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TITLE AN ECOLOGIC AND SYSTEMATIC ANALYSIS OF THE GENUS OPUNTIA MILLER IN THE BIG BEND REGION OF TEXAS

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# AN ECOLOGIC AND SYSTEMATIC ANALYSIS OF THE GENUS OPUNTIA Miller IN THE BIG BEND REGION OF TEXAS

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
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Committee in charge:

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# PREFACE

The author wishes to express sincere appreciation to her committee for their help, and particularly to the chairman, Dr. Elzada U. Clover, under whose guidance and inspiration these studies were carried out. Deep gratitude is felt toward Professor Harley H. Bartlett, Director of the Botanical Gardens, for his continued encouragement and assistance. Part of the work was carried out while the author held a Research Assistantship at the Botanical Gardens.

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Missouri Botanical Garden

New York Botanical Garden

University of Texas

United States National Herbarium

All dried specimens collected during this study are in the Herbarium of the University of Michigan Museum. Living material is growing at the University Botanical Gardens, making a total of 702 conserved specimens.

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# PART I - INTRODUCTION

The family Cactaceae, indigenous to our Western Hemisphere, is considered by Backeberg, 1942 (2) to have evolved in Cretaceous times from a center in the West Indies, with one broad migration path leading up through Mexico into arid regions of the United States, another terminating in the desert areas of South America. This theory is highly suppositious.

The most widely distributed genus of the family is Opuntia. Its species range from northern Alberta, (possibly from Alaska) to the Straits of Magellan in Chile. Most of the United States have at least one species. In southwestern desert regions, species of Opuntia are the most numerous and usually most conspicuous components of a rich cactus flora.

More than 900 members of the genus had been named in the years before 1919, when Britton and Rose in "The Cactaceae" (11) recognized about 250 distinct species. This discrepancy in classification is largely due to the capacity for great variation among individuals, and descriptions based on sterile material. Less highly specialized in their modifications than most other genera of Cactaceae, the Opuntiae respond more readily to the severely fluctuating environmental conditions of xerophytic habitats.

The Big Bend Region of Texas, with its great physiographic diversity and its desert, arid grassland, and mountainous belts, has a rich cactus flora and seemed to be a suitable region in which to study the natural populations of Opuntia. At least thirty species, hybrids and varieties can be recognized from the region.

Engelmann (26), who studied the family from 1848 to 1878, described many of these for the first time, but his information was necessarily limited to the often incomplete collections of the earliest botanical explorers.

K. Schumann (58), 1897 - 1899, gave short but graphic German descriptions of the Opuntiae, and in the years from 1906 to 1929, Griffiths (34), by drawing finer distinctions, created a number of new species; many of these are now reduced in the literature to synonyms or are maintained only as varieties. Species from southwestern Texas were little represented in his work.

Twenty-one of the species found in the Big Bend are discussed in Britton and Rose (11), but their descriptions are very brief with inconsistent choice of characteristics, too limited ranges of measurement, and obsolete distributional data. "Texas Cacti" by Schultz and Runyon (57) in 1930, is largely a reworking of Britton and Rose.

Naturally the broader range of the species has depended upon studies of many other botanists besides those mentioned. In particular, the Mexican botanists, Profesora Helia Bravo

Helia ( 7), and Profesor Isaac Ochoterena (52), have made interesting studies of the Mexican cacti.

With regard to ecological studies on the Cactaceae, especially the Opuntiae, very little has been done. At the Desert Botanical Laboratory, formerly maintained by the Carnegie Institution of Washington at Tucson, Arizona, Spalding (62), MacDougal ( 46 ), Cannon (12), and Markel (47), in particular, studied some of the ecological requirements and adaptations of a few species of Opuntia. Other studies on cacti in general have been contributed by Shreve, (59-61), Harvey, ( 37 ), Timmons ( 67 ), Clover, (16-17), and Riegel ( 55 ).

## SPECIAL METHODS

Special care is required to dry specimens of cacti properly for herbarium study because of the colloidal mucilaginous nature of the succulent tissue. The flower should be detached from the plant, cut in halves longitudinally and dried similarly to other herbaceous plants, in a separate press, as it is so much less bulky than the rest of the material. Occasionally the halves of the ovary require abrading as they dry much more slowly than the thin perianth segments.

Stems or joints of stems are cut in two, parallel to the flat surfaces. Cross sections as well should be made, especially of cylindrical forms of Escobaria, Echinocereus, Ferocactus and other genera. If there is a great deal of succulent tissue, some of this must be removed or the specimen will take literally months to dry! These cut sections are then laid out in the sun, on labelled newspapers, to bake. During this process, it is a good idea to abrade the cut surface frequently as it quickly seals over, retarding dehydration. When the internal tissue is no longer juicy and the edges are curling, the segments are arranged in a plant press, with ventilators only, since blotters become wet too quickly to keep changing. Use of ventilators alone allows more rapid evaporation until later stages of drying are reached. A strong pull on the ropes is necessary to straighten the curling edges and somewhat force the spines into one plane. The long spines of Hamatocactus and Opuntia in particular tend to stick up through the ventilators and out the sides of the press so caution in handling is soon acquired. During field work in desert regions a very practicable method of heating plant presses is to put them in a wire mesh luggage rack on the top of the car, with open ends of ventilators running front to back. The hot winds, augmented by the speed of the moving car, have a powerful drying effect.

Sections of prickly pears or other cacti may be dehydrated by spreading common salt on the cut surfaces. As it deliquesces it removes the water from the cells by osmosis, and likewise kills them, so that drying proceeds more rapidly. If salt is used, it is well to wash it from the specimens so that they will not be too hygroscopic as finally prepared for the herbarium. Submerging cacti in boiling water so as to kill the tissues and expedite drying has sometimes been recommended. The method may have some utility if carried out very carefully, but a decent specimen cannot be prepared from a cooked cactus. One which has been killed with alcohol or a mixture of alcohol and formaldehyde can be readily dried.

## PART II - HISTORY

Previous collections of *Opuntia*

The history of botanical exploration of this region is reflected in many specific epithets of the Cactaceae. The most important scientific exploration of Trans-Pecos Texas was conducted by the United States and Mexican Boundary Commission Survey (29), at first under Col. J. D. Graham, then under Lt. Col. W. H. Emory in 1851-53. Extensive notes and collections on this expedition were made by Dr. C. C. Parry, Mr. Charles Wright, Dr. J. M. Bigelow, Mr. George Thurber, and Mr. A. Schott who sent much valuable living, as well as dried, material to J. Torrey, A. Gray, and George Engelmann for subsequent identification and publication. The latter is principally responsible for work on the Cactaceae.

G. C. Nealley travelled through Brewster, Jeff Davis, and Presidio counties in 1887-1892, but there are no records of his having collected Opuntiae there.

Opuntiae were collected around the growing town of El Paso by A. Wislizenus in 1846; J. W. Toumey in 1896-98; E. Stearns in 1911-12; J. N. Rose, P. C. Standley and P. G. Russell in 1910; and J. N. Rose and W. R. Fitch in 1913.

Specimens from neighboring Chihuahua were gathered by E. A. Mearns in 1892, E. Palmer in 1908, J. N. Rose in 1908 and E. Stearns in 1912.

From the Big Bend Region itself, specimens of Opuntia have been collected by V. Bailey in 1901, W. L. Bray in 1902, B. Mackensen in 1909, and C. R. Orcutt in 1924. More recently H. C. Cutler, in the thirties, L. C. Hinckley, 1936, and B. H. Warnock, in the forties, have contributed specimens of Opuntia to herbaria.

There was therefore a good local basis for the field work of the present writer, conducted over eleven months from February to June in 1947 and from March to October in 1948. The actual field work took place in the three counties encompassing the Big Bend Region, but additional observations were made from San Antonio to El Paso.

Those who are interested in Cactaceae from a gardening standpoint have tended to neglect the genus Opuntia, because the plants are large and coarse for pot culture or even ordinary garden culture, and are difficult to handle because of the painful sores caused by the glochids. For the same reason, field botanists hesitate to handle the plants and seldom prepare useful herbarium specimens of them. Many otherwise useful and representative collections of desert plants lack Opuntia entirely or almost entirely. It is therefore to be expected that the systematic knowledge of the group would not be fully satisfactory for any given region, and that almost nothing would be known of ecological relations except in the most general way.

It is my purpose to describe ecological relationships of the species of Opuntia in the Big Bend, correlate their local distribution with environmental factors, analyze natural populations systematically to determine the significance of growth habit with respect to the taxonomy of the group, construct a key to identify clearly each variant, and describe each species completely.

Living specimens of Opuntiae have been grown at the Botanical Gardens of the University of Michigan from 1947 to the present under uniform conditions of heat, humidity, and moisture to test the constancy and value in classification of vegetative characteristics.

Ecological Observations of the Region

General discussions of the ecology of the Big Bend Region begin with Engelmann's account (27) in 1851 of interesting genera in western Texas. Valery Havard (38), published a description of vegetation in 1885, as a result of explorations along the Rio Grande River, "Botany of Western Texas" by J. M. Coulter (21) in 1891-94, was the first attempt at a complete manual for the Trans-Pecos. C. H. T. Townsend, in 1897, ( 69) wrote a biogeography of the boundary with a brief account of the fauna and flora. W. L. Bray not only collected some Opuntiae in this region but also analyzed the desert vegetation ecologically (8), ( 9 ), in 1901 and 1905. V. L. Bailey ( 3 ) deals mostly with mammals and life zones. Mearns ( 48) in 1907 gave a general summary of the natural history. E. J. Palmer, (53), (54), published on a trip through the Chisos Mountains in 1928, and on the ligneous flora of the Davis Mountains in 1929. In 1931, H. J. Cottle

(19), then Professor of Biology at Sul Ross State Teachers College in Alpine, Brewster County, discussed studies on the vegetation of southwestern Texas. In 1932, (20) he published on the xeric effects of southern and western exposures on mountains, contrasted with northern and eastern slopes with more mesic growth. A detailed flora of the Chisos Mountains and a monograph of the oaks of Trans-Pecos Texas were contributed by C. H. Müller (49), (50) in 1935 and 1936 respectively. He lists only Opuntia Engelmannii and O. imbricata as occurring in the Chisos Mountains.

Applicable in adjacent United States as well as in Chihuahua, Shreve's publication of 1939 (59) gives a lucid picture of distribution of associations there. In 1940, Blair ( 4 ) reported on associations and mammals of the Davis Mountain Region; some mention was made of the more common species of Cactaceae.

An account by Sperry and Warnock (63) of 1943 is the most authoritative and up-to-date record of what plants to expect in Brewster County. Seven species of Opuntia are listed. Vegetation on Mount Livermore and on Sierra Tierra Vieja was analyzed by L. C. Hinckley (43), (42) in 1944 and 1947, respectively. His work is being continued at the present time.

A posthumous dissertation by H. LeSeure (45) treats of the ecology of northern Chihuahua very thoroughly but cacti are little discussed. Warnock's unpublished doctoral thesis of 1946 (74), is one of the first systematic attempts in Brewster County to analyze vegetation ecologically in a naturally bounded area. E. R. Tinkham, 1949 (68) gives a detailed account of plant ecological conditions in Presidio County, with especial reference to orthopteran fauna. For Brewster and Jeff Davis counties his vegetative discussion is more general.

Other publications with reference to the Big Bend Region or adjacent Mexico have been made by: J. C. Newberry, 1883 (51); H. T. Fletcher, 1928, (33); W. T. Carter and V. L. Cory, 1930-31 (15); Van Tyne and Sutton, 1937, (73); O. E. Sperry, 1938, (63); C. J. Whitfield and E. L. Beutner 1938, (75); District Supervisors of Toyah-Limpia, 1941 (25), and Highland, 1947 (24), Soil Conservation Districts; and L. R. Dice, 1943 (23).

# PART III - ECOLOGICAL CONSIDERATIONS

## GENERAL PHYSIOGRAPHY

### Size of Area

The Rio Grande River in Trans-Pecos Texas executes a giant curve, delimiting a large portion of rough basin and range country which is known as the Big Bend Region. (Map I ). About 12,000 square miles, from longitude 102° 20' to 105°, from latitude 29° to 31°5', including Brewster, Jeff Davis and Presidio counties, are embraced by the curve, with much diversity in country rock, resultant topography and vegetation. Of these three counties, Brewster (5935 square miles) with greatest range in altitude, from 1400 feet along the Rio Grande River to 7835 feet in the Chisos Mountains, and greatest variation in physiography and plant associations, received the most detailed study; the adjacent two counties served as check areas.

