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The plant associations of the Carson Desert Region, western Nevada

W. Dwight Billings

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During the years of the journal's publication, the Butler University Botany Department had an active program of research and student training. 201 bachelor's degrees and 75 master's degrees in Botany were conferred during this period. Thirty-five of these graduates went on to earn doctorates at other institutions.

The Botany Department attracted many notable faculty members and students. Distinguished faculty, in addition to Cain and Friesner , included John E. Potzger, a forest ecologist and palynologist, Willard Nelson Clute, co-founder of the American Fern Society, Marion T. Hall, former director of the Morton Arboretum, C. Mervin Palmer, Rex Webster, and John Pelton. Some of the former undergraduate and master's students who made active contributions to the fields of botany and ecology include Dwight. W. Billings, Fay Kenoyer Daily, William A. Daily, Rexford Daudenmire, Francis Hueber, Frank McCormick, Scott McCoy, Robert Petty, Potzger, Helene Starcs, and Theodore Sperry. Cain, Daubenmire, Potzger, and Billings served as Presidents of the Ecological Society of America.

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THE PLANT ASSOCIATIONS OF THE CARSON DESERT REGION, WESTERN NEVADA*

By W. D. BILLINGS
University of Nevada

Except for scattered references of a generalized nature, little is recorded concerning the structure of vegetation in the arid and semi-arid portions of the western Great Basin. The delineation of the associations[1] of a part of this area and their particular environments is the prime funtion of this paper.

The name "Carson Desert" has long been applied to the region surrounding the Carson Sink and the lower Carson River in western Nevada. For the purposes of this investigation, the term "Carson Desert Region" will include not only the Carson Desert but also the deserts surrounding the lower reaches of the Truckee River, Pyramid Lake, the Walker River, and Walker Lake. Tbe resulting area is elongated in a northwest-southeast direction with its central axis parallel to and about 75 miles northeast of the summit ridge of the Sierra Nevada. About 5,000 square miles of territory are involved. The dry slopes and benches of the region are mainly used as winter range for livestock although, in most places, the grazing is very light or even absent. Agricultural land, irrigated and reclaimed, occupies a substantial acreage on the deep soils of the valley floors, particularly in the Fallon region south of Carson Sink.

GEOLOGY

The region is entirely within the Great Basin and, therefore, one of interior drainage. The topography is fairly typical of the Basin-and-Range Province with fault block mountain ranges more or less paralleling the meridians and separated by rift valleys or grabens. The floors of the valleys lie at elevations approximating 4,000 feet

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[1] The association as used here is that of the Zurich-Montpellier school as recommended by the Sixth International Botanical Congress, 1935. The association is considered to be made up of one or more unions. (See Lippmaa, 1939.)

above sea-level while the crests of the ranges average about 8,000 feet in elevation. By far the greater part of the Carson Desert region lies below 5,000 feet and, in this article, only that vegetation lying below 6,000 feet will be considered.

Most of the region was covered during the pluvial and glacial periods of the Pleistocene by the southern part of Lake Lahontan. Russell (1885) gives 4,378 feet above sea-level as the average elevation of the highest shoreline of this lake. Lake-laid sediments now cover almost all of the Carson Desert region below this elevation. They consist primarily of interbedded gravels, clays, and sands whose depth ranges from a few inches near the upper limits of the lake to well over a hundred feet in many places. Two types of post-Lahontan accumulations overlie the old lake sediments in a number of places. The first of these consists of aeolian sands of a light color and, therefore, clearly of extraneous origin in this region of dark volcanic rocks. Many of these dunes are active but the great majority are flat and quiescent and covered with a distinctive vegetation. Mud flats or playas constitute the second kind of post-Lahontan sediment. The lower parts of those rift basins not occupied at present by permanent lakes are filled during winters and wet years with shallow temporary lakes. Silts, clays, and salts carried into these playa-lakes are left behind upon the evaporation of the water during the summer months. Because of salinity and periodic drowning, most of the playas are completely devoid of vegetation except around the edges. They are known locally as "alkali flats."

The mountains and hills consist principally of basalts, andesites, and other basic lavas. They are covered by a thin, often broken, mantle of residual gray desert soils. Extending from the lower slopes are numerous alluvial fans and bajadas.

CLIMATE

Lying in the rain-shadow of the Sierra Nevada, the climate of the valley floors and the lower hills is distinctly arid. The higher slopes are semi-arid. Only in scattered places at the highest elevations does the climate approach humid types in the ranges immediately contiguous to the desert. Thornthwaite (1941) reports precipitation-effectiveness indices of below 16 for most of the Carson Desert region. According to his maps, this desert area lies in a narrow arm of aridity extending up the eastern side of the Sierra Nevada from the more extensive arid regions of southern Nevada, southeastern California, and western Arizona.

The mean annual precipitation at the following stations is probably typical of the greater part of the area: Fallon, 4.98 inches; Fernley, 5.29 inches; Lahontan, 4.54 inches; and Schurz, 5.68 inches. The precipitation shows a distinct winter maximum such as might be expected in a region lying fairly close to a west coast in the middle latitudes.

The climate is neither excessively hot in summer nor extremely cold in winter. Fallon shows an average January temperature of 29.8° F. while the July average is 73.1° F.. At Yerington, the averages for the same months respectively are 30.3° F. and 70.5° F.. Because of the aridity and altitude, there is a broad range between night minima and day maxima.

LITERATURE

The first botanical observations in the Carson Desert region were made by Frémont (1845) during January, 1844. He describes sagebrush vegetation, the cottonwoods along the rivers, and the greasewood on the alkali flats. He failed to note, however, the several distinct types of true desert vegetation through which he passed in crossing from the Truckee to the Carson River over the fairly level country of what is now known as Swingle Bench. He merely mentions this stretch as being covered "with small sage bushes."

Of the publications of the several taxonomists who collected in the region during the latter part of the nineteenth century, the report of Sereno Watson (1871) of his botanical explorations during 1868 contains the best vegetational descriptions. His generalized descriptions are quite accurate. Watson did not, however, clearly distinguish the communities lying in the true desert between the sagebrush on the higher elevations and the greasewood of the playas.

In more modern times, the vegetational types of the Bonneville Basin in Utah have been delineated by Kearney and his co-workers (1914) and by Flowers (1934). The communities which they describe as occurring on the more saline soils are quite like those on similar soils in the Carson Desert region. However, the upland desert communities, both successional and climax, which cover the greater part of the Carson Desert are distinctly different from those in the Bonneville region. A number of papers have been written on the vegetation of the warmer deserts in Arizona and southeastern

California. Notable among these are the works of MacDougal (1908), Shantz and Piemeisel (1924), Parish (1930), Shreve (1936, 1942), and Nichol (1937). In some respects, a close relationship seems to exist between the vegetation of the southern deserts and the upland communities of the Carson Desert.

Clements (1920) considers all of the shrubby vegetation of the drier parts of the Great Basin as belonging to what he calls the Atriplex-Artemisia association. Under this, he has established a great number of consociations based upon the apparent dominance of one shrubby species here and another there. The result is an extremely heterogeneous grouping of communities into a large and vague category whose structural bonds are open to question. The existence of numerous areas where a single species holds complete dominance can certainly be substantiated. However, most areas are populated by communities characterized by two or more co-dominants. In addition, the almost total lack of quantitative data fails to measure the degree of dominance or to bring out the true relationships hetween the consociations

Shantz (1924, 1925) has, perhaps, the most adequate descriptions to date of desert vegetation in the western Great Basin. He divides the vegetation in this region into two main types: sagebrush (northern desert scrub) and greasewood (salt desert scrub). Each of these he subdivides into three main associations under which are grouped a number of minor communities somewhat analagous to the consociations of Clements. Although descriptive only, the physiographic and edaphic array of the communities, as included, is rather clearly portrayed.

METHODS

Numerous reconnaissance trips were made into the Carson Desert region during 1939 and 1940 in order to become familiar with the vegetation and to set up an objective delineation of the communities. Fifteen distinct associations were established. Four of these, the little greasewood-shadscale type, the dalea type, the big greasewood type, and the big greasewood-shadscale type constitute by far the greater part of the natural vegetation of the region. These particular associations, therefore, were selected for quantitative study.

In 1941, ten stations were chosen for analysis in the little greasewood-shadscale association, ten in the Daleetum, three in the big greasewood association, and two in the big greasewood-shadscale type. The stations were well scattered throughout the region. Presence lists of all shrubby and herbaceous species[2] at each station were compiled for both 1941 and 1942. The shrubby stratum was analyzed by quadrats at five stations in the little greasewood-shadscale type, at seven stations in the Daleetum, and at all stations in the big greasewood and big greasewood-shadscale associations. In the cases of the first two associations, 25 quadrats of 9 square meters each were laid out in the form of a latin square at each station with the exception of three stations in the dalea community where quadrats of 4 square meters each were used. In all cases, the interval between quadrats was 20 meters. The number and size of quadrats used in sampling the latter two communities varied from 25 quadrats of 4 square meters each to 10 quadrats of 100 square meters each, depending on the density of the stand. The herbaceous vegetation at all stations in the little greasewood-shadscale and dalea associations was sampled by 25 random throws of a 1/5 meter hoop at each station during the growing season of 1941. The data from the shrubby quadrats were analyzed for frequency, density (number of individuals per square meter). percentage of coverage of total area, and pereentage of total shrubby cover. Density per square meter and frequency were determined for the herbaceous species from the data of the 1/5 meter quadrats. Since the densities of desert herbaceous species react sharply to differences in precipitation from year to year, it is realized that such data for just one year provide a mere starting point for quantitative work. The presence lists, however, developed over a longer period, provide a trustworthy record of the floristic composition of the herbaceous unions.

