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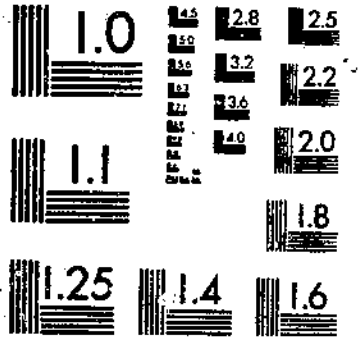

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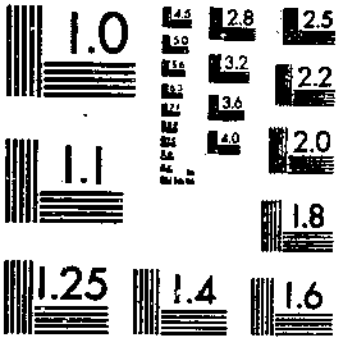

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TECHNICAL BULLETIN No. 713 MAY 1940

TYPES OF VEGETATION IN ESCALANTE VALLEY, UTAH, AS INDICATORS OF SOIL CONDITIONS

By

H. L. SHANTZ
Formerly Senior Physiologist in Charge

and

R. L. PIEMEISEL
Formerly Assistant Physiologist
Office of Plant Geography and Physiology
Bureau of Plant Industry

UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

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TYPES OF VEGETATION IN ESCALANTE VALLEY, UTAH, AS INDICATORS OF SOIL CONDITIONS [1]

By H. L. SHANTZ, formerly *senior physiologist in charge*, and R. L. PIEMEISEL, formerly *assistant physiologist, Office of Plant Geography and Physiology, Bureau of Plant Industry* [2]

CONTENTS

INTRODUCTION

Early investigations in the Great Plains dealt with the indicator value of grassland types (*7*). [3] Later studies in Tooele Valley, Utah (*3*), and in the southwestern desert region (*9*) dealt with the indicator significance of various types of desert vegetation. The large divisions of vegetation, northern desert shrub and southern desert shrub, indicate climatic differences. The types within each of these divisions indicate local differences in soil conditions, either in the chemical or physical nature of the soil or in its moisture content.

[1] Submitted for publication April 27, 1939.

[2] Authors' titles are those in effect at the conclusion of the work reported in this bulletin. H. L. Shantz is now Chief of the Division of Wildlife Management, Forest Service, and R. L. Piemeisel is physiologist in the Division of Sugar Plant Investigations, Bureau of Plant Industry. They are indebted to the following Bureau workers: T. H. Kearney, who, as head of the alkali and drought-resistant plant investigations, had charge of the work during the earlier years and contributed materially in actual studies as well as by advice and criticism; S. F. Blake, senior botanist, for the identification of the Compositae; Agnes Chase, associate botanist, for the identification of the grasses; and Ivar Tidestrom, formerly assistant botanist, for the identification of the other plants.

[3] Italic numbers in parentheses refer to Literature Cited, p. 46.

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Studies in Escalante Valley, Utah (fig. 1), reported in this bulletin, were begun shortly after those mentioned above, but the work, both in the field and on the manuscript, suffered long interruptions.[4] The vegetation of Escalante Valley, like that of Tooele Valley, belongs to

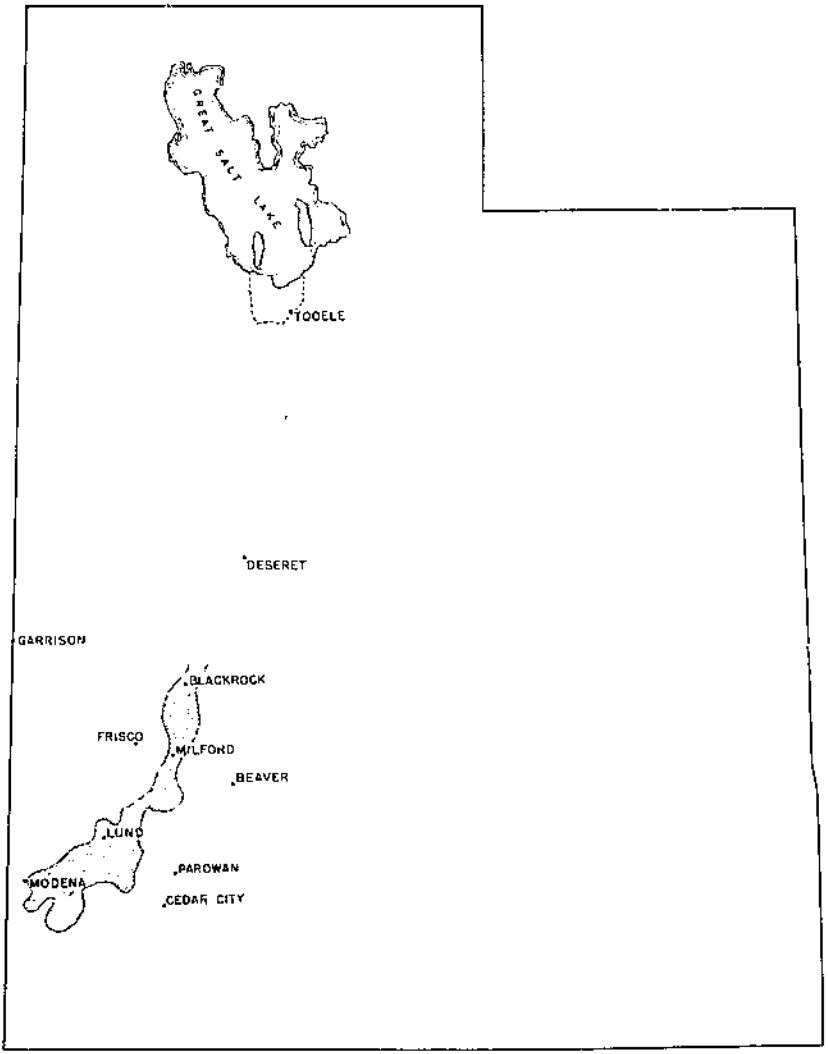


FIGURE 1.—Sketch map showing location of Escalante Valley, Utah.

the northern desert shrub. However, there are differences. Escalante Valley lies at one of the southernmost points of the northern desert shrub area, whereas Tooele Valley is more centrally located. In Escalante Valley there are additional vegetation types, notably that of grassland. Moreover, often over areas of considerable size,

[4] Reconnaissance trips were made through southwestern Utah in 1913–14 and were followed by detailed studies in 1915. The bulk of the manuscript was written shortly after. The mapping of the vegetation was completed in 1926–27.

there are different forms of growth of the same type. This is most marked in the sagebrush type, where a uniform growth of dwarfed sagebrush covers good-sized tracts and is often accompanied by obvious soil differences.

METHODS

The methods used have been described in detail in previous studies (*3*, *7*, *9*). After the locality had been selected for intensive study and a preliminary survey had been made of the vegetation, stations were selected in localities representative of the principal types. Here observations were made on the vegetation, and soil samples for salt-content and soil-moisture determinations were taken in the spring, when conditions were at or near the optimum and again in the fall when conditions were most unfavorable. Escalante Valley was mapped to show the relative areas and the distribution of the various types of vegetation. Quadrats in representative areas showed the relative densities of the stand, and photographs the character and appearance of the main types.

ENVIRONMENTAL CONDITIONS

PHYSIOGRAPHY

The southwestern part of Utah, being separated by a series of high mountain ranges from the southeastern part, is more closely related to the northwestern part in origin, topography, soils, and vegetation. The southwestern corner itself is cut up by somewhat lower mountain ranges having a general north and south direction.

Escalante Valley, at one time the southernmost bay of Lake Bonneville with a maximum depth of about 90 feet, was, according to Gilbert (*1*) "completely desiccated when the water retreated to the Provo level." At present it is a long irregular trough filled in with soils from the surrounding mountains to form a plain, broad and high at the south end and narrow and lower at the north. According to Lees (*4*), the thickness of the sediment in Escalante Valley, as shown by a well at Neels, is nearly 2,000 feet; the maximum thickness is not known.

A more detailed account of the physiography and geology, especially the ground water of Escalante Valley, is given by Lees (*4*) and Meinzer (*5*).

CLIMATE

The climate of Escalante Valley is in general similar to that of the northern desert shrub; that is, the winter temperatures are low (fig. 2, *A* and *B*), the total precipitation is low (fig. 2, *C*), though not so low as in the southern desert shrub (*9*), and the driest period occurs sometime during the summer months. In Escalante Valley (fig. 2, *C*) precipitation varies from 8.70 inches at Milford in the northern part to 10.14 inches at Modena at the southern end. Cedar City, Parowan, and Beaver, which lie in connecting valleys at higher elevations and in the upper edge of the sagebrush type (near to juniper or with juniper mixed in the sagebrush), have a higher precipitation but about the same relative monthly distribution. In the valleys to the west, separated from each other and from Escalante Valley by low mountain ranges, there is less rainfall, 6 to 7 inches at the Desert Range Experiment Station (*10*) and 7.36 inches at Garrison.

In Escalante Valley, June is the driest month. Throughout a large part of the northern desert shrub by far the driest months are July and August, with August somewhat the drier of the two and September the third driest month. From the central portion southeast to Escalante Valley the precipitation for July and August increases until at Modena these 2 months show the greatest precipitation of the year.

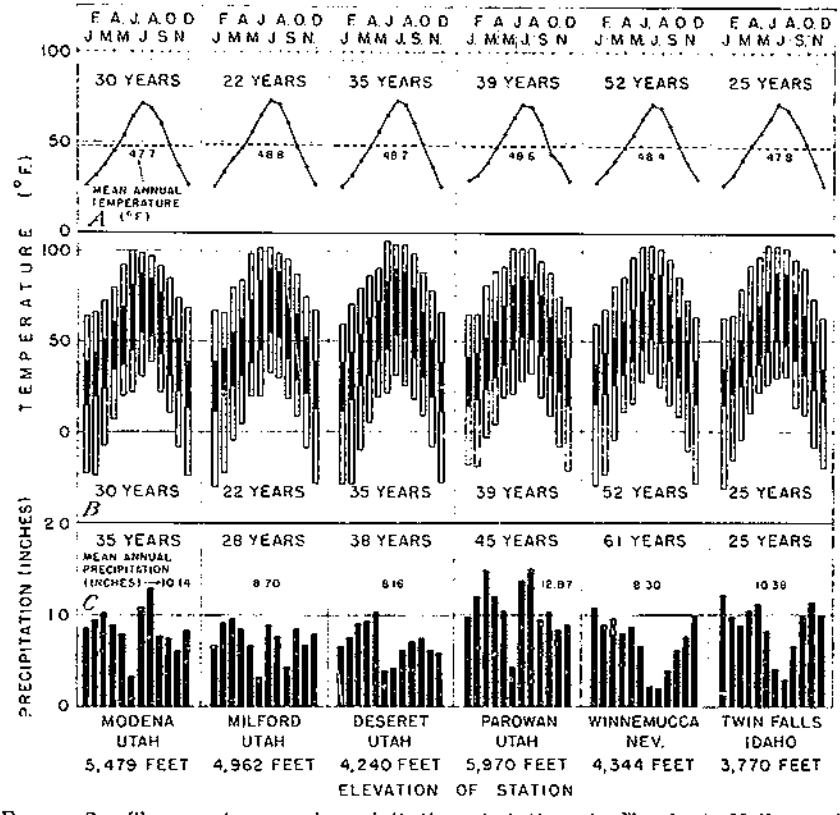


FIGURE 2.—Temperatures and precipitation at stations in Escalante Valley and, for comparison, at stations in the northern and western portions of the northern desert shrub type of vegetation: *A*, Average monthly temperature; *B*, lowest temperatures, average of minima, average of maxima, and highest temperatures for each month; *C*, average monthly precipitation. (From U. S. Weather Bureau data. Records are for periods indicated, ended with 1930.)

Near Modena, too, the northern desert shrub is less extensive and desert grass of the southern desert becomes an important part of the vegetation.

The summer rainfall, if compared to an equal amount in spring, is probably of slight benefit to most of the types of vegetation. Soil samples taken a week or 10 days after a storm of over 1 inch (September 2) indicate that such rains benefit the grass type more than the others.

The mean annual temperature varies slightly in the Escalante Valley from 47.7° F. at Modena, the higher southern end, to 48.8° at

Milford (fig. 2, *A*). The mean temperatures in the connecting higher valleys and at or near the juniper line are much the same, 50.8° for Cedar City and 48.6° for Parowan.

In the northern desert temperatures above 100° F. are rare, while in the southern desert these are the rule for 5 or 6 months of the year. In fact, this very high temperature of the southern desert shuts out most of the species of the northern desert, while the low temperature of the northern desert shuts out most of the succulents of the southern desert.

The northern desert has a cold rest period and usually a drought rest period in midsummer. The southern desert has no cold rest period but a drought period in both spring and fall (*9*). The northern desert has a relatively short frost-free growing period: 121 days at Milford; 131 at Modena; 116 at Deseret; 129 at Twin Falls, Idaho; and 136 days at Winnemucca, Nev. St. George and Lone Pine, at the northern edge of the southern desert, have 176 and 185 frost-free days, respectively, and Indio, Calif., 302. There is little doubt that ecologists will find in the physiology of the characteristic plants of the sagebrush and creosotebush deserts decidedly different temperature relations and temperature optima. The vegetation of the southern desert consists chiefly of succulents and evergreens, while that of the northern desert is made up chiefly of deciduous shrubs. The northern desert is not exposed so much as the southern desert to excessively high temperatures or to dry air during the growing season.

SALINITY OF SOILS

Concentrations of salts occur in the low places, which may be either dry bare flats or wet salt-incrusted flats. The former are temporarily covered with water from spring floods and heavy rains, though for the greater part of the year they are dry and without vegetation. At this time the surface is very hard and often cracked. The wet salt flats are covered with vegetation composed of salt-tolerant species. In these flats the subsoil at least is wet throughout the year and the surface soil is wet a large part of the year. Here conditions for the concentration of salt and its gradual accumulation are most favorable. The surface evaporation of water from the subsoil gradually concentrates the salt, which often forms a heavy layer or crust. The salt content of the surface foot is often over 2½ percent.

In table 1 are shown chemical analyses of representative samples of saline soils. In five out of the eight samples the sulfate radical predominated, especially so in the samples where salts were excessive (crust samples). Chlorine predominated in two cases (samples 4 and 8, both saltgrass soils), but sulfate in the crust sample in saltgrass. Sodium predominated in all eight samples. In the hardpan in shadscale (sample 1), sodium bicarbonate was greatest, and it was high in one of the saltgrass soils (sample 3). Meinzer (*5*), in analyses of two soil samples, one taken near Webster's Well, west of Table Buttes, and one near Lund, shows sulfates predominating in the upper 2 and 3 feet, respectively. Chlorides predominated in the third foot in one case and in the fourth in the other.

TABLE 1.—*Chemical analyses of soils of Escalante Valley, 1915* [1]

[Results shown in parts per 100,000 of dry soil]

Sample No.	Type of vegetation	Depth of soil sample	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	NO_3	Total solids (by evaporation)
1	*Atriplex confertifolia* (shadscale).	Hardpan at 1 foot, 9 inches.	0	100	22	36	(2)	0	69	...	...	250
2	*Allenrolfea occidentalis* (pickleweed).	First foot	0	131	320	540	(2)	0	518	...	...	1,520
3	*Distichlis spicata* (saltgrass)	Crust	2,650	2,420	4,870	6,200	57	62	8,504	703	20	27,270
4	do	First foot	10	202	510	350	48	(2)	529	...	...	1,740
5	*Sarcobatus-Distichlis* (greasewood-saltgrass).	Crust	28	272	5,850	36,830	286	43	20,926	444	...	64,840
6	*Sarcobatus-Atriplex* (greasewood-shadscale).	Composite sample, 3 and 4 feet	0	70	334	1,370	143	(2)	736	...	...	2,642
7	do	do	0	46	424	1,980	250	72	802	28	...	3,610
8	*Distichlis spicata* (saltgrass)	Second foot	0	145	528	340	46	0	509	...	...	1,650

[1] Analyses made by the Bureau of Soils, U. S. Department of Agriculture.
[2] Trace.

White (*13*) has recently made a map of the lower portion of Escalante Valley. The map gives the depth to ground water and shows four grades of land with a general statement of the plant cover for each grade.

The total salt content of each of the soil samples listed in tables 3 to 16 was determined by the electrical-resistance method. The method and its accuracy was discussed in an earlier publication (*3*).

TYPES OF VEGETATION

PLANT COMMUNITIES AND DOMINANT PLANTS

For ready reference the plant communities of Escalante Valley are given below with the names of the plants that characterize the community. The communities are listed in the order in which they are treated in the following pages.

Plant communities on nonsaline soils

Sagebrush association	*Artemisia tridentata.*
Galleta association	*Hilaria jamesii.*
Little rabbitbrush association	*Chrysothamnus* spp.
Winterfat association	*Eurotia lanata.*
Fourwing saltbush community	*Atriplex canescens.*
Juniper association	*Juniperus utahensis.*

Plant communities on saline soils

Shadscale association	*Atriplex confertifolia.*
Greasewood association	*Sarcobatus vermiculatus.*
Saltgrass association	*Distichlis spicata.*
Pickleweed association	*Allenrolfea occidentalis.*
Red samphire community	*Salicornia rubra.*
Saltsage community	*Atriplex falcata.*
Mixed vegetation on sand dunes or hummocks	*Chrysothamnus* spp. and others.

COMMON AND BOTANICAL NAMES OF VARIOUS PLANTS

The common and the botanical names of plants that are frequently mentioned in the text are given below. Less common plants not often mentioned are listed under the various vegetation types, under the subheads Botanical Composition.

Alkali sacaton (tussock grass)	*Sporobolus airoides* (Torr.) Torr.
Blistercress	*Cheirinia repanda* (L.) Link.
Bottlebrush squirreltail	*Sitanion hystrix* (Nutt.) J. G. Smith.
Cactus	*Opuntia* spp.
Creosotebush	*Covillea tridentata* (Moc. and Sesse) Vail.
Fourwing saltbush (chamiso)	*Atriplex canescens* (Pursh) Nutt.
Galleta (curly grass)	*Hilaria jamesii* (Torr.) Benth.
Giant wild-rye	*Elymus condensatus pubens* Piper (*E. cinereus* Scribn. and Merr.).
Greasewood	*Sarcobatus vermiculatus* (Hook.) Torr.
Hop-sage	*Grayia spinosa* (Hook.) Moq.
Indian ricegrass	*Oryzopsis hymenoides* (Roem. and Schult.) Ricker.
Juniper	*Juniperus utahensis* (Engelm.) Lemmon.
Mat saltbush	*Atriplex corrugata* S. Wats.
Matchweed (snakeweed)	*Gutierrezia sarothrae* (Pursh) Britton and Rusby.
Needle-and-thread	*Stipa comata* Trin. and Rupr.
Pickleweed	*Allenrolfea occidentalis* (Nutt.) Kuntze.
Rabbitbrush:	
Big rabbitbrush (2 to 5 feet)	*Chrysothamnus* spp.; for species, see under Mixed Vegetation on Hummocks and Sand Dunes, p. 40.
Little rabbitbrush (½ to 2 feet)	*Chrysothamnus* spp; for species, see under Little Rabbitbrush Association, p. 19.
White-flowered rabbitbrush	*Chrysothamnus albidus* (Jones) Greene.
Red samphire	*Salicornia rubra* A. Nels.
Russian-thistle	*Salsola pestifer* A. Nels.
Sagebrush	*Artemisia tridentata* Nutt.
Saltgrass	*Distichlis spicata* (L.) Greene.
Saltsage	*Atriplex falcata* (Jones) Standl.
Sand dropseed	*Sporobolus cryptandrus* (Torr.) A. Gray.
Seepweed (inkweed)	*Dondia depressa* (Pursh) Britton.
Shadscale	*Atriplex confertifolia* (Torr.) S. Wats.
Tansymustard	*Sophia pinnata* (Walt.) Howell.
Three-awn:	
Fendler	*Aristida fendleriana* Steud.
Red	*Aristida longiseta* Steud.
White sage	*Kochia vestita* (S. Wats.) A. Nels.
Winterfat [1]	*Eurotia lanata* (Pursh) Moq.

[1] Sometimes misnamed white sage.

DISTRIBUTION OF VEGETATION TYPES

The portion of the northern desert shrub that covers Escalante Valley forms one of the southernmost points of this type of vegetation. Sagebrush is found as far south as the Mexican border but only in scattered fragments at high altitudes. It ceases to be a dominant shrub in the desert vegetation about 75 miles south of Modena. From this point south, creosotebush, one of the dominant shrubs of the southern desert shrub type, takes the place of sagebrush. The two shrubs overlap only very slightly. Where they occur in the same valley they occupy different benches or different slopes, the creosotebush being found only in the hotter and drier places. Considerable areas of shadscale push much farther south on the lower land extending into the Mohave Desert. Fourwing saltbush, on the other hand, continues down into the lowest, hottest valleys of the Southwest (*9*) (Coachella, Imperial, and Gila River Valleys), forming considerable areas, especially on sandy soils. Greasewood, however, becomes less

important until in the valleys just mentioned it is rarely found and never in large areas. Species of rabbitbrush become less abundant in the south, never occurring in large areas, their place being taken by species of *Aplopappus*. Saltgrass and pickleweed cover the wet salt flats in both the Great Basin and southwestern deserts; although in the Southwest saltbush and arrowweed often cover strongly saline, wet lands. A comparison of the numbers of species found in the northern and the southern desert shrub is given by Tidestrom (*11*).

The plant communities near the Desert Ranger Station in a valley 50 miles west of Milford are given by Stewart and Keller (*10*).

Shantz (*8*) gives the extent and the various types of the northern desert shrub found in Utah and Nevada.

In any transection of the vegetation types of Escalante Valley one finds, with few exceptions, somewhere between the bottom of the valley and the higher benches, greasewood and shadscale. (See map at end of bulletin.) Likewise, in going from the greasewood-shadscale to the mountains, one will eventually pass through sagebrush and then juniper. The ground between the greasewood-shadscale and sagebrush may be variously covered, or sagebrush may immediately adjoin the greasewood-shadscale. In the southern and southeastern portions of Escalante Valley there are large areas of either galleta or little rabbitbrush above the greasewood-shadscale and bordering on the sagebrush. There may be sharp alternations or all three may be much mixed. In the more northern parts of the valley, winterfat, little rabbitbrush, and more rarely white sage or chamiso lie between the greasewood-shadscale and the sagebrush.

Going from the greasewood-shadscale area to the bottom of the valley, one encounters two different groupings of plant communities depending on whether he is going toward a dry, bare salt flat or a wet salt flat. In going toward the former, one passes from the greasewood through a zone of saltsage or sometimes through chamiso, then saltsage, and finally out upon the bare flat. In going toward the wet flat, one passes from a greasewood area to one of big rabbitbrush and alkali sacaton, then an area of saltgrass, one of pickleweed, and finally the open salt-covered flat with sometimes a scattered growth of red samphire beyond the outer edge of the pickleweed.

These areas are not always well defined, nor are all of them always present. In places the soil may be so cut up by drainage courses or heaps of sand or gravel that the vegetation is badly mixed. However, where there is a long stretch of gently sloping land the grouping will be one or the other of the two mentioned above.