### Physiography

Physiographically the area falls in southeastern Mexican Highland Section and southern Sacramento Section of the Basin and Range Province, defined by Fenneman in 1931 (32), and is characterized by block mountains, plateaus, bolsons, mesas capped with resistant igneous beds, and a few permanent surface streams. This area marks the eastern limit of conditions causing these features of the extensive southwestern desert region. Hill (41) points out that a high correlation exists between geologic formations and topography. Differential erosion of rocks of various strengths has caused most of the present relief.

Only Presidio, in Presidio County, Alpine in Brewster County and Mount Locke in Jeff Davis County have weather records of ten or more years' duration. These stations represent respectively: desert shrubland, arid grassland and mountainous climatic conditions. Climatological data from the Big Bend National Park has been regularly recorded only since February 1947. Because of great diversity in topography and differential pressure areas, weather is extremely localized in the Big Bend. The path of a heavy storm can be marked weeks later by the greener grass.

Summers are long and hot with torrential local storms during the rainy season, which lasts from June through September. Winters are short and mild with sometimes no killing frosts recorded. Snowfall is light on the plains, somewhat heavier on the mountains. Rainfall is of the Sonoran type and Yuma subtype with a maximum in August. This precipitated water is derived from the Pacific Ocean by way of Lower California and Arizona.

Excessive evaporation is facilitated by high temperatures, sparse plant cover, small amount of rainfall, and continuous winds, prevailing from the hot and arid southwest although there is considerable shifting in direction. Temperatures are subject to great diurnal fluctuation, falling 25°F more or less each night. March and April are the windiest months with correspondingly highest evaporation rate.

## ECOLOGY

Ecologically, the Big Bend Region is included in the Chihuahuan Biotic Province described by Dice[1]. The Pecos River marks the eastern boundary of the Province which extends from southern New Mexico and western Texas into parts of Chihuahua, Coahuila, Nuevo León, Zacatecas, and San Luis Potosí. This is a naturally delimited area with physiographic and biogeographic unity. Eastward lies the Comanchian Province of arid grassland with scattered shrubs and low trees. The Kansas Province of short grass and Navahonian Province with piñon - juniper woodland adjoin the region to the north. Adjacent on the west is the Apachian Province of grassy high plains and mountains with encinal and montane vegetation. The Big Bend Region affords a meeting ground for species from all these contigous provinces.

The Lower Sonoran of Bailey, 1905, is here represented by the desert and arid grassland life belts, the Upper Sonoran Zone by the encinal life belt, and the Transitional Zone by isolated small occurrences of some Rocky Mountain flora in the montane life belt.

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[1]"A biotic province...covers a considerable and continuous geographic area and is characterized...by peculiarities of vegetation type, ecological climax, flora, fauna, climate, physiography, and soil." L. R. Dice, (23) p. 3.

Occurrence of species of dominants is influenced by the texture of the soil to a greater degree than is the distribution of cacti.

Desert vegetation completely surrounds the grassland whose approximate outer margin is marked by mountains, plateau plains, and mesas as shown in Map. III. Islands of xerophytic vegetation are scattered throughout the arid grassland area where biotic disturbance or edaphic conditions allow that development.

In critical years of drought or cases of severe overgrazing, the desert shrub vegetation expands its margin by invasion.

## LOCAL DISTRIBUTION

### Correlation with Physical Factors

#### Geology

The mountains occur as groups (Chisos and Rosillos Mountains), series of long tilted blocks (Santiago Mountains and Sierra del Carmen), isolated peaks (Castolon Peak) and blocks (Talley Mountain), and associated with volcanic formations (Davis Mountains). They form three long, roughly parallel ranges, trending in a northwesterly-southeasterly direction across Trans-Pecos Texas between the Rio Grande and Pecos rivers (Map I ). Separating these are three belts of lowland basins and occasional plateau plains, well-discussed by Udden, Baker and Böse (70).

The most eastern range represents a low counterpart of the Front Range of the Rockies. It enters from New Mexico on the north as the Guadaloupe Mountains, reaching a height of 8751 feet; trends southeastward as the Delaware Mountains; Culberson Plateau; Apache Mountains; Davis Mountains, attaining a height of 8382 feet; Del Norte Mountains, 6700 feet high; Santiago Mountains, highest altitude 6521 feet; and the Sierra del Carmens, highest altitude on the American side 3500 feet, which is deeply canyoned by the Rio Grande east of Boquillas, and continues into Mexico.

Minor block mountains and peaks lie scattered between these high ridges; the Barilla Hills, Sierra Madera, Glass Mountains, Christmas Mountains, Corazones Peaks, Sierra del Caballo Muerto and Agua Fria Mountain are some of these.

The Appalachian and Laramide Revolutions both affected uplifts in southwestern Texas, the latter forming most of the present highlands. The Solitario region and the Pena Blanca Mountains, which trend northeast-southwest, are older mountains, contemporaneous with the Ouachita and Arbuckle uplift in the Paleozoic period.

Plains of Trans-Pecos Texas are mostly structural valleys which originated with the deformation that produced the mountains. Gradually the finer detritus, fed from surrounding talus slopes and alluvial fans, is filling in the floors of these valleys.

Although epeiric seas inundated the land several times in the Paleozoic Era and the Cretaceous Period, leaving extensive sedimentary beds, a few swamps, petrified trees, and small coal deposits, volcanic activities in the Tertiary

Period and later in the Pleistocene Epoch intruded and covered many of these sedimentaries with igneous rock.

Large plateaus formed by lava flows occur in the Davis Mountains, the area between Alpine and Marfa, west of Mount Ord, Santiago Mountains and the Sierra del Carmens, and extending into Mexico. Whirlwind, Mitchell, and Black Mesas are irregularly shaped, long-tongued, lava-capped, retreating mesas with grassland cover. It is typical of lava beds to weather with a flat surface and cliff edges. Nine-Point Mesa and Elephant Mountain are remnants of former, very extensive, igneous-capped mesas. The porous limestone mesas and cuestas, i.e. Cuesta Carlota like those of lava with its many joints, absorb water quickly, so that few surface drainage channels are cut. Instead, cliff recession occurs as underlying weaker rocks are exposed at the edge of the structure, and are subsequently eroded, thus undermining the resistant rock above, and leaving a series of benches with the lowermost retreating most slowly.

Occasionally a rock pediment is formed by mass wasting of a mountain, leaving steep slopes and a gravelly apron of coarse debris. The type locality of _Opuntia imbricata_ var _argentea_ is on the eastern pediment of Mariscal Mountain. (Plate XXIII.)

Within the Big Bend National Park the Chisos Mountains tower above desert plains to form a semi-mesophytic island surrounded by the lower flats with sparse xerophytic vegetation. These peaks are mostly igneous intrusions which uplifted and broke through sedimentaries, and have since been exposed by erosion. Such formations weather with rounded contours, producing irregular blocks. (Plate I.) Other ryolitic landmarks are Casolon Peak, Rosillos Mountains, Chilicotal Mountain and Agua Fria Mountain.

Following in close succession from south to north the Sierra del Carmens, dipping east, the Sierra del Caballo Muerto, dipping west, the Santiagos, dipping west, and the Del Nortes are all faulted blocks of resistant limestone. Paleozoic limestones and sandstones are exposed in the Glass Mountains, which dip north and trend northeastward, with the highest altitude at 5600 feet.

Southeast of Marathon the deeply folded cuestas of the Pena Blanca Mountains, dipping northwest, are of thick white chert, remains of Paleozoic diatoms and radiolaria which form a hard porcelain-like rock. Yucca Thompsoniana, species of Acacia, many plants of Opuntia Engelmannii, O. imbricata, Coryphantha species; Echinocereus stramineus, Escabaria spp. and a small form of Thelocactus bicolor occur on the steep escarpment slopes. The soil is unusually stony and porous.

Under arid conditions igneous rock is weathered more rapidly by degradation than is sedimentary rock, which is spared from the chemical action of much rainfall. Therefore soil is usually deeper, finer, loose and well-drained on igneous rock. In the desert shrub belt, a Larrea-Yucca vegetation develops on level igneous soils; there is a rich variety of annuals and vegetation is altogether more dense.

_Opuntia_ _Engelmanni_, _O._ _macrocentra_, _O._ _tenuispina_, _Echinocereus_ _enneacanthus_, and _E._ _stramineus_ are particularly conspicuous among the cacti. In grassland and mountainous areas also a more dense and mesophytic vegetation covers soils derived from igneous rock. _Opuntia_ _setispina_ and _O._ _tortispina_ are common subdominants.

Sedimentary rocks are most conspicuously represented in this area by limestones, especially Lower Cretaceous formations. The shallower and coarser chalky limestone soils have sparser vegetation because of their great porosity, and soil continues to develop slowly due to this lack of plant cover. Taken as a whole, the chalky white limestone outcrops have a much richer cactus flora than the igneous rocks; there seems to be a definite preference as well as less competition from other plants. These outcrops support a barren Larrea or Larrea-Agave vegetation with _Opuntia_ _Grahamii_, _O._ _leptocaulis_, _O._ _macrocentra_, _O._ _pheaecantha_, _O._ _rufida_, and _O._ _Schottii_ as the common subdominants. The brown Boquillas limestone, giving rise to a loose sandy soil with its peculiar flora of _Croton_ _neomexicana_ Muell., _Jatropha_ _spathulata_ Muell., and _Larrea_ _divaricata_ Cav. is a favorable substratum for _O._ _macrocentra_, and _O._ _rufida_.

Topography

The effect of latitude which increases from 29° in southern Brewster County to 31° in northern Jeff Davis County cannot well be appraised because altitudes rise from 2000 to 6000 feet within that same distance. Observation of desert vegetation with the decreasing altitudes (4200 feet and below) east, north and west of the Davis Mountains, indicates that _Opuntia Grahamii_, _O. rufida_, and _O. Schottii_ may be completely absent there. Within such short distances, it is not evident that latitude is correlated with geographic range of other species.

Altitude, through its direct effect on temperature, precipitation, and length of growing season, is one of the most important factors governing local distribution of the Opuntiae.

The climate of altitudes below 4200-3900 feet, depending on edaphic conditions, can be approximated from the weather station at Presidio. Twenty years of record there[1] show an average annual precipitation of 9.58 inches, maximum temperatures of 113°F., minimum temperature of 11°F., and an average growing season of 243 days. Average monthly precipitation for Alpine and Presidio with most of the rain falling during the hot months of July and August is shown in Graph I.

Desert shrub vegetation is prevalent, with spinose, woody or succulent plants most common. The northern and western edges of Jeff Davis County, and the southern halves of Brewster and Presidio counties and that portion of northern Mexico which borders the Rio Grande River are covered

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[1] These and following figures were obtained from _Climatological Data_ (72), augmented by records very kindly sent by the Director of the Big Bend National Park and by the meteorologist at the United States Weather Bureau in Houston, Texas.

by this vegetation. (Map III.) Here are the more desert species of the genus Opuntia - _O. Engelmannii_, _O. Grahamii_, _O. leptocaulis_, _O. macrocentra_, _O. phaeacantha_, _O. rufida_, _O. Schottii_, and _O. tenuispina_.

Altitudes from about 3900 feet to about 5000 feet, i.e. plateaus and high plains, account for the development of grassland vegetation and certain plains species of Opuntia, namely, _O. Davisii_, _O. setispina_, and _O. tortispina_. Precipitation measured at Alpine over an eighteen year period averaged 15.93 inches. The average monthly rainfall, with one high in August and another lower peak in December, is shown in Graph I. March and April are among the driest months of the year, yet that is the time when most Opuntiae are setting buds or beginning to flower, indicating little need for moisture during the budding and floral period.

Maximum temperature recorded in Alpine during seventeen years record was 106°F.; the minimum temperature 30°F. The growing season is about 214 days long with only six years of killing frosts in the seventeen years of record.

At high mountain altitudes, temperature is probably the limiting factor. Graph IV indicates relatively low minima (15°F. to -3°F.) for Mt. Locke where only _Opuntia polyacantha_, that cold-tolerant species which extends into Canada, is found.

Maximum temperature recorded at Mt. Locke over a period of ten years was 95°F. Total annual rainfall in the Davis Mountains can be approximated from the 20.60 inches per year at Mt. Locke over a ten-year record. Growing season with three years of killing frosts out of ten years' record, averaged 203 days, a relatively long period.

Variation in annual totals at each of these three stations is great, ranging from drought years with less than 2, 16, and 15 inches of rain respectively for Presidio, Alpine and Mt. Locke to wet years with more than 23, 33, and 36 inches respectively. Graph II. Note that in drought years the annual total (15.16 inches) at Mt. Locke is less than the annual total in a wet year (23.43 inches) at Presidio. But desert conditions are produced by a combination of edaphic and climatic factors over a long period of time. Graphs III and IV chart variation in maximum and minimum temperatures for the last seventeen years at the desert, grassland and mountain stations. Low temperatures are more subject to considerable annual deviation than are high temperatures. Extremes of climatic conditions are usually the limiting factors for the range of a population, freezing temperatures being more critical than high temperatures. As previously stated there are many years without killing frosts recorded for these stations at which times ranges of species extend beyond their critical limit, only to be eliminated again during a severe winter.

