Botanical Prospecting For Uranium in the Deer Flat Area White Canyon District San Juan County, Utah

By ALBERT J. FROELICH *and* FRANK J. KLEINHAMPL

BOTANICAL PROSPECTING FOR URANIUM ON THE COLORADO PLATEAU

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BOTANICAL PROSPECTING FOR URANIUM ON THE COLORADO PLATEAU

BOTANICAL PROSPECTING FOR URANIUM IN THE DEER FLAT AREA, WHITE CANYON DISTRICT, SAN JUAN COUNTY, UTAH

By Albert J. Froelich and Frank J. Kleinhampl

ABSTRACT

The plant-analysis method of botanical prospecting for concealed uranium deposits was employed from May to July 1953, in the Deer Flat area, White Canyon district, San Juan County, Utah. About 2,000 samples of tips of branches from as many junipers and pinyons were systematically collected along about 27 miles of outcrop of the Shinarump member of the Chinle formation of Triassic age or of laterally equivalent units and were analyzed in the laboratory for uranium content. Anomalously large amounts of uranium absorbed by trees imply a nearby source, which may be an ore deposit. The indicator-plant method of prospecting did not prove very useful in the Deer Flat area.

Botanically defined anomalies occur at all major known deposits at Deer Flat. Other botanically defined anomalies may reflect previously unknown mineralized parts of the Shinarump member. The distribution of botanical anomalies suggests that the south half of the Deer Flat area is much more favorable for concealed uranium deposits than the north half.

Additional physical exploration is recommended at Deer Flat to test the validity of the plant-analysis method of prospecting for uranium. The finding of mineralized ground at botanical anomalies would verify the reliability of the botanical-prospecting method for defining mineralized areas.

INTRODUCTION

The plant-analysis method of uranium prospecting depends on the absorption by plants and the subsequent detection, thereof, of abnormally large amounts of uranium in areas where large concentrations of this element are available in the rooting medium.

The indicator-plant method of prospecting relies on the close relation between selenium- and sulfur-indicator plants and uraniferous ground on the Colorado Plateau, where selenium and sulfur are associated with uranium in many places. In the Deer Flat area, however, this prospecting method proved ineffective because the copper-uranium ores of the area are extremely low in selenium, and sulfur is an ubiquitous element.

The purpose of prospecting by the plant-analysis method in the Deer Flat area was to indicate localities favorable for the occurrence of uranium deposits in advance of physical exploration, thereby reducing the cost of such exploration. This prospecting was done by the U.S. Geological Survey on behalf of the Division of Raw Materials of the U.S. Atomic Energy Commission. The fieldwork on which this report is based was begun in May 1953 and completed in mid-July 1953.

Original fieldwork was done by the senior author and E. E. Clebsch, W. R. Martin, P. F. Narten, and H. A. Hubbard; the junior author field checked some places and altered interpretations of analytical data where deemed necessary.

Analyses for uranium in the plant ash were made by Claude Huffman, Jr., E. J. Fennelly, G. T. Burrow, I. C. Frost, and J. A. Patten.

A list of the complete Latin and common names of the plants referred to in this report is given on pages 82–84.

GEOGRAPHY

Deer Flat, a gently sloping bench on the southwest flank of Elk Ridge, is in the White Canyon mining district, San Juan County, Utah. (See index map on plate 6.) As used in this report, the Deer Flat area includes the eastern part of Piñon Point, Hideout Canyon, Deer Flat, Deer Canyon, and Upper Lost Parks (pl. 6). The area under consideration is about 7 miles long by 6 miles wide and includes parts of Tps. 35 and 36 S., Rs. 17 and 18 E., Salt Lake meridian.

The climate is semiarid. Pinyon and juniper are the most abundant woody vegetation. Big sagebrush, Gambel oak, roundleaf buffaloberry, saskatoon and Utah serviceberry, and true mountain-mahogany, all woody plants, are common locally, as are legumes and other herbaceous plants.

Deer Flat is accessible by a graded dirt road, about 10 miles long, which joins Utah Highway 95 on Grand Flat about 35 miles west of Blanding, Utah (index map on plate 6). Another road, 13 miles long, connects with old Utah Highway 95 about 32 miles west of Blanding.

GEOLOGY

Sedimentary rocks that crop out in the Deer Flat area range in age from Permian to Late Triassic. They form part of the west flank of the Monument upwarp and strike N. 15°–45° W. and dip 1°–7° SW. (Tommy L. Finnell and others, written communication, 1954). Rocks exposed include the Cedar Mesa sandstone member and the Organ Rock and Hoskinnini tongues of the Cutler formation of Permian age, the Moenkopi formation of Early and Middle(?) Triassic age, and the Chinle formation of Late Triassic age.

The rocks of the Chinle formation exposed in the Deer Flat area consist of three units, the lowest of which is the principal ore-bearing unit, the Shinarump member. The Shinarump member rests unconformably on upper beds of the Moenkopi formation, which are commonly bleached or altered at the contact. Plate 6 shows the approximate position of the top of the Moenkopi formation. The Shinarump member in the Deer Flat area is generally a ledge-forming, cross-laminated coarse- to medium-grained sandstone with interbedded lenses of sandy conglomerate, sandy siltstone, and gray carbonaceous shale. Some lenses contain sandstone, quartzite, and limestone pebbles; silicified and carbonized wood fragments; clay balls; altered volcanic ash; and fragments of reworked siltstone from the Moenkopi (H.C. Granger and E. P. Beroni, written communication, 1950; Benson and others, 1952, p. 4; Tommy L. Finnell and others, written communication, 1952).

The lenticularity of the Shinarump member in the Deer Flat area is its most striking characteristic. The unit is absent at many places in the northern part of the area and, where present, beds 30 feet or more thick may thin to a featheredge within 1,000 feet. Thickening of the Shinarump has resulted locally from filling of channels at its irregular basal contact, and locally from thickening of the sandstone above, with a resultant thinning of the overlying shale in the Chinle. A maximum thickness of 75 feet is reported in White Canyon (Benson and others, 1952, p. 4), but the Shinarump rarely exceeds 40 feet in thickness at Deer Flat. The Shinarump member ranges in altitude from 6,400 feet in the southwestern part of Deer Flat to 7,700 feet in the northern part.

The Shinarump member is conformably overlain by a slope-forming member of the Chinle that consists of gray clay, variegated shale and siltstone, and lenticular beds of sandstone and conglomerate. A persistent bench-forming thin-bedded micaceous sandstone is about 50 feet below the top of the unit. A resistant cliff-forming sandstone and conglomerate member of the Chinle, 10 to 100 feet thick, overlies the slope-forming member and caps Deer Flat.

The uranium-copper ore deposits of the Deer Flat area are principally in the lower part of the Shinarump member where the unit fills channels in the Moenkopi formation. The ore deposits appear to have been localized by fractures in porous rocks which have favorable lithologic or chemical features. Minor uranium deposits are present in other parts of the Shinarump member, in siltstone of the upper part of the Moenkopi, and in the members of the Chinle overlying the Shinarump. The uranium deposits in the Shinarump are irregular in shape, and consist of primary and secondary uranium minerals and iron and copper sulfides, sulfates, and carbonates. The uranium minerals are found chiefly in replaced wood, as impregnations in sandstone and conglomerate, in clay stringers, along lithologic contacts, and at or near fractures, in that order of abundance.

The deposits at the Hideout and Dead Buck mines, two of the most promising deposits at Deer Flat, are closely associated with very porous and permeable channel-filling rocks of the Shinarump member.

Organic matter in the Shinarump member has probably influenced mineralization in some places, as both copper and uranium minerals replace logs and other carbonaceous material.

BOTANICAL PROSPECTING

Two principal methods of botanical prospecting have been applied to the search for uranium deposits in the Colorado Plateau region: the plant-analysis method and the indicator-plant method. These methods differ in application. By the plant-analysis method, plants must be sampled and analyzed chemically before any abnormal concentration of elements can be determined; whereas, by the indicator-plant method some plant species serve directly as a guide to abnormal concentrations of particular elements in the soil because the continued life of the plants depends on the presence of large amounts of these elements.

Inasmuch as selenium and sulfur are commonly associated with uranium and vanadium in the ore deposits, selenium- and sulfur-indicator plants have been used as indicators of mineralized ground in the Colorado Plateau region (Cannon, 1952, p. 737, 760–767; and 1954, p. 218). However, known selenium-indicator plants are rare at Deer Flat probably because the copper-uranium ores of the area contain small amounts of selenium (see table 1) and even lesser amounts are available to the plants. Sulfur-indicator plants are common at Deer Flat, but are useless in prospecting the Shinarump member because the sulfur that promotes growth of the plants is not restricted to the uranium deposits but commonly occurs as gypsum in strata above and below the Shinarump.

The common plants growing on Deer Flat are given in the partial plant list below, which was prepared by E. E. Clebsch during ecologic studies on the upper part of the Moenkopi formation and the lower part of the Chinle formation in several small areas. Both selenium- and sulfur-indicator plants are much more abundant on mudstone of the lower slope-forming member of the Chinle than on either sandstone of the Shinarump member or siltstone of the upper part of the Moenkopi.