Soil trenches were dug in several stations of each of the four major associations and in several of the other types. Notes were made of the profiles and samples taken at certain depths. The samples from certain representative profiles were analyzed mechanically by a modification of the Buoyoucos (1928) method. Colorimetric indicators were used to determine soil pH.

The relative amounts of soluble salts in the soils of the several associations is expressed as $K \times 10^5$ of a soil solution determined by conductance by the following method. The exact air-dry equivalent

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[2] The nomenclature is an attempt at the latest available synonymy. Authorities are given for all species in presence tables. For those not so listed, authorities are given at the first mention of the name in the text.

of 50 grams of oven-dry soil is weighed out and mixed with 250 ml. of distilled water in a tightly stoppered flask. The mixture is shaken periodically for 5 days and then filtered through a Pasteur-Chamberlain filter. The conductance of the filtrate is determined with a conductivity bridge equipped with a cathode ray tube null indicator. A dip cell with a constant of about 1.0 should be used and the filtrate brought to a constant temperature of about 20° C. in a water bath. The conductance of the filtrate is expressed as $K \times 10^5$ where $K = \frac{\text{cell constant}}{\text{resistance}}$. If the value $K \times 10^5$ is multiplied by a suitable factor, the parts per million of soluble material in the filtrate may be approximated and thence the percentage of such material in the soil. Further experimental work, however, is needed on such a factor before such absolute results are trustworthy.

ASSOCIATIONS

1. Little greasewood-shadscale association (*Sarcobatetum Baileyi*)

This association covers more territory within the Carson Desert region than any other community. It is clearly the matrix of the vegetation in this arid portion of the Great Basin where the precipitation is too low for the development of the sagebrush association. The floristic structure of the little greasewood-shadscale association is brought out in tables I, II, and III. Soil characteristics at three selected locations in the type are listed in table IX. Figure 1 presents the typical appearance of the community.

The little greasewood-shadscale association consists of three unions. The frutescent union is designated the *Sarcobatus Baileyi-Atriplex confertifolia* union. The Oryzopsis-Sphaeralcea union is perennial herbaceous and the Cryptantha-Coldenia-Gilia union is annual.

The characteristic species of the dominant union are *Sarcobatus Baileyi, Atriplex confertifolia,* and *Artemisia spinescens.* All are low, spiny, microphyll shrubs. These make up the bulk of the shrubby stratum. *Eurotia lanata* and *Lycium Cooperi* are often present but of low density and coverage. The perennial herbaceous union is typified by *Oryzopsis hymenoides, Sphaeralcea ambigua* subsp. *monticola,* and *Hermidium alipes.* At some stations, this union is fragmentary or even absent. It is seldom well developed in this particular association. The annual union is also poorly developed here. Of

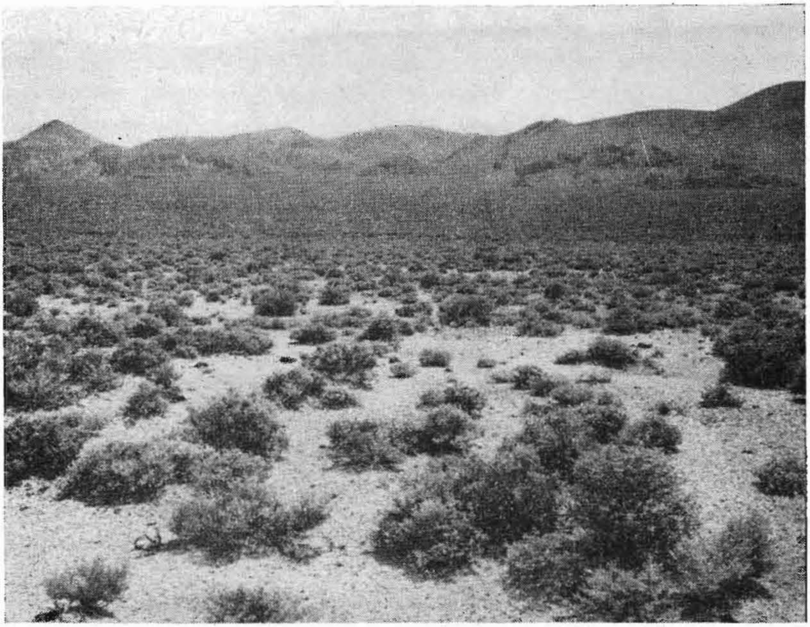

Figure 1. Little Greasewood-Shadscale association on Lahontan sediments at Station 3, 15½ miles south of Fallon, Nevada. Principal dominants are *Sarcobatus Baileyi, Atriplex confertifolia*, and *Artemisia spinescens*. Note the erosion pavement and almost total absence of herbs.

the principal species, *Cryptantha circumscissa, Coldenia Nuttallii,* and *Gilia leptomeria*, only the first is common in the Sarcobatetum Baileyi. *Eriogonum vimineum* and *Glyptopleura marginata* are often present in this association but are of lesser importance than certain other species in the union as a whole. The growth of the herbs, especially that of the annuals, is restricted to the late spring months when the soil still retains the moisture added by the winter precipitation.

The little greasewood-shadscale association occupies well-drained soils developed from the Lahontan sediments and also the residual volcanic soils of the hills, especially those in the drier southern part of the region. The soils are usually sandy loams or silt loams with marked amounts of gravel scattered through the profile. The surface of the soil is always more or less covered with a desert erosional pavement of gravel or rock left as the result of wind erosion. In places, this pavement may be poorly developed, but often it almost completely covers the soil. The soils of this type developed from Lahontan sediments are distinctly alkaline in reaction, approaching pH 9 in most cases. The residual soils of the hills are somewhat less alkaline. The upper 5 or 6 decimeters of the Lahontan sediment soils are low in soluble salts but there seem to be mild accumulations below this depth. The residual soils occupied by this association are shallow and relatively free of salts.

Over most of its area, this association presents an aspect of monotonous regularity characterized by rather evenly spaced, low, spiny shrubs separated from each other by barren soil covered with the rocks of its erosion pavement. At the five stations quantitatively analyzed, the total shrubby coverage ranged from only 5 to 12 per cent of the ground. In contrast to the even distribution of individuals over most of its area, there is a pronounced tendency, in some places on residual soils in the southern part of the region, for the shrubs of this association to become aggregated along small erosion channels. The prominent ribbons of shrubs are separated by miniature divides 10 to 15 feet wide and covered with an almost continuous erosion pavement.

The little greasewood-shadscale association is closely related to the shadscale community described by Shantz (1924). The principal difference seems to be that the association as described here is dominated by little greasewood (*Sarcobatus Baileyi*), a species which Shantz does not mention as a member of the community. At every one of the five stations where quadrat data were gathered, *Sarcobatus Baileyi* is clearly dominant, constituting over 50 per cent of the total shrubby cover in each case. The percentages of total shrubby cover shown by *Atriplex confertifolia* are in most cases close to 20 per cent.

This association appears to be the climatic climax of the region. Wherever the annual precipitation in this microthermal region falls below about 7 inches and there is no other source of water, the sagebrush association gives way to the little greasewood-shadscale association on normal mature soils. The shadscale association of Shantz is undoubtedly the counterpart of the Sarcobatetum Baileyi in similar regions to the east and north of the range of *Sarcobatus Baileyi.*

2. Winter-fat association
(*Eurotietum lanatae*)

In several places in the northern part of the Carson Desert region, especially north and east of Pyramid Lake, there are pure stands of winter-fat, *Eurotia lanata.* The environment of this association is similar to that of the little greasewood-shadscale type. Shantz (1925) states that Eurotia often becomes dominant where shadscale has been killed. It may be successional to the Sarcobatetum Baileyi or it may represent certain edaphic conditions slightly different from those characterizing that association. The winter-fat association probably provides the best winter range in the region but is far less abundant than the little greasewood-shadscale association.

