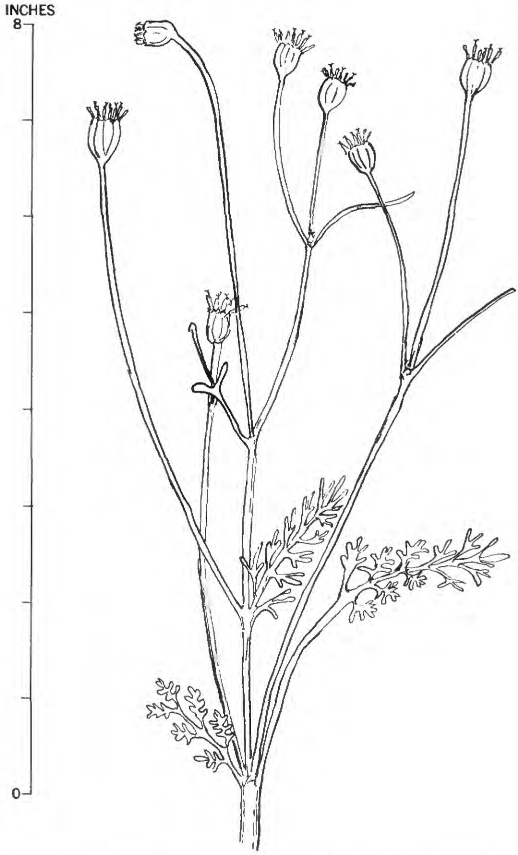

FIGURE 172.—*Hymenopappus filifolius* Hook.

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.

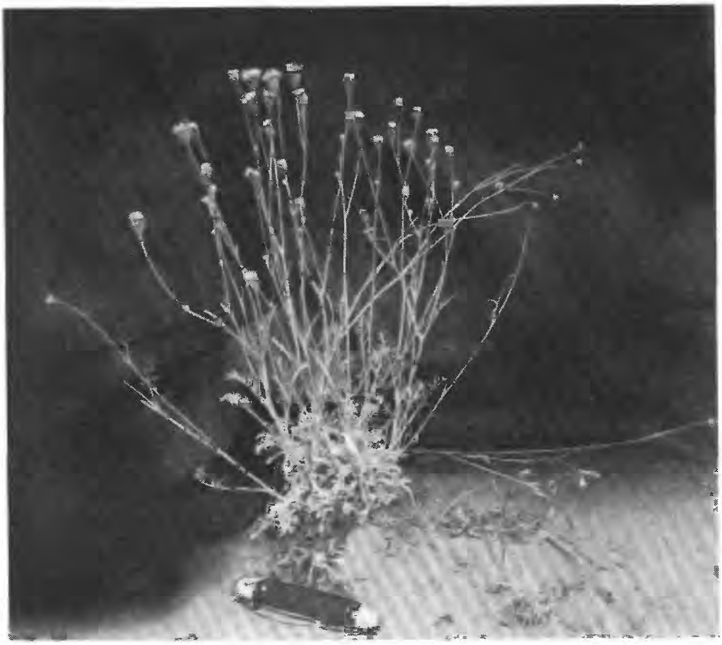

FIGURE 173.—Fineleaf hymenopappus.

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

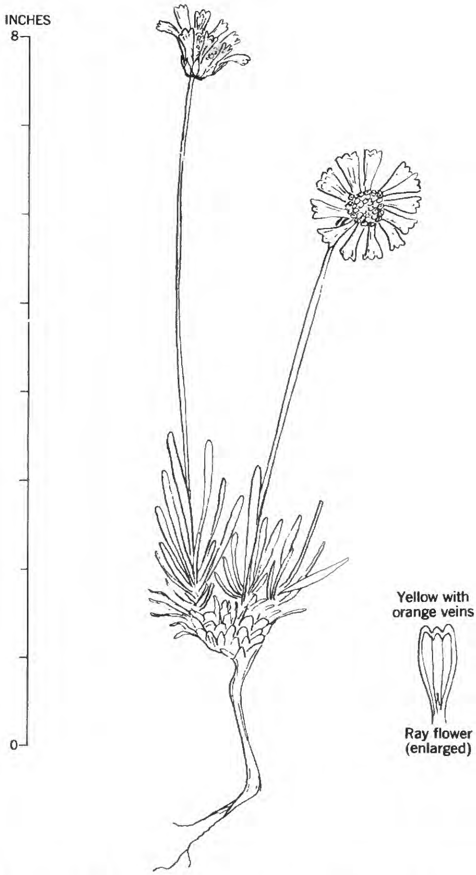

FIGURE 174.—*Actinea acaulis* (Pursh) Spreng.

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 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	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.