The plant-analysis method of botanical prospecting is based on the absorption and accumulation of uranium by deep-rooted plants growing on shallow uraniferous deposits. Cannon (1952 and 1953) demonstrated that junipers and pinyons, where rooted in mineralized ground,

Partial list of plants growing in the Deer Flat area, White Canyon district, San Juan County, Utah

[Symbols: P, plant present; PC, plant present at drill sites on lower part of the Chinle formation; dashes, plant not seen]

Plant name	Upper part of the Moenkopi formation; elevation 6,750 feet, northwest slope (sec 16, T. 36 S., R. 17 E.)	Shinarump member; elevation 6,800 feet, northwest slope	Lower part of the Chinle formation: Elevation 7,000 feet [1] (secs. 14 and 28, T. 36 S., R. 17 E.)	Lower part of the Chinle formation: Elevation 7,100 feet [2] (sec. 14, T. 36 S., R. 17 E.)	Lower part of the Chinle formation: Elevation 7,000 feet [2] (sec. 21, T. 36 S., R. 17 E.)
Probable selenium-indicator plants					
Astragalus sp. (a poisonvetch)	--------	--------	P	P	--------
Stanleya pinnata (desert princesplume)	--------	--------	P	P	P
Aster venustus (woody aster)	--------	--------	--------	--------	P
Oryzopsis hymenoides (Indian ricegrass)	P	--------	PC	P	P
Probable sulfur-indicator plants					
Arabis holboelli (Holboell rockcress)	--------	P	PC	P	P
Erysimum elatum (Tall erysimum)	--------	--------	P	--------	P
Lesquerella gordoni (gordon bladderpod)	--------	--------	P	--------	P
Physaria chambersi (double bladderpod)	--------	--------	P	P	P
Sisymbrium altissimum (tumblemustard)	--------	--------	P	P	P
Cryptantha ambigua (wandering Cryptantha)	--------	--------	PC	--------	P
Eriogonum corymbosum (Corymbed eriogonum)	--------	--------	--------	--------	P
Eriogonum deflexum (skeletonweed)	--------	--------	--------	--------	P
Euphorbia sp. (an euphorbia)	--------	--------	--------	--------	P
Senecio uintahensis (uintah groundsel)	--------	--------	PC	--------	P

[1] Undisturbed ground.
[2] Along roads or disturbed ground.

Partial list of plants growing in the Deer Flat area, White Canyon district, San Juan County, Utah—Continued

[Symbols: P, plant present; PC, plant present at drill sites on lower part of the Chinle formation; dashes, plant not seen]

Plant name	Upper part of the Moenkopi formation; elevation 6,750 feet, northwest slope (sec. 16, T. 36 S., R. 17 E.)	Shinarump member; elevation 6,800 feet, northwest slope	Lower part of the Chinle formation		
			Elevation 7,000 feet [1] (secs. 14 and 28, T. 36 S., R. 17 E.)	Elevation 7,100 feet [2] (sec. 14, T. 36 S., R. 17 E.)	Elevation 7,000 feet [2] (sec. 21, T. 36 S., R. 17 E.)
Plants not dependent on selenium or sulfur					
Amelanchier utahensis (Utah serviceberry)	P	P	P	P	P
Artemisia tridentata (big sagebrush)	--------	--------	PC	P	P
Artemisia sp. (a sagebrush)	--------	--------	--------	--------	P
Atriplex canescens (fourwing saltbush)	--------	--------	P	--------	P
Atriplex confertifolia (shadscale saltbush)	--------	--------	P	--------	P
Brickellia sp. (a brickellbush)	P	--------	P	--------	P
Bouteloua sp. (grama grass)	--------	--------	P	--------	P
Cercocarpus montanus (true mountainmahogany)	P	P	P	P	--------
Chrysothamnus linifolius (flaxleaf rabbitbrush)	--------	--------	--------	--------	P
Cirsium sp. (a thistle)	--------	--------	--------	--------	P
Cowania stansburiana (Stansbury cliffrose)	--------	--------	P	--------	P
Ephedra viridis (green ephedra, Mormon tea)	--------	P	PC	P	P
Erigeron aphanactis (fleabane)	--------	--------	--------	--------	P
Gilia leptomeria (fairy trumpet gilia)	--------	--------	P	P	P
Gutierrezia sarothrae (broom snakeweed)	--------	P	PC	P	P
Aplopappus clementis (clements goldenweed)	P	--------	PC	P	P
Juniperus utahensis (Utah juniper)	P	P	PC	P	P
Lappula sp. (a stickseed)	--------	--------	PC	P	P
Berberis sp. (a barberry)	--------	P	--------	P	--------
Mirabilis multiflora (Colorado four-o'clock)	--------	--------	P	--------	--------
Opuntia sp., probably *O. rhodantha* (pricklypear)	--------	--------	PC	P	--------
Penstemon sp. (a penstemon)	--------	--------	--------	P	P
Phlox diffusa (spreading phlox)	--------	--------	P	--------	P
Pinus cembroides var. *edulis* (pinyon pine)	P	P	P	P	P
Quercus gambeli (Gambel oak, scrub oak)	--------	--------	P	--------	--------
Salsola Kali tenuifolia (tumbling Russianthistle)	--------	--------	P	P	--------
Shepherdia rotundifolia (roundleaf buffaloberry)	P	P	PC	--------	P

[1] Undisturbed ground.
[2] Along roads or disturbed ground.

Partial list of plants growing in the Deer Flat area, White Canyon district, San Juan County, Utah—Continued

[Symbols: P, plant present; PC, plant present at drill sites on lower part of the Chinle formation; dashes, plant not seen]

Plant name	Upper part of the Moenkopi formation; elevation 6,750 feet, northwest slope (sec. 16, T. 36 S., R. 17 E.)	Shinarump member; elevation 6,800 feet, northwest slope	Lower part of the Chinle formation		
			Elevation 7,000 feet [1] (secs. 14 and 28, T. 36 S., R. 17 E.)	Elevation 7,100 feet [2] (sec. 14, T. 36 S., R. 17 E.)	Elevation 7,000 feet [2] (sec. 21, T. 36 S., R. 17 E.)
Plants not dependent on selenium or sulfur—Continued					
Sitanion hystrix (bottlebrush squirreltail)	--------	--------	P	P	--------
Solidago sp., probably *S. petradoria* (rock goldenrod)	--------	--------	P	P	--------
Streptanthus cordatus (heartleaf twistflower)	--------	P	P	P	P
Symphoricarpos sp., probably *S. oreophilus* (mountain snowberry)	P	P	PC	P	--------
Yucca sp., probably *Y. glauca* (small soapweed, Spanish bayonet)	--------	P	--------	P	--------

[1] Undisturbed ground.
[2] Along roads or disturbed ground.

absorb significantly large amounts of uranium, thereby, indicating areas favorable for further investigations. The uranium is absorbed through the roots, and detectable amounts are transferred to the twigs and leaves by the life processes of the plants. The moisture content of the ore bed and of intervening beds is a prime controlling factor in the absorption of uranium from ore bodies by plants, but the amount absorbed varies with the species, part of plant sampled, time of year, availability of uranium in the soil, and the structural nature and chemical composition of the country rock. The usefulness of the plant-analysis method is limited by the depth to which plant roots will penetrate. Cannon (1952, p. 747) stated that under favorable conditions juniper roots will penetrate 20 to 30 feet or more of sandstone, depending on the amount and location of available moisture.

The plant-analysis method for large-scale botanical prospecting has been made practical by the development of a sensitive method for detecting extremely small amounts of uranium in plant ash (Grimaldi and others, 1954, pts. 1 and 9). In this method plant samples are ground and mixed thoroughly, oven dried, quartered, ashed, predigested in nitric acid, quenchers extracted in ethyl acetate, and the evaporated residue analyzed fluorimetrically for uranium content.

The results are reported as parts per million (ppm) uranium in the ash. This analytical technique makes the plant-analysis prospecting method practical for large-scale botanical prospecting.

Cannon (1952, p. 748) has shown that contamination of trees that grow in areas of active mining introduces a source of error in comparative analysis. Contamination near mine entrances and along ore-haulage routes have made anomalous amounts of uranium available to nearby trees. The highest uranium content in ash is consistently obtained from trees growing on or near known deposits that were recently worked or were being mined at the time of sampling.

The washing in water of plant samples obtained from areas of mining activity, where contamination by uraniferous dust has occurred, generally does not alter their uranium content significantly. Most analyses of washed samples fall within the limits of analytical error of the same samples unwashed. The assay values obtained from trees in areas of mining activity are, therefore, unreliable for comparative purposes. Indicator-plant occurrences along access roads may reflect the increased availability of sulfur and selenium originally contained in newly disturbed ground, or the presence of contaminating material.

FIELD METHODS USED AT DEER FLAT AND INTERPRETATION OF DATA

Samples of tips of branches from the Utah juniper constituted the chief sample type, but in areas of greatest altitude or of great moisture content where the Utah juniper was absent, plants sampled were the Rocky Mountain juniper, pinyon pine, common Douglasfir, and roundleaf buffaloberry. Most sampled plants are directly comparable in uranium content, but locally, as in the southern part of Deer Flat, buffaloberry samples contained much more uranium than nearby junipers. Two samples of roundleaf buffaloberry in that area contained about 6 times, and 5 samples contained about 2 times as much uranium as nearby junipers. The broad, pubescent leaves of the roundleaf buffaloberry make it very susceptible to windblown contamination, probably accounting for the large uranium contents of the 2 samples. Though samples are too few to be conclusive, the comparisons made indicate that roundleaf buffaloberry could be sampled in a plant-analysis prospecting program.