3. Dalea association
(*Daleetum polyadeniae*)

The dalea association is one of the most interesting communities in the region. It is limited to areas of stabilized dune sands which are rather extensive, particularly in the region between the bend of the Truckee River at Wadsworth and Leeteville on the Carson River. The Daleetum is also abundant on the dunes in the valleys of the

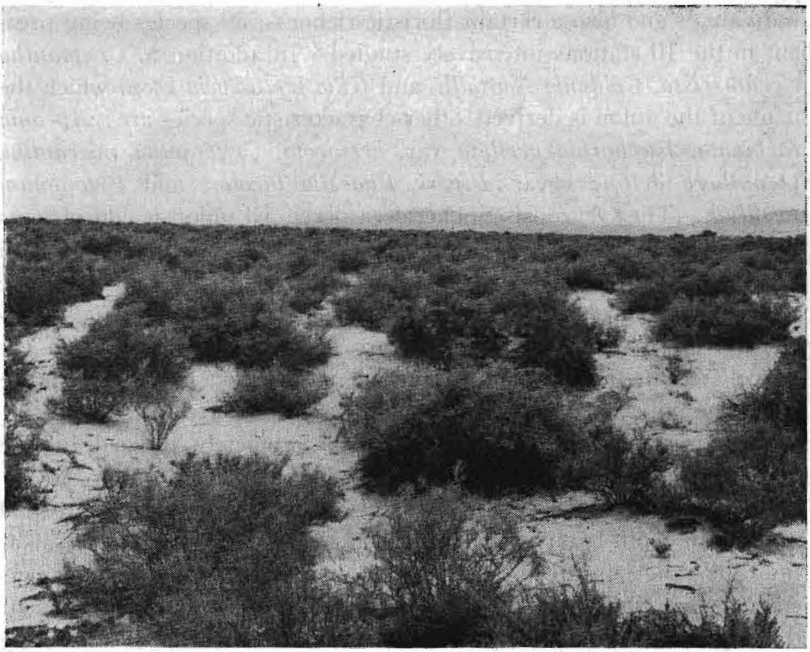

Figure 2. Dalea association on aeolian sand at Station 1, just west of Leeteville, Nevada. *Dalea polyadenia, Atriplex canescens,* and *Tetradymia comosa* are prominent.

eastern part of the Desert Mountains from the hills north of Schurz to Sand Springs at the east end of Eight-mile Flat. The floristic composition of this association is exhibited in tables IV, V, and VI. Table IX lists the soil characteristics at three typical stations. Figure 2 shows the general appearance of the Daleetum.

The dalea association could be considered as a twin association (Katz, 1929) to the Sarcobatetum Baileyi, since the same herbaceous unions are present in both. The frutescent stratum in the Daleetum is occupied by the *Dalea polyadenia-Atriplex canescens* union. The characteristic species of this union are *Dalea polyadenia, Atriplex canescens, Tetradymia comosa,* and *Tetradymia glabrata.* All of these are intricately branched, non-spiny, microphyll shrubs of medium height. *Sarcobatus Baileyi* and other shrubby species of the little greasewood-shadscale association are often present as survivors of a sand-drowned Sarcobatetum Baileyi. The two herbaceous unions are very well developed in the Daleetum. This is especially true of the annual union which exhibits here a relatively high density of individuals and also a certain floristic richness, 39 species being present in the 10 stations intensively studied. In addition to *Cryptantha circumscissa, Coldenia Nuttallii,* and *Gilia leptomeria* from which the name of the union is derived, other characteristic species are: *Abronia turbinata, Euphorbia ocellata* var. *arenicola, Cryptantha micrantha, Oenothera deltoides* var. *Piperi, Phacelia bicolor,* and *Eriogonum pusillum.* The Oryzopsis-Sphaeralcea perennial union is conspicuous here but is not much different floristically from its composition in the little greasewood-shadscale association. One difference is the frequent presence of *Pentstemon acuminatus* in the dalea type. *Hermidium alipes* seems to be more rare in the Daleetum than in the Sarcobatetum. The annual vegetation is conspicuous in late spring when the upper few decimeters of the sandy soil are moist from the winter precipitation. This moisture is completely utilized by the middle of June when the annuals are in fruit.

The soil of the Daleetum is a light-colored, siliceous, aeolian sand ranging in depth from 5 to over 20 feet. The pH is only slightly alkaline, the range usually being from about pH 7 to pH 8. The percentages of soluble salts are lower than in any of the other soils of the region. The whole profile is remarkably uniform, consisting almost entirely of pure sand.

Most of these dunes are broad, flat, and stable and at first glance do not appear to be dunes. Some of them are several square miles in extent. The dune sands cover the Lahontan sediments of gravels and clays and are, therefore, superimposed upon the substratum that normally supports the little greasewood-shadscale association. There are numerous places where this occupation has taken place rather recently. In these places, *Sarcobatus Baileyi* and *Lycium Cooperi* have acted as dune-formers. As the sand builds up, these two species are able to keep pace for some time and are, consequently, likely to remain as relicts in the Daleetum. The first shrub of the dalea association to invade is *Dalea polyadenia* itself. As the sand grows deeper other shrubby species appear. *Tetradymia comosa* seems to require the deepest sand of all, not appearing until the depth reaches 10 to 20 feet. Blowouts do occur, resulting in a resumption of active sand movement. Some of the dunes have extended out into the playas, bringing the dalea association into contact with the big greasewood association. In some places, also, the sand has been carried far up the mountains on the eastern sides of the valleys so that the Daleetum under such conditions occurs some distance above the highest Lahontan shore-line.

The ground cover of the shrubby stratum is somewhat greater in the Daleetum than in the little greasewood-shadscale type, ranging from 8 to 28 per cent at the seven stations where quadrat data were gathered. *Dalea polyadenia* is dominant but not predominant, making up on the average about 30 to 35 per cent of the shrubby cover. At all locations, *Atriplex canescens* showed lesser coverage than the Dalea in the same stand. *Tetradymia comosa* occasionally shares dominance with Dalea in the deeper sands.

The sandy soil and the relatively dense herbaceous vegetation of this association provide the environment for an abundant rodent population. Evidences of rodent activity are certainly less in the little greasewood-shadscale association even when immediately adjoining the Daleetum. Hall (1941) has found, that in almost all cases, the pallid kangaroo mouse (*Microdipodops pallidus*) is restricted to fine sands occupied by *Dalea polyadenia, Atriplex canescens,* and their associates. On the other hand, the dark kangaroo mouse (*M. megacephalus*) seems almost confined to the coarser soils containing gravel usually occupied by a different type of shrubby community.

The dalea association seems to exhibit relationship with certain of the associations of the warmer deserts of Arizona and southeastern California. One of the dominants, *Atriplex canescens*, is common on the sandy soils of the Southwest. Many of the herbaceous species also range to the southern deserts. Floristically, this community could have evolved from Mohavian sources with the disappearance of Lake Lahontan.

4. Big greasewood association
(*Sarcobatetum vermiculati*)

The big greasewood association is the most extensive of the truly halophytic communities within the region. It occupies the saline clay soils around the margins of the playas where the subsoil is always moist and only the surface crust dries in late summer. The structure of the shrubby stratum at three stations is shown in table VII while the soil characteristics at two of these locations are listed in table IX. Figure 3 presents the typical field appearance.

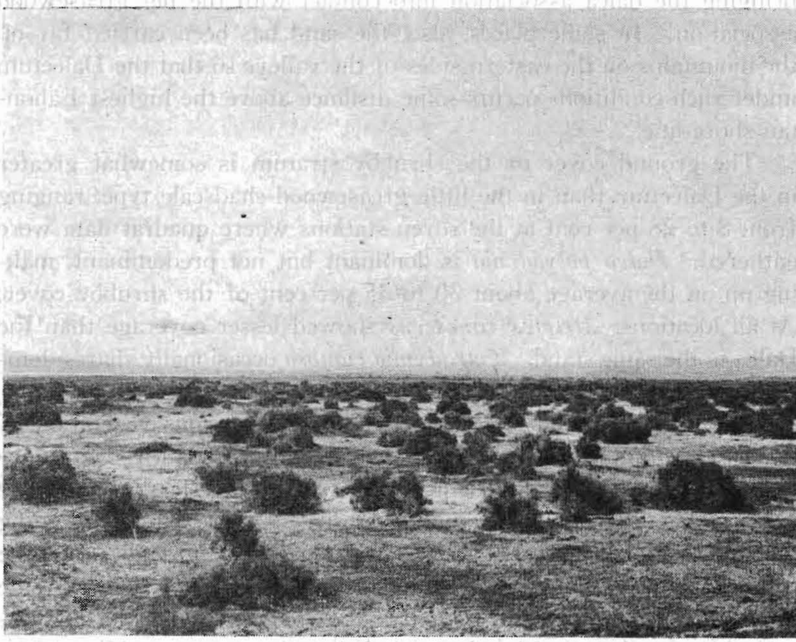

Figure 3. Big Greasewood association on wet saline clay at edge of Hot Springs playa. Station 3, 8½ miles northeast of Fernley, Nevada.

The big greasewood association is very poor in species. The dominant union is the *Sarcobatus vermiculatus* union which consists of only two species: *Sarcobatus vermiculatus* and *Atriplex lentiformis* subsp. *Torreyi*. In many cases, the latter species is absent and only big greasewood is present in pure stand. The sparse herbaceous flora usually consists of scattered clumps of seepweed, mainly *Dondia nigra*, and poorly developed patches of desert saltgrass, *Distichlis stricta* (Torr.) Rydb. Exotic chenopodiaceous herbs, notably *Salsola kali* var. *tenuifolia* and *Echinopsilon hyssopifolius* (Pall.) Moq. (*Bassia hyssopifolia* Kuntze), often invade this community after disturbance. At Station 1 in this type, patches of moss were present around the bases of the greasewood, being especially well developed where the greasewood had died.

The soil of this association is made up primarily of the finer fractions and varies in most cases from silt loams to clays. The surface soils are usually loamy and friable when dry, while the subsoils starting at a depth of about 3 decimeters tend to be heavy, prismatically jointed clay. In places, this situation may be reversed, the surface soil being a clay and the subsoil loamy. This raises the question as to whether the soils of the big greasewood association and the adjoining bare playas show true horizons or merely geological strata. Certainly, new material is constantly being washed or blown into the playas from the surrounding hills and ancient lake sediments. The soils seem to be solontchak with rather bigh alkalinity throughout the profile, ranging from pH 8.5 to about pH 9.5. The soils contain rather high quantities of soluble salts, the percentage increasing from the lower part of the profile to the upper. This is the result of evaporation of the soil water at the top of the profile which usually produces a whitish crust of salts over the soil surface by late summer.