Separating the main types of vegetation in Escalante Valley on the basis of alkali, there are, on the alkali-free lands, juniper, sagebrush, little rabbitbrush, galleta, fourwing saltbush, and winterfat; on moderately saline lands, shadscale, greasewood, and saltsage; and on the excessively saline lands, pickleweed, saltgrass, and red samphire. The mixed vegetation on sand dunes and hummocks may be put under any of these headings, since the dunes or hummocks may be formed on light soils with a low salt content or on the saline flats of heavy soils.

Of the former group the juniper occupies the highest lands, being found in narrow irregular strips between the sage and the piñons. Below the juniper lies the sagebrush belt. Still farther north there are alternations of sagebrush and shadscale. South of Milford sagebrush skirts the sides of the valley and leaves the lower, heavier, and

usually saline lands between Milford and Modena to greasewood, shadscale, pickleweed, and saltgrass. On the western slopes of the valley sagebrush is the most important type of vegetation, but on the eastern slopes sagebrush becomes of less importance than little rabbitbrush. The little rabbitbrush areas are closely connected with the lighter soil areas, although, where the soil is light enough to form dunes, little rabbitbrush is replaced by a mixed type of vegetation characteristic of the dunes. The galleta grass areas are scattered and not extensive in the north end of the valley but become more important going south, until near Modena they form the major part of the vegetation.

The areas of winterfat, meadowlike and usually not extensive, lie between the sagebrush belt above and the greasewood below and alternate with areas of shadscale, little rabbitbrush, or galleta.

The vegetation types on alkali lands can be divided into those on dry alkali land, including shadscale and saltsage, and those on wet alkali land, where the water table is high, including greasewood, greasewood-shadscale, pickleweed, and saltgrass.

The shadscale areas, while frequently alternating with sagebrush, little rabbitbrush, and galleta usually lie next to the greasewood and often mix with it over large areas.

Of the wet alkali lands, those covered with saltgrass are of greater extent than those occupied by pickleweed. Both of these plants grow on lands that are moist most of the year and that are the lowest in the valley, the pickleweed land, however, being slightly lower than the saltgrass land and extending farther into the bare salt-flat areas. Greasewood covers land between the saltgrass or the pickleweed areas and the winterfat or shadscale. Here the upper soil is not so wet as that of the pickleweed, saltgrass, or salt-flat lands and the salt content is lower.

The types of vegetation, especially those that occur on the higher slopes, alternate frequently, owing, at least in part, to the irregularity of the form of Escalante Valley, which causes sudden changes in the soils and in the direction of the slopes. These sudden changes are often reflected in the vegetation as sharp lines between adjoining types that stand out distinctly because of slight differences in color. Such abrupt changes appear between sagebrush and juniper (pl. 1, *A*, *B*); between sagebrush and rabbitbrush; between winterfat and little rabbitbrush (pl. 7, *A*, and pl. 11, *A*); and between galleta and little rabbitbrush (pl. 3, *B*). Such a change is shown between greasewood and shadscale in plate 11, *A*, with winterfat beyond, and in plate 11, *B*, between greasewood and winterfat.

The differences in density of some of the main types of vegetation are shown in table 2.

TABLE 2.—*Plants per 100 square meters, based on a representative quadrat, in each of the main types of vegetation*

Type of vegetation	Living plants	Dead plants	Young plants	Total
	Number	*Number*	*Number*	*Number*
Sagebrush	102	8	6	116
Little rabbitbrush	78	4	0	82
Winterfat [1]	1,625	50	225	1,900
Shadscale	255	45	7	307
Greasewood	89	0	0	89

[1] A calculation based on a 2-m. quadrat. All others are actual figures from 10-m. quadrats.

PLANT COMMUNITIES ON NONSALINE LAND

SAGEBRUSH ASSOCIATION

TOPOGRAPHICAL RELATIONS

The sagebrush association (pl. 1 and 2) occurs on the coarser material of the benches at the side of the mountains and on the fans at the mouths of canyons. Where the slopes are steep and the amount of material is small, this type is lacking. The largest areas are found on the fans at the mouths of canyons (see map).

Where sagebrush occurs in the center of the valley it is mixed with other plants, with rabbitbrush on the sand hills and with greasewood on areas of heavy soil that receive floodwaters or are subirrigated. Some of the small, high valleys that drain into the valley from the east are covered with sagebrush, with only narrow fringes of greasewood along drainage channels.

Scattered plants of sagebrush are found along drainage channels in many associations where unfavorable soil conditions, either too dry or too saline, do not permit a uniform growth over the entire area. Sagebrush occurs along the dry watercourses in the greasewood, the shadscale, the winterfat, and the galleta association and the saltsage community. In contrast, neither shadscale nor saltsage occurs along drainage channels in the sagebrush association. Greasewood may do so at the lower limits of the sagebrush area, while plants from the mountain-brush or juniper belts above may occur along drainage channels in the upper part of the sagebrush area.

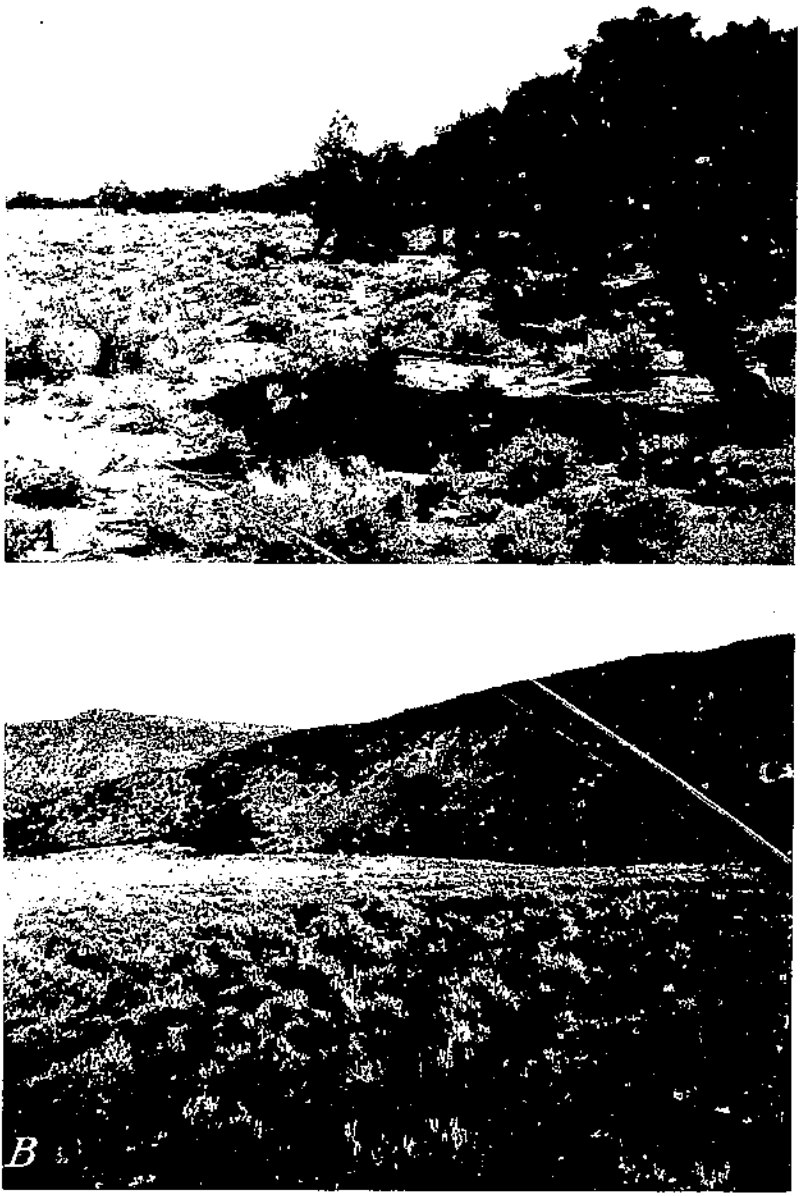
BOTANICAL COMPOSITION

Typical areas of sagebrush in Escalante Valley show almost no other woody species (pl. 2). Moreover, the herbaceous flora is almost entirely lacking, because of excessive grazing. Plants are few, both in the number of species and in the number of individuals. This was noted repeatedly in 1915 and again in 1925 and 1926.

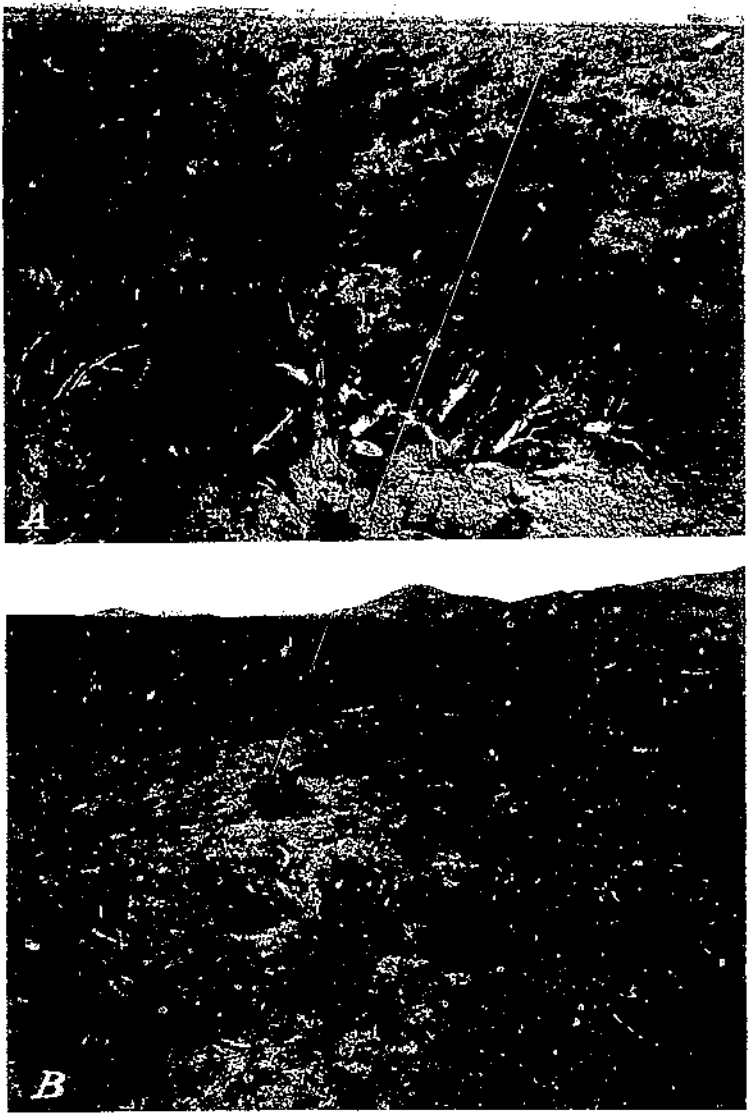
At the borders of the typical areas there is commonly an admixture of little rabbitbrush, and in other places shadscale, galleta, or winterfat may mix with the sagebrush. To a lesser extent, in the center of the valley on the heavier lands and sometimes on the sandy ridges, sagebrush mixes with greasewood and giant wild-rye. On the sandy ridges sagebrush is more often associated with fourwing saltbush or big rabbitbrush. Around Modena near the grass areas the spaces between sagebrush bushes are partly covered with grasses, chiefly galleta, with some ricegrass and bottlebrush squirreltail in the shelter of the bushes.

The density of a sagebrush stand and the location of the individuals as recorded in a 10-m. quadrat are shown in figure 3.

On rocky ridges, besides the three grasses just mentioned, the following are associated with a dwarf growth of sagebrush: Blue grama, red three-awn, sand dropseed, *Chenopodium fremontii* S. Wats., and *Eriogonum* sp. On not easily accessible rock-strewn slopes covered with sagebrush, in addition to the grasses common in typical areas, there were needle-and-thread, *Poa secunda* Presl, *Poa fendleriana* (Steud.) Vasey, *Agropyron inerme* (Scribn. and Smith) Rydb., *Crepis intermedia* Gray, *Erigeron concinnus* (H. and A.) T. and G., and



A, Juniper at the right and sagebrush at the left, an abrupt transition between these two communities. The sagebrush is small and dwarfed near the trees. Juniper trees are uniform in size and old. Both communities are relatively pure, and there is no evidence of one giving way to the other. (Milford, Utah, September 9, 1913.) *B*, Sagebrush in the foreground, meeting in the background the juniper of the hillsides. This photograph represents the condition along the east edge of the valley. The juniper has pushed out over the sagebrush on the alluvial fan at the left. (Parowan, Utah, September 6, 1914.)



A, Dead and dying sagebrush. In the fall of 1915 sagebrush died over a large area in the Escalante Valley. In this photograph most of the plants are dead or partly dead, with one or two branches living. (Three miles north of Milford, Utah, September 11, 1915.) *B*, Sagebrush dying out or giving way to galleta grass. Apparently when this grass begins to spread in a sage area it shuts off the water from the deeper rooted sage and replaces it. This type of change is probably favored by year of unusually light rainfall, which replenishes the soil moisture of the surface layers but does not permit of the deep storage of moisture essential for a good growth of sagebrush. The reverse of this process has been noted in other places. (Boring 14, Modena, Utah, August 27, 1913.)

Ephedra viridis Coville. On some of the higher rock-strewn hills to the west, black sage (*Artemisia nova* A. Nels.) takes the place of sagebrush.

Globemallow and cactus were seen in sagebrush in all parts of the valley, but the number of individuals in any one place was small. Other species noted in sagebrush were as follows: *Artemisia spinescens* D. C. Eaton, *Aplopappus nanus* (Nutt.) Gray, *Astragalus eibarius* Sheld. (*A. arietinus* Jones), *A. uintahensis* Jones, *Eriogonum hookeri*

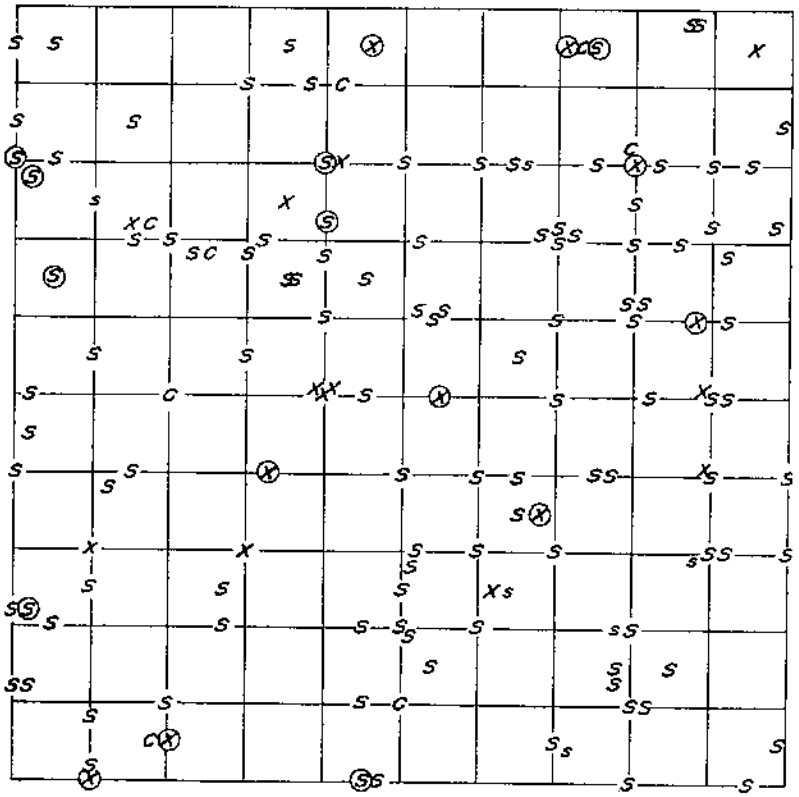


FIGURE 3.—A 10-m. quadrat in the sagebrush association, showing the location of each individual plant: *S*=sagebrush; *s*=young sagebrush; *C*=*Chrysothamnus puberulus*; *X*=unidentified plant. A circle around the letter denotes that the plant is dead. Other plants in the vicinity of the quadrat were a few scattered plants of globemallow, gallcta, and hop-sage.

S. Wats., *E. cernuum* Nutt., *Pteryxia foeniculacea* Nutt., *Plantago purshii* Roem. and Schult., *Phlox stansburyi* (Torr.) Heller, *Sphaeostigma boothii* (Dougl.) Walp., and *Tetradym a* sp.

The plants, including introduced weeds, that occur on cleared sagebrush lands are discussed under the subheading Effects of Disturbing Factors.

APPEARANCE

The monotonous appearance of large areas of sagebrush (pl. 1), so characteristic of much of the desert vegetation, is heightened in Escalante Valley by the dwarfed growth and the sickly condition of

many of the plants. Moreover, the seasonal aspects are less striking, owing chiefly to excessive grazing, with the result that the perennial herbs, perennial grasses, and even annuals are almost entirely lacking.

SOIL CONDITIONS

Typical sagebrush land in Tooele Valley was characterized by a moderately light soil (*3*). This is also true in Escalante Valley, as indicated by the relatively low moisture equivalents in table 3. The soil ranges from a sandy loam to a fine sandy loam. Heavier soils are found near the greasewood border (sample 28) and one (sample 32) was found in a very poor growth of sagebrush.

TABLE 3.—*Comparison of spring and fall soil conditions in areas of sagebrush, 1915* [1]

SPRING

Sample No.	Date of collection	Wilting coefficient at—				Moisture content above or below wilting coefficient at—				Salt content at—			
		1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
5	Apr. 7	8.2	7.0	7.4	6.0	−0.3	+4.2	+4.0	+2.7	0.01	0.02	0.02	0.08
15	Apr. 10	6.5	4.9	12.8	22.0	+1.8	+2.1	+10.5	+15.1	.02	.02	.15	.23
18	Apr. 12	6.0	6.6	...	...	−3.9	+.7	...	...	.02	.02	.12	.14
19	do	5.9	3.3	9.9	19.2	+1.5	+3.9	+3.9	+3.2	.02	.02	.14	.94
21	do	6.2	6.5	9.3	12.3	+.5	+1.6	+1.7	+3.8	.01	.02	.66	1.36
23	do	4.9	5.8	17.6	.....	+1.5	+1.8	+5.6	.....	.02	.02	.05	.....
24	Apr. 13	4.7	4.5	5.1	6.4	+2.0	+2.9	+3.9	+1.0	.01	.01	.02	.16
28	Apr. 16	14.2	12.6	12.3	18.7	+1.9	+.2	+1.8	+3.4	.08	.08	.12	.13
32	Apr. 20	13.7	10.0	13.9	13.6	−.2	+.5	+.5	−2.3	.08	.23	.20	.28
37	Apr. 22	6.1	9.8	7.7	...	+.3	+3.8	+.0	...	.02	.02	.02	.02
38	do	8.1	12.2	9.6	...	−1.4	+4.7	+2.0	...	.02	.03	.13	.14
42	Apr. 23	9.1	11.1	13.7	...	−.3	+3.1	−.4	...	.02	.02	.13	...
43	do	7.1	...	8.4	...	−.4	...	−.1	...	.02	.02	.07	...
3	Apr. 6	8.2	9.5	7.0	5.0	+3.2	+4.7	+1.4	−.6	.02	.02	.02	.14
Average		7.8	8.7	10.4	12.9	+.4	+2.6	[2]+2.1	[2]+1.6	.03	.04	.13	.33

FALL

5	Sept. 9	4.7	6.7	...	6.8	+2.5	+.6	...	−1.8	0.02	0.02	0.02	0.07
18	do	5.5	...	5.3	5.4	−.6	...	−3.4	+1.8	.02	.01	...	.07
19	do	4.8	5.3	11.3	19.1	+.7	−1.5	−.7	+.9	.02	.02	.28	.46
21	do	5.5	5.3	3.7	2.4	+1.2	−1.1	−.5	+.3	.02	.02	...	...
23	do	5.9	6.0	...	...	−.4	−1.8	...	...	.02	.02	.01	...
24	Sept. 10	4.5	4.5	4.7	5.4	+2.1	−.6	−.8	−1.3	.02	.02	.02	.07
28	do	16.6	13.7	15.8	19.3	−1.4	−.3	+1.7	+3.3	.08	.09	.13	.14
32	Sept. 12	10.4	18.8	...	13.6	−.5	−2.6	...	−1.4	.09	.14	.15	.17
37	Sept. 11	5.0	8.7	...	7.2	+.5	−.2	...	−2.9	.02	.02	.01	...
38	do	7.9	13.5	10.7	3.7	−1.6	−2.7	−2.7	+.2	.02	.07	.16	.12
Average		7.1	9.2	8.6	9.2	+.3	−1.2	−1.1	−.1	.03	.04	.10	.16

[1] All data are stated in percentages of the dry weight of the soil.
[2] High soil-moisture values for sample 15 (probably affected by subirrigation) have been omitted in computing averages. If included, averages would be +2.7 and +3.3 for third and fourth foot respectively.

The spring moisture-content determinations show a good supply of moisture to a depth of 3 or 4 feet. Averages for the fall show little or no available water at any depth to 4 feet. Slight amounts in the first foot of about one-half of the samples were due to the rain (1.02 inches) on September 2.

Optimum soil-moisture conditions are most nearly approached in some of the small areas near the center of the valley (sample 28, table 3), where there is available water to a depth of at least 4 feet in spring and some available water in the third and fourth foot in the fall. Here the plants have large trunks and form a bushy top 5 or even 6 feet high. The soil is very near to a loam, being heavier than that on which sagebrush is usually found, but it is permeable There is no hardpan and not an excessive salt content to a depth of 4 feet.

The good growth of sagebrush in table 4 shows moisture to a depth of 3 or 4 feet in spring at least. The poor growth of sagebrush in table 4 shows poor soil-moisture conditions, with a shallow hardpan or gravel or if the soil moisture conditions are good a high salt content in the third and the fourth foot. Sample 18 (table 4) contrasts with sample 28 mentioned above, for both spring and fall moisture determinations show little or no available water, and there is a hardpan at 12 inches. Here the sagebrush plants were some of the smallest in the valley, averaging 6 inches to 1 foot in height.

As shown in tables 3 and 4, the average salt content of sagebrush land is low. Where the salt content increases up to 0.5 percent in the third or fourth foot, as in samples 19 and 21, table 4, the sagebrush plants are sickly and stunted (at sample 19 many were only 6 inches high; at sample 21 they averaged about 1 foot in height). The effect of the high salt content is about the same as that of a deficient water supply, discussed above in connection with soil moisture. This is illustrated in sample 17, table 5 (p. 16), where there is a plentiful supply of moisture in both spring and fall but where the salt content reaches 0.5 percent in the second foot. The sagebrush plants are stunted and poor and are mixed with salt-tolerant plants—big rabbitbrush, saltgrass, and greasewood.

While a good growth of sagebrush indicates a light soil (from a sandy loam to a fine sandy loam), readily permeable, with available water during the growing season to a depth of 4 feet and with a negligible amount of salts to that depth, a dwarfed growth of sagebrush indicates a shallow soil with some obstruction to the development of roots, such as a calcareous hardpan, a layer of coarse gravel, or a high salt content (table 4).