During 1947 and 1948, Trans-Pecos Texas endured severe drought which drove many of the smaller ranchers into bankruptcy. During 1948 at Johnson's Ranch in the Big Bend National Park, where the average annual rainfall is 8 inches, only 4.43 inches fell. (In 1949, 6.5 inches had fallen by June, indicating a swing toward a very wet period.) Cacti suffered less than most other plants during the dry period but flowered later in the year and less prolifically than usual. The effect of decreased precipitation is more critical in grassland areas than in desert shrubland; grassland cover is thin and often overgrazed so Opuntiae invade and compete more successfully, often becoming well established in short time.

The profile and accompanying columns in Table 23 show the change in altitude, vegetation and associated species of cacti in the 155 miles from the Rio Grande River, over desert plains to the Chisos and Christmas Mountains, across Nine-Point Mesa up and over the Davis Mountains as far as the desert plains north of that igneous formation. The transition from desert shrub to encinal vegetation is illustrated by the following figures, when observed in the order listed: (Plates I, III, Fig. 2), (Plates II, XXVIII, Fig. 1), (Plates XXXIV, XXXVI, Fig 2), (Plate XXX, Fig. 2), (Plate XIX, Fig. 2) and (Plate XI, Fig. 2).

### Degree and exposure of slope

Steep talus slopes surround the mountain cores and grade into the plains. This semi-arid type of precipitous topography affords excellent habitats for Opuntiae, many of which, as _O. rufida_ and _O. spinosibacca_, are restricted perhaps by competition, to rugged cliffs, rocky slopes and shallow soils. On slopes of hills and mountains, southern and western exposure which are drier and warmer, are naturally more favorable habitats for xerophytic plants, and

Opuntiae are numerically more abundant there.

Badlands, which have evolved locally along the upper Tornillo creek-bed and west of the Christmas Mountains, are developed under arid conditions where soils are above base level, and easily eroded by torrential showers; vegetation is here sparse because of aridity and instability of the terrain. The soil is usually of a fine texture. Even cacti fail to establish a permanent foothold on these shifting slopes.

Drainage Channels

Drainage is rapid along intermittent, locally etched channels, which are called draws or arroyos. A wash in local parlance is a very wide draw or any broad area over which water sweeps in a thin sheet, and which therefore receives additional irrigation. Tornillo and Terlingua creeks and the Rio Grande River are the only permanent streams in Brewster County. Most of the arroyos are intermittent, or at least interrupted. Sheet erosion occurs between them. Torrents of water, coursing down these channels after a heavy storm, often sweep fragments of cacti down-stream where they lodge sooner or later among rocks or in the tangle of draw vegetation, starting new growth. Individuals of *Opuntia imbricata* var. *argentea* and *O. Lindheimeri* var. *chisosensis* were found several miles removed from the main colony along waterways. *Opuntia imbricata* and *O. Kleiniae* tend to grow along draws, especially in the grassland, indicating a preference for areas of higher moisture content. Where grass cover is too solid to be invaded, banks of draws with loose soil are the only available habitats for woody shrubs.

The Rio Grande is an antecedent stream which crosses the axis of uplifts and basins southwest of El Paso in a series of deep canyons. The river bed is dry most of the year from El Paso southeast to Presidio because of extensive withdrawal of water for irrigation. The Rio Concho, flowing from mountains in Mexico, joins the Rio Grande bed at Presidio, making a continuous flow to the Gulf of Mexico. South of the Chisos Mountains many wide and deep arroyos carry the heavy load of drainage from these high eminences.

## Soils

The soils of the Big Bend Region are more often transported than residual soils because of recent origin from surrounding highlands. Carter, Beck, Smith, Hawker, Templin, and Reitch (14) mapped the types in a reconnaissance survey of 1928.

Soils in the desert life belt are usually shallow and infertile, gravelly or sandy on the plains, with clay loams on the low slopes of cuestas. Alluvium occurs to a small extent along the main streams.

The only extensive deposits of gypsum in Trans-Pecos Texas are in Hueco and Culberson salt flats. There are no cacti on these playas whose high salt content restricts plant life to halophytes. Around Study Butte, there is a small deposit of gypsum with the usual calciphiles.[1] West

[1] T. Steyermark and T. A. Moore (64).

of the Christmas Mountains and in valleys within the mountains themselves, there are local patches of clayey soil that have such a high soluble mineral content that they cannot support plant cover of any kind. This soil is mined and sold as the fertilizer Min-Sol.

Texture, alkali content, and drainage of soil must be considered with respect to distribution of cacti. The pH factor was found to have no correlative effect except where excessively high in areas of halophytic vegetation and Min-Sol.

Chemical analyses, with acetic acid to test for lime, barium chloride and acetic acid to test for sulfate ion, and silver nitrate and acetic acid to test for chloride ion, were run on extractions of twelve soils which differed widely in cactus flora. The amount of chlorine and sulfate ions present seems to have no effect on the distribution of species of Opuntia.

Local conditions of soil drainage or porosity are another important factor governing local distribution. High areas with porous, well-drained gravelly or sandy soils, i. e. desert plains south and east of the Chisos Mountains, present the best development of natural cactus populations. Low-lying clayey wash areas have few cacti. Depth of soil cover has an indirect effect in that shallow soil eliminates many of the deep-rooted spatial competitors of the cacti.

Plant Associations as Indices

Closest correlations can be made between occurrence of the species of Opuntia and the sixteen distinct associations with their many local communities in the Big Bend Region. These plant communities are an accurate index to country rock, altitude, degree and exposure of slope, drainage, physical and chemical characteristics of soil and biotic disturbance. Tables 1 through 5 show which forms of Opuntia occur in each of the associations and to what degree of abundance.

Terms used for local distribution may be defined as follows:

<u>abundant</u>: conspicuously visible throughout the association.

<u>frequent</u>: scattered throughout association; a few visible from any spot.

<u>occasional</u>: widely scattered throughout association and only visible from a few places.

<u>rare</u>: encountered in a few localities with only one to several individuals there.

Desert Life Belt[1]

1) <u>Larrea-Flourensia</u>

The southern desert shrub formation is dominated by *Larrea divaricata* Cav., creosote bush. In the Big Bend Region it is associated with *Flourensia cernua* DC. wherever the soil is relatively deeper and contains more moisture, forming a creosote-blackbush association. Cacti are abundant and include *Opuntia Engelmannii*, *O. Grahamii*, *O. leptocaulis*, *O. macrocentra*, *O. phaeacantha*, *O. Schottii* and *O.*

[1]"A Life Belt is a vertical subdivision of a biotic province....(occurring under certain)...conditions of altitude and slope exposure." L. R. Dice, (23) p. 3.

*tenuispina*. Pure stands of evenly-spaced Larrea occur on gravel plains and clay washes. *Opuntia Grahamii* and *O. leptocaulis* are occasional sub-dominants.

2) *Dasylirion-Agave*

*Dasylirion leiophyllum Engelm.* and *Agave Lechuguilla* Torr. form the sotol-lechuguilla association which develops on gentle slopes of low desert hills with igneous or sedimentary rock debris. The most common Opuntiae are *O. Engelmannii*, *O. macrocentra*, *O. phaeacantha*, and *O. rufida*. *O. imbricata* occurs occasionally.

3) *Larrea-Agave*

Steeper talus slopes, limestone cuestas, and some desert flats support a Larrea-lechuguilla vegetation.

4) *Draw vegetation*

Desert draws etch a pattern of greenery through the pastel landscape with *Prosopis glandulosa* Torr., *Porlieria angustifolia* Gray, and species of Acacia. Very wide draws with extensive sandy bars support pure stands of *Hymenoclea monogyra* T. and C. with only sporadic plants of Opuntiae, usually the common species, *O. phaeacantha*.

*Local Communities*

*Fouquieria splendens* Engelm. may be a conspicuous element with Larrea where soil is very rocky or gravelly. *Larrea* is associated with *Prosopis glandulosa* Torr. on broad flats with deep, sandy and relatively moist soil. Some few plants of *Opuntia Engelmannii*, *O. macrocentra* and *O. phaeacantha* may be found there.

In small areas of brown Boquillas limestone, _Jatropha spathulata_ Muell. is codominant with Larrea, and _Opuntia macrocentra_, _O. rufida_ and _O. tenuispina_ are common. _Yucca Torreyi Shafer_ and _Agave Lechuguilla_ Torr. are predominant on coarse stony debris which makes a loose soil, too arid for good sotol development.

Dunes are formed in a few areas by the prevailing southwesterly winds acting on the shifting sands. _Prosopis glandulosa_ Torr. is often the only vegetation capping the two-to-five foot dunes; occasionally _Opuntia leptocaulis_ grows entangled in the mesquite stems. To my knowledge, these mesquite communities are best developed along the sandy upper reaches of Tornillo Creek in the Big Bend Park.

Small depressions and level divides in any part of the region always have a great mixture of species with various ecologic requirements, and dense thickets may develop. _Aloysia ligustrina_ (Lag.) Small may be very abundant locally. Usually there are few or no cacti.

5) _Flood Plain of the Rio Grande River_

Depending upon local edaphic conditions and width of the flood plain, thickets of _Baccharis glutinosa_ Pers., with _Opuntia Kleineae_ at Santa Elena Canyon; _Prosopis glandulosa_ Torr., or _Phragmites communis_ Trin. develop along the banks of the Rio Grande River. _Condalia spathulata_ Gray, _Prosopis odorata_ Torr., and _Populus Palmeri_ Sarg. are common associates. One salt cedar swamp was observed in Presidio County southeast of Ruidosa where stagnant pools, left from the flow of the Rio Grande, in the spring were concentrating salts by evaporation. No. cacti were found there.

## Arid Grassland Life Belt

Arid grassland, which is surrounded by mountains and desert shrubland, covers plains, plateaus and intermontane valleys from about 2500 feet to 5000 feet. Species of Bouteloua and Aristida are the predominant native cover, and are often found in association with woody shrubs.

6) Bouteloua-Aristida

Extensive flat plains with very fine soil are covered by grass alone, under natural conditions. Bouteloua gracilis (H.B.K. ) Lag., Bouteloua hirsuta Lag. and Aristida purpurea Nutt. are the most common species except where eliminated by poor grazing practices. Species of Muhlenbergia, Scleropogon, Andropogon, and Triodia are frequent components. Opuntia setispina and O. tortispina are of occasional occurrence only.

7) Hilaria mutica

Broad flat wash areas where the soil is crumbly, easily undermined, deep, fine and of a loamy to clayey nature are known as tobosa flats, and are almost exclusively occupied by Hilaria mutica.

In the arid grassland belt, Opuntia setispina and O. tortispina colonize the tobosa flats, frequently in codominant proportions. (Plate XLIII, Fig. 2).

In the desert shrub belt, this association is colonized almost exclusively by Opuntia macrocentra (with occasional plants of Echinocereus stramineus) since Opuntia setispina and O. tortispina are entirely restricted to grassland and encinal altitudes.

8) Bouteloua-Yucca

Where Yucca elata Engelm. and Yucca Torreyi Shafer have invaded broken grass cover on the broad plains, a short-grass-yucca association is established. Most of the Marfa Plateau supports this type of vegetation on a fine sandy soil. Specimens of Opuntia Engelmannii, O. imbricata and O. tortispina are usually present.

9) Bouteloua-Prosopis

Short grass-mesquite vegetation develops on low-lying deep, sandy soils with relatively greater supply of moisture. Frequently, Opuntia imbricata is a conspicuous subdominant which enters with disturbance of the cover. Other common species are O. Engelmannii, O. macrocentra, O. setispina, and O. tortispina.

Local Communities

Some of the shrubs commonly associated with the grassland associations are Microrhamnus ericoides Gray, Ephedra trifurca Torr., Nolina texana Wats., Koeberlinia spinosa Zucc., and species of Acacia and Mimosa.

Bouteloua and Nolina texana occur locally as a variant of the short grass-yucca community. Flourensia cernua occupies low-lying, poorly drained, clayey soils with occasional plants of Opuntia Engelmannii, O. leptocaulis, and rarely, O. setispina. Sandy areas of greater moisture content along desert, grassland, and mountainous washes support Fallugia paradoxa (Don) Endl.

A well-developed Bouteloua-Opuntia community is found in several broad valleys where soil is a deep, sandy loam. Opuntia imbricata is the only conspicuous cactus.