The ground coverage of the shrubs in the big greasewood type is quite variable, depending evidently upon the salinity and alkalinity of the soil. The coverage varied from about 4 per cent to 24 per cent at the stations studied. *Atriplex lentiformis* subsp. *Torreyi* is more intolerant of increasing salt content of the soil than is the greasewood. The saltbush is completely absent from stands where the soil salinity is too high and drops out before greasewood as one approaches a barren playa through this association. Lowrance (1939) at Station 2 found myrmicine ants, possibly Pogonomyrmex, burying seeds of the Atriplex under the friable surface crust at a depth of from 5 to 10 centimeters. Since the soil at this depth is more moist and less saline than the surface soil, the establishment of this species of Atriplex in the presence of a salt crust may be dependent to some extent upon the ant.

In an attempt to find the limit of tolerance of *Sarcobatus vermicu-*

latus to salinity and alkalinity, samples were taken from the bare playa of Eight-mile Flat about 40 meters beyond the edge of a stand of big greasewood. The pH of this soil was 9.6 throughout the profile. The salinity of the surface soil was over 5 times that of the surface crust within a normal stand of the big greasewood type, while the subsoil contained over twice as much salt as is usually the case in the subsoil of a normal stand.

The rising and falling of the playa-lakes over the years has a profound effect on this association. There are places in the Hot Springs Flat, northeast of Fernley, now covered with water, which once supported a big greasewood community. This is evidenced by the numerous dead greasewood bushes far out in the shallow lake. Conversely, in a greasewood stand about 14 miles south of Fallon, there are numerous remains of Typha rhizomes still embedded in the soil. This latter case is probably due to the draining of the surrounding land for agricultural purposes.

5. Big greasewood-shadscale association
(*Atriplico-Sarcobatetum*)

This luxuriant association results from the simultaneous occurence of the *Sarcobatus vermiculatus* union with the *Sarcobatus Baileyi-Atriplex confertifolia* union. The composition of the two shrubby layers as analyzed at two stations is presented in table VIII. Soil characteristics at Station 1 are listed in table IX.

The big greasewood-shadscale association occurs between the playa communities and the upland associations where soil conditions are just right for its development. The community is particularly well developed around the smaller, drier playas of the higher elevations. It is not too common. It may be that some stands of this type have been destroyed in the establishment of agricultural land in the Fallon area. Both stands utilized in the present study are in the far northwestern corner of the region. Although many more analyses are necessary, the soil seems to be a solonetz with the upper 2 or 3 decimeters loamy, low in salts, and with the pH slightly above 7. At about 3 decimeters, there is a sudden transition to a heavy, alkaline (pH 9) clay with a slightly higher salt content. This zonation could be caused by the washing out of the salts in the upper part of the soil by an unusual height of the playa-lake at some time in the past. On the other hand, the upper layer of soil could represent outwash material from the hills such as might be deposited in a bajada. This geological explanation for solonetz has been proposed by Schert (1935) in Hungary as cited by Jenny (1941).

In each of the two stands studied, the total shrubby cover was almost exactly 30 per cent of the area of the stand. The union represented by *Sarcobatus vermiculatus* and *Atriplex lentiformis* subsp. *Torreyi* is clearly dominant, making up from 70 to 80 per cent of the total shrubby cover. The low shrub stratum is occupied principally by *Atriplex confertifolia* and *Artemisia spinescens* of the *Sarcobatus Baileyi-Atriplex confertifolia* union. *Sarcobatus Baileyi* is rare or absent in this association. *Tetradymia spinosa, Grayia spinosa, Eurotia lanata,* and *Kochia americana* S. Wats. and its variety *vestita* S. Wats. are also present. No intensive survey was made of the herbaceous vegetation of this association. *Dondia nigra* seems to occur in the wetter spots, while most of the herbs appear to be concentrated under the shrubs. *Thelypodium sagittatum* (Nutt.) Endl. is, perhaps, the most prominent in this latter habitat.

6. Rabbitbrush association
(*Chrysothamnetum nauseosi*)

The principal dominants of this association are two kinds of rabbitbrush, *Chrysothamnus nauseosus* var. *consimilis* (Greene) H. M. Hall and *C. nauseosus* var. *hololeucus* (Greene) H. M. Hall. The community is not common in the region and seems to be successional in nature. It has been observed occupying drained or disturbed land. The two principal varieties are present on the recently exposed gravel beaches at Pyramid Lake where they are associated with *Distichlis stricta, Echinopsilon hyssopifolius, Salsola kali* var. *tenuifolia, Heliotropium curassavicum* var. *oculatum* (Heller) Johnston, and other species of a more or less transitory nature in succession.

7. Iodinebush association
(*Allenrolfeetum occidentalis*)

This association is usually represented only by scattered plants of the iodinebush, *Allenrolfea occidentalis* (S. Wats.) Kuntze. Occasionally, saltgrass, *Distichlis stricta,* forms an herbaceous synusia between the bushes. At one station where 25 quadrats of 9 square meters each were laid out, iodinebush showed a total coverage of about 6 per cent of the area with a density of 0.7 plants per square meter.

The usual location for the iodinebush association is on a terrace adjacent to and from 5 to 10 feet below a big greasewood community. These terraces appear to be the result of wave erosion of the sediments under big greasewood when the playa-lake is at an unusually high level. The surface soil in the Allenrolfeetum, unlike that in the Sarcobatetum, usually stays wet all summer. A small soil well in a stand of this type revealed a friable crust to about 5 centimeters, followed by a wet clay which in turn was underlain at about 20 centimeters by a heavy, wet subsoil of prismatic clay. Analysis of the surface soil showed a pH of 8.8 and a soluble salt content 3½ times greater than that of any big greasewood surface soil tested.

8. Samphire association
(*Salicornietum rubrae*)

Soils which are strongly saline and wetter than those under iodinebush provide the environment for an annual community dominated by *Salicornia rubra* A. Nels. The Salicornietum usually forms a prominent zone along the edges of small channels of water running into a playa. These streams are outlined in the autumn by the samphire's brilliant red. The individuals are usually very close together and, therefore, rather small. A series of 10 quadrats, each enclosing 1 square decimeter, evenly spaced throughout a stand of samphire revealed that the stocking was at the astounding rate of 13,570 plants per square meter at maturity.

9. Alkali-grass association
(*Puccinellietum fasciculatae*)

The alkali-grass association is characteristic of highly saline soils which are shallowly covered during most of the growing season by small ponds of still water. Sometimes, it occurs as a zone in the shallower channels just inside the Salicornietum. The typical situation shows tussocks of *Puccinellia fasciculata* (Torr.) Bicknell scattered rather openly and evenly through a small, shallow, saline pond.

10. Saltgrass association
(*Distichletum strictae*)

The dominant plant of this association, *Distichlis stricta,* apparently is able to tolerate a wide range of conditions. As a result, this community may be found on almost any saline soil except the very driest. Extensive stands occur in the shallow water around the edges of some of the more permanent playa-lakes. It may also occur along the more shallow flowing channels. From these locations, the long rhizomes spread out in all directions and establish the plant on the relatively dry saline soil of the banks. At Pyramid Lake, saltgrass is abundant as an invader of the recently exposed beach sands and gravels. In big greasewood stands adjacent to bare playas, saltgrass may be present as an herbaceous synusia. The *Distichlis stricta* union, thus, may exist as a unistratal association or represent the herbaceous layer in a multistratal association. In addition to the dominant species, *Distichlis dentata* Rydb. is sometimes present.

11. Bulrush association
(*Scirpetum*)

Emergent plants belonging to the genus Scirpus constitute almost the whole of the bulrush association. Present in varying degrees of abundance are *Scirpus americanus* Pers., *S. chilensis* Nees. and Mey., *S. paludosus* A. Nels., and *S. acutus* Muhl. At any one location, usually only one of the species is present in pure stand. Further investigations of the growth requirements of the species may reveal more than one association dominated by Scirpus. Some species seem to prefer running water, while others are most common in quiet, brackish water. Strictly speaking, the term "tule" should be applied to plants of this genus only. In western Nevada, however, the term is loosely applied to any narrow-leaved emergent vegetation and in this paper, emergent tule associations will include the Typhetum and Eleocharetum in addition to the Scirpetum.

12. Cat-tail association
(*Typhetum*)

The Typhetum in the Carson Desert region seems to be dominated almost entirely by *Typha angustifolia* L. It occurs principally in deeper water than does the Scirpetum. Like that association, it covers many square miles in the region especially around Carson Sink and in the region of the Stillwater Slough. The abundance of cat-tail in the region has led to investigation of the areas as a possible source of down ("typha") to replace kapok in various uses.

13. Spike-rush association
(*Eleocharetum*)

Spike-rush, mainly *Eleocharis macrostachya* Britton, occasionally forms pure stands in shallow water. It is particularly abundant in old ditches.

14. Cottonwood association (*Populetum Fremontii*)

The cottonwood association is the only arborescent community to enter the Carson Desert region below 6,000 feet. The Populetum forms galeria forests along the lower Truckee, Carson, and Walker Rivers. In places, these groves may be almost a mile in width although usually they are not more than a few hundred feet across. The dominant stratum is occupied by a union consisting entirely of *Populus Fremontii* S. Wats. Two shrubby unions are usually present; a Salix union immediately adjoining the river shore and the *Artemisia tridentata* union over much of the flood-plain. The herbaceous vegetation, because of continuously available fresh water, is relatively luxuriant. It consists of a number of species of perennial grasses and other herbs. Much of this type is now under cultivation or in grazing.