ADAPTATION OF SAGEBRUSH TO SOIL CONDITIONS [5]

While sagebrush can use, by means of its taproot, soil moisture to a depth of 15 feet, areas of sagebrush under such conditions, if present at all in Escalante Valley, are small. The depth (at least 4 feet) required for a normal, healthy growth of the sagebrush is found chiefly in the smaller areas in the center of the valley. In the large areas of sagebrush, the roots are confined to the upper layers of soil (18 to 30 inches) and the size of the bushes is correspondingly smaller.

EFFECTS OF DISTURBING FACTORS (SECONDARY SUCCESSIONS)

In 1915 sagebrush died from drought over a large area (pl. 2, *A*). In another place it was burned off and little rabbitbrush succeeded it. In some places sagebrush reseeded itself directly where conditions were very favorable for a rapid reseeding.

[5] A more detailed statement of the root development and the adaptations to physical conditions is given in an earlier publication (3).

TABLE 4.—*Comparison of soil conditions in areas of good and poor sagebrush, 1915*

GOOD SAGEBRUSH

Sample No.	Date of collection	Wilting coefficient [1] at—				Moisture content above or below wilting coefficient [1] at—				Salt content [1] at—				Depth of hardpan, gravel, etc.	Height of plants
		1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet		
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		
15	Apr. 10	6.5	4.9	12.8	22.0	+1.8	+2.1	+10.5	+15.1	0.02	0.02	0.15	0.23	No hardpan	4 to 5 feet.
24	Apr. 13	4.7	4.5	5.1	6.4	+2.0	+2.9	+3.9	+1.0	.01	.01	.02	.16	Hardpan at 44 inches	2 to 3 feet.
24	Sept. 10	4.5	4.5	4.7	5.4	+2.1	−.6	−.8	−1.3	.02	.02	.02	.07		
28	Apr. 16	14.2	12.6	12.3	18.7	+1.9	+.2	+1.8	+3.4	.08	.08	.12	.13	No hardpan	4 to 6 feet.
28	Sept. 10	16.6	13.7	15.8	19.3	−1.4	−.2	+1.7	+3.3	.08	.09	.13	.14		
37	Apr. 22	6.1	9.8	7.7	-------	+.3	+3.8	+.9	-------	.02	.02	.02	.02	Hardpan at 24 inches	2 to 4 feet.
37	Sept. 11	5.6	8.7	-------	7.2	+.5	−.2	-------	−2.9	.02	.02	.01	-------		
5	Apr. 7	8.2	7.0	7.4	6.0	−.3	+4.2	+4.0	+2.7	.01	.02	.02	.08	Hardpan at 18 inches	2 to 3 feet.
5	Sept. 9	4.7	6.7	-------	6.8	+2.5	+.6	-------	−1.8	.02	.02	.02	.07		
3	Apr. 6	8.2	9.5	6.8	5.0	+3.2	+4.7	+1.4	−.6	.02	.02	.02	.14	....do	2 to 3 feet.
Average or range.		7.9	8.2	9.1	10.8	-------	-------	-------	-------	.03	.03	.05	.12	Hardpan at 18 to 44 inches or lacking.	2 to 6 feet.
Spring		-------	-------	-------	-------	+1.5	+3.0	[2] +3.8	[2] +4.3	-------	-------	-------	-------		
Fall		-------	-------	-------	-------	+.9	−.1	+.5	−.7	-------	-------	-------	-------		

POOR SAGEBRUSH

23	Apr. 12	4.9	5.8	17.6	-------	+1.5	+1.8	+5.6	-------	0.02	0.02	0.05	-------	Hardpan at 22 inches	8 inches to 2¼ feet.
23	Sept. 9	5.9	6.0	-------	-------	−.4	−1.8	-------	-------	.02	.02	.01	-------		
18	Apr. 12	6.9	6.6	-------	-------	−3.9	+.7	-------	-------	.02	.02	.12	0.14	Hardpan at 12 inches	Less than 1 foot.
18	Sept. 9	5.5	-------	5.3	5.4	−.6	-------	−3.4	+1.8	.02	.01	-------	.07		
19	Apr. 12	5.9	3.3	9.9	19.2	+1.5	+3.9	+3.9	+3.2	.02	.02	.14	.94	Gravel at 12 inches	8 inches to 1½ feet.
19	Sept. 9	4.8	5.3	11.3	19.1	+.7	−1.5	−.7	+.9	.02	.02	.28	.48		
21	Apr. 12	6.2	6.5	9.3	12.3	+.5	+1.6	+1.7	+3.8	.01	.02	.66	.36	Hardpan at 24 inches	1 foot.
21	Sept. 9	5.5	5.3	3.7	2.4	+1.2	−1.1	−.5	+.3	.02	.02	-------	-------		
32	Apr. 20	13.7	10.0	13.9	13.6	−.2	+.5	+.5	−2.3	.08	.23	.20	.28	....do	4 inches to 1 foot.
32	Sept. 12	10.4	18.8	-------	13.6	−.5	−2.6	-------	−1.4	.09	.14	.15	.17		
38	Apr. 22	8.1	12.2	9.6	-------	−1.4	+4.7	+2.0	-------	.02	.03	.13	.14	Hardpan at 12 inches	1 to 1½ feet.
38	Sept. 11	7.9	13.5	10.7	3.7	−1.6	−2.7	−2.7	+.2	.02	.07	.16	.12		
42	Apr. 23	9.1	11.1	13.7	-------	−.3	+3.1	−.4	-------	.02	.02	.13	-------	....do	Do.
43	....do....	7.1	-------	8.4	-------	−.4	-------	−.1	-------	.02	.02	.07	-------	....do	Do.
Average or range.		7.3	9.5	10.3	11.2	-------	-------	-------	-------	.03	.05	.18	.30	Hardpan at 12 to 24 inches	4 inches to 2½ feet.
Spring		-------	-------	-------	-------	−.3	+2.3	+1.9	+1.6	-------	-------	-------	-------		
Fall		-------	-------	-------	-------	−.2	−1.9	−1.8	−.4	-------	-------	-------	-------		

[1] Percentage of dry weight of soil.

[2] If high values for sample 15 (probably affected by subirrigation) are omitted, averages are +2.4 and +1.6 for third and fourth foot respectively.

Russian-thistle was still restricted to definite portions of the valley in 1915. It covered some good-sized tracts near Milford and some in other parts of the valley. By 1925 it had increased greatly, and it has increased since then. [6] At first the greatest increase occurred on abandoned cultivated lands or in their vicinity. Now Russian-thistle is so widespread that it rapidly covers any area where sagebrush has been killed out by burning, excessive grazing, or clearing and plowing. Moreover, Russian-thistle quickly covers denuded areas in all of the types excepting only those where the surface soil has a high salt content or the sandy areas where there is active wind erosion. In drought years it fails as a cover and leaves the soil over large tracts exposed to the wind the year around. Where pronounced disturbance of the cover is not continued, little rabbitbrush may succeed the Russian-thistle, or sagebrush may reseed itself as stated above.

Globemallow occurs throughout the sagebrush area but only occasionally forms a good cover on denuded land. Blistercress often forms a good cover on small areas but usually on the lower lands, greasewood or greasewood-shadscale. Other weeds noted on cleared lands or railroad grades in the sagebrush area were as follows: *Marrubium vulgare* L., *Amaranthus blitoides* S. Wats., *Solanum triflorum* Nutt., *Nicotiana attenuata* Torr., *Verbena bracteosa* Michx., *Argemone hispida* A. Gray, *Sophia pinnata* (Walt.) Howell, *S. parviflora* (Lam.) Standl., *Norta altissima* (L.) Britton, *Polygonum aviculare* L., *Bromus tectorum* L., *Festuca octoflora* Walt., and *Sphaerostigma* sp.

Of the last-mentioned weeds, *Amaranthus blitoides* formed in 1915 a good cover on one cleared tract of good size. In general, all of these weeds occurred in small patches or as widely scattered plants.

The noticeable lack of herbaceous vegetation in the sagebrush and other shrub areas on nonsaline soils is attributed generally to excessive grazing and in places to the accompanying erosion of the topsoil between the bushes. The lack of penetration of water from the September rain (table 3) may be accounted for in part by erosion of the topsoil and the resulting increased run-off.

SAGEBRUSH-GREASEWOOD VARIATION

Mixtures of sagebrush and greasewood (pl. 3, *A*) are found on some of the lower lands opposite the mouths of canyons. Here floodwaters and in some cases subirrigation increase the supply of water and lessen the salt content. Of these two plants, the greasewood here more nearly approaches its optimum growth, though in parts of such areas neither is in a healthy condition. The sagebrush especially has much deadwood. Sample 58, table 5, taken in a place where greasewood and sagebrush were both sickly and stunted, showed the soil of the first 2 feet to be a nonsaline fine sandy loam, and this was underlain by a very hard, dry layer. Sample 16, table 5, was taken in an area where both plants were healthy and 4 to 5 feet high. Here there was no hard layer. The soil to a depth of 3 feet was a nonsaline black loam underlain by a heavier reddish loam. Within this area of sagebrush mixed with greasewood, where the soil is nonsaline and readily permeable to a depth of 4 feet, with no hard, dry layers, there are areas of a good

[6] Since the studies in Tooele Valley were published (*3*), a somewhat similar change has taken place. In 1912 Russian-thistle was not recorded in that valley, but it was widespread by 1926, and by that time the areas of desert shrub were greatly modified. By 1935 over 35,000 acres of land near Grantsville had been stripped of its topsoil by wind erosion (*12, p. 513*).

growth of sagebrush (sample 28, table 4). Where the soil is saline and the water table is within reach of the root system, there are areas of greasewood-shadscale (table 12, p. 34) or small pure areas of greasewood.

TABLE 5.—*Soil conditions in areas of sagebrush mixed with greasewood and with other plants* [1]

Plants mixed with sagebrush	Sample No.	Date of collection	Wilting coefficient at—				Moisture content above or below wilting coefficient at—				Salt content at—			
			1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet
			Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Greasewood	[2] 16	Apr. 10, 1915	14.4	18.4	14.3	18.8	+1.0	+0.1	−2.4	−3.9	0.07	0.12	0.13	0.15
	[4] 16	Sept. 10, 1915	12.7	16.6	12.3	16.7	+1.4	+1.6	+.5	−.5	.14	.14	.14	.16
	[3] 20	Aug. 27, 1913	..	..	..	..	(5)	(5)	(5)	..	.08	.21	.42	..
	[6] 58	Aug. 30, 1913	..	..	..	..	(7)	(7)	..	..	.04	.05	..	..
Average											.08	.14	.23	.16
Chrysothamnus nauseosus, greasewood, and saltgrass	[4] 17	Apr. 10, 1915	19.3	18.0	17.7	22.2	+2.0	+0.2	+8.7	+10.7	.21	.47	.24	.16
		Sept. 10, 1915	18.3	16.4	17.4	19.6	+1.1	+8.5	+7.9	+11.5	.42	.52	.50	.28
Juniper	[8] 56	Aug. 30, 1913	..	..	..	..	(7)	(7)	(7)	..	.04	.03	.08	..
Chrysothamnus nauseosus and greasewood	[10] 63	Aug. 31, 1913	..	..	..	..	(5)	(5)	(5)	(5)	.08	.14	.19	.28

[1] Data stated as percentages of dry weight of soil.
[2] Good growth of both sagebrush and greasewood.
[3] Sagebrush, good growth; greasewood, poor growth.
[4] No determination made; "nearly dry" in field notes.
[5] No determination made; "dry or nearly dry" in field notes.
[6] Sagebrush, rather poor growth; greasewood, small, poor growth, scattered. An impenetrable hard layer below the second foot. Sample taken near Tintic, Utah.
[7] No determination made.; "dry" in field notes.
[8] Poor growth of sagebrush.
[9] Poor growth of sagebrush. Sevier Valley, Utah.
[10] Good growth of sagebrush Rush Valley, Utah.

GALLETA ASSOCIATION

TOPOGRAPHICAL RELATIONS

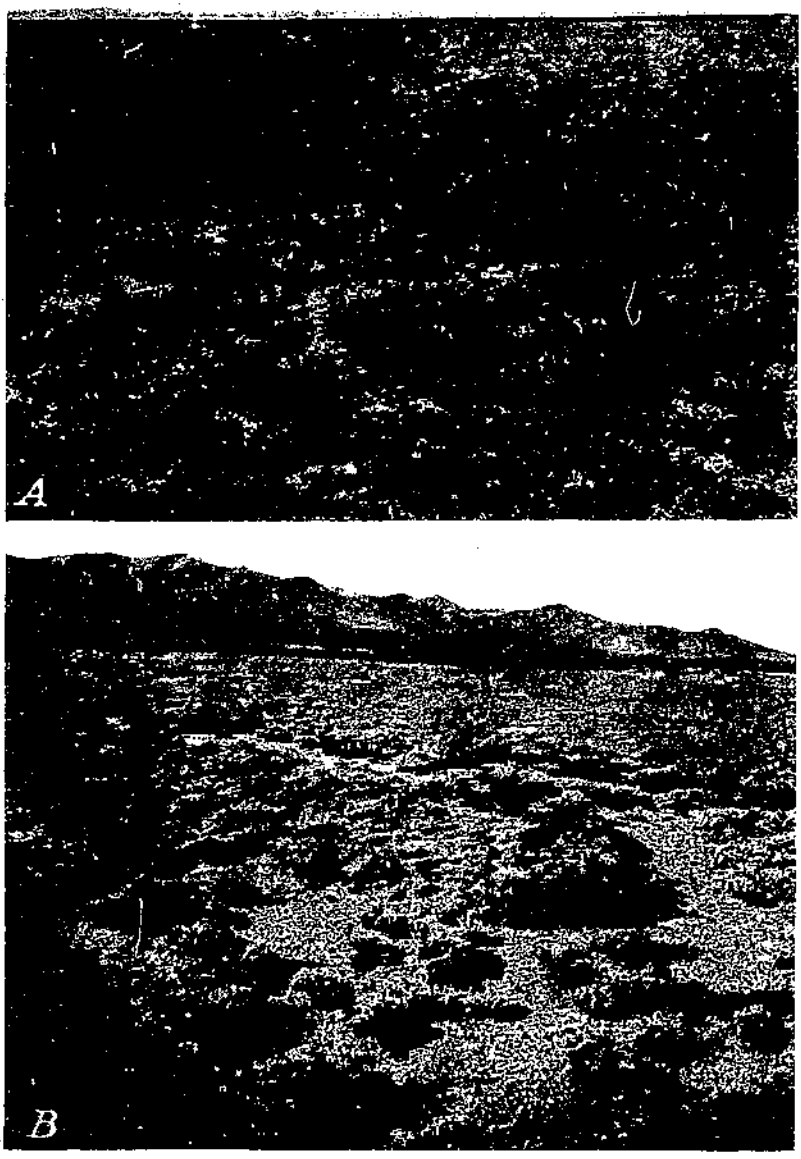
Galleta grass extends from the southern desert into the southern portion of the Escalante Valley, where it covers a considerable area northeast of Modena. Galleta borders juniper and mixes with it west of Cedar City. It occupies the higher benches and slopes of other portions of the valley and therefore either alternates with the sagebrush areas or adjoins them in a more or less continuous belt. However, while sagebrush also occurs to some extent on the better-drained, nonsaline portions in the center of the valley, other than the sandy tracts, galleta does not. Nor is the total acreage of galleta (see colored map) nearly so great as that of sagebrush at the present time.[7]

BOTANICAL COMPOSITION

While galleta may form a cover so dense as to exclude all other perennials, usually there are scattered plants or patches of varying size of other grasses. In the southern part of the valley, Fendler three-awn sometimes alternates with galleta. Blue grama occurs as patches of

[7] The statement was often made in 1915 by the older settlers that at one time, before cattle and sheep overran these parts, galleta covered most of the valley, presumably the portion now covered by dwarf sagebrush and, perhaps, most of that covered by little rabbitbrush, since galleta has not been found on the heavy, poorly drained saline soils of the valley.

A, Mixture of sagebrush and greasewood. This vegetation occupies relatively large areas in at least one of the lower parts of the valley, and most of this land has been put under irrigation. The age of the sagebrush, as estimated by its annual rings, is about 15 years. Age of the greasewood, not over 12 years. North of Modena, Utah, August 20, 1930. *B*, Galleta in the foreground, little rabbitbrush in the background. The grass is slowly replacing the rabbitbrush. North of Modena, Utah, August 27, 1913.



A, Large area of galleta, nearly a pure stand. Beyond this, in the background, is shown an area of little rabbitbrush. (North of Modena, Utah, September 12, 1925.) *B*, General view of the west side of Escalante Valley. In the immediate foreground is shown the edge of a winterfat area; in the center, a well-established galleta cover; and in the background, an area of little rabbitbrush. (Boring 20, near Milford, Utah, September 28, 1915.)

sod scattered in the general galleta cover. Sand dropseed occurs as scattered plants, and so does ricegrass and needle-and-thread, but the first named also often forms fringes along shallow drainage channels. False buffalo grass (*Munroa squarrosa* (Nutt.) Torr.) clusters about anthills and similar minor breaks in the grass cover.

In a large tract near Table Buttes (see colored map), Fendler threeawn and sand dropseed are more important than galleta. In some portions of this tract plants of big rabbitbrush (*Chrysothamnus nauseosus* (Pallas) Britt.) are scattered in the grass. West of Minersville chamiso mixes with the grass.

In places in the short, usually close-cropped galleta cover, conspicuous taller clusters of sagebrush, little rabbitbrush, matchweed, and winterfat occur frequently, and at the outer edges of the general galleta area the first two cover large tracts.

The widespread globemallow is frequent and so is blistercress, though the latter does not form dense patches as it does on the lower lands. Other plants found in this association are *Festuca octoflora* Walt., *F. octoflora hirtella* Piper, *Bromus tectorum* L., *Plantago purshii* Roem. and Schult., *Astragalus praelongus* Sheldon, *Eriogonum cernuum* Nutt., *Sitanion jubatum* J. G. Smith, and *Greeneocharis circumscissa* (H. and A.) Rydb.

APPEARANCE

Galleta (pl. 4) is a coarse perennial grass with purple spikes. In the early stages it forms bunches (or mats if closely grazed), but later these unite to form an even sodlike growth. In spring, before the new growth is made, and again late in fall, when mature, the plants have a "cured grass" color and the areas at a distance resemble a stubble field. This appearance is heightened by the light-colored soil spaces between the plants. At this time galleta areas contrast sharply with the darker-colored sagebrush and little rabbitbrush areas. During the growing period the galleta areas are much the same in color as sagebrush, but their resemblance to close-cropped meadows contrasts sharply with the taller shrubby growth.

SOIL CONDITIONS

The soil texture in galleta areas is not distinct from that found in sagebrush, particularly the poor growth of sagebrush (compare moisture equivalents in tables 4 and 6). The lands covered by the two types are also alike in the frequent admixture of gravel or rock fragments on the surface of the soil and the underlying layer of coarse gravel or hardpan. A galleta cover was never found on soil as heavy as that covered with a good growth of sagebrush (sample 28, table 3).

Soil-moisture determinations (table 6) show a good supply of moisture in spring in the first and the second foot of soil, less in the third, and practically none in the fourth. Here there is a similarity to the soil moisture found in the areas covered with a poor growth of sagebrush. In the fall the third and fourth foot showed no moisture and the second very little. The first foot, however, owing to the heavy rain (1.02 inches) on September 2, 10 days before the samples were taken, showed uniformly a good supply of moisture. The penetration of water from this rain was better on galleta land than on any other.

On little rabbitbrush land there was somewhat less, while on the sagebrush land it was not so invariably good. On the winterfat and shadscale lands the penetration was very poor.

TABLE 6.—*Comparison of spring and fall soil conditions in typical areas of galleta, 1915* [1]

SPRING

Sample No.	Date of collection	Wilting coefficient at—				Moisture content above or below wilting coefficient at—				Salt content at			
		1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
33	Apr. 20	9.1	12.2	9.8	5.3	+1.2	+0.6	−1.5	−0.5	0.02	0.06	0.05	0.02
34	Apr. 21	10.9	12.7	10.5	11.2	+3.6	+2.1	+2.2	−4.6	.00	.08	.06	.14
35	do	8.3	8.0	5.0	8.5	+2.1	+3.1	+1.7	+.0	.02	.02	.02	.07
Average		9.4	11.0	8.4	8.3	+2.3	+2.0	+.8	−1.4	.03	.05	.04	.08

FALL

33	Sept. 12	7.3	10.1	8.3	5.3	+2.1	−1.6	−0.9	−0.1	0.04	0.14	0.19	0.14
34	do	11.2	12.0	10.5	11.2	+3.6	−3.5	−3.8	−3.0	.13	.05	.05	.07
35	do	6.7	6.7	6.7	8.5	+3.3	+2.9	−2.5	−4.0	.03	.02	.02	.02
Average		8.4	9.6	8.5	8.3	+3.0	−.7	−2.4	−2.4	.07	.07	.09	.08

[1] Data stated as percentages of dry weight of soil.

The type of land covered with galleta shows a uniformly low salt content (table 6) and in this respect is similar to typical sagebrush land. Galleta was never found on a heavy soil with a high salt content in the third and the fourth foot. A stunted, sickly growth of sagebrush may occur on such a soil, though then it is marked by the proximity of salt-tolerant species or by an admixture of these.

Galleta indicates a soil that is nonsaline, of a light texture, more permeable than any other type of soil in the valley, with the exception of the sand hills. There is available soil moisture in at least the first 2 feet in spring and no available moisture in any of the 4 feet in fall except the first foot, where there may be a good supply after a rain. Galleta land, like sagebrush land, is never low, wet, and saline.

ADAPTATION OF GALLETA TO SOIL CONDITIONS

Galleta is better adapted than the shrubby types of vegetation to make use of the slight increases of moisture in the topsoil due to summer rains. Also, the depth of soil moisture in spring necessary for a good growth of galleta is much less than that needed for a good growth of sagebrush but similar to that found where the sagebrush is dwarfed. It is quite likely then that galleta, if not grazed too heavily, would occupy much larger areas than at present, perhaps considerable portions of the lands with shallow soils now covered by stunted, sickly sagebrush and perhaps large portions of the nearby lands covered with little rabbitbrush.

EFFECTS OF DISTURBING FACTORS (SECONDARY SUCCESSIONS)

In 1915 dead sagebrush plants were found in a stand of galleta (pl. 2, *B*) and in other places in stands of dead winterfat and little rabbitbrush. The grass was extending over lands formerly occupied by shrubs or shrubby perennials. This was probably a temporary increase, possibly aided by fires. On the whole there has been a reduction of the total galleta area. The statements of old settlers indicated that there had been marked reduction prior to 1915. By 1925 and 1926 irregular patches of Russian-thistle occurred in badly trampled grass areas and on galleta land broken for cultivation. Remote from cultivation the two grasses Fendler three-awn and sand dropseed, especially the former, covered disturbed areas, around the mounds of rodent colonies, anthills, gullies, and strips of land scraped for railroad grades. In some of the grass areas the little rabbitbrush (*Chrysothamnus greenei*) was appearing, and in the three-awn tract near Table Buttes the big rabbitbrush (*C. nauseosus*) was appearing. The spreading of both cactus and little rabbitbrush over lands formerly covered with galleta was noted near Modena in 1926.