10) Stream-bed

Extensive groves of Juglans rupestris Engelm. occur along wide, gravelly stream-beds. Opuntiae are found sporadically where joints have apparently washed down and ultimately become rooted.

11) In Jeff Davis County, large trees of Populus Palmeri Sarg. form a narrow belt along some of the main streams with no cacti in evidence.

Encinal Life Belt

This chapparal-type of growth may adjoin grassland or desert shrub vegetation. Pure oak groves come in at grassland altitude on rocky outcrops.

12) Juniperus-Bouteloua

Species of Bouteloua and Juniperus monosperma (Engelm.) Sarg. occupy low slopes of valleys on loams and sandy loams at altitudes from 4500 feet to 5000 feet in grasslands, and are conspicuous above 5000 feet in the Chisos Mountains. In the grassland area plants of Opuntia Engelmannii, O. imbricata, O. phaeacantha, and O. tortispina are equally abundant. On limestone slopes, as in the Glass Mountains, this association is replaced by sotol-lechuguilla, and Opuntia Engelmannii x phaeacantha is most common.

13) Quercus-Juniperus

Species of oak, especially *Quercus grisea* Lieb., come in with *Juniperus monosperma* on rocky ridges, steeper slopes and higher altitudes with loose soil, from 5000 feet to 6000 feet. *Opuntia Engelmannii*, *O. imbricata*, *O. macrocentra* (locally). *O. phaeacantha* and *O. tortispina* are of frequent occurrence.

14) Pinus-Juniperus

Above 6000 feet *Pinus cembroides* Zucc. becomes conspicuous, forming a pine-juniper association with oak. *Opuntia Engelmannii*, *O. imbricata*, *O. phaeacantha*, and *O. tortispina* also occur here.

Montane Life Belt

15) Such components of Transition flora as *Pinus ponderosa* Dougl., and *Populus tremuloides* Michx. are found around the highest peaks of the Davis and Chisos Mountains at altitudes of 6500 to 7400 feet, depending upon the degree of shelter. *Opuntia polyacantha* is the sole representative of this genus in the Davis Mountains, and *O. Lindheimeri* var. *Chisosensis* is the sole representative in the Chisos Mountains.

Desert Mountains

The Chisos Mountains in the Big Bend National Park arise abruptly from the desert plains of Larrea and Flourensia at 3000 feet, and Vegetation on the slopes changes gradually from encinal associations to reach a small montane belt in high sheltered situations. The highest altitude reached is 7835 feet on Emory Peak. No grassland associations intervene between desert shrub and encinal belts, the absence of which eliminates occurrence of Opuntia Davisii and O. setispina, although one specimen of O. tortispina was found in these mountains.

Precipitation figures for the Chisos Basin for the three years of record show a high degree of correlation in curves for seasonal distribution of rain with maxima in July and August. Graph V .

The curve of monthly average temperatures from a two years' record is plotted for the Chisos Basin in Graph VI, and shows a very smooth and consistent increase to the summer months of June, July, and August, with a symmetrical drop to winter. The high temperatures of those summer months, when rainfall is heaviest, means that the precipitation will be less effective because of higher evaporation rates.

As slopes lead up to the rocky cores, Larrea-Flourensia association, with Opuntia leptocaulis and many plants of O. macrocenta, is replaced by Dasylirion-Agave at about 3900 feet, with Opuntia Engelmannii and a few O. macrocentra present. The latter association passes into Bouteloua-Juniperus with only Opuntia Engelmannii still evident, at 4500 feet. Quercus-Juniperus, with Opuntia Engelmannii and O. Lindheimeri var. chisosensis, comes in at 4800 feet. The Quercus-Pinus association develops at altitudes of about 5000 to 7800 feet. Opuntia Engelmannii, O. imbricata, O.

Lindheimeri var. chisosensis, O. phaeacantha, and O. tenuispina are usual consociates of this association in the Basin at 5500 feet. Plate II. Small patches of such montane elements as Pseudotsuga taxifolia (Poir) Rehder, Pinus ponderosa Eupressus Arizonica Greene and Juniperus flaccida Schlecht are found; some in Boot Hollow at 6500 feet, others in Pine Canyon at about 6200 feet, and in similar sheltered canyons. Only Opuntia Lindheimeri var. chisosensis, an occasional O. Engelmannii, and a small form of Echinocereus triglochidiatus, occur with this vegetation. Plate II shows a view across the Basin and through the Window to desert flats and buttes. On the slopes of the igneous hills, Opuntia Engelmannii is occasional, and O. Lindheimeri var. chisosensis is frequent, especially in the red-spined form.

Opuntia tenuispina, O. Engelmannii, and O. Lindheimeri var. chisosensis are abundant along gentle grassy slopes on the north side of the Basin. Opuntia imbricata becomes very abundant on the open slopes around and above the long-established Park Headquarter Buildings. Near the recently-built concession cabins and camp grounds, where there is a preponderance of trees and shade, Opuntia Engelmannii is one of the dominant shrubs with very few plants of O. imbricata. Some of the specimens of Opuntia Engelmannii are entirely spineless, and some of O. Lindheimeri var. chisosensis have developed very few spines.

Nine-Point Mesa is another type of eminence which arises from desert flats of Larrea-Agave vegetation to a higher plateau of Dasylirion-Agave, then rises abruptly to an altitude of 5100 feet with a badly overgrazed Quercus-Juniperus association. _Opuntia Engelmannii_, _O. imbricata_, and _O. tenuispina_ occur frequently on the summit. Rocky slopes of the sedimentary Christmas Mountains, with Dasylirion-Agave association, support many plants of Opuntia rufida; talus slopes of the ryolitic Rosillos Mountains, with Dasylirion and Yucca, support _Opuntia Engelmannii_, which is abundant, with a few plants of _O. macrocentra_ and _O. tenuispina_. No plants of _Opuntia rufida_ were observed.

In conclusion, altitude, through its concurrent effect on climate; degree and exposure of slope; and porosity of soil, constitute the three most evident factors in local distribution of species of Opuntia. The best cactus flora is developed on high, gravelly desert plains. Vicissitudes of chance, such as transportation by torrential drainage or by animals account for occasional isolates not in preferred habitats.

## Correlation with Biotic Factors

### _Ease of vegetative propagation_

Among Cylindropuntiae in the Big Bend Region, all except _O. imbricata_ have terminal joints which are easily detached where the narrow end joins the branch. If mature, these are capable of withstanding dessication until roots develop from areoles and take hold wherever the joint is lying. Any slight disturbance of the plant, usually by animals and the action of wind or rain causes detachment of joints, which are often carried some distance before coming to rest. The joint lies with only the basal end touching the ground, since the longest spines are at the terminal end. The plant is well-oriented for continued growth.

Platyopuntiae, which all have firmly attached joints, root easily from areoles of the spreading branches which lie along the ground. The branch may be cut off at any point by disease or fragmentation as long as there is one whole fairly mature joint, and a new individual is thus started. Even old segments of the base may sprout after months of natural dessication. (Plate V, Fig. 2) Therefore, a clone may have many separate individuals, each alike in genetic constitution. Hybridization can occur and sterile hybrids may be perpetuated in great numbers since vegetative reproduction is more successful than sexual. Polyploid forms likewise would tend to be maintained. Opuntia imbricata, O. Kleiniae, O. leptocaulis, O. phaeacantha, O. rufida, O. spinosibacca, and O. tunicata have fruits which proliferate joints, or may even metamorphose into joints each with its imbedded locule. (Plate V, Figs. 1 and 2). These eventually fall from the parent to start new individuals.

Fauna

Cattle, deer, peccary, rabbits and other animals help spread Opuntiae by fragmenting and detaching the joints either in browsing or brushing against them. Evidence of browsing on flat joints, especially of the spineless forms of Opuntia Engelmannii and O. macrocentra is common in the area. (Plate XLI, Fig. 1). Cattle usually develop bad mouth sores if they eat joints which have not been prepared by singeing.

Woodrats have been known to use detached joints to build barricades around the entrances of their burrows. All of these animals, as well as gophers, ground squirrels, mice, birds and ants, act as disseminators by eating the fruits of many cacti.

Species with spiny fruits, such as Opuntia Grahamii, O. polyacantha, O. Schottii, O. strigil and O. trichophora, and species with dry fruits, such as Opuntia Davisii, O. imbricata, and O. tunicata, are not much affected by animals. It is interesting to note that these fruits are mostly sterile as well, so propagation is predominantly vegetative. All the juicy, edible fruits have abundant seeds.

Cook (18), Riegel (55 ), and Timmons (57 ), have described coäctions among Opuntiae, jack rabbits and ground squirrels. Rabbits eat the fruits, seeds and all; some seeds pass out in the feces unharmed and are retrieved by ground squirrels who cache or plant them. The percentage of germination is often high in such cases.

Some insect damage is noticeable, but Opuntiae grow fast enough to outpace it. Fungus damage is more evident and more destructive, especially where there are extensive thickets of prickly pear, perhaps because the plants seem to fruit and vegetate more prolifically when they are badly infected.

Competition

Under natural conditions in desert shrubland, Opuntiae do not seem to compete strongly, either among themselves or with other types of plants. Their roots are of a generalized type, so they are able to obtain moisture from several levels. Seedlings are neither good invaders nor competitors, since they are extremely subject to trampling and being eaten.

Effect of Grazing

The higher region of arid grassland is completely surrounded by land of lower altitude with desert vegetation, which needs only a slight tipping of the balance of environmental factors to encroach upon the grassland cover. Under such critical tension, any heavy pressure of grazing which disturbs the solid grass cover is soon followed by invasion of such woody desert shrubs as *Microrhamnus ericoides*, Acacia spp., Koeberlinia, and Flourensia. These are favored in establishment during dry years.

The natural vegetation, consisting of many species of grasses, is best adapted under prevailing climatic conditions and cacti do not compete successfully to any extent. But cacti, especially the prickly pears, may be found wherever man has overstocked rangeland and destroyed native grasses. When such decrease of competition pressure occurs, the cacti invade in pest proportions. The massive *Opuntia Engelmannii* is one of the earliest invaders on barren rangeland. It becomes well-established in a few years through the fragmentation of its branches by stock. *Opuntia imbricata* is another common invader.

Eradication by grubbing and stacking is most effective, but even then many broken joints take root to start anew. This serious problem of preserving the natural grass cover by reduction in grazing stock is being met effectively by the United States Department of Agriculture Soil Conservation Offices in the Toyah-Limpia and Highland Districts. Steps are now being taken to organize a similarly efficacious program for Brewster County.

*Economic Uses*

The common species of Opuntia, as *O. Engelmannii* and *O. Lindheimeri* in Texas, are considered by ranchmen to be valuable emergency food, although nutritional value is relatively very low. Spines must be singed off before stock can eat the joints.

*Reaction on environment*

It is doubtful whether cacti can claim any role at all in the control of water erosion, since their roots are not extensive enough or, as in the case of Opuntiae, not sufficiently consolidated to hold the soil. In the matter of wind erosion, individual cacti might serve as wind breaks or nuclei for deposition, but I know of no evidence that this is effective in modifying the terrain. Certainly desert grasses, and Prosopis in some sandy areas, are far more effectual in those roles.

The important reaction of cacti on the environment is as a spiny shelter for other plants, especially grasses which are so important to the rancher. Where an area is heavily grazed, there are virtually no seeds of grasses left to perpetuate the species. But among the branches of each cactus plant, Echinocerei, some Coryphanthae, Ferocacti, and again especially the Opuntiae, the grasses are left undisturbed to go to seed, and will often be the last stands of good range grasses in the area. The succulent seedlings of members of Cactaceae likewise often start life in the shelter of a spiny parent or relative, while those germinating in the open are soon eaten or trampled. Seedlings of Opuntia imbricata seem to be the most hardy ones.

Habitations

There are often great thickets of Opuntia Engelmannii and O. phaeacantha around abandoned dwellings in desert country along the Rio Grande (i.e., near Vivianne Mine and Terlingua). These undoubtedly invaded the barren land disturbed by human trampling, were propagated by fragmentation, and overgrew the areas after the buildings were deserted. Masses of Opuntia Engelmannii and O. imbricata around the concession and Park Headquarter buildings and campgrounds in the Chisos Mountains, illustrate this type of invasion.

Introductions

Some few instances of introduction of cactus species by Mexicans were noted. On the west bank of Tornillo Creek, one mile north of its mouth, in a garden near an abandoned Mexican dwelling, several large bushes of O. linguiformis have become well-established, and will eventually become a part of the natural vegetation, at least along the mesquite thicket in that valley. Since this species has only been recorded as native in the vicinity around San Antonio, Texas and is not listed by Bravo ( 7 ), it is remarkable to find even an introduction so far afield. This human factor is not to be ignored, since spontaneous crossing is very likely to effect a whole wild population in the course of time. There is no evidence yet of modification of the population by introduced species, but it is by no means unlikely to become an important factor in evolution.