15. Sagebrush association (*Artemisietum tridentatae*)

The sagebrush association is typical of the semi-arid steppe country surrounding the Carson Desert on the west and north and on the higher mountains to the east. The Artemisietum does, however, enter the region concerned in this paper under two circumstances. In its typical form, the sagebrush association replaces the little greasewood-shadscale association above the highest Lahontan beach on the hills in the northwestern part of the region. Here, it is the climatic climax under precipitation in excess of 7 inches per year. The line between the little greasewood-shadscale type on the Lahontan sediments and the sagebrush association on the hills is sometimes quite sharp in that part of the Carson Desert area. In places on the west side of Pyramid Lake where the precipitation is adequate, the Artemisietum may come down on the rather thin Lahontan gravels of the steep slopes of that vicinity. An occasional individual of *Juniperus utahensis* (Engelm.) Lemmon may also appear there with sagebrush. The second type of occurence of this community in the Carson Desert is along the lower flood-plains of the rivers in places either too dry or possibly too saline for *Populus Fremontii.*

Since the sagebrush association is more typical of areas outside the Carson Desert region, a detailed analysis of the community will not be presented in this paper. It will suffice to describe the association in general terms. On the residual soils of the hills where the sagebrush association is the climatic climax, the Artemisietum consists of three unions. The frutescent union is characterized by *Artemisia tridentata, Tetradymia glabrata, Ephedra viridis* Coville, *Grayia spinosa, Purshia tridentata* (Pursh) DC., *Ribes velutinum* Greene, *Chrysothamnus puberulus* (D. C. Eaton) Greene, and *Chrysothamnus nauseosus* (Pall.) Britton. The perennial union exhibits several bunch-grasses and numerous forbs. Characteristic of this synusia are *Sitanion hystrix, Poa secunda* Presl., *Delphinium Andersonii* A. Gray, *Zygadenus venenosus* S. Wats., and numerous others. The composition of the original annual union in this community is somewhat difficult to determine because of the present dominance in that stratum of the introduced *Bromus tectarum* and *Bromus rubens.* The abundance of these two species is due, in part, to repeated range fires in the region caused primarily by the very presence of the bromes themselves. The great amount of combustible material produced by these two species creates a considerable fire hazard in this association during the dry summers. The fires tend to eradicate the native perennial herbaceous and woody vegetation leaving almost pure stands of Bromus over considerable areas. It seems safe to say that *Amsinckia tessellata* A. Gray, *Collinsia parviflora* Dougl., *Mimulus montioides* Gray, and *Phacelia adenophora* J. T. Howell are at least prominent members of the native annual union in the sagebrush association.

CLIMAX RELATIONS

Figure 4 illustrates, in a general way, the topographic and geologic relationships of the principal plant associations of the Carson Desert region. On the broad, dry plains of the Lahontan sediments and on the residual soils of the lower mountain ranges in the southern part of the region, the little greasewood-shadscale association appears to be the climatic climax. The climate of the little greasewood-shadscale association is warmer and distinctly drier than that of the Artemisietum. The normal precipitation of the Sarcobatetum Baileyi ranges from 4 to 6 inches, 50 to 75 per cent of the minimum required by sagebrush when not supplied by underground water. In the slightly cooler and more moist northwestern part of the region, the lower elevational limit of the sagebrush community on upland soils more or less coincides with the highest level reached by Lake Lahontan. Post-climax sagebrush and post-climax cottonwood enter the desert along

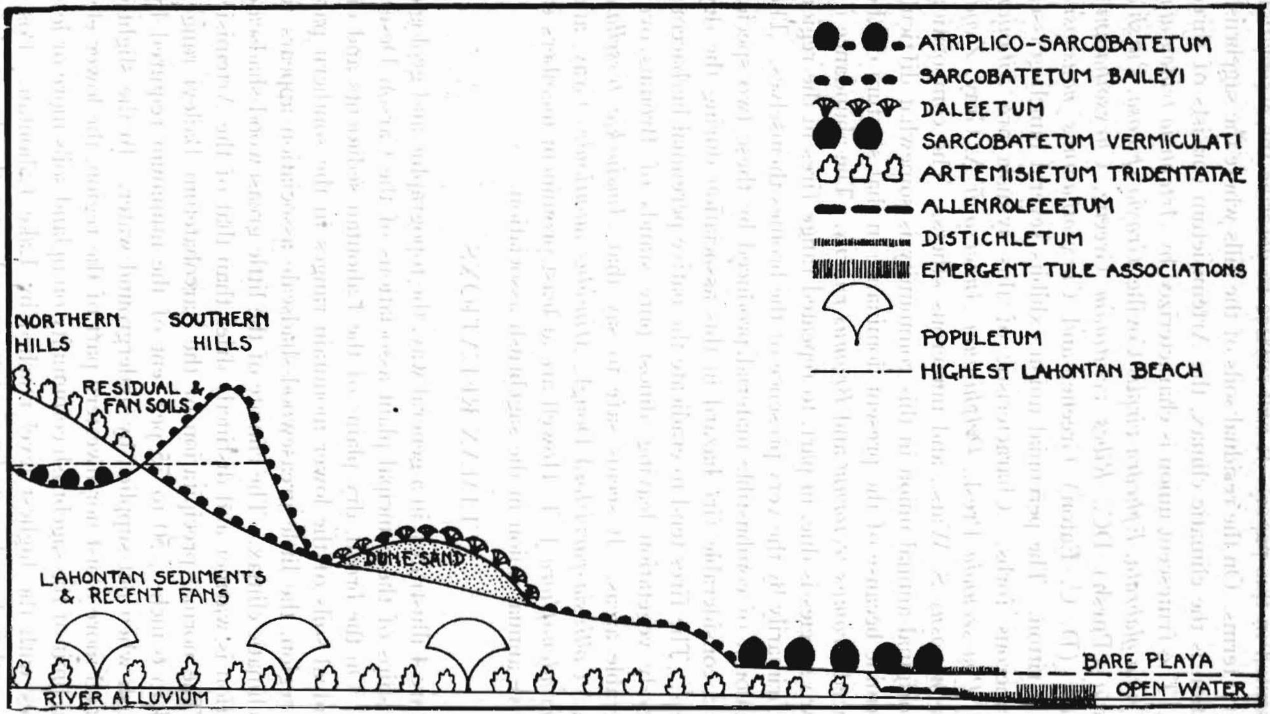

Figure 4. Diagrammatic representation of the topographic an d geologic positions of the principal associations in the Carson Desert region.

the rivers where the fresh water table is close enough to the surface to supply water throughout the dry season. The dalea association on dune sands and the big greasewood and other stable associations on saline playa clays evidently represent edaphic climaxes. It is difficult, however, to see how the vegetation and soils in these situations can change in the direction of the climatic climax under the present arid climate and interior drainage conditions.

SUMMARY

1. Fifteen associations are described in a phytosociological analysis of the vegetation of the Carson Desert region, an area of microthermal arid climate in western Nevada.

2. Particular emphasis is placed upon the frutescent associations. The little greasewood-shadscale association on Lahontan sediments and residual soils, the dalea association on aeolian sand, the big greasewood association and the big greasewood-shadscale association on saline clays are quantitatively analyzed at a number of stations.

3. The little greasewood-shadscale association is considered to be the climatic climax on normal soils in this region where the precipitation is too low for the development of the sagebrush association.

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LITERATURE CITED

Bouyoucos, George J. 1928. Making mechanical analyses of soils in fifteen minutes. Soil Sci. 25: 473-480.

Clements, Frederic E. 1920. Plant indicators. The relation of plant communities to process and practice. Carnegie Inst. Wash. Pub. 290.

Flowers, Seville. 1934. Vegetation of the Great Salt Lake region. Bot. Gaz. 95: 353-418.

Frémont, J. C. 1845. Report of the exploring expedition to the Rocky Mountains in the year 1842, and to Oregon and North California in the years 1843-'44. 28th Congress, 2d Session, Senate. Washington. 693 pp.

Hall, E. Raymond. 1941. Revision of the rodent genus Microdipodops. Zool. Series. Field Mus. Nat. Hist. 27: 233-277.

Katz, N. 1929. Die Zwillingsassoziationen und die homologen Reihen in der Phytosoziologie. Ber. deutsch. bot. Ges. 47: 154-164.

Kearney, T. H., L. J. Briggs, H. L. Shantz, J. W. McLane, and R. L. Piemeisel. 1914. Indicator significance of vegetation in Tooele Valley, Utah. Jour. Agric. Res. 1: 365-417.