Considerable wind erosion was noted in 1915 but not where galleta was in a sound condition. Galleta not only keeps soil from blowing but has a tendency to assist in building up the soil by catching and holding the wind-blown particles. In adjacent winterfat areas the soil is blown away between the bushes, but that immediately around the bushes is left, so that the bushes appear to be in a slight depression, each plant on a small mound, whereas galleta stands on a nearly level terrace. The crowns of the scattered winterfat in the galleta are at the same level as the winterfat in the depression (pl. 4, *B*).

LITTLE RABBITBRUSH ASSOCIATION

TOPOGRAPHICAL RELATIONS

The little rabbitbrush areas (pl. 5) are closely connected with sagebrush areas (see colored map). The two alternate frequently. In the southern portion of the valley little rabbitbrush alternates with either sagebrush or galleta. The total extent of the little rabbitbrush areas is exceeded perhaps only by sagebrush. Like sagebrush and galleta, this plant covers the higher portions of the valley, rarely covering to any extent ground in the lower middle portions, except, perhaps, some of the sandy stretches. While little rabbitbrush is closely connected with sandy soil, on dune-forming sand this plant is replaced by the mixed type of vegetation discussed later. Where little rabbitbrush and galleta alternate on rolling ground, the former occupies the tops of the stony or gravelly ridges, while galleta covers the flat areas.

BOTANICAL COMPOSITION

The dominant plant in the little rabbitbrush [8] community is a low-growing *Chrysothamnus* of which there are several closely related species or subspecies. Those collected and determined are *C. puberulus* (D. C. Eaton) Greene, *C. stenophyllus* (Gray) Greene, *C. laricinus* Greene, and *C. greenei* (Gray) Greene.[9] No reliable distinctions

[8] In some sections this plant is also known as yellowtop and yellowbrush.

[9] Hall and Clements (2) list the first two as subspecies of *C. viscidiflorus* (Hooker) Nutt., *C. viscidiflorus puberulus* and *C. viscidiflorus stenophyllus*. These two subspecies are regarded as scarcely distinguishable. Also, *C. laricinus* is thought to be *C. greenei*, probably the same as the subspecies *C. greenei filifolius*. These authors also regard *C. greenei* as closely related to *C. viscidiflorus* and state that specimens of *C. greenei* are often labeled as a variety of *C. viscidiflorus*, usually as the variety *stenophyllus*.

among these species were made in the field, and it has not been possible to find differences in the ecological requirements of the species. Specimens of both *C. stenophyllus* and *C. laricinus* were collected in the large areas near Milford. *C. puberulus* also occurred in this vicinity and in one large area near Modena. *C. greenei* was collected only from Lund south to Modena. To this species was ascribed the dominant vegetation of most of the areas near Modena and one near Yale.

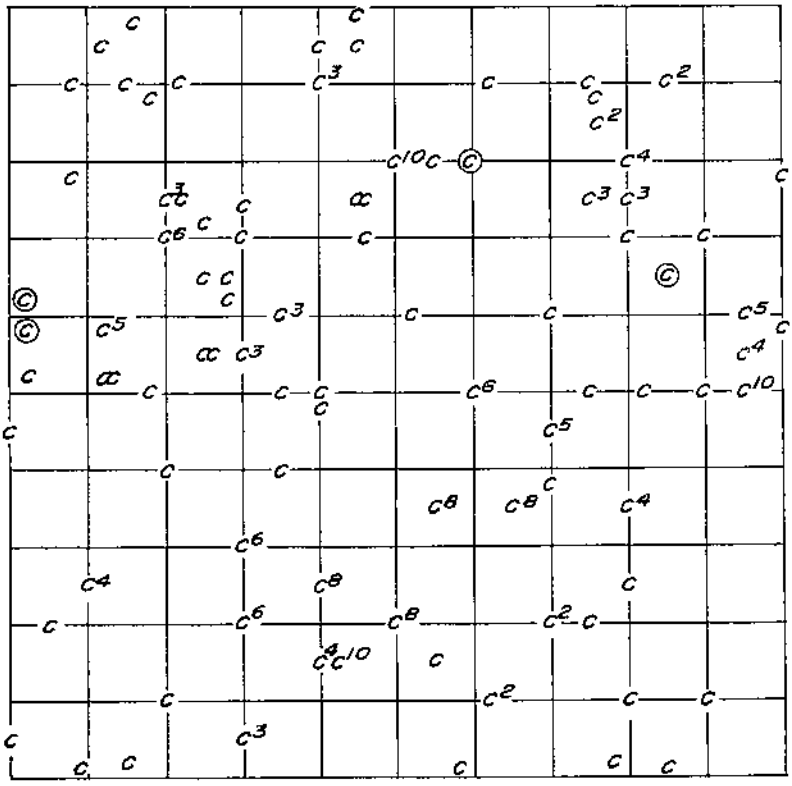


FIGURE 4.—A representative 10-m. quadrat in a typical growth of little rabbitbrush at boring No. 4. The location of each individual living plant is indicated by the letter *C*. A circle around the letter denotes that the plant is dead. The small numbers at the right of the letters show the number of stems growing from each clump. No other plants, woody or herbaceous, were found here. (Mapped April 23, 1915; Milford, Utah.)

It was also collected in the mixed communities found on hummocky wind-blown soils and on sandy soils. None of the species of little rabbitbrush association was found on soils with a high salt content as were some other species of big rabbitbrush (such as *C. albidus*, *C. consimilis*, and *C. newberryi*).

There are large areas of little rabbitbrush in which few other woody plants occur, but in one situation or another all of the dominant species of the higher lands are found mixed with little rabbitbrush. The more common mixtures are with sagebrush, galleta, matchweed, winterfat, and perhaps somewhat less often with shadscale. In

some places the grasses, sand dropseed and ricegrass, occur with rabbitbrush, as does globemallow. Other plants found in the little rabbitbrush association are *Astragalus cibarius* Sheld., *Tetradymia* sp., *Eriogonum cernuum* Nutt., *Verbena bracteosa* Michx., *Cheirinia repanda* (L.) Link, *Sophia pinnata* (Walt.) Howell, *Penstemon palmeri* A. Gray, *Opuntia* sp., *Ephedra* sp., and *Chamaesyce* sp.

The distribution of individuals of little rabbitbrush in a 10-m. quadrat is shown in figure 4.

APPEARANCE

The characteristic appearance of the little rabbitbrush association is shown in plate 5. In spring this plant appears at a distance to be of a light-green color, somewhat lighter than the sagebrush areas, in spite of the dark-green foliage of the plants. The light color is due to the straw-colored dead inflorescences held over from the preceding fall. In the fall of favorable years, when flowering is general, these areas are a mass of golden yellow. At close range the plants are seen as low, hemispheric, dark-green bushes with bright-yellow flower heads. The bushes range from 1 to 1½ feet high or, in very favorable places, even 2½ to 3 feet high. In typical areas the plants are widely spaced, with open spaces of bare soil between them (see pl. 5, *B*).

SOIL CONDITIONS

The soil texture of land occupied by little rabbitbrush is light, as shown by the moisture equivalents in table 7. However, the soil texture may not be distinct from adjacent land occupied by other associations. Sample 4 (table 7) is not distinct from sample 5 (table 4) in medium sagebrush and sample 25 is similar to that occupied by winterfat.

TABLE 7.—*Comparison of spring and fall soil conditions in typical areas of little rabbitbrush, 1915* [1]

SPRING

Sample No.	Date of collection	Wilting coefficient at—				Moisture content above or below wilting coefficient at—				Salt content at—			
		1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
4	Apr. 7	4.0	5.4	5.0	4.8	+2.5	+4.1	+4.7	+2.9	0.02	0.02	0.02	0.04
6	do	6.4	6.9	6.7	6.0	+2.1	+1.3	+3.1	+2.4	.02	.02	.03	.16
7	do	5.5	6.3	7.2	8.5	+1.6	+3.2	+3.4	+2.9	.02	.02	.02	.11
9	Apr. 9	5.6	5.8	6.1	6.7	+1.9	+3.8	+4.2	+3.4	.02	.02	.02	.02
25	Apr. 13	9.8	9.5	9.3	5.5	+.6	+1.1	+1.5	−.6	.02	.07	.32	.19
Average		6.3	6.8	6.9	6.3	+1.7	+3.3	+3.4	+2.0	.02	.03	.08	.10

FALL

4	Sept. 9	5.2	6.5	8.2	5.7	+2.2	−1.6	−2.0	−1.5	0.02	0.02	0.02	0.05
6	do	5.5	7.8	8.2	8.3	+.8	−2.9	−3.7	−3.1	.02	.02	.02	.15
7	do	5.5	5.5	7.0	9.1	+1.6	−.9	−2.1	−3.2	.02	.02	.02	.03
9	Sept. 8	5.4	6.0	5.4	5.9	+2.0	−1.3	−1.5	−2.5	.02	.02	.02	.01
25	Sept. 10	9.0	9.9	7.0	10.5	------	------	------	------	.07	.07	.26	.14
Average		6.2	7.1	7.2	7.9	+1.2	−1.7	−2.3	−2.6	.03	.03	.07	.08

[1] Data stated as percentages of dry weight of soil.

The soil-moisture determinations (table 7) show a somewhat better supply of available moisture in the spring for little rabbitbrush than for galleta. This soil moisture is due entirely to rains or snow and not to a high water table. In the fall there was no available water in the second, the third, and the fourth foot, but a slight amount in the first foot, due to the rain (1.02 inches) on September 2, about a week before the samples were taken. The increase of soil moisture in the first foot, as a result of this rain, was greater than in any of the other vegetation types except galleta.

The salt content of the little rabbitbrush land (table 7) in any of the upper 4 feet of soil is negligible. The highest amount found in any of the samples taken in typical areas was in the third foot, sample 25 (table 7), showing 0.32 percent.

Little rabbitbrush indicates a light soil that in some cases approaches sand. However, as this vegetation type quickly covers cleared lands formerly occupied by sagebrush, galleta, shadscale, and winterfat, it may also under present conditions indicate the same physical conditions as the other associations just mentioned. Little rabbitbrush, like galleta and sagebrush, never indicates low, wet saline lands.

ADAPTATION OF LITTLE RABBITBRUSH TO SOIL CONDITIONS

Little rabbitbrush is adapted to grow on a wide range of soils. Though it formed a better growth on light soils of good depth, it was also found on the lighter, shallow soils underlain by gravel or a lime-gravel hardpan and on the fine sandy loam similar to that indicated by winterfat. Little rabbitbrush is not adapted to grow on saline soils or on the heavy soils where the water table is high.

EFFECTS OF DISTURBING FACTORS (SECONDARY SUCCESSIONS)

Spaces denuded by one cause or another in sagebrush, galleta, shadscale, or winterfat areas are quickly seeded by little rabbitbrush if plants of it are in the vicinity. This shrub undoubtedly covers much larger areas than it did when herds were first driven into the valley and when settlement began. It also covers larger areas at present (1939) than it did in 1915 or 1925.

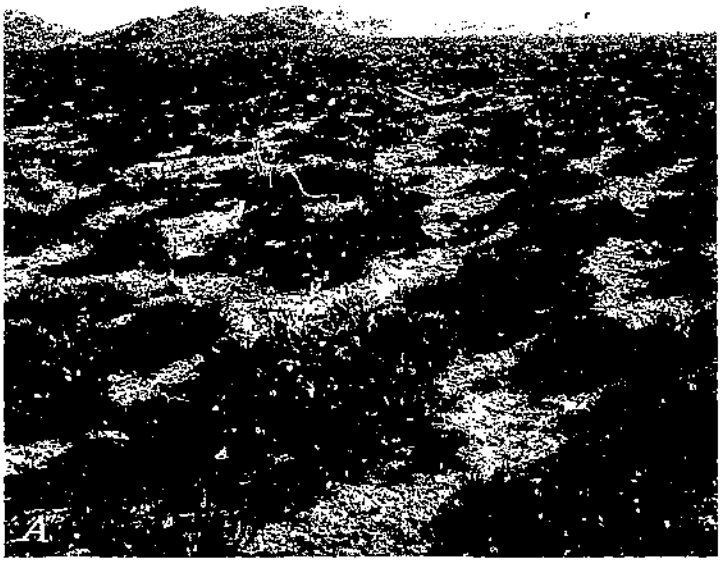
Little rabbitbrush, then, covers considerable tracts, where it is distinctly a secondary succession following the killing out of the original cover of other shrubs or grass. Some tracts were found in 1915 that were of this kind, but there were others, restricted areas of light soil, where there was no evidence of little rabbitbrush being a secondary succession, and it was considered a stable community on this type of soil.

When tracts of little rabbitbrush are destroyed by plowing or otherwise, Russian-thistle usually quickly covers the ground. In places globemallow and *Eriogonum cernuum* may be the important weeds, with some others present such as blistercress and tansymustard. Under favorable conditions little rabbitbrush may reseed the area directly.

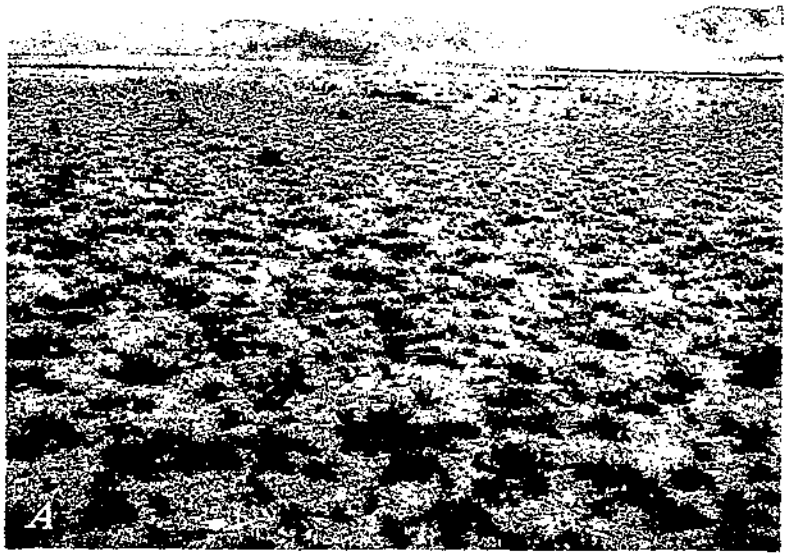
WINTERFAT ASSOCIATION

TOPOGRAPHICAL RELATIONS

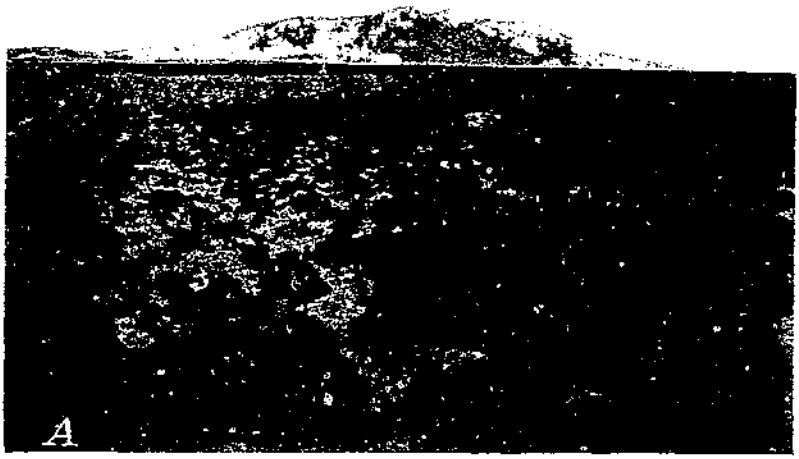
The winterfat association (pl. 6) occupies land that lies between the sagebrush and the greasewood-shadscale belts, where it may form a more or less continuous belt or may alternate with sagebrush. Winterfat areas do not occur on the low saline lands of the valley. In the

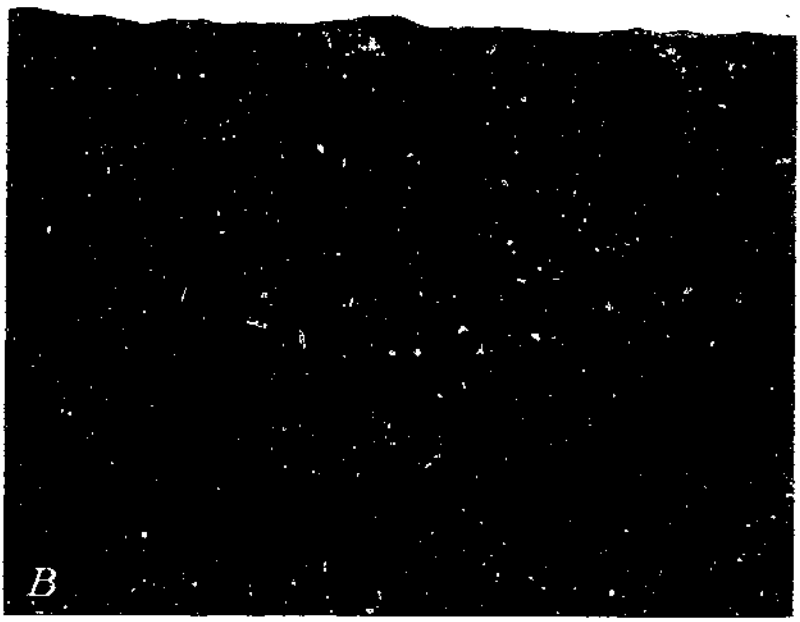


A, Little rabbitbrush, with an occasional dead plant of sagebrush. This does not necessarily indicate that sagebrush is giving way before the little rabbitbrush, but rather that, following a long drought or a fire, which has killed the sagebrush, rabbitbrush has been able to establish itself. (Three miles southwest of Milford, Utah, September 9, 1913). *B*, Little rabbitbrush in the foreground, with an occasional dead plant of sagebrush. The broad light band in the background is winterfat, and back of this again is an area of rabbitbrush. (Three miles southwest of Milford, Utah, September 9, 1913).

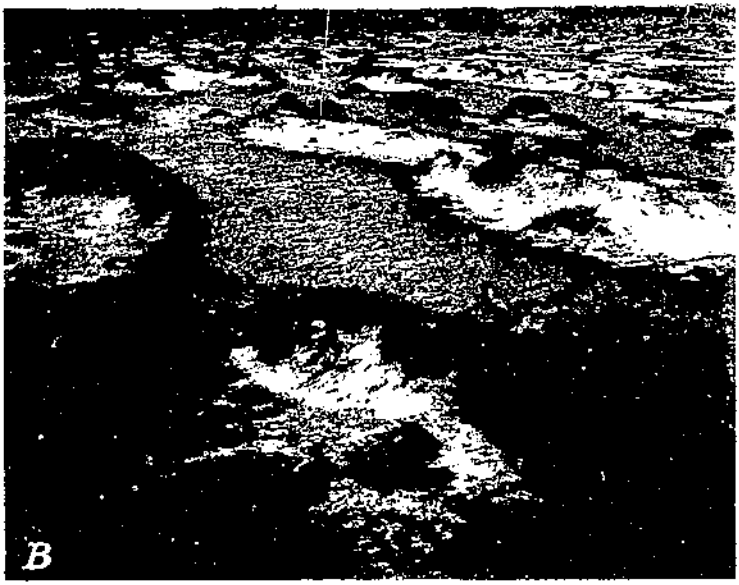


A, Large area of winterfat, with a few scattered plants of fourwing saltbush in the background. Both are suffering from drought; neither is doing well. (Boring 17, north of Modena, Utah, August 27, 1913.) *B*, Plant of winterfat, showing the type of branching, also the generalized fibrous type of the root system. This plant stood 4 inches above the ground, the lower 2 inches of the plant being covered with soil. The roots extended to the depth of about 1 foot. (Boring 30, near Milford, Utah, September 8, 1913.)





A, An illustration of the sharp alternations that are characteristic of the Escalante Valley. The vegetation at the left consists of winterfat and that at the right of little rabbitbrush. (Kerr, Utah, August 28, 1913.) *B*, Saltsage and winterfat growing together in about equal amounts. (West of Thermo, Utah, September 21, 1925.)



A, A pure stand of fourwing saltbush. Though this plant does not cover as large tracts as those of sagebrush and some of the other types, nevertheless it occupies good-sized areas near the center of the valley. It seeds rapidly the tracts where other types of vegetation are destroyed. It is generally found in this valley on lands subjected to an occasional flooding. (Modena, Utah, August 27, 1913.) *B*, Mat saltbush occurring on hummocks 3 to 15 inches high. The prevailing winds are from the south, and this photograph is taken looking almost due south. (Lund, Utah, August 28, 1913.)

flooded portion of winterfat areas where fine soil is being deposited this plant is mixed with saltsage (pl. 7, *B*). Where winterfat and galleta areas adjoin, the former are usually free of gravel, while the latter has a scattering of gravel throughout (pl. 4, *B*). Aside from the winterfat association as dealt with here, winterfat also occurs as a scattered plant in many other associations, notably in the desert grasslands of the high plains and deserts of the Southwest.

BOTANICAL COMPOSITION

The plants with which winterfat mixes over areas of any extent in Escalante Valley are shadscale, greasewood, and galleta. Sagebrush and little rabbitbrush occur in the winterfat areas usually where the

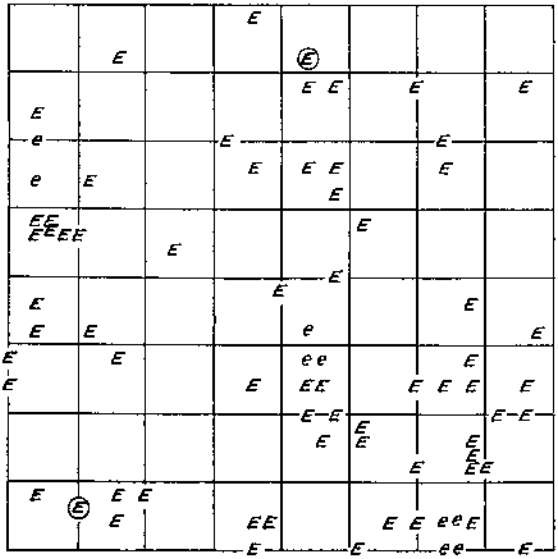


FIGURE 5.—A representative 2-m. quadrat in a typical area of winterfat. The locations of individual living plants are indicated by *E* for mature plants and *e* for seedlings. A circle around the letter *E* denotes a dead plant. There were no annuals here. (Mapped April 17, 1915; Milford, Utah.)

soil conditions are more favorable, such as along drainage courses or hummocks of lighter soil. Of these two plants, sagebrush occurs most frequently, usually along the drainage channels. Matchweed, globemallow, and ricegrass are quite frequent. More rarely fourwing saltbush occurs along the drainage channels. Sand dropseed and three-awn occur occasionally as patches and commonly as fringes along the drainage channels.

Other plants found in this association are *Astragalus cibarius* Sheld., *Eriogonum cernuum* Nutt., *E. hookeri* S. Wats., and *Sphaerostigma boothii* (Dougl.) Walp.