Cacti as plant indicators

The ubiquitous prickly pears serve immediate use as plant indicators, since a grassland area overgrown with these plants shouts of bad grazing practices, with a sheepman the usual culprit. (Plate XXXV and XXXVI, Fig. 2).

Aldous and Shantz ( 1 ) have this to say of the creosote bush-cactus type of vegetation:

> This type grows in rather broken or rocky areas in a southern New Mexico and the desert regions of Arizona, southern Nevada, and southeastern California. It is made up of scattered growth of creosote bush and an abundance of cacti, especially the barrel cactus and the round-stemmed

> opuntias...It is non-agricultural unless irrigated and of little or no value for grazing except over the large areas where it has invaded desert plains grassland.

This vegetation, excepting the large barrel cacti, also grows in western Texas and is illustrated in Plate XXIX, Fig. 2.

Transplant Experiment

On March 30, 1947, clones of *Opuntia Grahamii* from east of Mariscal Mountain, and of *O. macrocentra* from desert flats south of the Chisos Mountains were transplanted to an igneous outcropping just east of the Rosillos Mountain group. By June, 1948, *Opuntia Grahamii* had died, but *O. macrocentra* was growing well and showed little change in its characteristics.

A transplant plot was established on April 23, 1947, on the Victor Pierce Ranch in a valley of the Glass Mountains. Vegetation was Bouteloua-Juniperus, subject to grazing by sheep. The altitude was about 4600 feet, country rock a paleozoic limestone, soil a loam with high lime content and pH of 8.5. Exposure was gently sloping northwest in a sheltered valley with mountains on all sides.

One to several joints of *Opuntia Engelmannii* from Castolon and Chilicotal Mountain, *O. imbricata* var. *argentea* from Mariscal Mountain, *O. leptocaulis* from Castolon, Chilocotal and Mariscal Mountain, *O. macrocentra* from Castolon and northeast of Solis Ranch, *O. phaeacantha* from Castolon and Chilicotal Mountains, *O. rufida* from Chilicotal, and O. Schottii from northeast of Solis Ranch were planted and left until recollected on September 11, 1948. At that time, joints of Opuntia phaeacantha and O. rufida were dead but since root formation was negligible, it is more likely that these joints never took hold than that they were unadaptable. This experiment does indicate, however, that O. imbricata var. argentea and O. Schottii are not restricted to Mariscal Mountain and the desert life belt, respectively, by altitude or temperature limits, but perhaps have not yet spread as far as grassland or cannot invade the established vegetation successfully.

## AFFINITIES OF THE BIG BEND OPUNTIAE

### With Adjacent Provinces

A floristic affinity of this area with plains (Kansas Province) to the north is evinced by such grassland species as Opuntia Davisii, O. polyacantha, O. tortispina, and O. trichophora. These may possibly have migrated either way on paths following the Guadaloupe, Delaware, Apache and Davis Mountains, the adjoining valleys and high plateaus.

Opuntia Lindheimeri and O. Schottii grow in eastern and southern Texas (Comanchian Province) as well as in the Big Bend, the Stockton Plateau forming a natural bridge between the Basin and Range Section, Edwards Plateau, and the lower Coastal Plain Section. (Map X).

Opuntia Kleiniae, O. Pottsii, O. rufida, O. Schottii, O. setispina, O. tunicata, and perhaps O. spinosibacca, may have migrated from adjacent Mexico Chihuahuan Province across the Rio Grande River northward into desert and grassland associations. These have possibly migrated on long tongues of grassland which extend southward from latitude 30° along valleys sheltered by mesas, and it is equally possible that some of the migration may have been in the opposite direction.

The distributional areas of *Opuntia Engelmannii*, *O. macrocentra*, and *O. tenuispina* are more or less coincident with boundaries of the Chihuahuan and Apachian Provinces, and demonstrate an interchange in those floras.

General Distribution

Such species as *Opuntia setispina*, *O. rufida*, and *O. strigil* have relatively small ranges of distribution (Map XII). The two latter are also restricted in local range; *O. setispina* is more adaptable, being found throughout grassland and into woodland vegetation.

*Opuntia Davisii*, *O. Kleiniae*, *O. Lindheimeri*, and *O. Pottsii* have somewhat larger distributional areas (Map XIII). but all are sporadic in occurrence throughout the Trans-Pecos area, indicating a high degree of ecological restriction.

*Opuntia Engelmannii*, *O. imbricata*, *O. leptocaulis*, *O. polyacantha*, *O. tenuispina*, *O. tortispina*, and *O. trichophora* are species that are widespread throughout southwestern United States (Map XI). All except *O. polyacantha* and *O. trichophora* are also common in many habitats in the Big Bend. The latter two species may be found far south of their reported ranges in locally sheltered situations with montane vegetation. This definite correlation between extensive general distribution and widespread local distribution indicates that species vary greatly in degree of adaptability. Those which are found under many different conditions in an area have flexible ecological requirements which enable them to survive over greater expanses of territory than those which are specialized to one or a few habitats.

## EVOLUTIONARY IMPLICATIONS AND ENDEMISM

### Evolutionary Implications

The Opuntiae present an unusual problem in taxonomy with their plasticity; the highly-evolved, stem-like nature of the outer flower parts and of the fruits; and their overall response to environmental conditions.

After much study of these diverse forms, the author has come to interpret certain species, i.e. *Opuntia Engelmannii*, *O. phaeacantha*, and *O. tenuispina*, as consisting of polymorphous complexes with a continuum of graded variation within each species. This continuum may best be represented as a curve with minor peaks around which numerous individuals are clustered, more or less recognizable with distinctive combinations of characteristics. These peaks are separated by wide valleys where variants fall between one extreme, or peak, and the next peak, where another set of characteristics tends to occur in many individuals in a recognizable combination.

The trend in study of the genus has been toward lumping these varieties helter-skelter into a broadly defined species. Where there is no clear break in gradation this treatment is the most practical one, for most purposes. But one must not lose sight of the role the variants play in the complex; namely that of offering diverse material which may, through isolation, produce a potential new taxonomic entity.

Between two such species as _O._ _Grahamii_ and _O._ _Schottii_ intermediate forms which vary widely in resembling one or the other species have been interpreted in this study as hybrids because the variation has been expressed around a mean between the two parents rather than a continuous gradation from one to the other. Hybrids between _O._ _Engelmannii_ and _O._ _phaeacantha_ likewise form a highly variable population, whose representatives do not fit into either species but range around a mean between them. Individuals of _O._ _Kleiniae_ x _leptocaulis_ are far more restricted and of smaller number in the one locality where they do occur. The hybrid is clear-cut with characteristics always intermediate between _O._ _Kleiniae_ and _O._ _leptocaulis_.

If mutations occur, those affecting physiology may be much more significant than those affecting morphology, especially adaptations of response to moisture and in changes in time of flowering period so that genetic mixture with the parent type is rendered impossible.

Since time was lacking, in which to make chromosomal studies of these plants, it is not possible to state if any polyploids exist, as shown for Opuntia polyacantha by Stockwell (65). The O. phaeacantha complex suggests that sort of relationship.

The Opuntiae propogate vegetatively so readily that hybrids, mutants and polyploids are apt to form large colonies and may become distinct entities of a population.

Populations which seem to have little genetic variability, i. e. most of the Cylindropuntia group in our region, usually have greater habitat restriction and do not develop variants adapted to diverse environmental conditions. Evolution proceeds more slowly under constant conditions than if segments of the population were being subjected to a great variety of conditions. As populations of a genetically variable species spread out and adapt to more and more habitats, forming a number of variants, the possibility grows that some fraction of a population will become modified enough or isolated enough that a new species will evolve. The extreme diversity in topography of the Big Bend Region affords many small habitats separated by barriers of mountains or desert conditions.

Endemism

Each of the five varieties discussed in this study may be thought of as a potential source of new endemic types. Any especially adapted types which segregate out and attain dominance in a particular habitat are potential new species. <u>Opuntia spinosibacca</u> sp. nov. is the only known endemic Opuntia of the Big Bend which is considered to be of specific rank. The Big Bend region is therefore not one marked by extreme endemism so far as the Opuntiae are concerned.

The general flora extends north to southern New Mexico and south far into Mexico and the whole area to which the Big Bend belongs does have certain characteristics of a region of local endemism. The endemics in Opuntia are such as might be regarded as extreme selections from interbreeding polymorphic populations forming prevailing populations by propagation in favorable habitats. It must be borne in mind that in Opuntia the establishment as ecological dominants of especially adapted types is much facilitated by dispersal of joints and subsequent vegetative propagation.

## PART IV - TAXONOMIC DISCUSSION

### METHODS OF DESCRIPTION

I have undertaken to give as detailed descriptions as possible for each species, variety and hybrid, in accordance with past practice, and have also added consideration of bristles, details of floral parts, umbilicus, seed structure, seedlings and size of stomata. Nowhere in the literature are these cacti completely described with consistent contrasting of characteristics covering a broad range of variation and with up-to-date distributional data.

Mention of the absence of a characteristic, such as glaucousness, is omitted in description, since it would be included if present.

All except generic descriptions are based on observations from my own field work, herbarium and living collections. I did not feel justified in interpreting herbarium material from other regions, without having had field experience there also. The Cactaceae are particularly difficult to represent accurately by dried material alone. At least this is true of such material as casual collectors generally prepare, but it is possible to do much better if there is adequate time to devote to proper selection and preparation of specimens. (See section on Special Methods).

Ranges of variation are based on not less than ten samples of each character wherever sufficient material was available.

A number of terms peculiar to the Cactaceae are used in the descriptions. JOINTS are stem segments; the sessile leaves on young joints and ovary subtend the young areole and are caducous. The AREOLE is interpreted by Boke ( 5 ) as an axillary bud on an enlarged and persistent leaf base; it is an elliptic to circular break in the epidermis, filled with wool, some glochids (usually in the upper end), occasionally a few glands, and often with spines and bristles. (Plate VII, Fig. 1). Anatomically the WOOL consists of uniseriate, multicellular living hairs.[1] Color of wool is described as it appears in the areole; it is usually paler toward the base if examined by extraction. GLOCHIDS are structures restricted to the subtribe Opuntieae and resembling spines in having retorse barbs and stiff, multicellular structure but differing in much smaller size and ready detachment from the areole. They are often difficult to see. BRISTLES are intermediate in size between glochids and spines. They are weakly barbed and not as readily detached as are the glochids, less stout and persistent than the spines. They are usually white to gray and always deflexed in Opuntia. SPINES are described by Boke ( 6 ) as modified rudimentary bud scales and leaves. They are capable of regeneration.

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[1] A. F. Hemenway and M. J. Allen (39).

SHEATHS which occur in some Cylindropuntiae are formed by hairs closing over the spines in growth.

Flowering periods given are approximate because of variable climatic conditions, effect of drought in delaying the season and deficient observation, caused by the necessity of extensive travelling over the region at widely different altitudes. **(Table 17).**

Sepals grade imperceptably into petals so the terms OUTER and INNER PERIANTH SEGMENTS are employed. Floral parts are attached to the upper end of the ovary and leave a scar when the dried perianth falls off; this scar is termed the UMBILICUS. (Plate VII, Fig. 3) The OVARY is actually a fleshy hypanthium. The ARIL of the seed is an outgrowth of the funicle which is expanded in one plane, forming a thin to wide flange around the embryo, (Plate VII, Figs. 4 and 6). A small amount of endosperm is enclosed in the curve of the embryo.

"Rough" or "smooth" refers to the presence or lack of an angle between the body of the seed and the aril. If the aril is wing-like, the seed is "rough," as are the seeds of most species here discussed. If there is smooth gradation from the aril to the body of the seed, it is "smooth." (Plate VII, Fig. 6).

Seeds of Opuntia tortispina and O. tunicata occasionally have double embryos and two seedlings grow up side by side. One is always larger, greener and more apt to survive. Even if the larger one is removed early, the weaker, pinkish seedling does not persist. A very low percentage of tricotyledonous seedlings was observed in *Opuntia Engelmannii*, *O. Kleiniae* x *leptocaulis* hyb. nov. and *O. leptocaulis* germinated at the Botanical Gardens.