LIPPMAA, THEODOR. 1939. The unistratal concept of plant communities. (The unions). Amer. Midl. Nat. 21: 111-145.
LOWRANCE, E. W. 1939. Unpublished data. University of Nevada. Reno.
MACDOUGAL, D. T. 1908. Botanical features of North American deserts. Carnegie Inst. Wash. Pub. 99.
NICHOL, A. A. 1937. The natural vegetation of Arizona. Univ. Ariz. Agric. Exp. Sta. Tech. Bul. 68: 181-222.
PARISH, S. B. 1930. Vegetation of the Mohave and Colorado Deserts of Southern California. Ecology 11: 481-499.
RUSSELL, ISRAEL C. 1885. Geological history of Lake Lahontan. Monogr. U. S. Geol. Surv. 11: 1-288.
SCHERF, E. 1935. Geologische und morphologische Verhältnisse des Pleistozäns und Holozäns der grossen ungarischen Tiefebene und ihre Beziehungen zur Bodenbildung, insbesondere der Alkalibodenentstehung. Relationes Annuae Inst. Regii Hungarici Geol. Pro. 1925-28: 1-37. Budapest. Cited in Jenny, H. 1941. Factors of soil formation. New York. 281 pp.
SHANTZ, H. L. 1924. Grassland and desert shrub. In Shantz, H. L. and R. Zon. Natural vegetation. Atlas of American Agriculture. U. S. Dept. Agric. Washington. 29 pp.
——— ———. 1925. Plant communities in Utah and Nevada. In Tidestrom, Ivar. Flora of Utah and Nevada. Contr. U. S. Nat. Mus. 25: 15-23.
——— ——— AND R. L. PIEMEISEL. 1924. Indicator significance of the natural vegetation of the southwestern desert region. Jour. Agric. Res. 28: 721-802. 14 pl.
SHREVE, FORREST. 1936. The plant life of the Sonoran Desert. Scient. Monthly 42: 195-213.
——— ———. 1942. The vegetation of Arizona. In Kearney, Thomas H. and Robert H. Peebles. Flowering plants and ferns of Arizona. U. S. Dept. Agric. Misc. Pub. 423: 10-23.
THORNTHWAITE, C. W. 1941. Atlas of climatic types in the United States 1900-1939. U. S. Dept. Agric. Misc. Pub. 421. Washington. 7 pp. 96 pl.
WATSON, SERENO. 1871. Botany. U. S. Geological Exploration of the Fortieth Parallel 5. Washington. 525 pp.

STATION LOCATIONS

LITTLE GREASEWOOD-SHADSCALE ASSOCIATION

Sta. 1. 4.7 miles northeast of Hazen along power line.
Sta. 2. Adjoining Ft. Churchill at foot of Churchill Butte.
Sta. 3. 15.6 miles south of Fallon.
Sta. 4. 9.2 miles southeast of Fernley, on bench just west of Black Butte.
Sta. 5. 10.1 miles northeast of Fernley.
Sta. 6. 18.5 miles south of Fallon in Desert Mountains.
Sta. 7. 5.2 miles north of Schurz, south slopes of Desert Mountains.
Sta. 8. 3.5 miles north of Wabuska, Desert Mountains.
Sta. 9. 3 miles west of Sand Springs, just north of Eight-mile Flat.
Sta. 10. 5 miles southwest of Pyramid Lake, near Pyramid Mining Dist. 3 road.
Sta. 12. 6 miles north of Schurz in Desert Mountains.

DALEA ASSOCIATION

Sta. 1. Just west of Letteville, north side of Carson River.
Sta. 2. 4.2 miles northeast of Fernley.
Sta. 3. 5.7 miles northeast of Fernley.
Sta. 4. 10.9 miles northeast of Hazen along power line.
Sta. 5. 18 miles north of Schurz in Desert Mountains.
Sta. 6. 16 miles north of Schurz in Desert Mountains.
Sta. 7. 3 miles west of Sand Springs, just north of Eight-mile Flat.
Sta. 8. 2 miles west of Letteville, north side of Carson River.
Sta. 9. 1 mile north of Wadsworth.
Sta. 10. 5.2 miles northeast of Fernley.

BIG GREASEWOOD ASSOCIATION

Sta. 1. 1.4 miles east of Stillwater.
Sta. 2. Immediately southeast of Hazen.
Sta. 3. 8.7 miles northeast of Fernley in Hot Springs Flat.

BIG GREASEWOOD-SHADSCALE ASSOCIATION

Sta. 1. Roundhole Ranch, edge of Smoke Creek Desert.
Sta. 2. 8 miles southwest of Pyramid Lake, Cottonwood Creek Sink.

TABLE I

Species of the Sarcobatetum Baileyi listed in decreasing order of presence at ten stations.

SHRUBS	1	2	3	4	5	6	7	8	9	10
Sarcobatus Baileyi Coville.	x	x	x	x	x	x	x	x	x	x
Atriplex confertifolia (Torr. & Frém.) S. Wats.	x	x	x	x	x	x	x	x	x	x
Artemisia spinescens D. C. Eaton.	x	x	x		x	x	x	x	x	x
Eurotia lanata (Pursh) Moq.		x		x	x	x	x			x
Lycium Cooperi A. Gray.	x		x			x	x		x	
Opuntia pulchella Engelm.	x	x							x	
Dalea polyadenia Torr.	x	x								
Ephedra nevadensis S. Wats.		x				x				
Opuntia erinacea Engelm.		x						x		
Sarcobatus vermiculatus (Hook.) Torr.					x					
Tetradymia spinosa Hook. & Arn.					x					
Hymenoclea fasciculata A. Nels.						x				
Tetradymia glabrata A. Gray.							x			
Grayia spinosa (Hook.) Moq.										x
Artemisia tridentata Nutt.										x
PERENNIAL HERBS										
Sphaeralcea ambigua subsp. monticola Kearney.		x	x	x		x	x	x	x	x
Oryzopsis hymenoides (Roem. & Schult.) Ricker.		x				x	x	x		x

TABLE I (Continued)

Species of the Sarcobatetum Baileyi listed in decreasing order of presence at ten stations.

	1	2	3	4	5	6	7	8	9	10
Hermidium alipes S. Wats.	x	x		x		x		x		
Hilaria Jamesii (Torr.) Benth.						x		x		
Rhysopterus corrugatus (Jones) Coulter & Rose.							x			
Lygodesmia grandiflora (Nutt.) Torr. & Gray.									x	
Astragalus iodanthus S. Wats.										x
Stipa speciosa Trin. & Rupr.										x
Sitanion hystrix (Nutt.) J. G. Smith.										x
ANNUAL HERBS										
Cryptantha circumscissa (Hook. & Arn.) Johnston.	x	x	x	x		x	x	x	x	x
Eriogonum vimineum Dougl.		x		x		x		x		x
Glyptopleura marginata D. C. Eaton.			x	x				x	x	x
Bromus rubens L.			x		x	x		x		x
Cryptantha micrantha (Torr.) Johnston.	x	x					x		x	
Oenothera clavaeformis Torr. & Frém.		x				x		x	x	
Oenothera contorta Dougl.			x	x					x	x
Festuca octoflora Walt. and var. hirtella Piper.			x			x		x		x
Gilia leptomeria A. Gray.							x	x	x	x
Abronia turbinata Torr.		x					x		x	
Descurainia californica (A. Gray) O. E. Schulz.			x			x				x
Cryptantha pterocarya (Torr.) Greene.				x				x		x
Eriogonum pusillum Torr. & Gray.							x		x	x
Bromus tectorum L.		x			x					x
Streptanthella longirostris (S. Wats.) Rydb.		x							x	
Eriogonum angulosum Benth.				x					x	
Coldenia Nuttallii Hook.				x			x			
Lepidium flavum Torr.						x		x		
Euphorbia ocellata var. arenicola (Parish) Jepson.						x			x	
Nama aretioides (H. & A.) Brand.							x			x
Erodium cicutarium (L.) L'Her.								x		x
Amsinckia tesselata A. Gray.								x		x
Descurainia sp.		x								
Gilia floccosa A. Gray.			x							

TABLE I (Continued)

Species of the Sarcobatetum Baileyi listed in decreasing order of presence at ten stations.

	1	2	3	4	5	6	7	8	9	10
Cryptantha sp.				x						
Caulanthus pilosus S. Wats.						x				
Dondia nigra (Raf.) Standl.					x					
Oenothera chamaenerioides A. Gray.						x				
Amsinckia sp.?							x			
Oenothera deltoides var. Piperi Munz.							x			
Astragalus sp.							x			
Tripterocalyx crux-maltae (Kellogg) Standl.							x			
Plagiobothrys Harknessii (Greene) Nels. & Macbr.								x		
Mentzelia albicaulis Dougl.								x		
Cleome sp.								x		
Blepharidachne Kingii (S. Wats.) Hack.								x		
Astragalus diphysus A. Gray.									x	
Chaenactis stevioides Hook. & Arn.										x
Malacothrix glabrata A. Gray.										x
Eriogonum sp.?										x
Descurainia paradisa (Nels. & Kenn.) O. E. Schulz.										x
Descurainia sophia (L.) Webb.										x
Gilia polycladon Torr.										x

TABLE II

Quantitative composition of the frutescent (dominant) stratum of the Sarcobatetum Baileyi at five stations. All figures based on 25 quadrats of 9 square meters each at each station. f = frequency, d = density per square meter, c = percentage coverage of total area, pc = percentage of total shrubby cover.

Species		1	2	3	4	5
Sarcobatus Baileyi	f	92	100	100	96	88
	d	.35	.33	.51	.26	.15
	c	3.24	5.36	6.88	4.32	3.48
	pc	54.36	53.49	58.01	56.54	67.97
Atriplex confertifolia	f	96	84	100	92	76
	d	.21	.28	.82	.46	.19
	c	1.12	1.52	2.24	3.32	1.20
	pc	18.79	15.17	18.88	43.46	23.45

TABLE II—(Continued)

Quantitative composition of the frutescent (dominant) stratum of the Sarcobatetum Baileyi at five stations. All figures based on 24 quadrates of 9 square meters each at each station. f = frequency, d = density per square meter, c = percentage coverage of total area, pc = percentage of total shrubby cover.