Figure 5 shows the distribution of winterfat in a 2-m. quadrat.

APPEARANCE

The areas of winterfat are meadowlike (pl. 6, *A*), very much like those of the white sage (*Kochia vestita*). At a distance the meadows of these two plants are hard to distinguish, for they both have a slightly blue-green color, though winterfat is the whiter of the two.

At close range winterfat is seen as a low plant with a shrubby base 2 to 4 inches from the ground, from which rise shoots ordinarily about 4 to 6 inches high (pl. 6, *B*) but under favorable conditions much higher. The shoots are a blue-green, but this color is nearly hidden by a soft white wool. This plant is well liked by stock in the winter, so that by spring it is eaten off very close to the ground. The height of the winterfat is often scarcely 6 inches, with the shrubby base almost covered by the soil lodged around it (pl. 4, *B*). In the bare spaces between the plants the soil blows away, leaving the plants on small hummocks.

SOIL CONDITIONS

The type of land occupied by winterfat, as based on soil texture, belongs with the greasewood, shadscale, saltgrass group rather than with the sagebrush, galleta, little rabbitbrush group. The texture is heavier than that of the latter group, as shown by the moisture equivalents in table 8. The soil moisture in the winterfat land is much more limited than in the sagebrush, galleta, little rabbitbrush land. In this valley in spring there is available water only in the upper 2 feet of soil (table 8). In fall there is no available water in any of the 4 feet of soil. The heavy rain of September 2 added nothing to the soil moisture content (except in sample 36), indicating the more impervious nature of this type of soil (see fall moisture content of the first foot, table 8) than that occupied by galleta. The impervious nature of the soil is increased by the erosion of the topsoil between the bushes, as previously mentioned.

TABLE 8.—*Comparison of spring and fall soil conditions in typical areas of winterfat, 1915* [1]

SPRING

Sample No.	Date of collection	Wilting coefficient at—				Moisture content above or below wilting coefficient at—				Salt content at—			
		1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
10	Apr. 9	11.8	13.3	14.3	13.5	−2.8	+1.0	−2.1	−1.9	0.02	0.06	0.54	0.87
30	Apr. 16	8.0	7.7	8.6	8.5	+1.7	+3.2	+.2	−2.9	.02	.02	.06	.25
31	Apr. 19	13.5	13.0	11.9	11.1	−1.4	−.7	−4.5	−4.2	.05	.05	.12	.20
36	Apr. 21	12.6	16.5	14.6	8.2	+1.7	+1.7	−4.3	−3.3	.05	.07	.07	.08
Average		11.5	12.6	12.4	10.3	+1.2	+2.1	−2.7	−3.1	.04	.05	.20	.35

FALL

10	Sept. 9	11.5	13.1	13.3	13.4	−3.4	−5.0	−4.1	−1.9	0.13	0.07	0.30	0.55
30	Sept. 8	7.2	6.5	7.8	9.2	−1.5	−2.5	−3.0	−3.6	.07	.02	.05	.23
31	Sept. 11	12.6	13.3	12.0	11.2	−3.2	−4.9	−4.0	−2.5	.14	.07	.13	.24
36	Sept. 12	12.0	14.5	12.8	8.7	+2.2	−2.5	−4.4	−2.4	.08	.07	.08	.14
Average		10.8	11.9	11.5	10.6	−1.5	−3.7	−3.9	−2.6	.11	.06	.14	.29

[1] Data stated as percentages of dry weight of soil.

The salt content of winterfat land is negligible in the upper 2 feet of soil in spring, averaging 0.04 and 0.05 percent, respectively, but increases in the third and the fourth foot (table 8). Winterfat does not endure high concentrations of salt. The salt content of the fourth

and sometimes of the third foot was high, but the roots of this plant, though extensive, are not deep and may not extend much below the first foot (pl. 6, *B*). Under some conditions the roots may go down 3 feet. The third foot consisted of sandy soil and the fourth foot of gravel. Winterfat was found growing luxuriantly on soil where the salt content of the fourth foot reached 1 percent.

Winterfat in this valley indicates a soil of finer texture than that indicated by any of the associations dealt with so far. There is a good supply of soil moisture only in the upper 2 feet in spring. The soil is very dry in fall, and the moisture is increased very little by the late summer storms. The upper 2 feet of soil normally have a low salt content, but the soil beneath may contain amounts up to 1 percent. For this reason winterfat lands may be classed as near the border line between saline and nonsaline lands, and this position is usually held in its topographical relations in this valley.

EFFECTS OF DISTRIBUTING FACTORS (SECONDARY SUCCESSIONS)

In 1915 some badly trampled winterfat areas were nearly covered with Russian-thistle. This weed was also noted on plowed winterfat land and around rodent mounds or anthills. Other weeds noted in the trampled places were tansymustard, some borages (*Lappula* sp. and *Greeneocharis circumscissa* (H. and A.) Rydb.), *Cleome lutea* and *C. serrulata*.

In 1915 in some areas winterfat was being replaced by galleta but probably more generally by little rabbitbrush. Since 1915 many tracts where winterfat has been killed out by clearing or trampling have been covered by Russian-thistle, and where the disturbance has not continued little rabbitbrush has entered. Marked wind erosion has taken place in winterfat, as discussed under galleta.

ADAPTATIONS OF WINTERFAT TO SOIL CONDITIONS

The fibrous roots of winterfat intensively occupy a soil, though usually this means the upper layer of a foot or so, as the roots do not penetrate the more saline lower soil. Where the soil was loose and sandy below, roots were found at a depth of 3 feet. In long drought periods the winterfat is in a semidormant condition, but it forms a luxuriant growth under favorable moisture conditions.

FOURWING SALTBUSH COMMUNITY

Although fourwing saltbush [10] is scattered over a considerable part of the lower sections of the valley, the areas where it is unmixed with other plants (pl. 8, *A*) are not extensive, and in many of them the plants are stunted and suffering. Nowhere does it form the areas of vigorous plants found so frequently on sandy tracts in the southern deserts (*9*).

In Escalante Valley fourwing saltbush is not confined to sandy soils. It is found mostly near the boundary line between saline and nonsaline soils, just above the greasewood or greasewood-shadscale belt and mixed with or alternating with winterfat. The largest areas were found in belts around dry salt flats, in such cases lying just above the saltsage patches. These were nearly always lands subjected to flooding after rains. In little rabbitbrush, galleta, and, more rarely, shad-

[10] Also called chamiso, chamiza, and chamise.

scale areas it was found on the slopes toward dry creeks or flats. Of the annuals, tansymustard is perhaps the one most frequently found with fourwing saltbush.

In table 9 are given two samples taken in areas of fourwing saltbush. In both samples the soil is heavier than sand and more like the soil of winterfat land. Neither showed alkali in the upper 2 feet, though sample 35 showed 0.62 in the third foot. In sample 35 there was no moisture, but in sample 18 there was a slight amount in the first foot.

TABLE 9.—*Soil conditions in areas of fourwing saltbush, 1913*

Sample No.	Date of collection	Salt content [1] at			Soil moisture [2] at			Soil type at		
		1 foot	2 feet	3 feet	1 foot	2 feet	3 feet	1 foot	2 feet	3 feet
		Per cent	*Per cent*	*Per cent*						
27	Aug. 27	0.05	0.06	0.07	Slightly moist.	Nearly dry.	Nearly dry.	Fine sandy loam.	Sand	Sand.
35	Aug. 28	.08	.07	.62	Dry	Dry	Dry	Sandy loam.	Sandy loam.	Sandy loam.
Average		.07	.07	.35						

[1] Data stated as percentages of dry weight of soil.
[2] Field notes.

Fourwing saltbush in Escalante Valley indicates land that may be somewhat saline in the subsoil but not excessively so. It probably requires more moisture than winterfat, for in some of the areas where it is mixed with winterfat chamiso is dead or in bad condition while winterfat is thriving, though this may be a difference in the response to heavy grazing.

Fourwing saltbush readily reseeds disturbed areas along washes, in flooded areas, in sandy areas, and along railroads or roads. It is commonly the first plant to reseed lands subjected to flooding where a layer of sediment is deposited. Of the shrubs in the valley it is equaled perhaps only by little rabbitbrush in its quick reseeding of denuded lands.

In 1915, tracts formerly occupied by fourwing saltbush were covered with galleta and other tracts with little rabbitbrush. However, as already stated, fourwing saltbush increased in other places where disturbance of the original cover had occurred.

JUNIPER ASSOCIATION

TOPOGRAPHICAL RELATIONS

The juniper association (pl. 1) lies above the sagebrush belt, forming in places a forest that covers the lower slopes of the higher mountains and the tops of the lower mountains. In other places, however, between the first belt of juniper and the mountains, there are one or more alternations with sagebrush. In the latter case there are apt to be considerable tracts where the juniper occurs only as a scattered shrublike tree in the sagebrush. The sagebrush becomes more and more dwarfed as the juniper increases in number. When the growth of trees is dense the sagebrush is shut out altogether.

BOTANICAL COMPOSITION

Juniper where it is not in pure stands is closely associated with sagebrush. Other plants frequently found with it are hop-sage, big rabbitbrush (*Chrysothamnus nauseosus*), and *Ephedra*. Juniper was observed on dry ridges with shadscale and cactus. Occasionally the lower edge of the juniper area is mixed with galleta or, where the soil is sandier, with little rabbitbrush.

APPEARANCE

The juniper is a large shrub or small tree. In places the stand is dense enough to form forests, a constant shade, but usually the growth is more open. Its dark-green foliage sets it off from the sagebrush even at a great distance.

SOIL CONDITIONS

The soil occupied by the Utah juniper is light, like that of the sagebrush, but usually either very gravelly or stony.[11] In some places there seems to be no difference between the juniper and sagebrush areas except the steepness of the slope. With a soil of coarse texture and unusually good drainage, it is to be expected that the salt content is low.

Removal of scattered stands of juniper results in an increased growth of the sagebrush already present. Where dense stands of juniper are removed sagebrush usually seeds the area and eventually covers it.

PLANT COMMUNITIES ON SALINE LAND

SHADSCALE ASSOCIATION

TOPOGRAPHICAL RELATIONS

The shadscale areas (pl. 9) are less continuous than those of sagebrush. As a rule they lie just below the sagebrush and above the greasewood and pickleweed belts (see map). However, where the valley floor is wide, level, and well drained, shadscale may occupy the lowest land in the valley. Again, where drought conditions are very severe in the higher parts of the valley, that is, where the soil is heavier and penetration of water from the rains is greatly reduced, or where the soil is too well drained by a gravel subsoil, shadscale may alternate with sagebrush. Shadscale is usually sharply separated from sagebrush; there are no large tracts where the two are mixed. But shadscale mixes readily with greasewood, and there are large tracts where the two plants grow together and both do well. This mixture of the two plants is discussed under Greasewood-Shadscale Variation. Shadscale may also be sharply separated from little rabbitbrush and galleta.

BOTANICAL COMPOSITION

Large tracts covered with shadscale (pl. 9) contain practically no other woody species. Within the areas where soil conditions are favorable, especially along drainage courses, sagebrush or greasewood is found. Near the borders there occur scattered plants of galleta, little rabbitbrush, and winterfat. Of the grasses, big squirreltail (*Sitanion jubatum* J. G. Smith) was seen most frequently. The two

[11] That juniper is not confined to light soils is shown in other parts of the Great Basin, where it grows on shale hills, especially along the drainage courses.

annuals found most frequently are tansymustard and a large-flowered blistercress (*Cheirinia aspera* (Nutt.) Rydb.). Other plants noted in shadscale areas are globemallow and *Plantago purshii* Roem. and Schult.

The distribution and number of individuals of shadscale in a 10-m. quadrat are shown in figure 6.

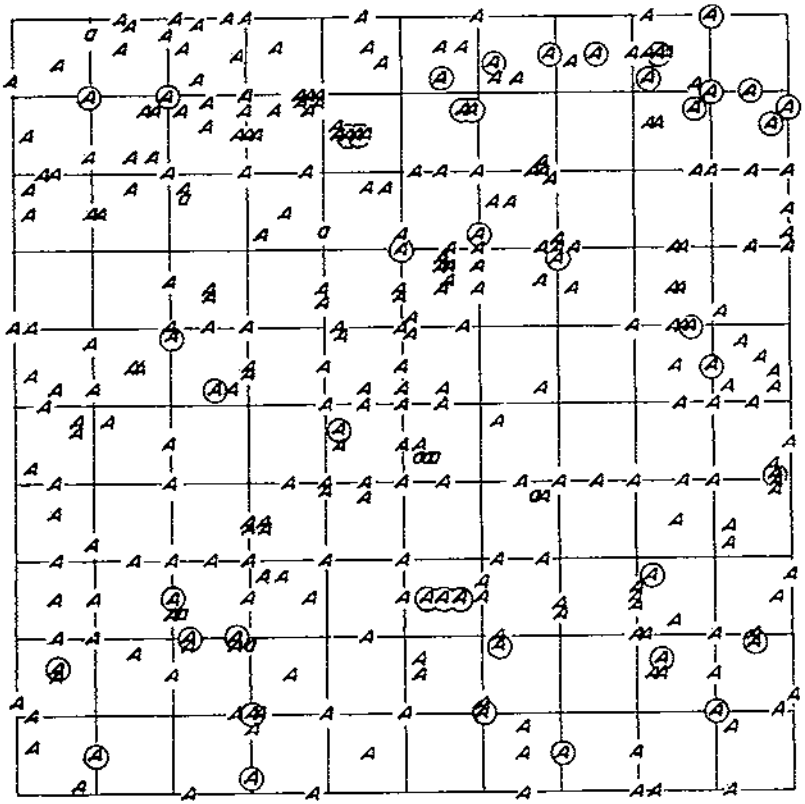


FIGURE 6.—A representative 10-m. quadrat in a typical area of shadscale. Individual living plants of shadscale are represented by *A* for mature plants and *a* for seedlings. A circle around the letter *A* denotes a dead plant. Annuals were represented by one individual of a large-flowered blistercress (*Cheirinia aspera*). (Mapped where sample 29 (table 10) was taken, April 16, 1915; Milford, Utah.)

APPEARANCE

The shadscale tracts appear as a uniform stand of low, bushy shrubs ranging in height from 4 to 6 inches where the growth is dwarfed (pl. 9, *B*) to about 2 feet where the growth is good (pl. 9, *A*). In spring these areas are straw-colored, owing to the dead leaves of the preceding season and to the color of the numerous thorns. This, together with the large amount of deadwood on the individual plants and the lack of more brightly colored associated species, gives the shadscale areas an extremely monotonous appearance. Later in the year, when the season's growth has been made, the tracts appear a

light gray, contrasting with the greener sagebrush. In fall, where the plants are healthy and a good growth has been made, the areas are bright with color ranging from yellow to brown and red purple.

SOIL CONDITIONS

A comparison of the spring and fall soil conditions in typical areas of shadscale is given in table 10. There is usually an admixture of gravel or coarse sand in the first foot of soil and below this a heavier soil. In 7 out of the 10 borings there was hardpan at 18 to 30 inches below the surface; in 1, a coarse gravel at 24 inches; in 2, a hard layer of heavy clay or shale at 24 inches. In shadscale areas that alternate with sagebrush there is more gravel in the soil (samples 1, 20, and 29, table 10), while in those bordering greasewood the soil is quite heavy (samples 11 and 26). Lands covered by shadscale mixed with greasewood show consistently a rather heavy soil. (See table 12, p. 34.)

TABLE 10.—*Comparison of spring and fall soil conditions in typical areas of shadscale, 1915* [1]

SPRING

Sample No.	Date of collection	Wilting coefficient at—				Moisture content above or below wilting coefficient at—				Salt content at—			
		1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	Apr. 6	5.9	8.6	.....	.....	+1.6	+3.1	.....	.....	0.02	0.03	0.15	0.29
2	do	7.9	7.8	8.6	5.1	+1.3	+3.0	+1.3	−1.0	.02	.02	.03	.15
11	do	13.4	16.8	19.1	18.2	+6.1	+3.9	−2.7	−1.7	.08	.23	.88	.75
20	Apr. 12	6.3	6.3	4.1	.....	+1.0	+2.5	+.6	.....	.02	.01	.02	.....
22	do	12.8	15.6	7.6	10.1	+1.7	+2.3	−3.0	−4.0	.07	.13	.16	.23
26	Apr. 13	13.1	16.8	19.3	10.5	−1.7	−3.1	−8.3	+1.0	.07	.15	.31	.67
29	Apr. 16	4.4	6.4	15.1	17.5	+.9	+2.3	+2.9	−3.0	.02	.02	.40	.90
39 [2]	Apr. 22	11.4	.....	7.1	..	+1.1	.....	−.6	.....	.02	.02	.13	.....
40	do	4.0	13.2	12.7	10.8	+4.7	+4.3	−2.9	−4.7	.02	.05	.07	.....
41	do	10.8	11.0	13.4	9.2	+.1	+3.8	−7.0	−6.0	.02	.02	.02	.....
Average		9.0	11.3	11.9	11.6	+1.7	+2.5	−2.2	−2.7	.04	.07	.22	.50

FALL

1	Sept. 11	5.5	8.8	10.3	9.3	+0.3	−2.0	−2.4	−2.4	0.02	0.05	0.15	0.35
11	Sept. 8	11.3	15.6	18.4	20.9	−1.6	−1.4	−1.4	−4.7	.10	.31	.64	.60
20	Sept. 9	5.3	4.7	4.4	4.6	+.1	−2.0	−2.5	−2.0	.01	.01	.01	.....
22	do	13.9	18.0	10.4	7.9	−3.4	−5.4	−3.7	−1.6	.06	.14	.18	.36
26	Sept. 10	10.4	14.3	14.6	.....	+1.6	−1.3	−1.5	.....	.07	.14	.23	.54
29	Sept. 8	4.8	6.6	18.3	17.2	+2.4	.0	−1.9	+2.5	.02	.02	.23	.68
39	Sept. 11	10.7	10.3	9.2	9.6	−3.4	−4.1	−2.6	−2.4	.02	.06	.02	.....
40	do	10.1	12.0	9.5	7.9	−3.8	−3.5	−3.9	−2.2	.03	.02	.07	.15
41	do	10.8	12.0	7.2	4.2	+1.2	−.5	+1.3	−.3	.02	.02	.02	.....
Average		9.2	11.4	11.4	10.2	−.7	−2.2	−2.0	−1.6	.04	.09	.17	.45

[1] All data are stated in percentages of the dry weight of the soil.
[2] Hardpan at 1 foot 9 inches. Chemical analyses are shown in table 1.

In spring there is a good supply of available water in the first and second feet of soil, but in the fourth foot it is lacking. Whether or not it is present in the third foot depends on the depth at which hardpan [12] occurs. Where there is a layer of coarse gravel in the third

[12] The effect of the hardpan is dependent on its character and the amount of moisture that penetrates the soil above it. In shadscale areas this may be complicated by an injurious salt content of the hardpan (analysis sample 1, table 1). The roots of the shadscale were matted above the hardpan and did not penetrate it. In the sandy soils of sample 4 (table 7) in little rabbitbrush and sample 5 (table 4) in medium-sized sagebrush, the hardpan was dry and hard in fall but in spring it was wetted and easily bored for sampling.

and the fourth foot, rather than a hardpan, there is a slight amount of available water. In fall there is no available water in the second, the third, or the fourth foot of soil. Moisture is found in the first foot in the fall only after heavy rains and where the surface soil is not too heavy. The depth of penetration is shown in table 10 by samples taken about a week after the heavy rain (1.02 inches) of September 2. This penetration was far from uniform, and with the exception of sample 29 (table 10) the penetration was very slight, approaching only in this one instance the amount shown in the first foot in the galleta areas (September samples, table 6). Shadscale can endure more severe drought conditions than either sagebrush or greasewood, as shown by the soil-moisture determinations. This is supported by the occurrence within the shadscale areas of sagebrush or greasewood wherever soil-moisture conditions are more favorable, especially along the shallow drainage courses.

The salt content of the soil in the shadscale areas is shown in table 10. In typical areas of a good growth of shadscale the first foot and usually the second foot have low salt content. In the third and the fourth foot the salt content may be high, occasionally as much as 2½ percent of salt. Exceptions to this are the soils with an admixture of gravel. Where the salt content is not high in the third and the fourth foot there is usually a hardpan or a coarse gravel at about 18 to 24 inches. The hardpan itself may have a salt content unfavorable for the growth of roots. Shadscale roots did not penetrate but were matted above the hardpan, a chemical analysis of which is given in sample 1 (table 1). If the salt content is high in the first foot the shadscale plants are sickly, there is much deadwood, and the stand is thin.

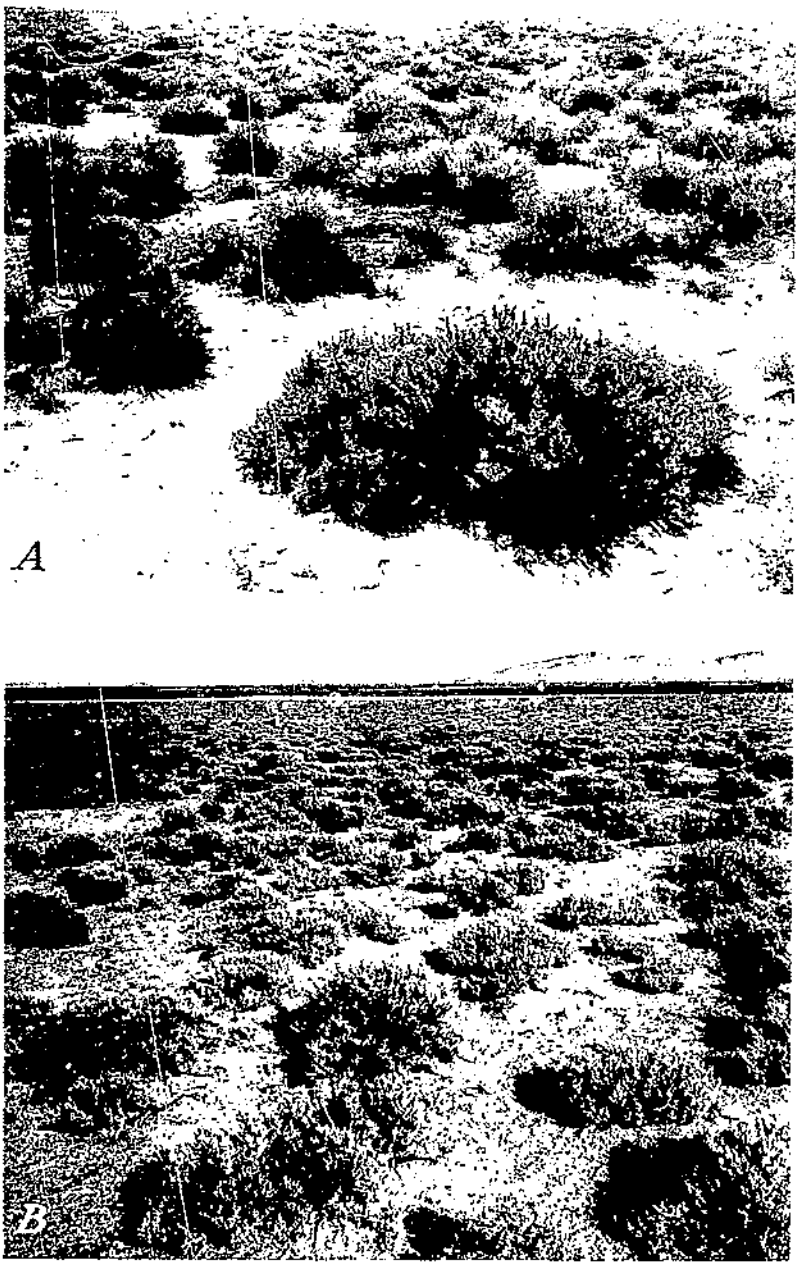
Shadscale indicates land that has a high salt content, hardpan or a coarse gravel at 18 to 24 inches below the surface. If hardpan occurs, the upper 18 to 24 inches of the soil is lighter, with more or less gravel, and if the salt content is high below 18 to 24 inches the upper soil is of a fine texture. Wherever the hardpan is nearer the surface, at 10 to 12 inches, or where there is a high salt content in the first foot, the shadscale plants are sickly, with much deadwood, and the stand is thin.