About 2,000 branch-tip samples from as many trees were collected along approximately 27 miles of the Shinarump member or related rock units in the Deer Flat area. Trees were selected at 200-foot intervals where the Shinarump is exposed, at 50-foot intervals where covered by rubble or vegetation, and at 100-foot intervals where the Shinarump is absent. The ore-bearing strata tested form cliffs and very steep slopes. Back from the slopes, thick sequences of younger rocks overlie the test horizon; consequently, sampling was restricted to a single traverse line at the top of the ore-bearing unit.

A 1-quart container was filled with branch tips (twigs and needles) collected from the entire periphery of a tree selected for sampling. Sampled trees were tagged, labeled, located on aerial photographs, and plotted as accurately as possible on topographic base maps.

A representative suite of rock samples was collected from barren layers of the upper part of the Moenkopi formation and from outcrops of the Shinarump and other lower members of the Chinle formation, as well as from mineralized Shinarump at most known prospects. The rocks were analyzed for uranium, equivalent uranium, vanadium, and selenium in order to provide information on the background content of these elements in rocks of Late Triassic age in the area (see table 1).

The differences in uranium content of plants sampled in the Deer Flat area are generally indicative of a barren or mineralized rooting medium. The minimum uranium content in sampled plants for indicating mineralized ground was established in the field by comparing uranium assays from trees growing over known mineralized ground in the Shinarump member with assays from trees growing over apparently barren ground. Other test samples were collected upslope on the Chinle in an attempt to acquire information on the trend of the mineralized part of the Shinarump.

Botanical anomalies are tentatively defined as those areas indicated by sampled trees whose branch tips contain 1.0 ppm or more uranium in the ash,[1] and the anomalous areas are regarded as indicating mineralized ground. This value is partly substantiated by values employed in previous plant studies (Perry F. Narten, written communication, 1953). A graph of assay results from Deer Flat plotted against the total number of analyses shows that most samples contained less than 1.0 ppm uranium (fig. 2*A*, *B*). Although the anomaly cutoff value has not been statistically picked in the Deer Flat area, the graph and empirical data from field tests suggests that 1.0 ppm uranium would be at or near a statistically derived value. For example, good positive correlation exists between botanical and

[1] All uranium contents of plants reported in this text are in parts per million uranium in plant ash, but for simplicity the words "in ash" are omitted.

TABLE 1.—*Chemical and radiometric analyses of repesentative soil and barren and mineralized rock samples, Deer Flat area, White Canyon district, San Juan County, Utah*

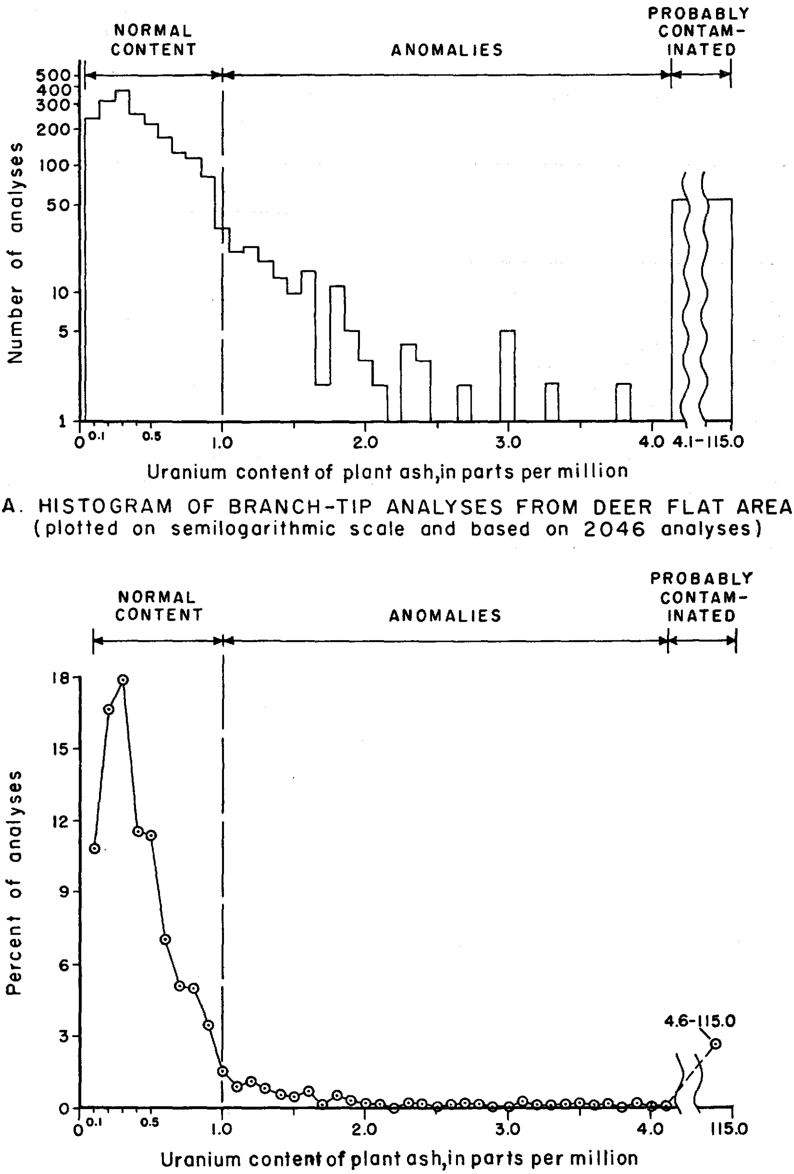
[Analysts: S. Furman, J. Silverly, J. S. Wahlberg, E. J. Fennelly, and R. C. Tripp]

Sample No.	Location and type of sample	Uranium (percent)	Equivalent uranium (percent)	Vanadium (percent)	Selenium (ppm)
	Mineralized Shinarump member				
AJF-53-972	Hideout mine	0.060	0.44	<0.03	<2.0
522-13	Hideout mine [1]	.050	.072		<.1
AJF-53-973	Dead Buck mine	1.49	1.4	<.03	5.0
AJF-53-976	Sandy No. 1 mine (sandstone)	.007	.021	<.03	<2.0
AJF-53-977	Sandy No. 1 mine (shale)	.022	.084	<.03	<2.0
AJF-53-974	SW¼SE¼ sec. 28, T. 36 S., R. 17 E.	.032	.087	<.03	<2.0
AJF-53-975	Near Standard prospect	.027	.23	<.03	<2.0
EEC-53-351	Camel (Bridges) mine	.030	.089		
EEC-53-364	W. N. mine	.020	.040		
	Unmineralized Shinarump member				
EEC-53-355	Near Hideout mine (sandstone)	0.0002	0.001		
EEC-53-366	Siltstone lens at W. N. mine	<.0001	.001		
(2)	NE¼ sec. 28, T. 36 S., R. 17 E.	.002	.001		
	Upper part of Moenkopi formation				
EEC-53-365	Bleached siltstone below W. N. mine.	0.007	0.011		
EEC-53-352	Red siltstone from NE¼ sec. 16, T. 36 S., R. 17 E.	.0005	.006		
EEC-53-358	Red siltstone from SE¼ sec. 21, T. 36 S., R. 17 E.	<.0001	.001		
	Lower part of Chinle formation				
EEC-53-354	Soil from road in sec. 34, T. 36 S., R. 17 E.	0.0002	0.002		
EEC-53-360, -361, -369	Gray shale above Shinarump (3 samples).	<.0001-.0004	<.001-.001		
EEC-53-362, -363, -367, -368	Sandstone lenses within mudstone of the Chinle.	<.001-.0001	<.001-.001		

[1] Spectrographic analysis shows the following percentages of elements:

Element	*Percent*	*Element*	*Percent*
Manganese	0.0X	Molybdenum	.0X
Silver	.000X	Nickel	.0X
Cobalt	.00X	Lead	0.0X
Chromium	.00X	Vanadium	.00X
Copper	X.	Zinc	.0X

[2] Number not known.



A. HISTOGRAM OF BRANCH-TIP ANALYSES FROM DEER FLAT AREA (plotted on semilogarithmic scale and based on 2046 analyses)

B. GRAPH OF PERCENT OF TOTAL ANALYSES VERSUS ANALYTICAL VALUES, DEER FLAT AREA (based on 2046 analyses)

FIGURE 2.—Graphical representation of plant analyses, Deer Flat area, White Canyon district, San Juan County, Utah.

geologic evaluations of Deer Flat localities with respect to their relative favorableness for the occurrence of uranium (see table below).

Botanical and geologic evaluation of relative favorableness for the occurrence of uranium in six localities in the Deer Flat area, White Canyon district, San Juan County, Utah

Locality	Favorableness	
	Geologic	Botanical
Piñon Point—head of Hideout Canyon locality.	Unfavorable	Semifavorable-unfavorable.
Head of Deer Canyon locality	Semifavorable	Semifavorable.
Upper Lost Parks locality	Very favorable	Very favorable.
Hideout locality	do	Do.
Dead Buck locality	do	Do.
Southern Deer Flat locality	do	Do.

In areas remote from mines and prospects, where windblown uraniferous dust (contamination) is negligible, anomalous uranium contents of plants range from 1.0 to 5.4 ppm, whereas, normal contents are less than 0.6 ppm. These anomalous values contrast markedly with concentrations of 8.0 to 115.0 ppm contained by plants in mine areas where there is windblown contamination. The lower values, therefore, provide a more reliable and more valid guide in prospecting at Deer Flat than the extremely high but erratic values, which generally may be presumed to indicate windblown contamination.