SPECIES		1	2	3	4	5
Artemisia spinescens	f	68	96	100		28
	d	.22	.97	1.53		.08
	c	.76	3.08	2.72		.12
	pc	12.75	30.74	22.93		2.34
Lycium Cooperi	f	48		12		
	d	.22		.01		
	c	.72		.02		
	pc	12.08		.16		
Dalea polyadenia	f	8				
	d	.01				
	c	.12				
	pc	2.01				
Ephedra nevadensis	f		4			
	d		.01			
	c		.04			
	pc		.40			
Eurotia lanata	f		8			40
	d		.01			.09
	c		.02			.20
	pc		.20			3.90
Sarcobatus vermiculatus	f					8
	d.					.02
	c					.12
	pc					2.34

TABLE III

Quantitative composition of the herbaceous unions of the Sarcobatetum Baileyi at ten stations in 1941. All figures based on 25 quadrats of 1/5 square meter each at each station. f = frequency, d = density per square meter.

PERENNIALS		1	2	3	4	5	6	7	8	9	10
Oryzopsis hymenoides	f		4				4	8			
	d		.2				.2	.6			
Sphaeralcea ambigua monticola	f						4	24		16	
	d						.2	1.2		1.0	
Astragalus iodanthus	f										4
	d										.2
Stipa speciosa	f										4
	d										.2

TABLE III (Continued)

Quantitative composition of the herbaceous unions of the Sarcobatetum Baileyi at ten stations in 1941. All figures based on 25 quadrats of 1/5 square meter each at each station. f = frequency, d = density per square meter.

ANNUALS		1	2	3	4	5	6	7	8	9	10
Cryptantha circumscissa	f	16	36					8	4	64	16
	d	1.0	3.2					.6	.2	12.2	2.4
Cryptantha micrantha	f	36						20			
	d	4.0						1.8			
Oenothera clavaeformis	f		4							4	
	d		.2							.2	
Eriogonum vimineum	f		8				4		4		52
	d		.4				.2		.2		6.8
Cryptantha sp.	f				8						
	d				.4						
Eriogonum angulosum	f				4					16	
	d				.2					1.2	
Descurainia californica	f						16				
	d						1.8				
Eriogonum pusillum	f							12		20	8
	d							.6		1.6	1.0
Amsinckia sp.?	f							4			
	d							.2			
Oenothera deltoides Piperi	f							4			
	d							.2			
Lepidium flavum	f								4		
	d								.2		
Erodium cicutarium	f								4		
	d								.2		
Bromus rubens	f								24		12
	d								2.2		.8
Astragalus diphysus	f									4	
	d									.2	
Streptanthella longirostris	f									4	
	d									.2	
Oenothera contorta	f									12	12
	d									1.6	.8
Gilia leptomeria	f									8	20
	d									.6	1.2
Bromus tectorum	f										8
	d										.4
Chaenactis stevioides	f										20
	d										2.0
Glyptopleura marginata	f										12
	d										1.0
Malacothrix glabrata	f										12
	d										.6

TABLE IV

Species of the Daleetum listed in decreasing order of presence at ten stations.

SHRUBS	1	2	3	4	5	6	7	8	9	10
Dalea polyadenia Torr.	x	x	x	x	x	x	x	x	x	x
Atriplex canescens (Pursh) Nutt.	x	x	x	x	x	x	x	x	x	x
Tetradymia glabrata A. Gray.	x	x	x	x	x	x	x	x	x	x
Tetradymia comosa A. Gray.	x	x	x		x	x	x	x	x	x
Sarcobatus Baileyi Coville.	x	x	x	x			x	x	x	x
Eurotia lanata (Pursh) Moq.	x			x				x	x	x
Opuntia pulchella Engelm.	x					x	x	x		
Atriplex confertifolia (Torr. & Frém.) S. Wats.		x		x						x
Artemisia spinescens D. C. Eaton.		x								x
Grayia spinosa (Hook.) Moq.							x		x	
Tetradymia spinosa Hook. & Arn.		x								
Hymenoclea fasciculata A. Nels.				x						
Ephedra nevadensis S. Wats.				x						
PERENNIAL HERBS										
Oryzopsis hymenoides (Roem. & Schult.) Ricker.		x	x	x	x	x	x	x	x	x
Sphaeralcea ambigua subsp. monticola Kearney.		x		x	x	x	x			
Pentstemon acuminatus Dougl.	x				x	x	x	x		
Rhysopterus corrugatus (Jones) Coulter & Rose.	x					x		x		x
Lygodesmia grandiflora (Nutt.) Torr. & Gray.	x						x			
Rumex venosus Pursh.					x		x			
Hermidium alipes S. Wats.		x								
ANNUAL HERBS										
Coldenia Nuttallii Hook.	x	x	x	x	x	x	x	x	x	x
Abronia turbinata Torr.	x	x	x	x	x	x	x	x	x	x
Cryptantha circumscissa (Hook. & Arn.) Johnston.	x	x	x		x	x	x	x	x	x
Gilia leptomeria A. Gray.	x	x	x	x		x	x	x	x	x
Euphorbia ocellata var. arenicola (Parish) Jepson.	x	x	x		x	x	x	x		x
Oenothera deltoides var. Piperi Munz.	x	x	x		x	x	x	x	x	
Cryptantha micrantha (Torr.) Johnston.	x		x		x	x	x	x	x	x
Eriogonum pusillum Torr. & Gray.	x	x	x	x			x	x	x	x
Phacelia bicolor Torr.	x		x		x	x	x	x	x	x
Tripterocalyx crux-maltae (Kellogg) Standl.	x	x			x			x	x	x

TABLE IV (Continued)

Species of the Daleetum listed in decreasing order of presence at ten stations.

SHRUBS	1	2	3	4	5	6	7	8	9	10
Nama aretioides (H. & A.) Brand.	x				x		x	x	x	
Mentzelia albicaulis Dougl.		x	x					x	x	x
Malacothrix sonchoides (Nutt.) Torr. & Gray.			x				x	x	x	x
Oenothera clavaeformis Torr. & Frém.		x	x	x			x			
Bromus tectorum L.			x				x		x	x
Streptanthella longirostris (S. Wats.) Rydb.			x		x		x		x	
Glyptopleura marginata D. C. Eaton.	x					x			x	
Salsola kali var. tenuifolia Tausch.		x	x							x
Chaenactis Xantiana A. Gray.			x						x	x
Oryctes nevadensis S. Wats.			x				x			x
Eriogonum vimineum Dougl.			x			x				x
Oenothera contorta Dougl.					x		x	x		
Bromus rubens L.						x	x		x	
Lupinus intermontanus Heller.							x		x	x
Astragalus diphysus A. Gray.	x						x			
Chenopodium leptophyllum Nutt.			x							x
Eriogonum angulosum Benth.			x						x	
Descurainia californica (A. Gray) O. E. Schulz.					x				x	
Plagiobothrys Harknessii (Greene) Nels. & Macbr.					x				x	
Descurainia longipedicellata (Fourn.) O. E. Schulz.					x	x				
Malacothrix glabrata A. Gray.									x	x
Cryptantha sp.		x								
Nama depressum Lemmon.					x					
Festuca octoflora Walt. and var. hirtella Piper.						x				
Gilia floccosa A. Gray.							x			
Helianthus anomalus Blake.							x			
Chenopodium sp.									x	
Franseria acanthicarpa (Hook.) Coville.									x	
Cleome lutea Hook.									x	

TABLE V

Quantitative composition of the frutescent (dominant) stratum of the Daleetum at seven stations. Figures for first three stations based on 25 quadrats of 4 square meters each; figures for remaining four stations based on 25 quadrats of 9 square meters each.

SPECIES		1	2	3	4	8	9	10
Dalea polyadenia	f	60	44	52	84	100	64	84
	d	.27	.26	.23	.27	.52	.16	.25
	c	9.48	3.84	5.72	3.32	9.60	2.88	3.10
	pc	33.52	39.83	23.87	31.92	84.51	24.44	39.00
Atriplex canescens	f	52	24	56	12	8	48	4
	d	.20	.06	.18	.01	.01	.07	.004
	c	8.64	1.12	3.68	.48	.10	2.00	.04
	pc	30.55	11.61	15.35	4.61	.88	17.24	.54
Tetradymia comosa	f	12	4	32			72	4
	d	.06	.01	.14			.11	.004
	c	3.00	.20	13.48			5.08	.30
	pc	10.60	2.07	56.26			43.79	3.77
Sarcobatus Baileyi	f	24	44	16	12	8	36	40
	d	.16	.39	.04	.02	.01	.04	.08
	c	7.16	3.68	.68	.76	.10	1.14	2.10
	pc	25.31	38.17	2.83	7.30	.88	9.83	26.40
Tetradymia glabrata	f			4	4	4	4	28
	d			.01	.004	.004	.004	.06
	c			.40	.08	.04	.10	1.94
	pc			1.66	.76	.35	.86	24.40
Eurotia lanata	f				92	96	36	4
	d				.26	.34	.06	.004
	c				1.40	1.52	.30	.01
	pc				13.46	13.38	2.59	.13
Atriplex confertifolia	f		4					8
	d		.03					.01
	c		.20					.14
	pc		2.07					1.76
Hymenoclea fasciculata	f				92			
	d				.30			
	c				4.20			
	pc				40.38			
Ephedra nevadensis	f				8			
	d				.01			
	c				.16			
	pc				1.53			
Grayia spinosa	f						12	
	d						.01	
	c						.10	
	pc						.86	

TABLE V (Continued)

Quantitative composition of the frutescent (dominant) stratum of the Daleetum at seven stations. Figures for first three stations based on 25 quadrats of 4 square meters each; figures for remaining four stations based on 25 quadrats of 9 square meters each.