Stomata on joints were difficult to observe because of abundant calcium-oxylate crystal formation in the hypodermis. Therefore epidermal strips from leaves were examined under a compound microscope with ocular micrometer. Stomata from leaves and cotyledons of the same specimens showed no significant difference. Stomata of various species showed differences of from 1 to 23 µ in length, this difference established by ten measurements for each specimen. The total range in size of stomata is from 20.9 µ to 43.2 µ, but did not differ significantly in the distance apart. A graded series of increasing sizes of stomata shows no evident correlation with any other factor, Table 16. Cylindropuntiae tend to have somewhat smaller stomata than the Platyopuntiae. Two accessory epidermal cells are present with each stoma, (Plate VII, Fig. 2). The following species have epidermal cells with more or less straight walls: *Opuntia Davisii*, *O. imbricata*, *O. Kleiniae* x *leptocaulis*, *O. macrocentra* var. *minor*, and *O. tunicata*. The others have more or less lobed cell walls.

The lattice pattern of old wood skeletons, (Plate VIII, Fig. 1 ), is caused by the reticulate nature of the dictyostele, each gap being a vascular break where tissue terminated in an areole.

## DISTINGUISHING CHARACTERISTICS FOR SPECIES

The Opuntiae are a plastic group and grow under such adverse climatic and edaphic conditions that there are few taxonomic characteristics not subject to considerable modification. Tables 9 through 17 summarize occurrence of certain taxonomic characteristics in all forms of Opuntiae here discussed.

Habit of growth is relatively constant, ranging from prostrate through large-shrubby to arborescent. Of the species under consideration, two of the Cylindropuntiae group and one of the Platyopuntiae group have tuberous roots; the others are all fibrous, although the taproot may be somewhat fleshy in _Opuntia imbricata_, _O. phaeacantha_ and _O. tortispina_. (Plate IX, Figs. 1 and 2). Distance between areoles is another constant taxonomic characteristic. Areoles are relatively closely set in eleven of the species.

Number of spines and bristles per areole varies somewhat among individuals but each species has a consistent tendency for this number to fall within a certain range. Only a few species bear areoles with almost all the spines deflexed. Definite bristles are always lacking in six of the species, may be present or absent in some, or always present in still others.

In floral structure the style is short and thick in six species, definitely long and narrow in eight others, and intermediate in the remaining types of flowers studied.

About half of the Opuntiae have juicy fruits and half have dry fruits. The latter type is far more common among the Cylindropuntiae, which also have more joint-like fruits. Opuntia Davisii, O. Grahamii, O. Schottii, O. trichophora and O. tunicata usually have sterile fruits. They appear to be completely adapted to vegetative propagation. Spiny or very bristly fruits occur in six of the Opuntiae. Most fruits have a more or less v-shaped umbilicus but a very shallow, saucer-shaped umbilicus is characteristic of three species.

A sixth of the species have relatively minute seeds; measurements of seed size are remarkably constant within a population. A few of the species have definitely beaked seeds. Wide arils are distinctive in about half of the Opuntiae.

Cotyledons of seedlings are always more or less unequal; in some species they are long and thin, in others short and thick. The tips may be obtuse or acute. Altogether, however, these differences are not large enough to constitute specific characteristics. (Plate X, Figs. 1 and 2.)

In summary, the most important differences between species are in habit, distance between areoles, and size of seed and nature of the aril, whether sharply flanged or beaked, (Plate VII, Fig. 5), or with an undifferentiated aril. Other differences are less outstanding but nevertheless do help in identification of the plants.

## VARIATION OF CHARACTERISTICS WITHIN SPECIES

The significance of variation within species with regard to speciation is discussed under a previous chapter entitled "Evolutionary Implications," page 45.

Within species greatest variation is expressed in size of leaves, proportion of spine-bearing areoles on joint, number of spines per areole, and length and color of individual spines. A smaller range of variation occurs in presence or absence of trunk, amount of glaucous covering of joints, (only *Opuntia polyacantha* has joints which entirely lack a glaucous surface), color and number of stigma lobes, as well as size and shape of ovary and fruit.

Variation is more frequent where critical environmental conditions change sharply within a small area because of local differences in water supply, exposure, altitude or soil. Plants of Opuntia growing in the shade of densely-branched trees are often so modified with elongate joints, areoles further apart and many less spines than is typical (Plate VIII, Fig. 2) that they are difficult to identify correctly except after experience in growing them under uniform conditions.

Some species are inherently more variable than others. All Cylindropuntiae of the area were constant in appearance or had very distinct varieties, as *Opuntia leptocaulis* var. *brevispina* and *O. imbricata* var. *argentea*. Populations of the hybrid *O. Grahamii* x *Schottii*, however, show considerable variation as they tend to resemble one or the other of the parents. In the Platyopuntiae great variation is shown among individuals of Opuntia Engelmannii, O. Lindheimeri, O. phaeacantha, and O. tortispina. This is attested by lengthy synonymy.

These more variable species with local races adapted to diverse habitats are also among those with widest local distribution, excepting Opuntia Lindheimeri and O. polyacantha, which in our area, are really at the western and southern edges, respectively, of their ranges.

Six species have distinct varieties, namely O. Engelmannii var. Wootonii, O. imbricata var. argentea var. nov., O. leptocaulis var. brevispina, O. Lindheimeri var. chisosensis var. nov., O. macrocentra var. minor var. nov. and O. rufida var. tortiflora var. nov.

## HYBRIDS

Hybrids have been found between Opuntia Grahamii and O. Schottii, O. Kleiniae and O. leptocaulis and O. Engelmanii and O. phaeacantha. Only the latter hybrid has fruits which are usually fertile, but the two hybrid Cylindropuntiae can reproduce prolifically by fragmentation. The parent species of each overlap in their flowering periods, are present in the same locality with the hybrids and the hybrid individuals are intermediate between them. One specimen of a plant which looks like a hybrid of O. setispina and O. tortispina was collected. The living specimen has not yet flowered, so its fruits are unknown.

## THE GENUS OPUNTIA

The genus Opuntia Miller has three subgenera, based on form of the stem joint. Cylindropuntia includes species with cylindrical stems throughout. These are considered more primitive than the other subgenera in phylogeny because they have woody stems, relatively large, succulent leaves, and bear tubercles.

Species in Tephrocactus show a transition from the cylindrical joints of Cylindropuntia to the flat joints of Platyopuntia. Since they are entirely restricted to South America, they are not considered here.

The majority of our southwestern species of Opuntia are in the Platyopuntia group, known colloquially as prickly pears. This group has at least some flat joints which are tuberculate, and spines which are always sheathless.

Opuntia (Tournefort) Miller

Cactodendron Bigelow, Pac. R.R.Rep. 3:102; 4:7, 11, ill. 1856.

Consolea Lemaire, Rev. Hort. 1862: 174. 1862.
Tephrocactus Lemaire, Cact. 88. 1868.
Cactus Lemaire, Cactees 86. 1868. Not Linnaeus, 1753.
Ficusindica St. Lager, Ann. Soc. Bot. Lyon 7:30. 1880.
Brasiliopuntia Knuth, Kaktus A.B.C. 147. 1935.
Corynopuntia Knuth, ibid. 114. 1935.
Cylindropuntia Knuth, ibid. 117. 1935.
Tephrocactus Knuth, ibid. 104. 1935.

Common names: (Cylindropuntia) - "abrojos", "alfilerillo", "cane cactus", "cardenches", "chirrioncillos", "cholla", "choyas", "fosajillo", "tasajo"; (Platyopuntia) - "bullsucker", "nopales" ( "cimarrones, monteces and rastreros"), "prickly pear", "sucker", "tuna". PLANTS forming low clumps, small to large shrubs, or trees; TRUNK present or absent; BRANCHES prostrate, creeping, spreading, or ascending, with 3 to many joints, one species (O. Chaffeyi) with annual stems; ROOTS mostly fibrous, rarely tuberous; JOINTS cylindrical, globose to flat, succulent, with or without glaucous covering, rarely pubescent, yellow-green to blue-green; TUBERCLES present in some species, with areole at base of upper end; LEAVES arising from base of areoles with spines on 3 upper sides, mostly relatively small, subulate, terete, succulent, caducous; AREOLES arranged in spiral order, axillary in deciduous leaves, becoming larger and more closely set along upper margins toward apex of joints, bearing wool, glochids, bristles, spines, occasionally with glands; WOOL present in all areoles, usually persistent; SPINES from lower part of areole, longer spines above shorter ones, from none or upper or all of areoles on joint, porrect, spreading or deflexed, barded at apical end, terete, elliptic, angular or flattened dorso-ventrally, straight, curved or twisted spirally, naked or sheathed, stiff or flexible, papery in a few Tephrocacti, mostly white, yellow, red, brown or black, color sometimes in annulate bands, spines often more abundant in age; BRISTLES occasionally present in lower margins of areole, stiff, deflexed, usually of pale color and persistent; GLOCHIDS mostly in upper end of areole, stiff, in rows or concentric circles, especially conspicuous in apical and marginal areoles; FLOWER BUDS from upper end of areole, between glochids and spines; FLOWERS mostly diurnal, sessile, some combination of green, yellow or red, corolla rotate, no definite sepals and petals but outer perianth segments grading into inner ones, in 3 to 5 whorls, segments always broader toward apex, fimbriate or entire margins, mucronate or emarginate; STAMENS attached along throat of corolla, sensitive, anthers attached at one end; STYLE longer than stamens, bulbous at or near base, stigma with 3 to 12 lobes; OVARY inferior, embedded in fleshy receptacle, one-celled, many ovuled, bearing areoles with subulate, apiculate leaves, wool and glochids, sometimes with bristles or spines; FRUIT a dry or juicy berry, often edible, sweet, insipid, non-acid, with areoles bearing wool and sometimes glochids, bristles and/or spines, globular, obovoid, ellipsoid, often capable of proliferation from areoles, of roots, vegetative shoots or less commonly one to many successive flowers; FLESH sparse to abundant; UMBILICUS a conspicuous scar, saucer-shaped to V-shaped; SEEDS flattened, circular or angularly-shaped, smooth or rough, none to many per fruit, yellow, yellowish-green, or brown, with narrow to wide, bony aril, usually notched at hilum, sometimes beaked, never shed from fruit, small amount of endosperm enclosed by u-shaped embryo, occasionally with double embryo; SEEDLINGS with 2 to 3 succulent foliacious cotyledons, these often unequal; STOMATA abundant on all sides of cotyledons, leaves and joints, with 2 accessory epidermal cells. DISTRIBUTION: Dry or sandy places from Peace River, Alberta, Canada (possibly from Alaska), from east coast to west coast in United States, throughout Central America, to Magellan Straits in South America and on the Galapagos Islands. Naturalized around Mediterranean Sea, in India, Australia, New Zealand, Philippine Islands and Hawaiian Islands.

KEY TO OPUNTIAE OF THE BIG BEND REGION

Many species of Opuntia bloom sporadically. Consequently, numbers of individuals are encountered with only vegetative characteristics as a clue to identity. Furthermore, flowers and fruits of closely related species, as _Opuntia Engelmannii_ and _O. phaeacantha_, _O. Grahamii_ and _O. Schottii_, are variable enough within a species so that clear-cut distinctions based on these alone would be most difficult. Flowers and fruits are equally difficult to distinguish when dried because of their succulent nature. Between definable extremes of difference in shape and size of perianth segments and pistil, there is often a gradation so far as these organs alone are concerned, from one species to a closely related one.