Considerable caution must be exercised in the interpretation of botanical assay data, especially where anomalies are indicated by analyses of single, isolated trees. These may be particularly misleading because of sampling and analytical errors. Leonard B. Riley (written communication, 1956) stated that, for pine and juniper samples, analyses have a standard deviation equal to 0.092 plus 0.066 times the concentration (expressed in parts per million of uranium). The calculated standard deviation applies to uranium concentrations in the range from 0.4 to 40.0 ppm. Movement of uranium-bearing surface or ground water from mineralized into barren localities could also cause misleading botanical anomalies. Perry F. Narten (written communication, 1953) stated that anomalous amounts of uranium can be absorbed by trees growing above weakly mineralized ground; thus it is to be expected that there will be some botanical anomalies where there are no deposits of ore grade.

The descriptive term "significant" as applied to botanical anomalies in the following section has an economic connotation denoting places thought favorable for the occurrence of uranium-ore deposits. These places have some features characteristic of ore deposits, such as, abnormally high radioactivity and special geologic features, visible uranium or copper minerals, carbon, and channel-fill sandstone of the Shinarump member. Although abnormally high radioactivity and visible uranium or copper minerals are themselves guides to uranium deposits on Deer Flat, these guides could not always be discerned before they were emphasized by the broader guide of plants containing anomalously large amounts of uranium. Those botanical anomaly localities that on reinspection have no visible ore minerals or abnormally high radioactivity at well-exposed outcrops are considered to be less significant anomalies than ones with these guides. An application of the term "significant" implies that exposures are good enough to discern geologic features; places of poor exposure have not been economically classified.

A good botanical anomaly, as distinguished from a poor one, has more tree samples with uranium contents exceeding 1.0 ppm and has more consecutively or adjacently sampled trees with abnormally large uranium contents. The qualifiers "good" and "poor" relate only to anomaly reliability and do not serve to evaluate the economics of a deposit. Thus, a good anomaly is not synonomous with a significant anomaly, because a significant anomaly would mark a place favorable for the occurrence of an ore deposit.

RESULTS OF PROSPECTING AT DEER FLAT

Botanical anomalies, defined by plants containing 1.0 ppm or more uranium, occurred above most known mineralized parts of the Shinarump member and in many other places. The anomalies not associated with known mineralized ground may indicate that the ground is underlain by uranium minerals, and they suggest new areas to be tested by drilling. An attempt to wash windblown contaminating uranium from branch-tip samples proved unsuccessful and probably indicates that the dust adheres too well to plant surfaces for removal and (or) that the uranium from the dust has been absorbed through the roots or above-ground plant parts, such as leaves (Mehlich and Drake, 1955, p. 291). The authors favor the explanation that most of the contaminating uranium has been absorbed, but the types of contamination could not be differentiated or evaluated. Whatever the explanation, it is apparent that collections too close to mine localities will yield unreliable results for comparative purposes.

For the purpose of reporting results of this study the Deer Flat area is divided into six contiguous localities (pl. 6). Specific botanical anomalies and the relative favorableness for the occurrence of uranium in each locality are discussed in the following pages. Fa-

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vorableness has been determined by data from both geologic and botanical prospecting.

Plate 6 and table 2 present information essential for locating ground defined by the plant-analysis method as favorable for the occurrence of uranium. A few reference trees designated by their sample numbers appear on the map (pl. 6) to facilitate finding tagged and numbered trees in the field. Dashed circles and numbers on leaders refer to specific botanical anomalies discussed by locality in the report. Table 2 lists by locality, specific numbered anomaly, and sample numbers all trees containing significantly anomalous or near-anomalous amounts of uranium.

TABLE 2.—*Trees containing significantly anomalous or near-anomalous amounts of uranium*

[Trees in this table may be approximately located on the map (pl. 6) by referring to the locality and the anomaly number and by counting from the sample numbers shown on the map. Sample No.: Letters (WRM), collector's initials; numbers, (-53) year sample collected, (-409) specimen No. Kind of tree: J, juniper; P, pinyon pine; B, roundleaf buffaloberry. Analyses for uranium in plant ash by Claude Huffman, Jr., E. J. Fennelly, G. T. Burrow, I. C. Frost, and J. A. Patten]

Anomaly No.	Sample No.	Kind of tree	Uranium assay value (ppm)
Piñon Point—Head of Hideout Canyon locality			
1	WRM-53-409	J	1.6
	AJF-53-999	J	1.1
	-1001	J	.9
2	WRM-53-414 (AJF-53-994)	J	1.8
	AJF-53-995	J	1.0
	-996	J	1.1
	-997	J	1.3
3	WRM-53-488	J	.9
4	WRM-53-522	J	1.5
5	WRM-53 551	J	1.0
6	WRM-53-567	J	.8
	-570	J	.9
	-571	J	.9
	-572	J	.8
	-573	J	.9
	-574	J	.9
7	WRM-53-584	J	1.3
	-585	J	.8
	-586	J	.8
	-588	J	.9
	-589	J	.8
8	WRM-53-284	J	1.0
9	WRM-53-213	J	1.5
10	WRM-53-199	J	1.4
11	WRM-53-192	J	1.1
12	WRM-53-684	J	1.0
13	WRM-53-168	J	1.0

TABLE 2.—*Trees containing significantly anomalous or near-anomalous amounts of uranium*—Continued

Anomaly No.	Sample No.	Kind of tree	Uranium assay value (ppm)
Head of Deer Canyon locality			
1	AJF-53-1015	J	1.3
	-1016	J	1.0
2	WRM-53-903	J	1.1
	-904	J	1.0
3	WRM-53-916	J	1.3
4	WRM-53-979	J	1.8
	-981	J	.8
	-1113	J	1.0
Upper Lost Parks locality			
1	WRM-53-1071	J	0.8
	-1072	J	.9
	-1075	J	.8
	-1077	J	.9
	-1078	J	.9
2	WRM-53-1025	J	2.4
	-1026	J	1.1
	AJF-53-959	J	1.9
	-960	P	7.1
	-961	J	2.4
	-962	P	4.1
	-963	P	2.2
	-964	P	2.8
	-965	P	8.8
	-966	J	2.8
	-967	J	2.0
	-968	J	1.4
	-969	J	1.7
	-970	J	1.5
	-971	J	1.2
3	WRM-53-1144	J	1.3
4	WRM-53-1158	J	6.7
	-1159	J	3.2
	-1160	J	4.8
	-1161	J	1.2
	-1164	J	.9
5	WRM-53-1166	J	1.0
	-1167	J	.8
	-1169	J	1.0
6	WRM-53-1191	J	1.2
Hideout locality			
1	EEC-53-1	J	1.2
	-2	J	1.6
	-3	J	8.0
	-4	J	56.0
	-5	J	1.3
	-7	J	1.3
	-8	J	1.6
	-9	J	2.3
	-10	J	1.1
	-11	J	.9
	-12	J	1.1

TABLE 2.—*Trees containing significantly anomalous or near-anomalous amounts of uranium*—Continued

Anomaly No.	Sample No.	Kind of tree	Uranium assay value (ppm)
Hideout locality—Continued			
1	WRM-53-232	J	10.0
	-233	J	53.0
	-234	J	77.0
	-235	P	71.0
	-236	J	38.0
	-237	J	77.0
	-238	J	45.0
	-239	J	33.0
	-240	P	54.0
	-241	J	11.0
	-242	J	11.0
	-243	J	15.0
	-244	J	6.0
	-245	J	18.0
	-246	J	19.0
	WRM-53-1116	J	1.5
	-1117	J	.8
	-1123	J	.8
	-1124	J	2.0
	-1125	J	2.4
	-1126	J	9.2
	-1127	J	11.0
	-1128	J	1.4
	-1129	J	1.0
	AJF-53-955	J	15.3
	-956	J	18.2
	-957	J	18.0
	-958	J	22.5
2	EEC-53-18	J	.9
	-19	J	1.5
	-20	J	.8
3	EEC-53-24	J	1.3
	-25	J	.8
	AJF-53-992	J	1.1
	EEC-53-27	J	1.3
	-28	J	1.4
	-30	J	1.5
	-31	J	2.3
4	EEC-53-37	J	1.6
5	EEC-53-51	J	1.1
	-52	J	2.7
	-53	J	3.7
	-54	J	1.4
	-55	J	1.8
	-176	J	.9
	-178	J	.9
	-179	J	1.2
	-180	J	.9
	-181	J	.9
	-182	J	.8
	-183	J	.8
	-185	J	.9
	-186	J	1.2
	-187	J	1.1
	-188	J	.8

TABLE 2.—*Trees containing significantly anomalous or near-anomalous amounts of uranium*—Continued

Anomaly No.	Sample No.	Kind of tree	Uranium assay value (ppm)
Hideout locality—Continued			
5	EEC-53-189	J	1.0
	-190	J	.8
	-191	J	.9
	-192	J	1.2
	-193	J	.8
	-194	J	1.1
	-195	J	1.4
	-196	J	.8
6	EEC-53-158	J	1.2
7	EEC-53-197	J	.9
	-198	J	2.7
	-199	J	.8
	-200	J	.8
Dead Buck locality			
1	WRM-53-121	J	1.1
2	WRM-53-112	J	.9
	-114	J	1.5
	-116	J	.9
3	WRM-53-92	J	1.2
	-93	J	1.2
	-95	J	1.3
	-96	J	1.3
	-98	J	1.0
	-99	J	3.1
	-100	J	1.1
	-102	J	1.0
	-103	J	1.7
4	WRM-53-82	J	1.4
	-83	J	.9
	-84	J	1.1
	-85	J	.9
5	WRM-53-72 (AJF-53-1025)	J	1.8
	AJF-53-1026	J	.9
6	WRM-53-39 (AJF-53-1022)	J	1.6
	AJF-53-1023	J	4.4
7	WRM-53-10	J	1.0
8	H-53-330	J	.8
	-331	J	.8
	-332	J	1.1
	-333	J	.8
	-334	J	1.7
	-335	J	1.8
	-336	J	1.8
	-337	J	1.4
	-338	J	5.4
	-339	J	2.4
	-340	J	.8
	-341	J	1.0
	-343	J	.8
	-344	J	2.3
	-346	J	3.5
	-347	J	4.0
	-348	J	1.3
	-349	J	1.0