Species		1	2	3	4	8	9	10
Artemisia spinescens	f							20
	d							.05
	c							.32
	pc							4.02

TABLE VI

Quantitative composition of the herbaceous unions of the Daleetum at ten stations in 1941. All figures based on 25 quadrats of 1/5 square meter each at each station. f = frequency, d = density per square meter.

Perennials		1	2	3	4	5	6	7	8	9	10
Oryzopsis hymenoides	f		8	4	8	48	24	4	24	44	44
	d		.4	.2	.6	3.0	3.6	.2	1.2	3.2	2.8
Sphaeralcea ambigua monticola	f					28	8				
	d					1.8	.4				
Pentstemon acuminatus	f	8				8	64				
	d	.4				.4	4.2				
Annuals											
Coldenia Nuttallii	f		52	80		48	8	28	56	76	88
	d		5.8	14.4		4.8	.4	2.0	10.8	14.8	10.0
Cryptantha circumscissa	f			48		60	80	68	96	88	48
	d			3.8		7.2	16.8	9.4	25.6	19.0	3.4
Abronia turbinata	f	8	4	4		4		16	8	4	16
	d	.4	.2	.2		.2		.8	.4	.2	.8
Gilia leptomeria	f		20	40	4		4	92		4	40
	d		1.6	3.2	.2		.4	23.2		1.4	4.0
Euphorbia ocellata arenicola	f	4	4	8			4		8		4
	d	.2	.2	.4			.2		.4		.2
Cryptantha micrantha	f	4		4			16	44	28	12	
	d	.2		.2			1.2	3.0	3.0	.8	
Phacelia bicolor	f			8		8	12	28	8	36	
	d			.4		.4	.6	1.8	.4	2.0	
Salsola kali tenuifolia	f		20	8							32
	d		1.4	.6							1.6
Cryptantha sp.	f		4								
	d		.2								
Mentzelia albicaulis	f		4						4	4	28
	d		.2						.2	.2	1.6
Tripterocalyx crux-maltae	f		4								
	d		.2								

TABLE VI (Continued)

Quantitative composition of the herbaceous unions of the Daleetum at ten stations in 1941. All figures based on 25 quadrats of 1/5 square meter each at each station. f = frequency, d = density per square meter.

		1	2	3	4	5	6	7	8	9	10
Eriogonum pusillum	f			12	16			8	32	24	
	d			.8	.8			.6	1.6	1.4	
Chaenactis Xantiana	f			4							20
	d			.2							1.0
Bromus tectorum	f			20						28	36
	d			1.4						2.8	2.0
Oryctes nevadensis	f			4							8
	d			.2							.6
Eriogonum vimineum	f			8							4
	d			.8							.2
Chenopodium leptophyllum	f			8							4
	d			.4							.2
Streptanthella longirostris	f			4		4				12	
	d			.2		.2				.6	
Malacothrix sonchoides	f			8						12	12
	d			.6						.6	.6
Nama aretioides	f				20		4		4		
	d				1.6		.2		.2		
Oenothera deltoides Piperi	f					4					
	d					.2					
Oenothera contorta	f						4	4			
	d						.2	.2			
Astragalus diphysus	f						4				
	d						.2				
Eriogonum angulosum	f						4				
	d						.2				
Chenopodium sp.	f								4		
	d								.2		

TABLE VII

Quantitative composition of the frutescent (dominant) stratum of the Sarcobatetum vermiculati at three stations.

Species		1	2	3
Sarcobatus vermiculatus (Hook.) Torr.	d	.59	.105	.07
	c	24.00	6.75	3.80
	pc	100.0	100.0	95.0
Atriplex lentiformis Torreyi (S. Wats.) H. & C.	d			.004
	c			.20
	pc			5.0

TABLE VIII

Quantitative composition of the frutescent strata of the Atriplico-Sarcobatetum at two stations.

Species		1	2
Sarcobatus vermiculatus	d	.41	.38
	c	19.04	13.17
	pc	63.05	42.80
Atriplex lentiformis Torreyi	d	.23	.48
	c	6.24	8.64
	pc	20.66	28.07
Artemisia spinescens	d	.34	.51
	c	.92	4.00
	pc	3.05	13.00
Atriplex confertifolia	d	.44	.29
	c	2.76	3.42
	pc	9.14	11.11
Tetradymia spinosa	d	.14	.08
	c	.60	.94
	pc	1.99	3.05
Grayia spinosa	d	.08	.03
	c	.40	.60
	pc	1.32	1.95
Eurotia lanata	d	.11	
	c	.16	
	pc	.53	

TABLE IX

Soil characteristics at representative locations in the principal associations.

Location	Soil type	% Rock Greater Than 2 mm.	% Sand	% Silt	% Clay	% Total "Colloids"	pH	Conductance of solution as $K \times 10^5$
Bare region—Eight-mile Flat								
0—2 cm.	Clay	0	41.3	28.4	30.4	35.7	9.6	5006.2
25 cm.	Clay loam	0	39.3	34.4	26.4	32.7	9.6	2053.8
50 cm.	Sandy clay loam	0	63.3	14.4	22.4	26.7	9.6	1780.0
Sarcobatetum vermiculati—Sta. 2								
0—2 cm.	Silt loam	0	19.4	76.0	4.6	46.6	8.5	1128.2
30 cm.	Silty clay	0	7.4	59.0	33.6	85.6	8.6	843.2
50 cm.	Clay	0	9.1	23.6	67.3	77.9	9.0	801.0
Sarcobatetum vermiculati—Sta. 3								
0—2 cm.	Sand	0	85.3	8.7	6.0	8.4	9.4	315.4
25 cm.	Clay	0	13.3	20.0	66.7	76.7	9.1	272.4
50 cm.	Clay	0	31.3	24.4	44.4	56.7	9.4	161.8
Atriplico—Sarcobatetum—Sta. 1								
0—2 cm.	Sandy loam	0	60.6	24.7	14.7	21.4	7.3	22.3
30 cm.	Clay	0	45.6	12.0	42.4	46.4	9.1	66.4
Sarcobatetum Baileyi—Sta. 3								
0—2 cm.	Sand	24.9	82.1	15.0	2.9	4.9	7.7	16.4
30 cm.	Sandy clay loam	17.6	61.4	17.6	20.9	25.6	8.9	48.3
50 cm.	Sandy loam	0	71.4	18.6	9.9	12.5	9.0	89.6
100 cm.	Clay loam	3.9	49.8	25.6	24.6	28.2	8.9	295.2

TABLE IX (Continued)

Soil characteristics at representative locations in the principal associations.

Location	Soil type	% Rock Greater Than 2 mm.	% Sand	% Silt	% Clay	% Total "Colloids"	pH	Conductance of solution as K x 10^5
Sarcobatetum Baileyi—Sta. 4								
0—2 cm.	Sand	12.5	83.7	13.0	3.3	7.3	9.4	92.6
30 cm.	Sandy loam	10.0	64.7	21.0	14.3	18.3	8.9	18.7
50 cm.	Sandy loam	2.9	58.7	34.0	7.3	11.3	9.4	46.8
100 cm.	Silt loam	0	17.1	79.0	3.9	3.9	8.5	326.9
Sarcobatetum Baileyi—Sta. 12*								
0—2 cm.	Sand	18.0	83.1	13.6	3.3	4.9	7.8	13.2
30 cm.	Sand	7.0	85.1	9.6	5.3	7.9	7.9	12.0
50 cm.	Sand	4.4	90.7	6.0	3.3	5.3	8.0	11.3
Daleetum—Sta. 3								
0—2 cm.	Sand	0	95.1	3.6	1.3	1.9	7.3	30.1
25 cm.	Sand	0	95.1	3.6	1.3	2.9	7.4	3.6
50 cm.	Sand	0	95.1	3.6	1.3	2.9	7.4	3.3
100 cm.	Sand	0	92.1	4.6	3.3	3.9	9.1	15.4
Daleetum—Sta. 8								
0—2 cm.	Sand	0.4	95.4	3.6	0.9	0.9	7.4	94.4
30 cm.	Sand	0.8	94.4	4.0	1.6	1.6	7.9	16.2
50 cm.	Sand	0	94.4	4.6	0.9	1.6	7.8	13.5
100 cm.	Sand	0	98.4	1.0	0.6	0.6	8.0	13.7
Daleetum—Sta. 9								
0—2 cm.	Sand	0.8	93.4	5.0	1.6	3.6	7.2	5.3
30 cm.	Sand	1.1	90.4	6.0	3.6	4.6	7.0	4.8
50 cm.	Sand	1.0	88.8	5.6	5.6	7.2	7.0	6.0

* This station of the Sarcobatetum Baileyi is located on residual volcanic soil at an elevation of 4850 feet in the Desert Mountains. No vegetational analyses other than presence are available for this station at present.