For these reasons the following key is not based principally upon the usual characteristics of reproductive structures, but upon habit and other vegetative features which are more readily recognized and are of more practical field use. Knowledge of the appearance of the plant as a whole is almost prerequisite to interpretation of its fragments. The key is based on mature plants because immature individuals with only a few small joints lack definite characters. If habit is not known, such other characteristics as shape of joint, spine-arrangement, flowers and color and nature of fruit may be used to identify specimens.

| | | | Page |
|---|---|---|---|
| 1. | Joints cylindrical -- CYLINDROPUNTIA . . . . . . | (3) | 67 |
| 2. | Joints flattened to form "pads" -- PLATYOPUNTIA | (5) | 120 |
| 3. | Branches ascending, joints linear-oblong, spines sheathed . . . . . . . . . . . . . . . . . . . . | (7) | |
| 4. | Branches prostrate, only terminal joints ascending, joints clavate tubercles broad spines scabrous, without sheaths . . . . . . . . . . . | (9) | |
| 5. | Plant a large bush, surface glabrous or pubescent | (11) | |
| 6. | Plant a small bush, surface glabrous . . . . . . | (13) | |
| 7. | Habit shrubby to arborescent, tubercles strong, laterally compressed . . . . . . . . . . . . . . | (15) | |
| 8. | Habit bushy, ultimate joints less than 16 mm. thick, readily detached, some long, others always short and relatively spineless, tubercles weak or absent spines sheathed . . . . . | (17) | |
| 9. | Joints 4.5 - 7 cm. long tubercless weak spines acicular, mostly terete, only a few flattened, leaves long subulate . . . . . . . . . . | **O. Grahamii** | 107 |
| 10. | Spines subulate, mostly flattened, leaves short subulate . . . . . . . . . . . . . . . . . . . . . | (21) | |
| 11. | Surface pubescent, branches mostly ascending, joints relatively thick, spines always absent | (23) | |
| 12. | Surface pubescent, branches mostly ascending, joints relatively thick, spines always absent | (25) | |
| 13. | Branches creeping, only terminal joints ascending, roots fibrous, joints obovate to elliptic, areoles closely-set, spines acicular, from all but lowermost areoles, fruit spiny . . . . | (27) | |

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14. Plant small, inconspicuous, branches ascending, with only 2-3 small joints, reaching 2.5 dm. in height, roots tuberous, flower rose-red, fruit pale dull purple . . . . . . . . O. Pottsii 201

15. Shrubs or trees with definite erect trunk . . (31)

16. Low clump with many short, erect branches, up to 5 dm. high, no definite trunk, ultimate joints mostly 2.5 cm. in diameter, tubercles about 30 mm. long, 3 mm. wide, 12 mm. high, spines yellow with whitish sheaths, flowers yellow . . . . . . . . . . . . . . . O. tunicata 82

17. Ultimate joints 6-15 mm. thick, short ones mostly 5-7 cm. long, gently curving upwards, arising at acute angles to branch, surface somewhat tuberculate, flowers rose or pinkish-brown . . . . . . . . . . . . . . . . . . .(35)

18. Ultimate joints 5-6 mm. thick, short ones mostly 2-4 cm. long, sharply curved upwards, arising mostly at right angles to branch, surface lacking protuberances, flower lemon yellow, about 2.2 cm. long . . . . . . . . . (37)

21. Spines 1.5-2 mm. wide, joints 2.5-9 cm. long, strongly tuberculate . . . . . . . . O. Schottii 111

22. Joints 2.5-6.3 cm. long, tubercles only moderately developed, spines .5-1.3 mm. wide . . . . . . . . . . . . . O. Grahamii x Schottii 117

23. Joints relatively thick, areoles distant . . (47)

24. Joints thin to thick, mostly orbicular, (elongate in O. tortispina), areoles closely set (49)

25. Areoles mostly 17 cm. apart, joints obovate, perianth segments broad lanceolate and not swirled . . . . . . . . . . . . . . . . . . O. rufida 163

26. Areoles mostly 12 cm. apart, joints short obovate to short elliptic, outer perianth segments narrow lanceolate and swirled . . . . . . . . . . . O. rufida var. tortiflora 167

27. Joints obovate, long spines porrect in marginal areoles, hairs absent . . . O. polyacantha 193

28. Joints long-elliptic, spines all spreading downwards, long hairs conspicuous on older joints . . . . . . . . . . . . . . . . . . . . O. trichophora 198

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31. Tall shrubs to trees, ultimate joints 1.5-4 cm. thick, flowers magenta . . . . . . . . . . . (63)

32. Small shrubs, up to 7.5 dm. high, ultimate joints .6-2 cm. in diameter, typically wrinkled, tubercles about 25 mm. long, 7 mm. wide, 7 mm. high, spines yellow or rufous, with yellow sheaths, flower yellow . . O. Davisii 78

35. Ultimate joints 7-15 mm. thick, short ones mostly 7 cm. long, flowers dull rose, about 4 cm. long . . . . . . . . . . . O. Kleiniae 88

36. Ultimate joints to 8 mm. in diameter, short ones mostly 5 cm. long, flower pinkish brown, 2.5-3 cm. long. O. Kleiniae x leptocaulis 103

37. Spines 3-5 cm. long, with conspicuous persistent sheaths . . . . . . . . . . O. leptocaulis 94

38. Spines .8-2.8 cm. long, with fugacious sheaths . . . . . . . . . O. leptocaulis var. brevispina 102

47. Branches all ascending to 2.5 m. in height, joints with elongate, cow-tongue shape, spines acicular, bristles absent, flower yellow . . . . . . . . . . . . . . O. linguiformis 120

48. Branches spreading and ascending, joints obovate to orbicular, spines subulate, 2.5 spreading, only one shorter spine deflexed . . . . . . . . . . . . . . . . . . . . (97)

49. Spines acicular, from areoles on upper half of joint, radial spines or bristles lacking . (99)

50. Long spines subulate, radial spines acicular, from all but lowermost areoles, spreading downwards . . . . . . . . . . . . . . . . . (101)

63. From 1.5-6 m. in height, tubercles 3 cm. long and 8 mm. high or more, spines yellow or reddish-brown, with dull white sheaths . . . . . . . . . . . . . . . . . . . . . O. imbricata 67

64. From 6-12 m. in height, tubercles only 2 cm. long and 5 mm. high, spines silver with silver sheaths . . . O. imbricata var. argentea 75

97. Spines tereteor elliptic, spreading outward, fruit small obovate to pyriform, seeds relatively large, 4-7 mm. in diameter . . . . (195)

Page

98. Spines flattened, mostly spreading downward, fruit large pyriform, seeds small, 2.5-4 mm. in diameter . . . . . . . . . . . . . . . . . . (197)

99. Joints relatively thin, usually 4-6 mm. in thickness, spines 0-7, mostly spreading upwards, more or less rufous . . . . . . . (199)

100. Joints relatively thick, about 10 mm. thick, spines 1-10 per areole, mostly spreading downwards, brown or black with white above . . . . . . . . . . . . . . . . . . . . . . . <u>O.</u> <u>setispina</u> 178

101. Branches spreading and ascending, joints mostly orbicular, spines dark reddish-brown with yellow tips, fruit spiny . . . . . <u>O.</u> <u>strigil</u> 182

102. Branches mostly spreading, little ascending, forming a low, wide-spread bush, joints long-obovate, spines red to orange below, white above, spreading outwards and downwards, twisted spirally, fruit naked . . <u>O.</u> <u>tortispina</u> 186

195. Branches ascending to form a tall bush, joints somewhat tuberculate, 2-4 rufous spines per areole, 2 conspicuous bristles, ovary and fruit spiny . . . . . . . . . . . <u>O.</u> <u>spinosibacca</u> 120

196. Some or all branches spreading to form extensive bush, joints not tuberculate, ovary and fruit without spines . . . . . . . . . . . . . . . . (393)

197. Areoles ovate, young spines white, older spines reddish-brown and white, bristles often present, glochids rufous . . . . . . . (395)

198. Areoles circular to elliptic, spines yellow to reddish-brown throughout, bristles always absent . . . . . . . . . . . . . . . . . . . . . (397)

199. Branches spreading and ascending gradually, joints usually more than 11 cm. long and 8 cm. wide, spines reddish-brown below, white above . . . . . . . . . . . <u>O.</u> <u>macrocentra</u> 168

200. Branches mostly spreading, a few ascending vertically, joints to 10 cm. in length and 7 cm. in width, spines rufous throughout . . . . . . . . . . <u>O.</u> <u>macrocentra</u> var. <u>minor</u> 175

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393. Branches spreading and ascending, most spines spreading outward, subulate, joints thick . (787)

394. Branches mostly spreading, joints thin spines terete acicular, from upper areoles, 1 long, porrect, 1-2 others spreading downward, dark rufous to black at base, white toward tip, conspicuous rufous or yellow glochids, fruit oblong to short pyriform . . . . . O. tenuispina 151

395. Branches mostly ascending, joints short-obovate to orbicular, spines 3-5.6 cm. long . . . . . . . . . . . . . . . . . . O. Engelmannii 141

396. Branches mostly spreading, joints long-obovate with attenuate base, spines 5.5-7.3 cm. long . . . . . . . . O. Engelmannii var. Wootonii 149

397. Areoles circular, spines straight, twisted spirally, fruit large pyriform, to 7 cm. long . . . . . . . . . . . . . . . . . . O. Lindheimeri 156

398. Areoles long-elliptic, spines curved, not twisted, fruit globular, to 4.5 cm. long . . . . . . . . . O. Lindheimeri var. chisosensis 160

787. Two to five reddish-brown spines per areole, mostly in areoles on upper third of joint (1475)

788. Three to four yellow spines per areole, young spines white, old spines black . . . . O. azurea 125

1475. Joints 9-23 cm. long, 6-19 cm. wide, areoles not elevated, spines terete, young spines rufous and white . . . . . . . . . . . . . . O. phaeacantha 127

1476. Joints 15-45 cm. long, 12-40 cm. wide, areoles somewhat elevated, spines more or less flattened, young spines blackish O. Engelmannii x phaeacantha 136

In the following descriptive discussions, citation of the type description differs from that given by Britton and Rose (11) in instances where they use "Proc. Amer. Acad. 3, 1856," which is Engelmann's "Synopsis of the Cactaceae of the Territory of the United States and Adjacent Regions." Engelmann himself uses E. & B. as authorities for the species in question; the complete original descriptions are given in

"The Report of the United States and Mexican Boundary Survey" 11, Pt. 1, 1859, which includes "Cactaceae of the Boundary."

In the citation of the specimens examined from herbaria, the type specimens for each species and variety are preceded by an asterisk (*). The abbreviations for the herbaria are listed below following the standards set up by Lanjouw (44), except in omission of the period:

| | |
|---|---|
| Allan Hancock Foundation, University of Southern California | (AHLA)[1] |
| University of Arizona | (ARIZ) |
| Dudley Herbarium of Stanford University | (DS) |
| University of Michigan | (MICH) |
| Missouri Botanical Garden | (MO) |
| New York Botanical Garden | (NY) |
| University of Texas | (TEX) |
| United States National Herbarium | (US) |

Since the actual species descriptions are based upon my own collections, citation of those specimens as a group, follows citation of material from other herbaria. To spare repetition it may be stated here that those specimens are all from counties in Texas, have my own collection number unless otherwise stated, and are in the herbarium of the University of Michigan, (MICH). Altitudes given are all approximate within one hundred feet.

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[1]Lanjouw (44) did not list this herbarium so I have given my own abbreviation.

A study of the extensive collection of Opuntiae under cultivation at the University Botanical Gardens has augmented my understanding of this genus.

## CYLINDROPUNTIA

Opuntia imbricata (Haworth) De Candolle, Prodr. Sys. Nat. Reg. Veg. 3:471, 1828.

Cereus imbricatus Haworth, Rev. Pl. Succ. 70. 1821.
Cactus cylindricus James, Cat. 182. 1825. Not Lamarck. 1783.
Cactus ~~ble~~ Torrey, Ann. Lyc. N. Y. 2:202. 1828. Not Humboldt, Bonpland, and Kunth. 1823.
Opuntia rosea De Candolle, Prodr. 3:471. 1828.
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Opuntia exuviata De Candolle, Mém. Mus. Hist. Nat. Paris 17: 118. 1828.
Opuntia exuviata augustior De Candolle, Mém. Mus. Hist. Nat. Paris 17:118. 1828.
Opuntia exuviata spinosior De Candolle, Mém. Mus. Hist. Nat. Paris 17:118. 1828.
Opuntia exuviata stellata Lemaire, Cact. Gen. Nov. Sp. 67. 1839.
Opuntia exuviata viridior Salm-Dyck, Cact. Hort. Dyck. 1844. 48. 1845.
Opuntia arborescens Engelmann in Wislizenus, Mém. Tour. North. Mex. 90. 1848.
Opuntia imbricata crassior Salm-Dyck, Cact. Hort. Dyck. 1849. 249. 1850.
Opuntia imbricata ramosior Salm-Dyck, Cact. Hort. Dyck. 1849. 73. 1850.
Opuntia imbricata tenuior Salm-Dyck, Cact. Hort. Dyck. 1849. 73. 1850.
Cactus imbricatus Lemaire, Cactees 88. 1868.
Opuntia vexams Griffiths, Rep. Mo. Bot. Gard. 22:28. 1912.
Opuntia magna Griffiths, Proc. Biol. Soc. Wash. 27:23. 1914.
Opuntia spinotecta Griffiths, Proc. Biol. Soc. Wash. 27: 24, 1914.
Cylindropuntia imbricata Knuth. Kaktus A.B.C. 125. 1935.

Common names: "cardenche", "cardon", "coyonostle", "coyonostli", "coyonoxtle", "entrana", "foconoztle", goconoxtie", "jaconoxtli", "joconostle", "joconoxtle", "tasajo", "tuna huell", "tuna joconoxtli", "tuna juell", "velas de coyote", "xoconochtli", "xoconostle", "xoconostli", "candelabrum cactus", "cane cactus", "cholla", "tree cactus".