Table 2.—*Trees containing significantly anomolous or near-anomalous amounts of uranium*—Continued

Anomaly No.	Sample No.	Kind of tree	Uranium assay value (ppm)
Dead Buck locality—Continued			
9	H-53-318	J	1.0
	-321	J	7.5
	-322	J	1.4
	-325	J	1.6
10	H-53-5 (AJF-53-1002)	J	1.5
	AJF-53-1003	J	1.7
	-1004	J	1.9
11	H-53-24	J	.8
	-25	J	.9
12	H-53-34	J	.9
	-35	J	.9
13	H-53-39	J	.9
	-40	J	.8
Southern Deer Flat locality			
1	EEC-53-210	J	1.8
2	EEC-53-227	J	2.6
	-228	J	1.3
	-230	J	1.6
3	EEC-53-267	J	.8
	-268	J	1.0
4	EEC-53-278	B	9.3
	-279	J	1.3
	-280	J	.9
5	EEC-53-301	J	1.2
	-302	J	1.0
	-303	J	1.0
	-304	J	1.2
	-305	J	.9
	-306	B	1.8
6	EEC-53-322	J	1.0
	-323	J	1.2
7	EEC-53-327	J	1.2
	-328	J	1.2
	-329	J	3.4
	-330	J	1.8
	-331	J	1.2
8	EEC-53-335	J	1.2
	-336	B	8.9
	-337	J	1.0
9	H-53-309	J	1.5
	-311	J	1.1
	-312	J	.8
	-313	J	1.0
	-315	J	1.0
	-317	J	1.3
10	H-53-279	J	2.1
	-280	J	.8
	-281	J	.8
11	H-53-221	J	.9
	-222	J	.8
12	AJF-53-1011 (H-53-116)	J	1.3
	-1012	J	.8

TABLE 2.—*Trees containing significantly anomalous or near-anomalous amounts of uranium*—Continued

Anomaly No.	Sample No.	Kind of tree	Uranium assay value (ppm)
Southern Deer Flat locality—Continued			
13	H-53-105	J	.8
	-106 (AJF-53-1006)	J	1.0
	-107 (AJF-53-1005)	J	1.0
	AJF-53-1007	J	1.1
14	H-53-80	J	.8
	-81	J	.9
15	H-53-64	J	.9
	-65	J	1.0
16	H-53-43	J	.9
	-44	J	.9
	-45	J	.9

PIÑON POINT-HEAD OF HIDEOUT CANYON LOCALITY

The Piñon Point-Head of Hideout Canyon locality includes parts of secs. 25, 26, 35, and 36, T. 35 S., R. 17 E.; secs. 1, 2, 3, 10, 11, 12, and 15, T. 36 S., R. 17 E.; and the western part of secs 30 and 31 (unsurveyed), T. 35 S., R. 18 E. (pl. 6). The eastern part of the area is accessible by a dirt road that parallels the southeast wall of Hideout Canyon, and the western part of the area may be reached by means of a dirt road that extends across the north half of Piñon Point. There are no working mines in this area.

The Shinarump member does not crop out in the area. In the NE¼SE¼ sec. 25, T. 35 S., R. 17 E., a small prospect pit exposes only shale of the lower part of the Chinle resting unconformably on siltstone of the upper part of the Moenkopi. Where bedrock is not exposed, light-purple and gray sandstone rubble at widely spaced irregular intervals may indicate a few concealed thin lenses of the Shinarump member.

The trees sampled were the Utah and Rocky Mountain junipers, pinyon pine, and common Douglasfir. No significant differences are apparent between the relative uranium absorption of these different species. About 500 samples were collected along 7½ miles of the ore-bearing zone in this area, and only 15 samples had assay values of 1.0 ppm or more uranium. Indian ricegrass, which requires only small amounts of selenium, was the only indicator plant recognized in this area. It grows in widely scattered sparse clumps which do not correlate with botanical anomalies found by the plant-analysis prospecting method.

The 13 botanical anomalies in this locality are generally small, widely separated, and based on low assay values. The anomalies in sec. 35 (nos. 1 and 2, pl. 6) are represented by three or more closely spaced trees which absorbed from about 1.0 to 2.0 ppm uranium. Both are in an area where jasper, locally stained green by a secondary copper mineral, is abundant, and where a thin lower sandstone of the Chinle formation is slightly radioactive at the outcrop. Two widely separated anomalies (nos. 8 and 9, pl. 6) based on single-tree analyses are in sec. 36, three single-tree anomalies (nos. 3, 4, and 5, pl. 6) are in sec. 25, two single-tree anomalies (nos. 10 and 11, pl. 6) are in sec. 2, and two single-tree anomalies (nos. 12 and 13, pl. 6) are in sec. 10. Two elongate anomalies (nos. 6 and 7, pl. 6) based on five or more samples are present in sec. 30 (unsurveyed), T. 35 S., R. 18 E.

HEAD OF DEER CANYON LOCALITY

Sampling at the Head of Deer Canyon locality was done in parts of secs. 12 and 13, T. 36 S., R. 17 E.; parts of secs. 5, 6, and 7, T. 36 S., R. 18 E.; and parts of secs. 31 and 32 (unsurveyed), T. 35 S., R. 18 E. (pl. 6). The area is accessible from the west by foot from dirt roads on Deer Flat, and from the east from a road to the prospects on Upper Lost Parks. No mines or prospects are in this area; however, some drilling was done by private contractors for the U.S. Geological Survey in S½ sec. 12 to define the Camel channel (Tommy L. Finnell and others, written communication, 1954).

The rim formed by the Shinarump member is heavily covered by colluvium and vegetation, and outcrops of conglomerate and sandstone are sparse. The trees sampled were the Utah and Rocky Mountain junipers, common Douglasfir, and ponderosa pine. No significant differences were noted between the relative absorption of these different species. Few sulfur-indicator and no selenium-indicator plants grow on the Shinarump member in this area. About 350 samples were collected along 5 miles of sample horizon, and only 7 had assay values of 1.0 ppm or more uranium.

Four widely separated botanical anomalies occur in this area. A good anomaly (no. 1, pl. 6) is in the SE¼ sec. 12 at a conglomeratic sandstone channel-fill deposit known as the Camel channel. Where the sandstone crops out there is local anomalous radioactivity, prominent local interstitial secondary copper minerals and hematite-stained joint surfaces. Drilling to define the channel west of the outcrop located no ore-grade rock (Tommy L. Finnell and others, written communication, 1954).

A botanical anomaly (no. 2, pl. 6) in the western part of sec. 5 is indicated by two adjacent trees growing on the east wall at the head of Deer Canyon. Thick colluvium covers bedrock here, but in nearby exposures the Shinarump member is locally absent. The anomaly may be due to other mineralized parts of the Chinle.

Two widely separated botanical anomalies are on the east rim of Deer Canyon; one is in the eastern part of sec. 6 (no. 3, pl. 6), and the other in the SE¼ sec. 7 (no. 4, pl. 6). Both anomalies are on colluvium-covered parts of the rim, and talus probably derived from the Shinarump member was recognized only at the anomaly in sec. 7. Secondary copper minerals were noted in some exposed parts of the overlying Chinle in sec. 7. Reanalysis of samples from both anomalies verified their greater than normal uranium content.

UPPER LOST PARKS LOCALITY

The Upper Lost Parks locality includes parts of secs. 5, 8, 17 and 18, T. 36 S., R. 18 E., Salt Lake meridian (pl. 6). The area is accessible from the north by dirt roads which cross Upper Lost Parks and terminate at the Sandy No. 1 and No. 3 mines on the southeast rim. Neither of the mines was being worked at the time of sampling.

The Shinarump member is well exposed along the south rim of Upper Lost Parks, but along the north rim outcrops are partly or wholly covered by vegetation and colluvium. The Shinarump member is generally 15 to 35 feet thick at the south end of Upper Lost Parks and is composed of an upper and lower sandstone, both of which thin irregularly to the north. Locally the upper sandstone thickens and channels into the lower sandstone. Blue and green copper minerals stain the Shinarump member locally along the south rim, and copper sulfides were tentatively identified at the Sandy No. 3 mine in the NE¼ sec. 17 (Tommy L. Finnell, oral communication, 1955).

The trees sampled were pinyon pine and Utah and Rocky Mountain junipers. No significant differences were noted in the relative absorption of uranium by these different species. Few indicator plants are present in this area. About 190 plant samples were collected along about 2⅓ miles of rim formed by the Shinarump member, 23 of which had assay values of 1.0 ppm or more uranium.