ADAPTATION OF SHADSCALE TO SOIL CONDITIONS

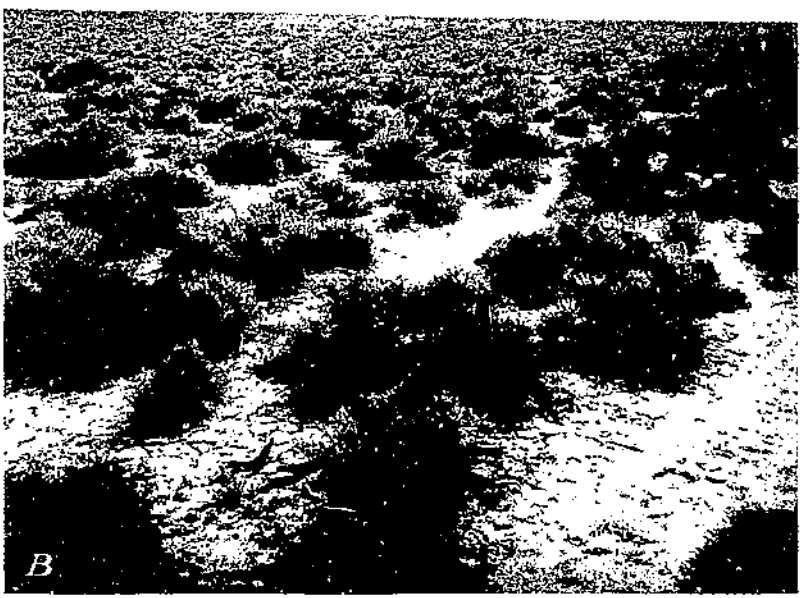
Shadscale is better adapted than sagebrush to grow in an extremely dry and shallow soil. Two feet of soil free of hardpan or excessive salt content is sufficient for a normal growth of shadscale. It can endure a higher salt content than sagebrush, but it is not adapted to grow well on the excessively saline dry flats or on the wet flats. Neither is it well adapted to grow on extremely light soils. It is noticeably absent from sand hills where sagebrush, juniper, greasewood, rabbitbrush, and fourwing saltbush are frequently found.

EFFECTS OF DISTURBING FACTORS (SECONDARY SUCCESSIONS)

Obvious disturbances of the vegetation were not often noted in the shadscale areas. Of lands plowed and later abandoned, some showed a direct reseeding of shadscale and others a cover of *Amaranthus blitoides*. Little rabbitbrush may succeed shadscale where plants of the latter have been killed out, but this was noted less frequently than in the sagebrush, galleta, and winterfat types.



A, A pure stand of shadscale, typical of large areas in the valley. There are very few annuals; Sophia was noted. (Kerr, Utah, August 28, 1913.) *B*, A pure stand of shadscale on heavy soil. The plants are small, are not in good condition, and are partly filled with soil, forming hummocks. (North of Modena, Utah, August 27, 1913.)



A, A pure stand of greasewood, almost defoliated. The cracked, silty nature of the saline surface soil is shown in the open space between the bushes. (Kerr, Utah, August 28, 1913.) *B*, Shadscale and greasewood, both small. The shadscale is 6 to 12 inches high; the greasewood, 6 to 18 inches high. This mixed type of vegetation is extensive near the bottom of the valley. (Modena, Utah, August 27, 1913.)

GREASEWOOD ASSOCIATION

TOPOGRAPHICAL RELATIONS

The greasewood association (pl. 10, *A*) occupies the lower, heavier, more saline soils in the middle of the valley where the soil-moisture supply is increased by a high water table (see map). With reference to the other associations, this area lies below the shadscale belt (pl. 9, *A*) and slightly above the saltgrass and pickleweed. Between the areas of shadscale and those of greasewood there are wide tracts of greasewood mixed with shadscale (pl. 10, *B*), usually of greater extent than the areas where greasewood forms pure stands.

Greasewood also occurs on sand hills. But here it is not the dominating plant, being mixed with sagebrush, rabbitbrush, and fourwing saltbrush. There are areas of low, wind-blown hummocks (pl. 15, *B*) on the lower lands where greasewood predominates (in fact is often the only plant), but here the greasewood grows on a heavy clay flat and the wind piles the soil around the bushes. It is often found along drainage courses on the more arid lands, such as those occupied by the shadscale association.

BOTANICAL COMPOSITION

Typical areas of greasewood contain few other shrubs. In the lower and wetter areas of greasewood, big rabbitbrush and saltgrass are very common. More rarely greasewood is associated with white sage, little rabbitbrush, and even sagebrush. In the wetter portions, where greasewood is rather poor, there is often a growth of seepweed between the shrubs.

Figure 7 shows the distribution and number of greasewood plants in a 10-m. quadrat. There were no annuals, since this area, like the others, has been excessively grazed. However, both the number of individuals and the number of species of the annuals are much less in greasewood, even under lightly grazed conditions, than in the associations found on a lighter soil. The globemallow is frequent and of the annuals noted, blistercress and tansymustard were the most common. Also noted in this association were *Thelypodium sagittatum* (Nutt.) Endl. and *Atriplex expansa* S. Wats.

APPEARANCE

When in full leaf, the succulent leaves of the greasewood give it something of the luxuriant appearance of pickleweed (pl. 11, *A* and *B*, in foreground and at left). Greasewood is readily distinguished from pickleweed by its color and larger woody growth. It is easily distinguished from the gray-colored shadscale areas by its light yellow-green color, except when the greasewood is leafless, then the light-colored bark of the previous season's growth and the gray thorns give greasewood a light-gray color. Where greasewood areas are near to sagebrush, the lighter yellow green sets off the former from the blue-green of the latter. In pure stands of greasewood (pl. 10, *A*) the plants are widely spaced, even more so than sagebrush, with large open spaces of bare soil. Where greasewood is mixed with shadscale (pl. 10, *B*) these open spaces are occupied by the shadscale plants, resulting, at least for desert plants, in a dense stand.

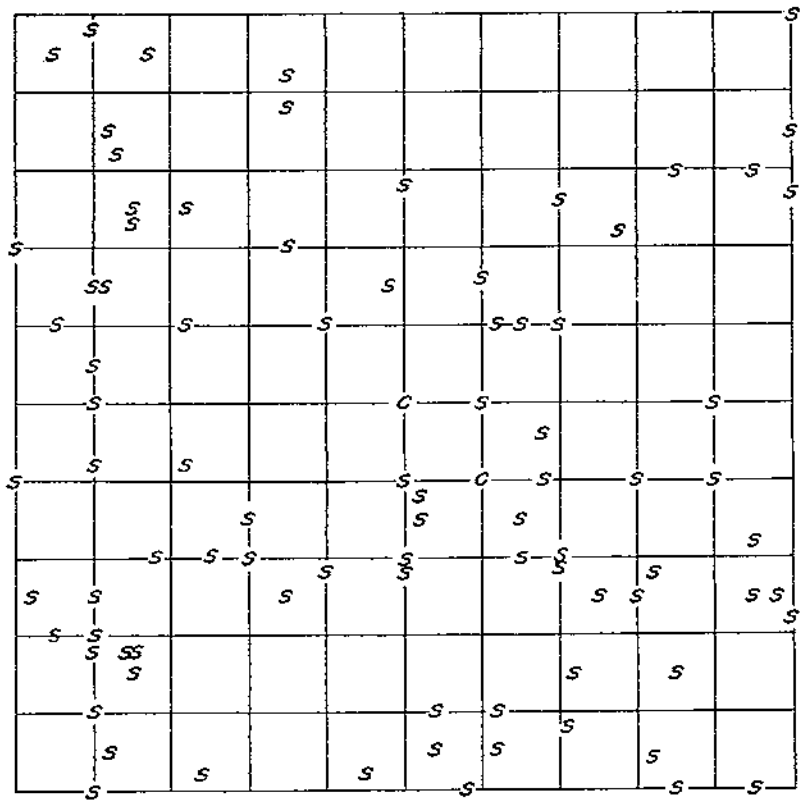


FIGURE 7.—A 10-m. quadrat taken in a representative area of greasewood, showing individual plants of greasewood by the letter *S* and the only other woody species present, rabbitbrush (*Chrysothamnus newberryi* Rydb.), by the letter *C*. No annuals were present. (Mapped April 17, 1915; Milford, Utah.)

SOIL CONDITIONS

Greasewood grows under a wide range of soil-moisture conditions (table 11). Stands of uniform growth are found on flat, level tracts of heavy soil, where the roots are within reach of soil moisture augmented by the water table, or in slight depressions, where an accumulation of floodwater increases the soil moisture. Where the influence of the water table reaches the surface and this condition exists throughout the growing season, greasewood gives way to saltgrass and other plants that cover wet saline lands. On the deep alluvial soils the water table may lie at a great depth and still be reached by the roots of the greasewood. White (*12*) states that the largest areas occur where the depth to the water table is less than 15 feet, though the upper limit of the plant ranges from the 25-foot to the 40-foot depth to water. Near Moab, Utah, along a creek where the water had cut away the bank, exposing the roots, a greasewood 6 feet tall had roots down 18 feet, a taproot 3 inches in diameter down 6 feet, and abundant feeding roots, some 10 feet long, at a depth of 10 to 12 feet. Meinzer (*6*) reports roots down 20 feet and one 57

A, Greasewood in the foreground and to the left, followed by a zone of shadscale through an island of little rabbitbrush and a very large area of winterfat. The greasewood continues around to the left and comes in contact with the winterfat in the background. In the right of the background winterfat comes in contact with little rabbitbrush. (Two miles southwest of Milford, Utah, September 9, 1913.) *B*, Sharp alternations of vegetation. Greasewood, at the left, adjoins a denuded area occupied largely in its outer portion by Russian-thistle. Beyond this there is practically a pure stand of winterfat and in the extreme background a large area of little rabbitbrush. Milford, Utah, September 9, 1913.

feet below the surface. The ability of the greasewood to feed at great depths must be taken into account in a consideration of soil-moisture conditions. White (*12*), in a series of graphs, shows the effect of a greasewood cover on the fluctuations of the water table.

TABLE 11.—*Soil conditions in greasewood areas, 1913 and 1915* [1]

Sample No.[2]	Date of collection	Wilting coefficient at—				Moisture content above or below wilting coefficient at—				Salt content at—			
		1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet
	1915	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
S	Apr. 9	11.5	11.3	7.3	7.4	+1.3	+0.2	−2.3	−1.5	0.03	0.04	0.14	0.23
8	Sept. 9	12.0	10.8	9.6	7.2	−6.0	−4.3	−3.0	−.8	.05	.04	.15	.35
Average		11.8	11.0	8.5	7.3					.04	.04	.15	.29
	1913												
30	Aug. 28					(3)	(4)			.14	.48		
47	Aug. 30					(4)	(4)	(4)		.41	.64	1.08	
59	Aug. 31					(4)	(4)	(4)	(4)	.06	.08	.13	.07
99	Sept. 9					(5)	(5)	(5)	(5)	.05	.03	.05	
Average										.17	.31	.42	

[1] All data for 1915 and salt-content data for 1913 are stated as percentages of dry weight of soil. Field notes are used for 1913, as shown in footnotes 3, 4, and 5.
[2] Sample 47 was taken in Sevier Valley; sample 59, near Tintic, Utah; other samples, in Escalante Valley.
[3] Dry. [4] Slightly moist. [5] Nearly dry.

Greasewood is not an infallible indicator of a high salt content (*3*). Salt contents of the samples in table 11 differ greatly. The first foot ranges from 0.03 to 0.41 percent, the second from 0.03 to 0.64 percent, and the third from 0.05 to 1.08 percent. Greasewood grows to a good size on sand hills (*3*) and also mixes with sagebrush on heavy nonsaline soils (table 5). Alkali is not necessary for its growth. It is indifferent to alkali, and if soil-moisture conditions are favorable it can grow in very saline soils. However, a uniform cover of greasewood is usually found either where floodwaters collect or where the water table is within reach of the roots, conditions that also favor a concentration of salts, and for that reason such a growth is generally closely connected with a high salt content.

While scattered plants of greasewood grow on a wide range of soils, an even growth of greasewood is quite regularly connected with a rather heavy soil where at least in spring there is moisture within 4 feet of the surface. In fall the moisture may be lower, yet within reach of the deeply penetrating root system. Where there is a uniform growth the salt content is apt to be high, though there is great variation.

GREASEWOOD-SHADSCALE VARIATION

TOPOGRAPHICAL RELATIONS

The greasewood-shadscale variation from the greasewood and the shadscale associations is a mixture of the two plants (pl. 10, *B*) on lands where physical conditions are intermediate between those indicated by each of the two associations. The mixture of the two usually occurs where the two associations meet unless there is an abrupt change in the level from one to the other. Greasewood-shadscale covers a much larger area than that occupied by greasewood alone.

BOTANICAL COMPOSITION

The two dominating plants, often the only woody species present, are greasewood and shadscale. Other shrubs found with the two dominants are big rabbitbrush (*Chrysothamnus consimilis* and *C. nauseosus newberryi*) and less often hop-sage and the white-flowered rabbitbrush. At the lower edge of the greasewood-shadscale area scattered plants of saltgrass and seepweed are common. At the upper edge are found winterfat, white sage, and saltsage. Among the greasewood and shadscale bushes, globemallow and the two annuals blistercress and tansymustard are common. The two annuals may form good-sized patches. Other plants found are big squirreltail (*Sitanion jubatum*), *Thelypodium sagittatum* (Nutt.) Endl., and *Chamaesyce glyptosperma* (Engelm.) Small.

APPEARANCE

At a distance this mixed cover looks like a thin, pure stand of greasewood. At close range the spaces between the greasewood are seen to be covered with the ashy-colored shadscale, more important in point of numbers than the greasewood (pl. 10, *B*). Usually the total space covered by shadscale is also greater. The two plants together form the densest stand of desert shrubs found in this valley.

SOIL CONDITIONS

It is to be expected that a desert soil supporting a plant growth as dense as this (greasewood with shadscale) must receive a water supply in addition to that resulting from precipitation directly. In table 12, where a comparison is made of spring and fall conditions, all of the samples show an abundance of soil moisture in all of the 4 feet of soil in spring, and even in the fall show a good supply in all but the first foot. The increase in soil moisture with depth indicates the presence of a high water table.

TABLE 12.—*Comparison of spring and fall soil conditions in typical areas of greasewood and shadscale, 1915* [1]

SPRING

Sample No.	Date of collection	Wilting coefficient at				Moisture content above or below wilting coefficient at				Salt content at—			
		1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
12	Apr. 9	13.1	13.6	11.8	11.3	−2.0	+6.2	+1.4	+1.5	0.42	1.51	1.28	1.38
13 [2]	Apr. 10	17.8	16.9	22.8	10.8	+1.3	+6.7	+10.5	+9.2	.15	1.08	2.30	2.30
27 [2]	Apr. 15	13.5	14.1	11.5	12.7	−3.9	−5.1	+7.6	+8.4	.17	1.08	1.87	2.30
Average		14.2	14.9	16.4	11.6	−3.1	−4.1	−7.5	−7.4	.25	1.23	1.82	1.89

FALL

12	Sept. 8	14.0	13.1	12.1	11.8	+1.3	+2.7	+2.7	+4.3	0.35	1.12	1.22	1.18
13	do	12.6	13.7	19.2	18.5	−.9	+7.4	+13.8	+10.7	.31	.91	2.14	1.84
27	Sept. 10	11.2	15.4	16.6	15.1	+.2	+4.6	+1.2	+6.8	2.70	2.70	2.50	2.50
Total		13.3	14.1	17.8	15.1	−.1	+4.7	+7.6	+7.3	1.05	1.52	1.95	1.84

[1] All data are stated in percentages of dry weight of soil.

[2] Chemical analyses of a composite sample of the third and fourth foot of samples 13 and 27 are shown in table 1. A few scattered plants of seepweed were in the area of sample 27, and neither shadscale nor greasewood grew well.

The salt content of the soils covered by this type of vegetation varies greatly. The samples collected in widely separated places in the valley showed on a gravel ridge 0.02 percent in the first and the second foot and 0.15 and 0.26 in the third and fourth, respectively, and in the large areas in the center of the valley a uniformly high salt content from the second foot down to the fourth and less than 0.5 percent in the first foot. At the latter neither of the plants was doing well; the greasewood was yellowish with very little growth, the shadscale scraggly with much deadwood, and in this growth there were scattered plants of seepweed. While the total salt content is high (samples 13 and 27), chemical analyses of samples 6 and 7 (table 1) indicate the preponderance of less harmful [13] salts than those of sample 1 (table 1); the hardpan found at 1 foot 9 inches (sample 39, table 10). The latter was taken at a place where shadscale plants were also in very poor condition but on dry land and where the total salt content was low.

Greasewood-shadscale indicates a heavy soil with a high salt content, at least in the third and the fourth foot, and a high water table that influences the moisture of at least the third and the fourth foot always in the spring and often in the fall. In the large areas, near the center of the valley, even the second foot has available water the year around, and here the second foot also has a high salt content. The first foot has an appreciable amount of salts, but where this is high neither of the plants does well.

ADAPTATION OF GREASEWOOD-SHADSCALE TO SOIL CONDITIONS

Because of a better supply of moisture, shadscale makes a better growth in the situations where it is associated with greasewood than where it grows alone in pure stands and where the sole soil-moisture supply comes directly from precipitation. The growth is poor, however, where the salt content of the first foot is high. Greasewood, as stated previously, grows where its roots are within reach of moisture increased by the water table, though the best development of the individual plant is found on sand hills (*3*), where the upper soil is well drained. It is likely that a water table high enough to benefit shadscale is too high for the best growth of greasewood. So that, though the two grow together, shadscale suffers if the salt content becomes too high in the surface foot, whereas greasewood suffers if the upper few feet are too wet and neither can grow where the surface foot is constantly wet.

EFFECTS OF DISTURBING FACTORS

When the shrub cover of greasewood, or greasewood and shadscale, has been damaged or removed, the most common growth that follows is seepweed. This plant naturally occurs in the spaces between the shrubs in the moister portions of greasewood or greasewood-shadscale. It seeds well and covers bare areas quickly. It is seen in fenced pastures where the shrubs have been killed out by trampling and along the roads where the shrubs have been removed. Blistercress and tansymustard are common where the upper soil is dry, and the two frequently form good-sized patches, especially where the shrubs have been damaged but still maintain some growth.

[13] See also discussion of salinity in Tooele Valley, Utah (*5*).

On land that has been plowed and abandoned, Russian-thistle forms the cover. In 1925 there were some good-sized tracts of Russian-thistle on such abandoned lands, though the total was small as compared to that on lands formerly covered by sagebrush and some of the other types. Globemallow is usually present and may be an important plant but occurs as scattered individuals. This plant is also present in the fenced pastures, though a dense stand was seen only in one of them.

SALTSAGE COMMUNITY

Saltsage, with which mat saltbush (*Atriplex corrugata*) is often associated (pl. 7, *B*), occurs in southwestern Utah over only small areas as compared to the sagebrush, shadscale, or greasewood areas. It is a low shrub, about 6 inches high, forming mats sometimes several feet in diameter, often situated on a low hummock (pl. 8, *B*) on an otherwise barren, dry flat. The plants are grayish and when vigorous appear at a distance much like a low growth of shadscale.

In pure stands there are often wide barren spaces between the mats. Sometimes annuals such as *Eriogonum inflatum* Torr. and Russian-thistle occupy these spaces, the latter often confined to the cracks in the hard, dry soil. It mixes to some extent with winterfat (pl. 7, *B*), ricegrass, shadscale, and chamiso, or with greasewood, with which, like shadscale, it is sometimes associated.

The barren salt flats are shallow depressions where drainage water accumulates and stands until evaporated or taken up by the soil. After rains shallow ponds form, but later these dry up and the soil becomes hard and cracked. The centers are flat and smooth, but the edges are covered with low hummocks, formed by accumulations of wind-blown particles.

Saltsage is one of the first of the desert shrubs to occupy the dry, barren, saline flats, just as red samphire and pickleweed are the first plants to occupy the wet, saline flats. Two annuals, saltbush (*Atriplex* sp.) and Russian-thistle, are sometimes seen extending out into the dry flat. Though outside of Escalante Valley saltsage also lives on dry shale hills and gravelly ridges, it is found in pure stands usually on the tops of low hummocks on otherwise bare, smooth flats, where if the water table were high enough to moisten the top layers of soil, one would expect pickleweed or saltgrass. On the more porous soils saltsage was found to root to a depth of 3 feet, but on the bare saline flats its root system is extremely shallow, often only a little below the hummock on which it lives. In this case, though the subsoil is highly saline, the superficial layers have a low salt content. In table 13 are shown data from two samples taken in a growth of saltsage. Sample 25 represents a more porous type of soil that shows a low salt content and is dry in all 3 feet. Here the growth was thin, small, and scattered, though the roots grew to a depth of 3 feet. Sample 28 represents the bare flat type of heavy soil, where the plants grew on low hummocks. Here, though the soil below the first 6 inches was moist, it was highly saline.

Saltsage in pure stands indicates a soil the surface foot of which is extremely dry, at least part of the year, while the subsoil is saline.

TABLE 13.—*Soil conditions in areas of saltsage, 1918* [1]

Sample No.	Date of collection	Salt content at—			Soil moisture at—			Soil type at—		
		1 foot	2 feet	3 feet	1 foot	2 feet	3 feet	1 foot	2 feet	3 feet
		Per cent	*Per cent*	*Per cent*						
25	Aug. 28	0.06	0.04	0.18	Dry	Dry	Dry	Fine sandy loam.	Fine sandy loam.	Fine sandy loam.
28	do	.62	1.22	2.30	Moist	Moist	Moist	Loam	Loam.	Loam.
64 [2]	Aug. 31	1.68	2.50	2.50	do	do	do	Fine sandy loam.	Fine sandy loam.	Fine sandy loam.
67 [2]	do	.52	2.40		do	do		do	do	
Average		.57	1.51	1.66						

[1] Salt-content data are stated as percentages of dry weight of soil. Other data are field notes.
[2] From Rush Valley, Utah.