In the Upper Lost Parks locality (table 2) there are six separate botanical anomalies and two can be considered as significant anomalies. The significant anomalies (nos. 2 and 4, pl. 6) are at the Sandy mines in sec. 17 and are represented by very high assay values of 4 or more trees. These trees are listed in table 2, but all are not shown on the map (pl. 6). Both anomalous areas were sampled in detail, and rock specimens for chemical analysis were collected in the vicinity of the Sandy No. 1 mine (table 1, samples AJF–53–976 and 977). Uranium occurs at the base of the lowest of two sandstone units at the Sandy No. 3 mine. Trees sampled along the top of the barren upper sandstone unit had normal uranium contents, whereas, trees sampled along the uranium-bearing lower standstone, 20 feet below, had absorbed up to 10 times more uranium. The presence of a perched water table in the upper barren sandstone would explain this phenomenon, as roots of the upper trees would in all likelihood only extend to water. Drilling by private contractors for the U. S. Geological Survey has not proved the presence of a perched water table; drill core generally shows only that the upper sandstone is yellowish brown and is underlain by gray, yellow, or red siltstone and mudstone (Tommy L. Finnell, oral communication, 1955).

The significance of the yellowish-brown color of the upper sandstone with respect to the present water table is not known; however, much water is present in steep fractures that cut the gray ore-bearing lower sandstone in the Sandy No. 3 adit. Where cut by the water-filled fractures, the sandstone is stained yellowish brown. In the area east of Upper Lost Parks, seeps occur locally at the base of sandstone ledges underlain by shale strata, indicating perched water tables do exist in the area under circumstances similar to those at the Sandy No. 3 site.

The four other anomalies in Upper Lost Parks are represented either by single trees or by several trees with uranium content near the cutoff value. One anomaly is in sec. 18, at the southwest tip of Upper Lost Parks (no. 1, pl. 6) and is represented by uranium contents near the anomaly cutoff (1.0 ppm uranium). Green copper carbonate stains were noted on the Shinarump member in this area. A second anomaly (no. 3, pl. 6), represented by the assay of one isolated tree, is at the southeast tip of Upper Lost Parks in sec. 17. It is above a well-exposed channel which is less than 45 feet wide and which is filled with the Shinarump member. No mineralized rock was seen. The third anomaly (no. 5, pl. 6) is represented by several adjacent samples with analyses near the anomaly cutoff and is in sec. 8 a few hundred feet north of the Sandy No. 3 mine. Where the Shinarump is exposed, limonite stains are abundant. The fourth anomaly is in sec. 8 (no. 6, pl. 6) near the head of Deer Canyon, which forms the west boundary of Upper Lost Parks. This anomaly is indicated by the assay value of one tree growing in colluvium.

HIDEOUT LOCALITY

The sampled part of the Hideout locality includes parts of secs. 14, 22, and 23, T. 36 S., R. 17 E. (pl. 6). The area is accessible by dirt roads; one of these parallels the east rim of Deer Flat in this area, and the other branches from the first and extends to the Hideout mine. The Hideout mine, near the center of sec. 14, was the only mine in the Deer Flat area that was active during the prospecting.

The Shinarump member is generally thick and well exposed along most of the rim in the Hideout area, but it thins locally and at these places is partly or completely covered by colluvium and vegetation.

The principal tree sampled was the Utah juniper, but pinyon pine and roundleaf buffaloberry were also sampled for comparative purposes. No significant differences were noted between the relative uranium absorption of the Utah juniper and pinyon pine; however, roundleaf buffaloberry generally absorbed about twice as much uranium as nearby junipers. Excluding the detailed sampling above the Hideout mine, about 230 samples were collected along 2¼ miles of outcrop of the Shinarump member, and of these samples 32 of them assayed 1.0 ppm or more uranium. Some of these sampled trees were omitted from the map (pl. 6) to permit clearer presentation. Figure 3 shows the location of some of these trees, and table 2 lists all samples considered to contain significantly large amounts of uranium.

The most prominent botanical anomaly (no. 1, pl. 6) is at the Hideout mine, where an ore deposit is near the base of the Shinarump member that fills a broad channel that trends N. 70° W. At this anomaly some samples came from trees growing more than 100 feet above the ore zone at the Hideout mine on a landslide block of the Chinle (Tommy L. Finnell, oral communication, 1954). Sample results were then compared with drilling data to determine the efficacy of plant-analysis prospecting. A comparison of distributions (fig. 3) shows that trees containing anomalously large amounts of uranium correlate fairly well with drill holes cutting mineralized rock. Depth to the ore layer averages 120 feet, and it is unlikely that tree roots have penetrated so deeply. However, fractures may provide a passageway for rising uranium-bearing ground water, which could account for a large uranium content in trees more than 100 feet above the ore bed.

The results of chemical and spectrographic analysis of selected ore samples collected near the outcrop at the Hideout mine are summarized in table 1, samples AJF–53–972 and 522–13.

Contamination of trees near the Hideout mine and along the access road is common but no significant changes in interpretation resulted by using analyses of washed rather than unwashed samples.

Six other botanical anomalies, as defined by juniper samples, are along the rim formed by the Shinarump member. All are southwest of the Hideout mine, and three are in sec. 14. Anomalies 2 and 4 (pl. 6) are each represented by single samples that contained over 1.0 ppm uranium; anomaly 2, however, is supported by two samples that contained almost 1.0 ppm uranium. Anomaly 3 (pl. 6) has six trees, almost consecutive with values above 1.0 ppm uranium. All

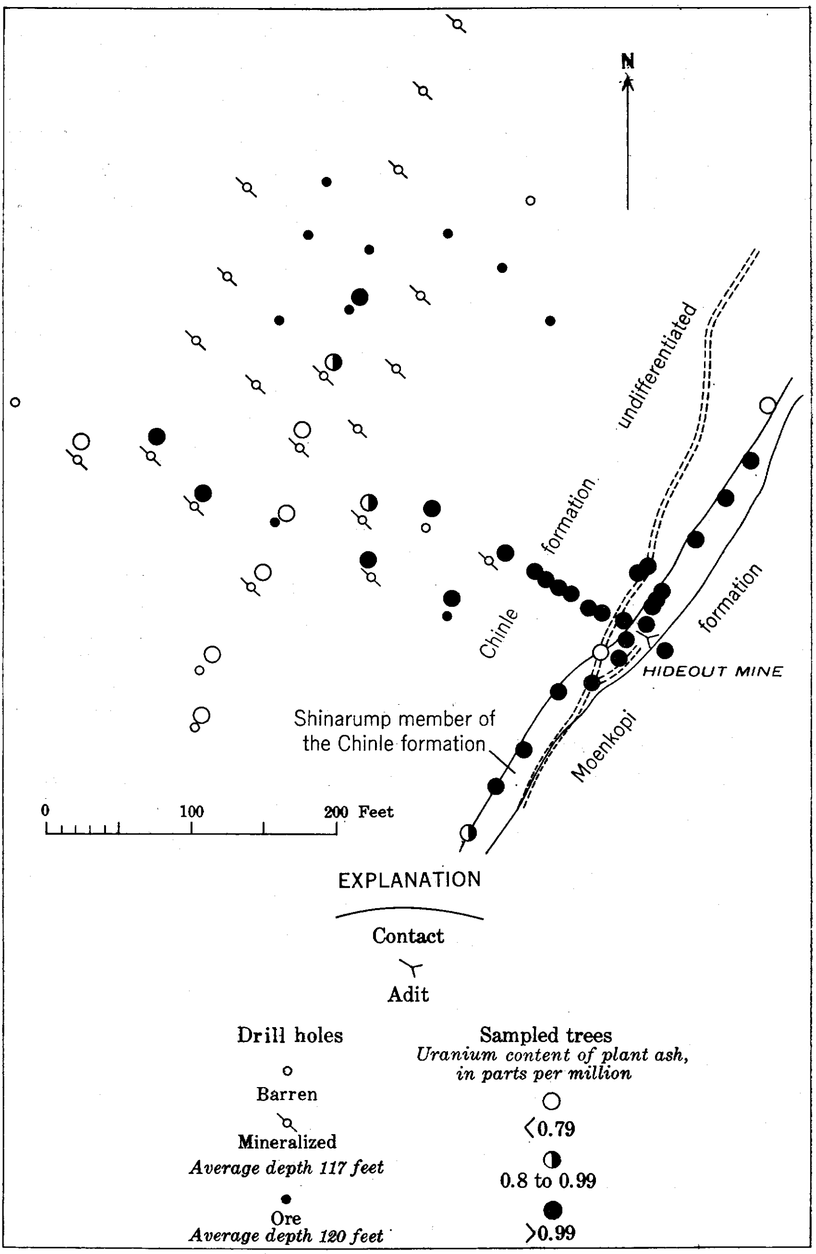

FIGURE 3.—Sketch map showing the location of drill holes and sampled trees in the vicinity of the Hideout mine, Deer Flat area, White Canyon district, San Juan County, Utah.

three anomalies are supported by outcrop manifestations such as secondary copper minerals and limonite stains, abnormal surface radioactivity, and very radioactive carbon pods and seams.

A significant botanical anomaly (no. 5, pl. 6) the fourth of the six southwest of the Hideout mine, is indicated by analyses of samples of about 24 closely spaced trees. Eleven of the trees are above the anomaly cutoff grade and 13 are at or just below it. The thick conglomeratic lower sandstone unit of the Shinarump member at this location is not mineralized along the outcrop. However, a thin coarse-grained upper sandstone ranging from 2 to 10 feet above the lower conglomeratic sandstone is locally stained with secondary copper minerals and impregnated with limonitic material. All outcrops of this standstone show abnormally high radioactivity, and mudstone above and below the sandstone is also locally radioactive. This sandstone probably supplies most of the uranium necessary to account for the anomaly; however, it is possible that the thick lower sandstone is mineralized behind the outcrop or where covered by talus.