SALTGRASS ASSOCIATION

TOPOGRAPHICAL RELATIONS

Saltgrass forms meadows in the lowest parts of the valleys between the greasewood-shadscale belt and the pickleweed areas. It does not push out into the salt-incrusted flats so far as the pickleweed does. The meadows are on flat, level tracts where, at least in spring, the water table is near the surface.

BOTANICAL COMPOSITION

The meadows of pure stands of saltgrass are not very extensive. They are bordered by areas of saltgrass mixed with seepweed, big rabbitbrush (*Chrysothamnus consimilis*), and a medium-sized rabbitbrush (*C. newberryi*), white-flowered rabbitbrush (pl. 12, *A*), alkali sacaton (pl. 15, *A*), and other grasses. Often saltgrass grows in the interspaces between shrubs of big rabbitbrush, greasewood (pl. 12, *B*), or pickleweed (pl. 13, *A*). Less frequently there are scattered plants of shadscale, and very rarely scattered plants of dwarfed, sickly sagebrush, with this grass. Bordering the meadow, but usually extending farther out into the salt flats, are patches of red samphire or Utah samphire (*Salicornia utahensis* Tidestrom). Other plants noted in this association are *Aplopappus lanceolatus* (Hook.) Torr. and Gray, *Spartina gracilis* Trin., *Thelypodium sagittatum* (Nutt.) Endl., *Juncus balticus* Willd., and *Phragmites communis* Trin.

APPEARANCE

At a distance the saltgrass areas appear as light-green meadows in spring, but by September, owing to the curing of the grass, they resemble a stubblefield in color.

Where saltgrass meadows are not pastured the grass forms a dense stand knee high. Since the meadows offer good natural pasturage they are usually cropped close to the ground, forming an even sod.

SOIL CONDITIONS

The soil-moisture supply in the saltgrass meadows comes from floodwaters following rains and from a high water table. There is an abundant supply the year around. Scattered plants of saltgrass are found on soils where the water supply, at least in fall, is scant. In such places the saltgrass forms a meager growth, not a sod.

The salt content of the saltgrass lands is high. Of the types of vegetation studied, only pickleweed and sometimes greasewood-shadscale occupy lands that have as high a salt content. Soils having more than 2.5 percent of salts were found (sample 84, table 14). Nevertheless, a high salt content is not necessary for a good growth of saltgrass, and where the soil is subject to flooding by fresh water the salt content may be quite low. A chemical analysis of soils in saltgrass areas is shown in table 1, samples 3, 4, and 8.

TABLE 14.—*Soil conditions in areas of saltgrass* [1]

Sample No. [2]	Date of collection	Wilting coefficient at—			Moisture content above or below wilting coefficient at—			Salt content at—			
		1 foot	2 feet	3 feet	1 foot	2 feet	3 feet	1 foot	2 feet	3 feet	4 feet
		Per-cent	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
14	Apr. 10, 1915	23.5	23.7	25.8	+24.2	+18.4	+22.4	[3] 0.90	0.48	0.44	0.51
14	Sept. 10, 1915	18.9	19.4		+25.3	+29.3		1.70			
84	Sept. 5, 1913							>2.50	>2.50	2.40	
Average		21.2	21.6	25.8	+24.8	+24.0		1.30	.48	.44	.51

[1] Data stated as percentages of dry weight of soil.
[2] Sample 84 was taken at Nelson, Nev., at the border line of saltgrass and a bare salt flat. It is not included in the averages of salt content. The soil was a sandy loam and moist in the first foot, and sandier and nearly saturated in the second and third feet. Sample 14 was taken in the Escalante Valley.
[3] Chemical analyses of sample 14, for the first and second feet, are shown in table 1.

A uniform growth of saltgrass, a sod, indicates a heavy type of soil, a high salt content, and a good supply of soil moisture throughout the year. Saltgrass may grow on soil that is wetted by fresh water and is nonsaline. However, since such conditions are not often found in the semiarid regions, saltgrass areas on this kind of land are few and not very extensive. Where the soil becomes drier the saltgrass does not form a sod, but the growth is scattered and the plants are not very vigorous.

ADAPTATIONS OF SALTGRASS TO SOIL CONDITIONS

Saltgrass, like pickleweed, is adapted to grow on a soil saturated, at least in spring, to the surface. Unlike pickleweed, it grows equally well in a wet nonsaline soil and a wet saline soil. Its root system is shallow in the waterlogged soils but may reach a depth of many feet where the water table is low.

EFFECTS OF DISTURBING FACTORS

Saltgrass is not easily injured by heavy grazing but forms a close-cropped sod. Where the sod is broken by trampling or in the comparatively rare instances of plowing, saltgrass readily reseeds itself directly. An intervening weedy growth is usually lacking because of the saline soil. Where seepweed is present it may temporarily cover the broken ground.

PICKLEWEED ASSOCIATION

TOPOGRAPHICAL RELATIONS

Pickleweed areas do not occur outside of the flat, poorly drained lands in the bottom of the valley, where they are closely associated with saltgrass and greasewood. Pickleweed and saltgrass patches alternate so frequently or the two are so mixed (pl. 13, *A*) that no attempt

A, White-flowered rabbitbrush (*Chrysothamnus viscidiflorus*), sagebrush (*Artemisia tridentata*), and *Prosopis*. Scarp of Milford, Utah, August 28, 1913. *B*, Saltgrass and greasewood. This combination of vegetation is found on low lands that have a high water table and are flooded after rains. It is valuable as grazing land. Boring 11, Milford, Utah, September 28, 1915.

A, Saltgrass and pickleweed on strongly saline land, near the bottom of the valley. In the foreground a sparse growth of saltgrass covers the edge of a flat flooded after rains. (Lund, Utah, August 28, 1913.) *B*, General view in the bottom of the valley after a heavy rain (1.02 inches). Red samphire, in the foreground, extends to the shallow water. The cattle are grazing on saltgrass land. The large darker bushes in the foreground and at the border of the saltgrass and red samphire are clumps of pickleweed. (Milford, Utah, September 8, 1915.)

has been made to separate them in the map. With respect to the greasewood belt, the pickleweed areas are found on lower land, where the water table is higher and where in the spring of the year the soil is apt to be boggy. Pickleweed areas extend beyond the saltgrass into the salt flats, often covering small hummocks that are surrounded by level stretches covered with a snow-white layer of salt. In plate 13, *B*, a narrow fringe of pickleweed lies between a saltgrass area and a narrow strip of red samphire. Just as the annual saltbush or saltsage is found farthest out in the barren dry salt flats, so red samphire extends into the wet salt flats.

BOTANICAL COMPOSITION

While there are pure stands of pickleweed in Escalante Valley, they are not large. These pure stands merge gradually with greasewood, or more often with saltgrass. Red samphire, Utah samphire (*Salicornia utahensis*), and seepweed are often associated with pickleweed. The high salt content of the surface soil here bars the growth of annuals other than red samphire.

Other plants noted in this association are *Juncus balticus*, *Spartina gracilis*, *Sporobolus airoides*, *Phragmites communis*, and *Chrysothamnus newberryi*.

APPEARANCE

Pickleweed has a dark-green luxuriant color. No other plant, with the possible exception of greasewood, forms such a striking contrast to the rest of the desert plants. In summer its dark-green color distinguishes at a great distance these areas from the surrounding expanse of gray. The plants are from 1 to 2 feet high, with succulent, jointed stems and a shrubby base. In the summer in the typical areas the plants are a dark green; in the fall they are yellowish to bright red; but in winter and early spring, before the new growth is out, the plants have the brown color of dead or dormant plant growth. Several plants may be found grouped together on slight rises above a flat that is white with salt.

SOIL CONDITIONS

The texture of the soil in pickleweed land is heavy. There is an abundant supply of moisture to a depth of 4 feet the year round. In spring the soil may be quite boggy. Where pickleweed occasionally occurs along dry creeks or drainage courses and the first foot or the first 2 feet become dry later in the season, the plants are scattered and of a very poor, scraggy growth.

The salt content of the upper 3 feet of soil in the pickleweed areas is excessive, often as high as 2.5 percent and usually over 1 percent (table 15). Frequently there is a uniform white incrustation of salt, resembling a covering of snow, that completely covers the barren spaces between the plants. Pickleweed more than any of the other types of vegetation can develop a normal, uniform growth in the presence of a high salt content.

Pickleweed indicates a heavy type of soil, a high-water table, with the upper 4 feet wet in spring, moist even in fall, and a higher salt content than any other type of vegetation in this region.

TABLE 15.—*Soil conditions in typical areas of pickleweed* [1]

Sample No.	Date of collection	Salt content at—			Water content at—			Soil type at—		
		1 foot	2 feet	3 feet	1 foot	2 feet	3 feet	1 foot	2 feet	3 feet
		Per-cent	*Per-cent*	*Per-cent*						
27	Aug. 28, 1913	2.50	2.50	2.50	Moist	Moist	Moist	Loam	Loam	Loam.
45	Sept. 8, 1915	1.23	2.50		do	Wet		Clay loam	Clay loam	
Average		1.86	2.50	2.50						

[1] Salt-content data are stated as percentages of dry weight of soil. Other data are field notes.

ADAPTIONS OF PICKLEWEED TO SOIL CONDITIONS

Pickleweed is one of the few plants that actually thrive in the presence of a high salt content, high even in the surface foot of soil. This plant is also adapted, as few of the desert plants are, to grow on a soil that, at least in spring, is saturated to the surface.

EFFECTS OF DISTURBING FACTORS

Owing to the high salt content and the wet soil, pickleweed land is not plowed i. scalante Valley. Where it is plowed in other places the conditions are changed by drainage and irrigation. Because there are few or no forage plants, there is no overgrazing. Where pickleweed is destroyed along roadsides it seems to reseed slowly and may be preceded by a growth of seepweed.

RED SAMPHIRE COMMUNITY

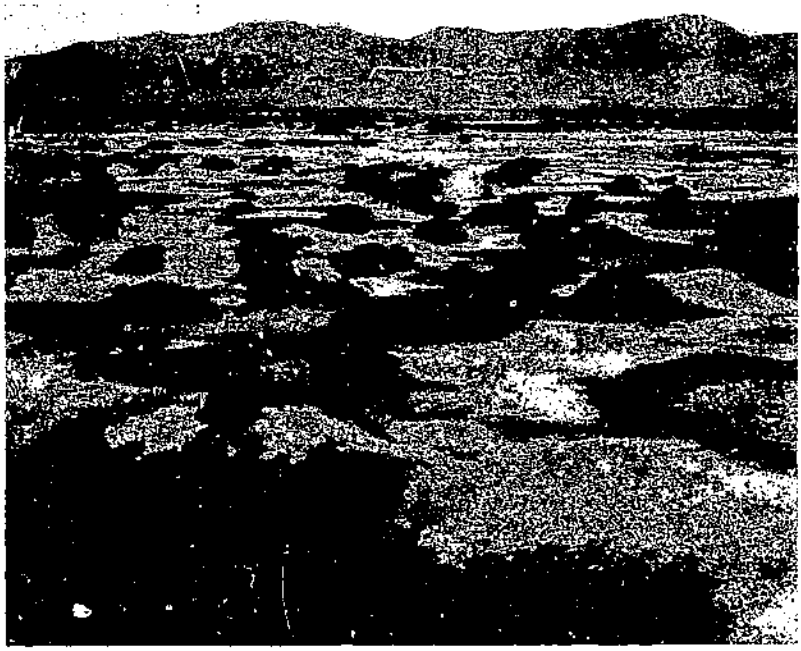
Red samphire (*Salicornia rubra*), a small, shallow-rooted annual, which appears in hues from green to deep red, occurs at the edges of salt flats, especially where drainage water collects after heavy rains (pl. 13, *B*). It may occur throughout the greasewood, saltgrass, or pickleweed communities. It often covers the low flat spaces between the slight mounds topped by pickleweed. The salt content of the soil is usually in excess of 2 percent.

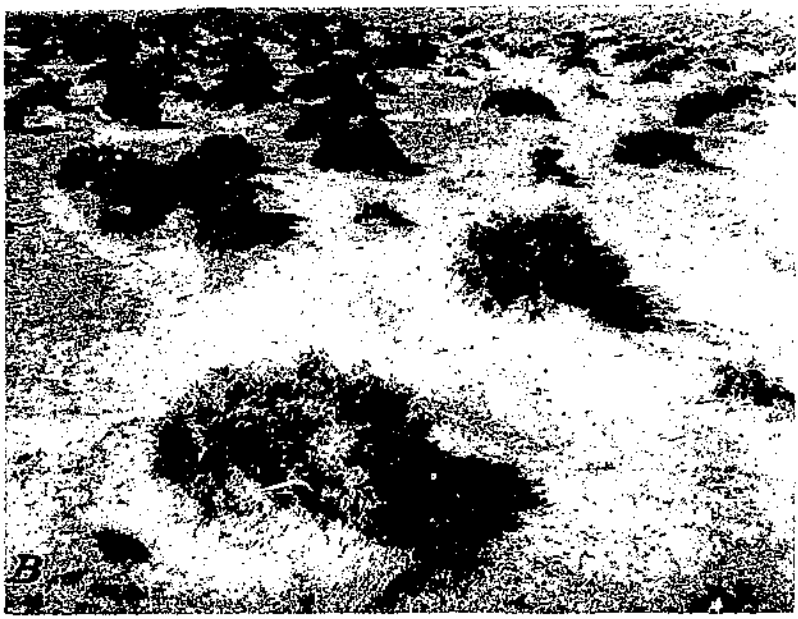
MIXED VEGETATION ON HUMMOCKS AND SAND DUNES

In the lower parts of the valley (pls. 14 and 15), especially south and west of Lund, there are stretches of sandy areas that take the form of low ridges or of scattered, low hummocks topped by big rabbitbrush,[14] alkali sacaton, greasewood, Fendler and red three-awn, or by *Agropyron inerme* (Scribn. and Smyth) Rydb. and Russian-thistle. Often all of these occur, but the dominant plants are determined largely by the height, age, and location of the sand hummocks. Sometimes the latter are superimposed on a level, clay, salt flat; the upper or hummock part of the soil, 1 to 4 feet high, is sandy and nonsaline, while the lower portion is clay and strongly saline. Here greasewood or alkali sacaton may be dominant, while big rabbitbrush and red three-awn are also present. More often, where greasewood

[14] Big rabbitbrush includes several closely related species, which Hall and Clements (2) list as subspecies under *Chrysothamnus nauseosus*. They are *C. nauseosus* (Pall.) Britton, *C. speciosus* Nutt., *C. turbinatus* (Jones) Rydb., and *C. consimilis* Greene. All of these were found in the mixed vegetation of the sand dunes and hummocks. *C. nauseosus* was also common in sagebrush, sagebrush-juniper, and one grass area. *Chrysothamnus newberryi* Rydb., a smaller species not closely related to *C. nauseosus* and listed by Hall and Clements as a variation of *C. parryi albicaulis*, also occurred on these sandy tracts, as did the little rabbitbrush (*C. greenei*). However, *C. newberryi* was most commonly found in the vegetation types on saline lands, and so were the big rabbitbrush (*C. consimilis*) and the white-flowered rabbitbrush (*C. albidus*), the latter on excessively saline soil near pickleweed.

A, Mixture of salt-tolerant species, such as often occurs near the bottom of the valley. Big rabbitbrush, shadscale, greasewood, and occasional plants of saltgrass. (Boring 36, Nada, Utah, August 28, 1913.) *B*, Small dunes such as have occasionally been developed in the bottom of the valley. Here there is a great mixture of vegetation and relative abundance of animal life. The vegetation is chiefly big rabbitbrush. The sand in the foreground is covered with rodent, bird, and beetle tracks. (Lund, Utah, June 8, 1926.)





A, Hummocks of alkali sacaton on heavy alkali land, showing the south side The heaviest growth is on the west side. (Lund, Utah, August 28, 1913.) *B*, Greasewood forming hummocks. These are somewhat higher than the alkali sacaton hummocks. The wind-blown soil is caught in the bushes so that frequently only the outer 3 or 4 inches of the branches stick out of the mound.

Abandoned fields. The big rabbitbrush (*Chrysothamnus speciosus*) in the foreground shows a root spread of 8 feet, exposed. The soil has been blown away from this plant. Russian-thistle and other short-lived plants have established themselves on the wind-blown area in the background. (Three miles northeast of Lund, Utah, September 24, 1925.)

(pl. 15, *B*) dominates, it is growing on a clay flat over which fine soil particles are blowing and filling in around the plants. These mounds are not of sand but of clay, which, after being wetted and dried, cracks and fissures as does the clay on the flat. The outer portions of this area, grading into the salt flat, may be dominated by shadscale, the vegetation of the flat. If sandy hummocks occur in the higher part of the valley, sagebrush or big rabbitbrush may predominate. Sagebrush occupies the older parts of dunes or the older dunes, and big rabbitbrush the newer.

Except where the dunes are shifting rapidly, the vegetation is made up largely of plants from the adjoining vegetation areas. Thus, much of the hummock area bordering greasewood is dominated by greasewood and that portion bordering sagebrush by sagebrush. In very recently disturbed areas, where the soil is moving rapidly to form dunes, the vegetation is badly mixed, usually with an abundant growth of big rabbitbrush (pl. 16).

In addition to those noted above, the following plants are frequently found on the sandy or hummocky tracts: Fourwing saltbush, little rabbitbrush, giant wild-rye, ricegrass, blistercress, and globemallow. Other species noted are *Lygodesmia grandiflora* (Nutt.) T. and G., *Lepidium campestre* (L.) R. Br., *Anogra* sp., *Abronia fragrans* Nutt., and *Sphaerostigma* sp.

When the hummocks are high or located in the upper part of the valley, the upper 4 feet are sandy and nonsaline. Where they occur superimposed on a salt flat and are sandy, the upper part is nonsaline while the lower clay portions are saline, 0.88 percent in the third foot. Water from summer rains is readily absorbed by the loose soil. Three of the four samples showed moisture in late summer or fall in the first foot, and one showed moisture in all 4 feet.

Where light soil has been farmed and then abandoned, the unprotected soil is blown about by the wind and low dunes are formed (pls. 14, *B*, and 16). Big rabbitbrush and little rabbitbrush are usually the first shrubs to appear on the newly formed dunes. Russian-thistle forms an irregular cover on the less disturbed slopes of the dunes. Sagebrush appears on the older dunes. Hummocks and low dunes are formed in the heavy soil types, as discussed above, and wherever a bare soil is subjected to the force of the wind.

CORRELATIONS BETWEEN PLANT COMMUNITIES AND SOIL CONDITIONS AS INDICATING CROP POTENTIALITY

The most reliable indicators of soil conditions (tables 16 and 17) are the stable plant communities that have occupied the soil over a long period of time and have nearly reached equilibrium with soil and climate. The mixed growth of a variety of species that ordinarily are not associated with one another indicates disturbed soil conditions that may include a wide range of soil types from low dunes of sand to hummocks of heavy soil. The mixed vegetation listed under minor communities is of this type. The temporary communities of annuals such as Russian-thistle indicate damaged or destroyed original plant covers with or without a pronounced disturbance of the soil. Russian-thistle may cover pasture land where enclosed stock has killed out the shrubs by trampling, or it may cover land that has been plowed and then abandoned, and either of the foregoing may take place on the heavy soil of greasewood land as well as on the lighter soil of little rabbitbrush or sagebrush land.

TABLE 16.—*Summary of soil conditions in representative areas of principal plant communities* [1]

Type of vegetation and season of year	Moisture equivalent at—				Wilting coefficient at—				Moisture content above or below wilting coefficient					Salt content				
									At depth of—				Mean	At depth of—				Mean
	1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet	1 foot	2 feet	3 feet	4 feet		1 foot	2 feet	3 feet	4 feet	
	Per-cent	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
Sagebrush (*Artemisia tridentata*):																		
Spring 1915	14.4	16.0	19.0	23.8	7.8	8.7	10.4	12.9	+0.4	+2 [illegible]	+2.7	[2]+3.3	[2]+2.3	0.03	0.04	0.13	0 33	0.13
Fall 1915	13.1	16.4	16.4	16.9	7.1	8.9	8.9	9.2	+.3	− .2	−1.7	−.1	−.9	.03	.04	.10	.16	.08
1913														.16	.12	.12		.10
Average	13.8	16.2	17.7	20.4	7.5	8.8	9.7	11.1	+.4	+.7	+.5	+1.1	+.8	.07	.07	.12	.25	.10
Galleta grass (*Hilaria jamesii*):																		
Spring 1915	17.4	20.2	15.5	15.3	9.4	11.0	8.4	8.3	+2.3	+2.0	+.8	−1.4	+.9	.03	.05	.04	.08	.05
Fall 1915	15.5	17.6	15.6	15.4	8.4	9.6	8.5	8.3	+3.0	−.7	−2.4	−2.4	−.6	.07	.07	.09	.08	.08
1913														.03	.05	.02		.03
Average	16.5	18.9	15.6	15.4	8.9	10.3	8.5	8.3	+2.7	+.7	−.8	−1.9	+.2	.04	.06	.05	.08	.05
Little rabbitbrush (*Chrysothamnus laricinus*):																		
Spring 1915	11.5	12.4	13.7	11.6	6.3	6.8	6.9	6.3	+1.7	+3.3	+3.4	+2.0	+2.6	.02	.03	.08	.10	.06
Fall 1915	11.4	13.2	13.2	14.5	6.2	7.1	7.2	7.9	+1.2	−1.7	−2.3	−2.6	−1.9	.03	.03	.07	.08	.05
1913														.02	.02	.02		.02
Average	11.5	12.8	13.5	13.0	6.3	7.0	7.1	7.1	+1.5	+.8	+.6	−.3	+.4	.02	.03	.06	.09	.04
Winterfat (*Eurotia lanata*):																		
Spring 1915	21.2	23.3	22.8	19.0	11.5	12.6	12.4	10.3	+1.2	+2.1	−2.7	−3.1	−.6	.04	.05	.20	.35	.16
Fall 1915	19.9	21.8	21.1	19.5	10.8	11.9	11.5	10.6	−1.5	−3.7	−3.9	−2.6	−2.9	.11	.06	.14	.20	.15
1913														.05	.06	.14	.14	.10
Average	20.6	22.6	22.0	19.3	11.2	12.3	12.0	10.5	−.2	−.8	−3.3	−2.9	−1.8	.07	.06	.16	.26	.14
Shadscale (*Atriplex confertifolia*):																		
Spring 1915	16.5	20.9	21.9	21.4	9.0	11.3	11.9	10.6	+1.7	+2.5	−2.2	−2.7	−.2	.04	.07	.22	.50	.21
Fall 1915	16.9	20.9	20.9	18.8	9.2	11.4	11.4	10.2	−.7	−2.1	−2.4	−1.6	−1.7	.04	.09	.17	.45	.19
1913														.04	.09	.24	.55	.23
Average	16.7	20.9	21.4	20.1	9.1	11.4	11.7	10.4	+.5	+.2	−2.3	−2.2	−1.0	.04	.08	.21	.50	.21

Greasewood-shadscale (*Sarcobatus* and *Atriplex confertifolia*):																	
Spring 1915	26.2	27.4	30.1	26.9	14.2	14.9	16.4	14.6	[2]+3.4	+6.1	+7.5	+7.4	+6.1	.25	1.23	1.82	1.99	1.32
Fall 1915	24.4	25.9	29.0	27.8	13.3	14.1	15.8	15.1	.0	+4.7	+7.6	+7.3	+4.9	1.05	1.52	1.95	1.84	1.59
1913	------	------	------	------	------	------	------	------	------	------	------	------	------	[3].08	.22	.47	.38	.29
Average	25.3	26.7	29.6	27.4	13.8	14.5	16.1	14.9	+1.7	+5.4	+7.6	+7.4	+5.5	.46	.99	1.41	1.40	1.07
Greasewood (*Sarcobatus vermiculatus*):																		
Spring 1915	21.2	20.8	13.4	13.5	11.5	11.3	7.3	7.4	+1.3	+.2	−2.3	−1.5	−.6	.03	.04	.14	.23	.11
Fall 1915	22.1	19.9	17.7	13.3	12.0	10.8	9.6	7.2	−6.0	−4.3	−3.0	−.8	−3.5	.05	.05	.15	.35	.15
1913	------	------	------	------	------	------	------	------	------	------	------	------	------	.17	.31	.42	.09	.25
Average	21.7	20.4	15.6	13.4	11.8	11.1	8.5	7.3	−2.4	−2.1	−2.7	−1.2	−2.1	.08	.13	.24	.22	.17
Saltgrass (*Distichlis spicata*):																		
Spring 1915	43.2	43.7	47.4	------	23.5	23.7	25.8	------	+24.2	+18.4	+22.4	------	+21.7	.90	.48	.44	.51	.58
Fall 1915	34.7	35.7	------	------	18.9	19.4	------	------	+25.3	+29.3	------	------	+27.3	1.70	------	------	------	1.70
Average	39.0	39.7	47.4	------	21.2	21.6	25.8	------	+24.7	+23.9	+22.4	------	+23.7	1.30	.48	.44	.51	.68

[1] Data expressed as percentages of dry weight of soil.
[2] Average a little high owing to a sample with subirrigation.
[3] Average high, plants poor, in a sample taken at limit of community.

TABLE 17.—*Summary of soil conditions and capabilities for crop production as indicated by principal plant communities of Escalante Valley*

Type of vegetation	Soil type	Soil moisture		Salinity		Suitability of land for crop production
		Surface foot	Subsoil	Surface foot	Subsoil	
Juniper	Stony	Moist after rains only	Moist after rains only	Nonsaline	Nonsaline	Too stony or slope too steep.
Sagebrush:						
Normal growth	Sandy loam or fine sandy loam; admixture of gravel.	do	do	do	do	Suitable, if irrigated.
Poor growth	Sandy loam or fine sandy loam, underlain with hardpan, coarse gravel, or rarely saline.	do	Apt to be dry, due to lack of penetration.	do	Rarely slightly saline.	Doubtful.
Galleta	Sandy loam or fine sandy loam.	do	Moist after rains only	do	Nonsaline	Suitable, if irrigated.
Little rabbitbrush	Sandy loam	do	do	do	Rarely slightly saline.	Do.
Winterfat	Fine sandy loam or loam.	do	Dry most of the year	do	Slightly saline	Do.
Shadscale	do	do	Apt to be dry most of the year.	Nonsaline or only slightly saline.	Saline	Do.
Greasewood-shadscale	do	Moist after rains; rarely moist, owing to high water table.	Moist; high water table.	Moderately saline	Highly saline	Suitable, under irrigation, though usually the land must be handled so as to reduce the salinity.
Greasewood	do	Moist after rains only	do	do	do	Suitable, if irrigated, though drainage may be necessary.
Saltgrass	Loam or clay loam	Moist most of year; rains and high water table.	Wet all the year; high water table.	Highly saline	do	Affords natural pasturage or meadow. Too saline for crops, and the high water table makes drainage necessary.
Pickleweed	do	Wet most of the year; high water table	do	do	do	Too saline and too wet.

Little rabbitbrush may be a stable community that indicates reasonably well-defined soil conditions, but, more than any of the others, it may also be a temporary community following the destruction of a stable one. This capacity of little rabbitbrush to form a temporary cover on widely varying soils lessens its value as an indicator in areas where much disturbance of the plant cover has taken place.

Of the established communities, the lightest soils are occupied by little rabbitbrush, followed by galleta, sagebrush, greasewood, shadscale, winterfat, greasewood-shadscale, and saltgrass, in the order of increasing heaviness of the soil. On the basis of surface soil, the following is the order, beginning with the community characterized by the lightest soil: Little rabbitbrush, sagebrush, galleta, shadscale, winterfat, greasewood, greasewood-shadscale, and saltgrass.

Soil moisture, based on available water in the soil, is most abundant in saltgrass and pickleweed areas, where the soil was decidedly wet at all depths. In the greasewood-shadscale areas moisture was more abundant than in pure stands of either greasewood or shadscale. No other communities had water available to 4 feet both in the fall and spring samplings. Little rabbitbrush, next to the greasewood-shadscale, had the most water available in the spring, although the fall reading showed less than in sagebrush. Sagebrush, next to little rabbitbrush, had a soil well moistened to 4 feet.

During the spring growing season water was present in every type, but fall droughts are marked in greasewood, winterfat, little rabbitbrush, shadscale, sagebrush, and galleta. Only the saltgrass and greasewood-shadscale lands showed available water in fall samplings. Pickleweed and red samphire are similar to saltgrass.

The first foot is relatively free of salt in little rabbitbrush, galleta, shadscale, sagebrush, and winterfat areas, moderately saline in greasewood and greasewood-shadscale areas, and excessively saline in saltgrass and pickleweed areas.

In the second foot the least salt is shown in rabbitbrush, followed in turn by winterfat, galleta, sagebrush, and shadscale, none of which show harmful amounts. Pickleweed, greasewood-shadscale, greasewood, and saltgrass show saline soils. Shadscale shows a high salt content below the second foot, and salt often occurs in the third and deeper feet in winterfat and under the poorer stands of sagebrush. Galleta and little rabbitbrush on lighter soils show no appreciable amounts of salt in the first 4 feet of soil.

In Escalante Valley, lands covered with a large bushy growth of sagebrush or sagebrush-greasewood indicate two of the best types for crop production under irrigation. Little rabbitbrush, galleta, winterfat, and shadscale land can become productive under irrigation. The first-mentioned may need special handling because of its light texture. Lands with a very poor growth of sagebrush or shadscale are less desirable because of a gravelly or a saline subsoil. With these, leaching and draining may be necessary, as well as irrigation, as is the case with greasewood or greasewood-shadscale lands. Saltgrass already subirrigated is valuable for grazing. Both saltgrass and pickleweed lands are wet and saline and need draining and leaching before crops can be produced. The expense would usually be prohibitive. In this valley most of the juniper land is too stony and rough for crop production. Most of the irrigated land lying near the mountains was formerly covered with sagebrush.

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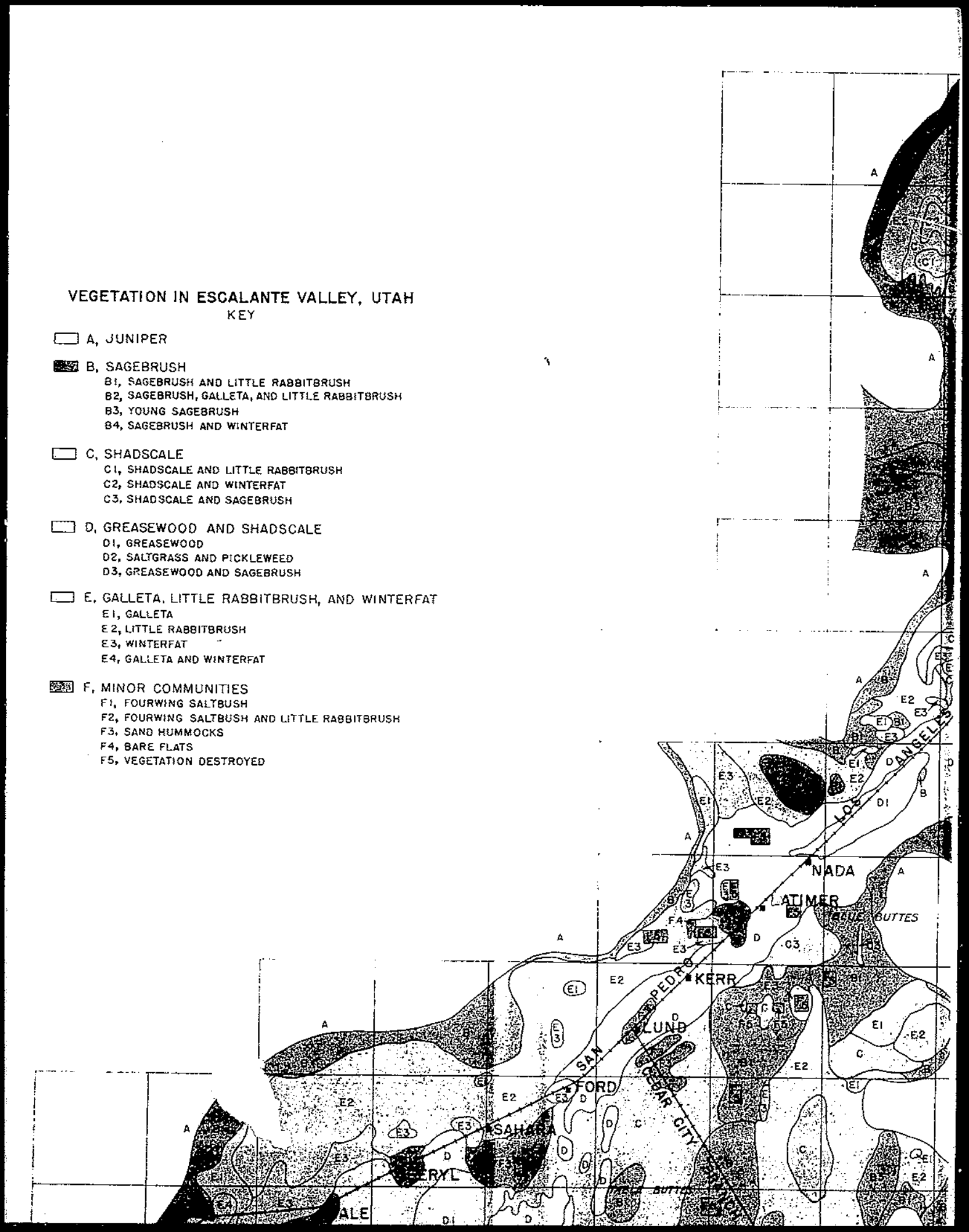
VEGETATION IN ESCALANTE VALLEY, UTAH
KEY
A, JUNIPER
B, SAGEBRUSH
B1, SAGEBRUSH AND LITTLE RABBITBRUSH
B2, SAGEBRUSH, GALLETA, AND LITTLE RABBITBRUSH
B3, YOUNG SAGEBRUSH
B4, SAGEBRUSH AND WINTERFAT
C, SHADSCALE
C1, SHADSCALE AND LITTLE RABBITBRUSH
C2, SHADSCALE AND WINTERFAT
C3, SHADSCALE AND SAGEBRUSH
D, GREASEWOOD AND SHADSCALE
D1, GREASEWOOD
D2, SALTGRASS AND PICKLEWEED
D3, GREASEWOOD AND SAGEBRUSH
E, GALLETA, LITTLE RABBITBRUSH, AND WINTERFAT
E1, GALLETA
E2, LITTLE RABBITBRUSH
E3, WINTERFAT
E4, GALLETA AND WINTERFAT
F, MINOR COMMUNITIES
F1, FOURWING SALTBUSH
F2, FOURWING SALTBUSH AND LITTLE RABBITBRUSH
F3, SAND HUMMOCKS
F4, BARE FLATS
F5, VEGETATION DESTROYED
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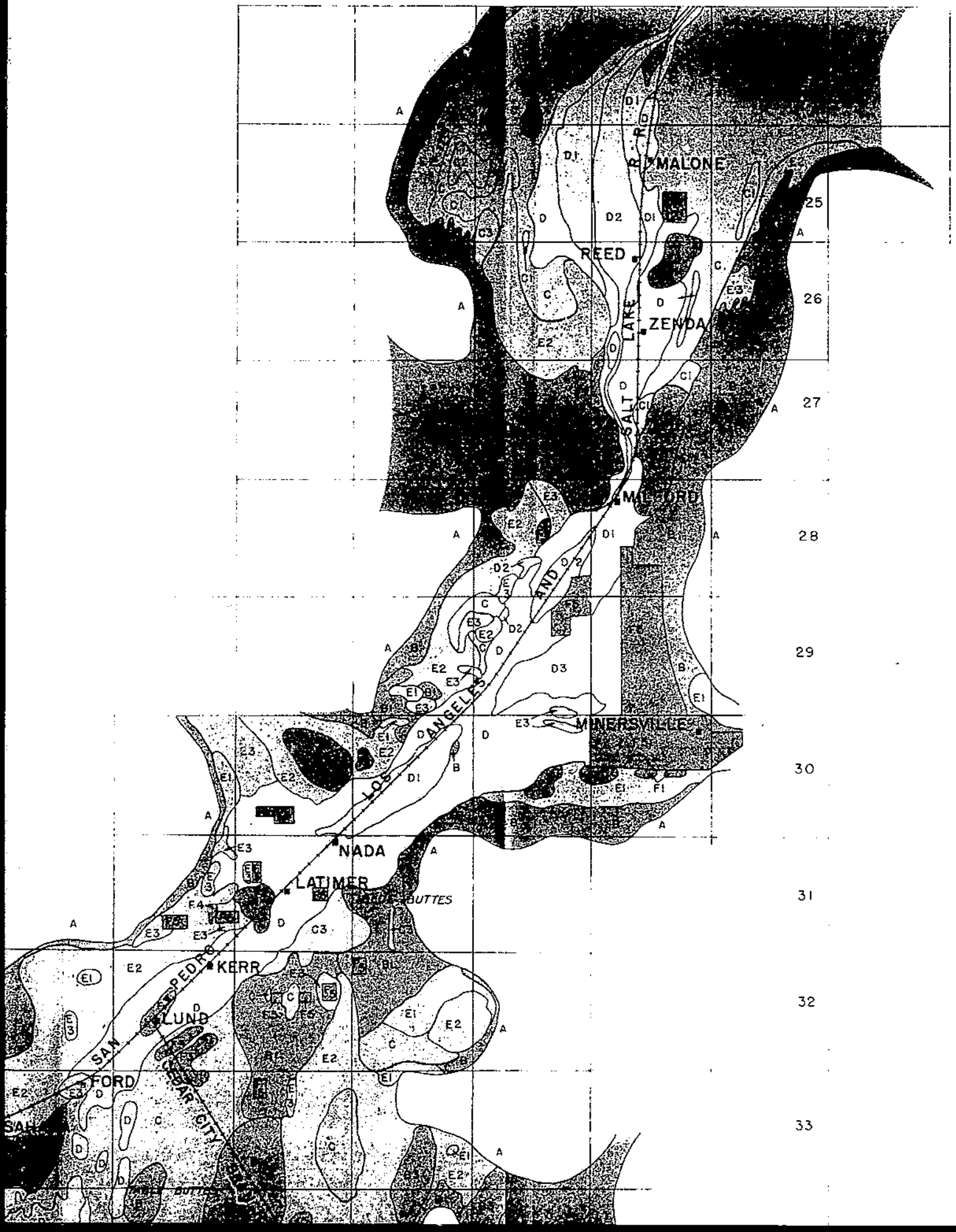
BLUE BUTTES
KERR
LUND
SAN PEDRO
FORD
CEDAR CITY
SAHARA
BLUE BUTTES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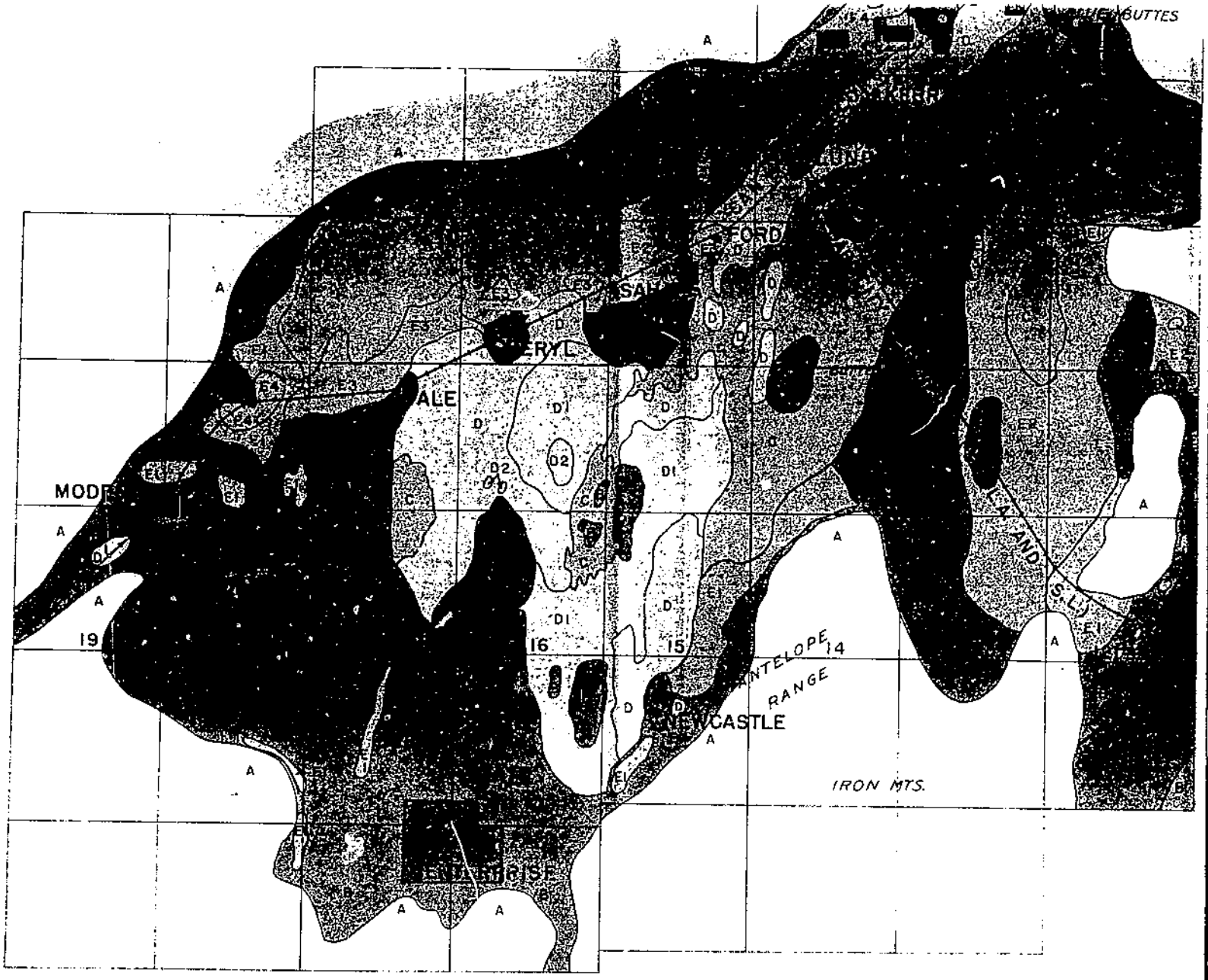
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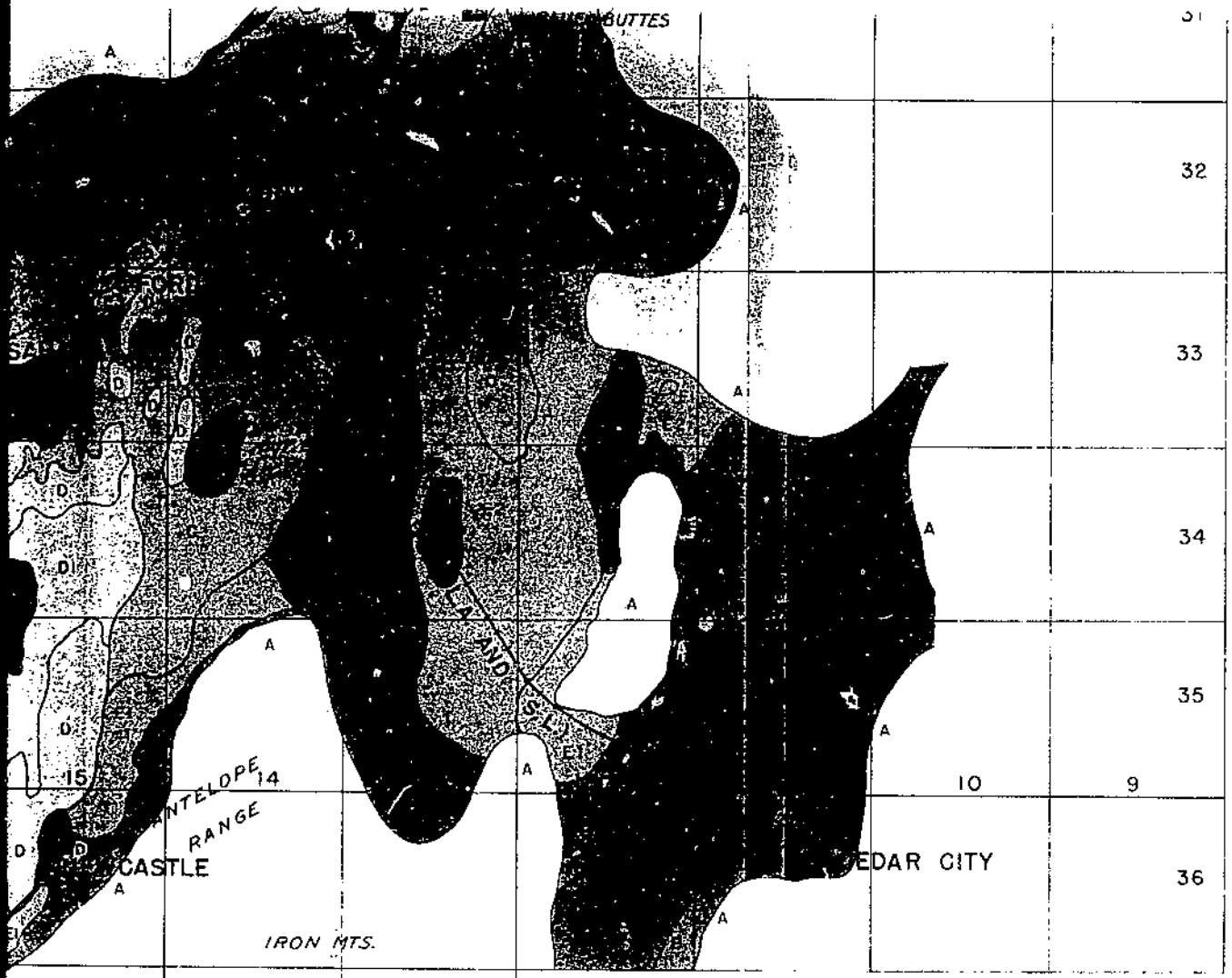
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