The two remaining anomalies southwest of the Hideout mine, both small, are in the east half of sec. 22. One of these (no. 6, pl. 6) is indicated by a single juniper analysis, and the other (no. 7, pl. 6) is indicated by three analyses near the anomaly cutoff value and one analysis much greater than this value. The Shinarump member at both places is thin and covered by colluvium and vegetation.

DEAD BUCK LOCALITY

The Dead Buck locality includes parts of secs. 15, 16, 21, and 22, T. 36 S., R. 17 E. (pl. 6). The southern part of this area is accessible by mine roads which terminate at the principal prospects, but the northern part can be reached only by foot. Several mines, the Dead Buck, Camel, and W. N. are closely grouped in sec. 21.

The Shinarump member in the Dead Buck locality has a considerable range in thickness and appears to thin irregularly to the north. It is poorly exposed at most places due to colluvial and vegetative cover, but roadcuts and rim stripping have exposed several sandstone lenses of the Shinarump member. Uranium deposits at the mines in the Dead Buck locality appear to be localized in fractured scour channel fillings of the Shinarump.

The Utah juniper was the only kind of tree sampled in this area. About 235 samples were collected along 3¾ miles of sample horizon and about 40 of these had uranium contents of 1.0 ppm or more. The sulfur- and selenium-indicator plants, Indian ricegrass, uintah groundsel, and wandering Cryptantha, are common locally on the slopes of the Chinle formation, and are particularly common along roads or in areas of disturbed ground. In sec. 21, there are two large and five smaller anomalies, and in adjoining sec. 16 there are six separate anomalies (pl. 6). The two large, elongate anomalies (nos. 8 and 9, pl. 6) in sec. 21 are above the three mines and along the roads which join them. The greatest uranium content in the trees is at the Dead Buck and W. N. mine areas, with the next greatest content in trees at the Camel mine. Three small possible botanical anomalies (nos. 11, 12, and 13, pl. 6), each represented by two analyses just below the cutoff value of 1.0 ppm, are in the SE¼SE¼ sec. 21. Locally here the sample horizon is partly or completely covered by colluvium and vegetation. Mineralized rock is not exposed. An anomaly (no. 10, pl. 6) originally represented by the analysis of one tree is about 20 feet east of the Camel mine in the SE¼ sec. 21. Reanalysis of this sample and sampling of two nearby trees verified this anomaly. The presence of desert princesplume, uintah groundsel, wandering Cryptantha, and Indian ricegrass on nearby undisturbed ground further supports this anomaly. The only botanical anomaly (no. 7, pl. 6) in the N½ sec. 21 is represented by a single tree which had absorbed 1.0 ppm uranium. No surface indications of mineralized rock were found at the poorly exposed Shinarump below the sampled tree.

A good anomaly (no. 3, pl. 6) in an area not yet intensely prospected occurs in the NW¼SE¼ sec. 16. Of 12 adjacent sampled trees, which test more than 600 feet of partly covered basal strata of the Chinle, 9 had absorbed 1.0 ppm or more uranium and 1 of these had absorbed more than 3.0 ppm uranium. The Shinarump member is absent, and mineralized strata consist of fissile black carbonaceous shale and thin lenses of sandstone and siltstone of the slope-forming member of the Chinle. About 300 feet south of this anomaly in a partly covered area, another good anomaly (no. 4, pl. 6) is represented by four consecutively sampled trees. The Shinarump member here is a maximum of about 15 feet thick and is locally absent. A few poor exposures indicate that the unit consists of lenses of sandstone and mudstone, none more than a few feet thick. One source of the uranium causing anomalies 3 and 4 is probably a mineralized carbonaceous shale unit that lies just above the sample horizon, but at anomaly 3, exposures indicate an additional source in some mineralized sandstone and siltstone lenses that lie at and just below the sample horizon. Four isolated anomalies (nos. 1, 2, 5, and 6, pl. 6) originally indicated by single-tree analyses are in sec. 16. Resampling, reanalysis, and in some cases sampling of nearby trees verified these anomalies, and the presence of Corymbed erigonum, wandering Cryptantha, and a euphorbia may be an additional indication of mineralized Shinarump near the southernmost two anomalies. The anomaly in the SE¼ sec. 16 (no. 6, pl. 6) is supported by two trees, one of which absorbed more than 4.0 ppm uranium.

SOUTHERN DEER FLAT LOCALITY

The southern Deer Flat locality includes secs. 27, 28, and parts of secs. 29, 32, 33, and 34, T. 36 S., R. 17 E. (pl. 6). The eastern part of this area is accessible by a dirt road paralleling the rim and terminating at the southeast tip of Deer Flat, but the western part can be reached only on foot.

The Shinarump member is generally thick and well exposed along most of the rim in the southern Deer Flat area, but locally it is partly or completely covered by colluvium and vegetation. At places a thick upper sandstone channels into a lower sandstone. The base of the Shinarump has been exposed by rim stripping for about one-third of a mile along the south rim.

Sparse patches of sulfur- and selenium-indicator plants are generally associated with areas of disturbed ground along roads made on that part of the Chinle formation overlying the Shinarump member in the southern Deer Flat locality. Indicator plants in this area show no apparent relation to mineralized ground.

About 430 branch-tip samples were collected along 4½ miles of Shinarump in this area; 33 samples contained 1.0 ppm or more uranium. These 33 samples are distributed among 13 anomalies (pl. 6 and table 2). The principal tree sampled was the Utah juniper, but roundleaf buffaloberry was sampled at several places for comparative purposes.

No good anomalies are present along the southwest tip of Deer Flat in secs. 29, 32, and the western one-third of sec. 28, but one small anomaly (no. 11, pl. 6) is indicated by the near-cutoff uranium contents of two adjacent samples.

The eastern two-thirds of sec. 28 contains five good anomalies (nos. 12–16, pl. 6). All have been verified either by resampling and reanalysis, or by sampling of nearby trees. Rim stripping in this area exposed weakly mineralized rock in the lower part of the Shinarump member. No botanical anomaly was indicated by samples of trees growing on upper sandstone ledges in the Shinarump 33 feet above the weakly mineralized lower part of the Shinarump, but a small anomaly was indicated by a tree growing 8 feet above a prominent mineral-stained joint.

Two anomalies are in sec. 27; the northernmost anomaly (no. 1, pl. 6) is indicated by a single-tree analysis of nearly 2.0 ppm uranium, and the other anomaly (no. 2, pl. 6) is indicated by three trees, one of which contained 2.6 ppm uranium. Three anomalies are in sec. 34, where the Shinarump member is relatively continuous and well exposed except at its base. One of the anomalies (no. 5, pl. 6), conspicuous because of its length, is indicated by six consecutively sampled trees. The basal strata of the Chinle at the anomaly consist predominantly of thin lenses of silty fine- to medium-grained sandstone and of some poorly sorted conglomeratic coarse-grained sandstone. Mudstone of the Chinle rests directly on the Moenkopi at the south end of the anomaly. Minor anomalous radioactivity is present locally. Of the other two botanical anomalies in sec. 34, the northernmost one (no. 3, pl. 6) is based on samples of two trees which contained uranium near the cutoff amount but the other (see Zebra prospect, anomaly 4, pl. 6), a significant anomaly, is indicated by samples from two junipers and from one buffaloberry. The latter sample contained about 10.0 ppm uranium, which is about seven times the amount of uranium contained in samples of neighboring junipers. The Shinarump member at anomaly 4 fills a sharply incised channel about 200 feet wide and a maximum of about 20 feet deep at the outcrop. There is local minor anomalous radioactivity near the base of the unit in some of the lenticular fine- to medium-grained sandstone and siltstone, which dominate the lithology, and also in a thin lens of black carbonaceous shale.

The N½ sec. 33 contains five botanical anomalies. One (no. 10, pl. 6) is indicated by one tree sample with 2.1 ppm uranium and two tree samples with uranium content near the anomaly cutoff value. Another botanically favorable area (no. 9, pl. 6) is in the NE¼NW¼ sec. 33 where five of eight consecutively sampled trees absorbed 1.0 ppm or more uranium. The other three anomalies, nos. 6, 7 and 8, are distributed along 1,500 feet of outcrop where the base of the Shinarump member is exposed by rim stripping in the NE¼ of the section. Anomaly 6 (pl. 6) is represented by samples from two consecutive trees that contain near-cutoff amounts of uranium and that grow on well-exposed ledges of the Shinarump. No mineralized rock was seen at this anomaly, though radioactive carbonaceous seams and pods are common in the area. Near the Standard prospect, a much longer anomaly (no. 7, pl. 6) is represented by samples of five consecutive trees. At this anomaly the radiation background is from 6 to 15 times the normal background, and the tree samples contained more than 1.0 ppm uranium. The most radioactive material at the Standard prospect is limonite-stained sandstone and underlying sandy carbonaceous siltstone.

Samples of mineralized rock taken from near the surface at both the Standard prospect and the Hideout mine have similar ratios of chemical uranium to equivalent uranium (table 1, samples AJF–53–

972 and–975). Mining behind the outcrop at the Hideout mine has exposed unoxidized uranium-ore minerals, copper sulfides, and pyrite. The ore appears to increase in grade behind the outcrop. These factors, together with the occurrence of limonite and secondary copper minerals near the surface of the deposit, and the disequilibrium of the uranium suggest that an oxidizing sulfuric acid environment removed uranium by selective leaching from rocks near the surface (Phair and Levine, 1953). The apparent similarity in chemical environments of the exposed parts of the deposits at the Standard prospect and the Hideout mine indicate that the Standard deposit may increase in grade behind the outcrop.

About 450 feet west of the Standard prospect a botanical anomaly (no. 8, pl. 6) is represented by two low juniper assay values (table 2) and a roundleaf buffaloberry sample that contained about 9.0 ppm uranium. No mineralized rock was seen, but radiation is somewhat more than the normal background amount.

SUMMARY

Botanical prospecting for uranium in the Shinarump member or related rocks of the Chinle formation extended over about 27 miles of rim in the Deer Flat area, White Canyon district, San Juan County, Utah. Botanical anomalies occur at all major known deposits, which suggests that uranium deposits underlie some of the anomalies not known to be associated with mineralized rock. The distribution and quantity of significant and good botanical anomalies indicate that the south half of the Deer Flat area is more favorable for concealed uranium deposits than the north half. Many botanical anomalies are in areas where the ore zone is partly or completely obscured by rock debris and vegetation, but verification of these anomalies can be determined by rim stripping or shallow drilling. In addition, it is possible to check some anomalous areas by close inspection of outcrops of the Shinarump member and adjacent rock units. The presence of visible uranium minerals or abnormally high radioactivity would verify botanical anomalies.

Roundleaf buffaloberry may prove useful in plant-analysis prospecting programs as it generally absorbs about twice as much uranium as the Utah juniper, but additional research should be done before the plant is widely used.

RECOMMENDATIONS FOR EXPLORATION

Piñon Point-Head of Hideout Canyon locality.—Inasmuch as no significant botanical anomalies were found, large-scale exploration of the Piñon Point–Head of Hideout Canyon locality for uranium-ore deposits probably is not justified. All except two of the anomalies consist of single, isolated tree analyses or of several analyses below the cutoff value of 1.0 ppm uranium. The Shinarump member is absent throughout most of this area and thus the area is also unfavorable by geologic criteria. The 13 widely separated botanical anomalies may be indicative of other mineralized parts of the lower part of the Chinle or of the upper part of the Moenkopi.

Head of Deer Canyon locality.—Four botanical anomalies are present in the Head of Deer Canyon locality. Although the Shinarump member is thin or absent in most of this area, thick channel deposits are locally present. Only one anomaly (no. 1, pl. 6) occurs at an outcrop of Shinarump, and at this place secondary copper minerals stain sandstone in a thick channel-filling deposit. Drilling in the channel deposit did not locate ore-grade rock. The other three anomalies are in areas where the Shinarump and related beds are thickly covered by colluvium or vegetation.

Upper Lost Parks locality.—Three good anomalies, all prominent, and three poorer anomalies are in the Upper Lost Parks locality. Two of the good anomalies (nos. 2 and 4, pl. 6) are significant and are at the Sandy mines; the third (no. 5, pl. 6) is a few hundred feet north of the Sandy No. 3 mine. All anomalies in this area appear to justify checking for ore deposits because the Shinarump member is thick throughout most of the area and copper minerals are commonly associated with the Shinarump in the anomalous areas.

Hideout locality.—Numerous good botanical anomalies are present at the Hideout locality; some are associated with the Hideout mine and vicinity, but some are in areas not known to contain uranium deposits. Thick strata of the Shinarump member cropping out along the rim in most of this area justifies checking the anomalies to determine if they are related to ore deposits.

Dead Buck locality.—Many good botanical anomalies are present in the Dead Buck locality, and most of these coincide with areas known to be mineralized. Two good elongate anomalies (nos. 3 and 4, pl 6) occur where the Shinarump member is absent or only a few feet thick, but other strata of the lower part of the Chinle are mineralized. All anomalies in this locality warrant close inspection because thick Shinarump is present over most of the area.

Southern Deer Flat locality.—Many good botanical anomalies are in the southern Deer Flat locality, and some of these are supported by visible uranium minerals or high radioactivity. Anomalies are distributed completely around the rim formed by the Shinarump in this area, but those in the south and east appear to be most indicative of concealed ore deposits. All the anomalies in the southern Deer Flat locality warrant additional examination, however, because the Shinarump member is relatively thick at most outcrops.

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STANDARD PLANT NAMES USED IN THIS REPORT

In the following list the plants are arranged alphabetically within their families, which are listed in the commonly accepted order of primitive families to complex composites. The Latin and common names are from Kelsey and Dayton (1942), the authority and classification are according to Harrington (1954), and abbreviation according to Rydberg (1917).

Family Pinaceae:	
Juniperus scopulorum Sarg.	Rocky Mountain juniper.
utahensis (Engelm.) Lemmon	Utah juniper.
Pinus cembroides var. *edulis* Zucc.	Colorado pinyon pine.
ponderosa Dougl.	ponderosa pine.
Pseudotsuga taxifolia Britt.	Common Douglasfir.
Family Gnetaceae:	
Ephedra viridis Coville	green ephedra (Mormon tea).
Family Gramineae:	
Bouteloua sp.	grama grass.
Oryzopsis hymenoides (R. and S.) Rick	Indian ricegrass.
Sitanion hystrix (Nutt.) J. G. Smith	bottlebrush squirreltail.
Family Liliaceae:	
Yucca glauca Nutt.	small soapweed (Spanish bayonet).
Family Fagaceae:	
Quercus gambeli Nutt.	Gambel oak (scrub oak).
Family Polygonaceae:	
Eriogonum corymbosum Benth	Corymbed eriogonum (Sulfur flower).
deflexum Torr.	skeletonweed.
Family Chenopodiaceae:	
Atriplex canescens (Pursh) Nutt.	fourwing saltbush.
confertifolia (Torr. and Frem.)	shadscale saltbush.
Salsola Kali tenuifolia Tausch	tumbling Russianthistle.
Family Nyctaginaceae:	
Mirabilis multiflora (Torr.) Gray	Colorado four-o'clock.
Family Berberidaceae:	
Berberis sp.	barberry.
Family Cruciferae:	
Arabis holboelli Hornem.	Holboell rockcress.
Erysimum elatum Nutt.	Tall erysimum (hedgemustard).
Lesquerella gordoni (Gray) S. Wats	gordon bladderpod.
Physaria chambersi Rollins	double bladderpod.
Sisymbrium altissimum (L.) Britt.	tumblemustard.
Stanleya pinnata (Pursh) Britt.	desert princesplume.
Streptanthus cordatus Nutt. ex. Torr. and Gray	heartleaf twistflower.

Family Rosaceae:	
Amelanchier alnifolia Nutt.	saskatoon serviceberry.
utahensis Koehne	Utah serviceberry.
Cercocarpus montanus Raf.	true mountainmahogany.
Cowania stansburiana Torr.	Stansbury cliffrose.
Family Leguminosae:	
Astragalus sp.	milkvetch, poisonvetch.
Family Euphorbiaceae:	
Euphorbia sp.	euphorbia.
Family Cactaceae:	
Opuntia rhodantha Schumann	prickleypear.
Family Elaeagnaceae:	
Shepherdia rotundifolia Parry	roundleaf buffaloberry.
Family Polemoniaceae:	
Gilia leptomeria A. Gray	fairy trumpet gilia.
Phlox diffusa Benth.	spreading phlox.
Family Boraginaceae:	
Cryptantha ambigua (Gray) Greene	wandering Cryptantha.
Lappula sp.	stickseed.
Family Scrophulariaceae:	
Penstemon sp.	penstemon.
Family Caprifoliaceae:	
Symphoricarpos oreophilus A. Gray	mountain snowberry.
Family Compositae:	
Aplopappus clementis (Rydb.) Blake	clements goldenweed.
Artemisia tridentata Nutt.	big sagebrush.
sp.	sagebrush.
Aster venustus M. E. Jones	woody aster.
Brickellia sp.	brickellbush.
Chrysothamnus linifolius Greene	flaxleaf rabbitbrush.
Cirsium sp.	thistle.
Erigeron aphanactis Greene	fleabane.
Gutierrezia sarothrae (Pursh) Britt. and Rusby	broom snakewood.
Senecio uintahensis (A. Nels.) Greenman	uintah groundsel.
Solidago petradoria Blake	rock goldenrod.

Several of the plant names listed require short supplementary statements. The ponderosa pine of the Colorado Plateau is distinguished by some workers as a variety, *P. ponderosa* var. *scopulorum* Engelm. (Little, 1953, p. 270). The Douglasfirs of the Rocky Mountain and Pacific coast regions appear to be different enough to cause some authors to regard the two kinds as different species (Little, 1953, p. 308), and the accepted name of the tree of the Rocky Mountains, as given by Little (1953, p. 307) is *P. menziesii* var. *glauca* (Beissn.) Franco, a name not listed in "Standardized Plant Names" (Kelsey and Dayton, 1942). The presence of the mountainmahogany, *Cercocarpus montanus*, was determined by Edward E. Clebsch during the fieldwork. The kind common to the area, however, is given as *C.*

betuloides Nutt. (Birchleaf mountainmahogany) by A. Perry Plummer of the U.S. Dept. of Agriculture (written communication, 1956) to conform to the accepted name given by Little (1953, p. 104–105). Both *C. montanus* and *C. betuloides* are listed as separate species in "Standardized Plant Names" (Kelsey and Dayton, 1942); consequently, the kind of mountainmahogany in the area is not clearly known to the authors, it is possible that both species are present.