PLANT bushy and arborescent, often 1.5-4.5 m. high, 1.5 m. wide at crown; TRUNK short, thick, woody, soon branching, 7.5-20 cm. in diameter; BARK 3-4 mm. thick, rough, black with yellow wood showing through; BRANCHES many, sturdy, spreading to erect, to 7.5 cm. in diameter; ROOTS fibrous but tap root often fleshy; ultimate JOINTS shorter, verticillate, 2-6 arising at right angles or curving upwards, from the node, not readily detached, 15-28 cm. long, 2-4.1 cm. in diameter; strongly tuberculate, with tubercles,long-elliptic, laterally compressed 30-45 mm. long, 5-10 mm. wide, 8-15 mm. high; glaucous, TEXTURE fibrous, gray-green with purplish tinge on tubercles; dry; LEAVES narrowly subulate, shortly mucronate, terete, recurving at tips, 9-17 mm. long, 1-2 mm. wide, bright green to purple; AREOLES at upper ends of tubercles, relatively distant, 11-20 mm. apart, long-elliptic to ovate, large, 7-10 mm. long, 4-7 mm. wide, becoming no larger but more spiny in age; WOOL abundant, creamy or yellow, becoming tan or gray; SPINES 11-24, from bases of all areoles, somewhat flattened, neither twisted nor curved, unequal young spines white, or greenish at base; 6-14 central spines, longer, 2.3-4 cm. long subulate, spreading, reddish-brown with yellow or orange tips, and loose, persistent, dull-white sheaths with yellow tips, 5-10 radial spines around lower half of areole, shorter, 8-2.5 cm. long acicular, spreading, creamy to grayish, without sheaths; BRISTLES indistinguishable; GLOCHIDS inconspicuous in very short tufts at upper ends of areoles, 2 mm. long, yellow when young, white to pale yellow in older areoles; FLOWER BUDS from areoles near tips of terminal joints, 2-6 in a cluster, conic; FLOWER relatively small, up to 4 cm. long and 5 cm. across; with perianth segments in 3 whorls, outer segments with light magenta margins, olive green trace short obovate, apiculate, to 2 cm. long and 2 cm. wide, inner segments magenta or less commonly pale pink, long-obovate to spatulate, mucronate, margins entire, up to 3.4 cm. long, 1.6-2.9 cm. wide; FILAMENTS magenta, rarely green, to 12 mm. long, anthers white to yellow; STYLE creamy white to pinkish, bulbous and 4 mm. in diameter, above base, 17-24 mm. long, stigma lobes 6-9, yellow, 2-10 mm. long; OVARY bristly above, tuberculate, short oblong to obovate with truncate base, 1.6-3.7 cm. long, 2.5-3.0 cm. in diameter with linear-oblong tubercles, areoles oval, uppermost ones bearing scales 6 mm. long, 2 mm.wide, white to tan wool, a few, very short, inconspicuous, white glochids; 1-9 setiform bristles, white with pinkish bases in areoles of upper half of ovary; FRUIT abundant persistent for more than a year, dry, oblong to obovate, orange, yellow or burnt amber with truncate base, 3.5-5.0 cm. long, 2-3.5 cm. wide when mature, with large tubercles up to 2 cm. long, 4-6 mm. wide, 7-8 mm. high, wooly areoles, many yellow glochids, spines absent; UMBILICUS v-shaped, to 13 mm. deep and 13 mm. wide; FLESH dry, granular; SEEDS smooth, slightly beaked and notched at hilum, yellow-creamy, 4 mm. in diameter, 15 mm. thick, aril. .1 mm. wide; SEEDLINGS with slightly unequal bronze-green long, narrow but thick cotyledons, 11-23 mm. long, 5 mm. wide with somewhat tapering tips, leaf STOMATA small, averaging 20.9 µ in length. TYPE LOCALITY: unknown, introduced into England by Loddiges in 1820. GENERAL

DISTRIBUTION: Central to southeastern Colorado, Texas, Oklahoma, New Mexico, high plains of Mexico, Chihuahua, Queretaro, Hidalgo, Distrito Federal. Reported from Utah by Rydberg, reported from Kansas. LOCAL DISTRIBUTION: woodland, grassland and desert associations in Brewster, Presidio and Jeff Davis counties.

The specific name refers to the sublobular tubercles which overlap on the stem.

*Opuntia imbricata* is the only arborescent cactus in the region and reaches its greatest height (eight meters) locally in broad intermontane valleys of the Davis Mountains.

The trunk is sturdy and divides into three or more main branches, six inches to four feet above the ground. At each node, two to six branches are verticillate, usually arising at right angles, and curving upwards. At the terminus of each branch, one joint continues growth to become the new node. Mockingbirds, owls, wrens, and other birds favor these plants as nesting sites. (Plate XII, Fig. 1).

Along washes or local areas of greater moisture, irrigated by run-off water, plants may be relatively spineless or with very short spines, and joints are more often turgid with broader tubercles. The surface is light green with a less glaucous covering. (Plate XII, Fig. 1).

Flowering is prolific over a period from the end of April to as late as the end of July with the peak in May. Fruits ripen in two to three months but persist on the plant, so that two years' crop may be present at once. Fruits occasionall undergo vegetative reversion and develop into joints with the locule imbedded in the upper part.

Seedlings are of frequent occurrence; probably because there are so many fertile seeds that chances of one surviving are relatively high. Seeds planted in the Botanical Gardens showed a high percentage of germination in thirteen days.

Skeletons of dead branches are distinguished by the long, wide, vascular gaps. (Plate VIII, Fig. 1).

Opuntia imbricata is equally abundant on broad flat valleys, rocky ridges and gentle slopes but is seldom found on steep slopes. It tends to follow draws and to colonize local depressions, showing preference for greater moisture and an ability to compete successfully with other draw vegetation. It occurs in both desert and grassland associations but is most common in the Dasylirion-Agave areas on moderate slopes in the desert belt; in Bouteloua-Yucca and Bouteloua-Prosopis in the grassland belt; oak groves, and Quercus-Pinus in the encinal belt in the Davis Mountains. Individuals occur occasionally in most of the other associations as well.

The distribution of the few, circumscribed Bouteloua-Opuntia communities which were observed in the Big Bend is shown on Map II. This local community, often with Prosopis as a subdominant, occurs on broad valleys where soil is usually a red sandy loam. In its general distribution as a subdominant, gravelly and sandy loams of desert plains and grasslands are favorable substrata, at altitudes from 2700 feet at Ruidosa along the Rio Grande to 6160 feet in the Davis Mountains.

The most common consociates of Opuntia imbricata are O. Engelmannii, O. leptocaulis, O. macrocentra, and O. phaeacantha; Echinocereus dasyacanthus Engelm, E. enneacanthus Engelm., E. stramineus Engelm Rumpler, E. triglochidiatus Engelm, and E. viridiflorus Engelm; Escobaria tuberculosa (Engelm) Britt. & Rose; Ferocactus hamatacanthus (Muhlenpfordt) Britt. & Rose and Ferocactus uncinatus (Gal.) Britt. & Rose.

Some plants of Opuntia imbricata grow with drooping branches, shrunken joints, smaller tubercles, yellow spines, and yellow sheaths. The explanation of this as a temporary condition caused by lack of available water comes to mind. Yet nearby plants of the same species have typical growth. Neither roots nor stem showed evidence of disease. (Plate XII, Fig. 2).

Collections of this form were made in Larrea-Flourensia and Prosopis associations on sandy silt loam.

Living specimens at the Botanical Gardens are sending up normal shoots; seeds germinated well in thirteen days, and cannot be distinguished from seedlings of the typical form. The typical condition in the field is probably caused by local edaphic factors.

SPECIMENS EXAMINED:

ARIZONA: Tucson, Evans 1891 (US); vicinity of Benson, March 2, 1910, J. N. Rose, P. C. Standley and P. G. Russell 12309 (US).

COLORADO: Piedra, July 11, 1899, C. F. Baker 476 (US); Fountain, June 29, 1896, Biltmore Herbarium Colorado Expedition 1498 (US); near Pueblo, 1913, Miss Divelbiro (NY, US); Pueblo, July 1891, A. Eastwood (US); shore of Arkansas river near Parkdale, 5700 ft., Fremont Co., July 2, 1925, E. W. Erlanson 1281 (MICH); Colorado Springs, 1929, Mathias 481 (MO); Trinidad, March 31, 1881, C. G. Pringle 368 (US); vicinity of Trinidad, Sept. 26, 1913, J.N. Rose and W. R. Fitch 17520 (NY, US); mesas near Pueblo, 1500-1600 m., May 15, 1900, P.A. Rydberg and F.K. Vreeland 5871 (NY); dry hills, 1800-1950 m. vicinity of Trinidad, June 17, 1911, P.C. Standley 6010 (US); Purgatoire River, La Junta, June, 1905, F. W. Stanton (US).

KANSAS: cult. at Richfield, Sept. 20, 1912, J.N. Rose and W. R. Fitch, 17104 (NY, US).

NEW MEXICO: Raton, Jan. 10, 1896, Ashmun (US); San Rapel, April 1, 1897, Ashmun (US); ecotone between oak scrub and mesophytic bottom, granite gravel, near White Signal, Grant Co., Sept. 30, 1934, F. A. Barkley 14NM887 (TEX); Sante Fe, 1896, Bayle (MO); dry ground near Lake Valley, Sierra Co., July 1904, Mrs. J. M. Beals (MICH); Neutral Strip, Aug. 1891, M. A. Carleton 358, 385 (US); Sandia Mts., June 19, C. C. Ellis 116 (US); Sante Fe, A. Fendler (MO); mesa above river, San Antonio, Socorro Co., June 24, 1921, R. S. Ferris and C. D. Duncan 2314 (NY); Socorro, Aug. 17, 1909, E. A. Goldman 1635 (US); Monica Springs, 8000 ft. San Mateo Mts., Sept. 22, 1909, E. A. Goldman 1722 (US); on hills at Sante Fe, 7300 ft., Sante Fe Co., May 28, 1897, A. A. and E. G. Heller 3776 (US); Hondo River, east of Roswell, Oct. 1920, E. C. Prentiss (US); Alamogordo, 4350 ft., April 7 - May 24, 1902, J.A.G. Rehn & H. L. Viereck (NY); vicinity of Raton, Sept. 27, 1913, J. N. Rose & W. R. Fitch 17532 (NY, US); between Las Vegas and Anton Chico, Sept. 29, 1913, J.N. Rose & W. R. Fitch 17629 (NY, US); plains near El Rito, Aug. 1880, leg. H. H. Rusby 145 (MICH); Organ Mts., June 11 & 14, 1906, P. C. Standley (US) volcanic hills, 2100-2925 m. on and near Sierra Grande, Union Co., P. C. Standley 6230 (US) Sante Fe, 1911, P. C. Standley 6486 (MO); Rincon & Cubero, Dec. 1, 1896, T. W. Toumey & Achmun (US); Socorro, May 1881, G. R. Vasey (US); Sante Fe, June 30, 1934, M. V. Walcott (US); 1866, A. Wislizenius 38, (MO); Hermosa, (photo only), 1904, E. O. Wooton (US); E. O. Wooton, 3019 (US); prairies between Limpio and Leon Spring, 1852, C. Wright (MO).

TEXAS: Big Springs, May 20-23, 1899, W. L. Bray 405 (US); Terlingua Creek, 11 mi. n.of Terlingua, Brewster Co., 1937, H. C. Cutler 708 (MO); Fresno Canyon, 1938, H. C. Cutler 1906, (MO) El Paso, 1891, W. H. Evans (US); Alpine, Sept. 1909, B. Mackensen 4 (US); near El Paso, 1913, J. N. Rose (NY); Franklin Mts., near El Paso, Oct. 9, 1913, J.N.Rose & W. R. Fitch 17863 (NY, US); vicinity of Big Spring, Feb. 23, 1910, J. N. Rose, P. C. Standley & P. G. Russell 12202 (MO, NY); vicinity of Sierra Blanca, Feb. 24, 1910, J.N. Rose, P. C. Standley, P. G. Russell 12237 (US); in canon, 10 mi. from Post City, Garza Co., Oct. 10, 1923, Edith Ruth (US); El Paso, May 20, 1896, J. W. Toumey (MO, NY); El Paso, March 1881, G. R. Vasey (US); El Paso, 1857, C. Wright (MO).

MEXICO: CHIHUAHUA - vicinity of Chihuahua, about 1300 m. April 8-27, 1908, E. Palmer 122 (US), (NY).

COAHUILA - mountain pass, 1150 m. Guadalupe, April 11, 1939, L. H. Harvey 1122 (MICH); vicinity of Saltillo, July 28, 1905, E. Palmer 713 (US).

My description is based on 28 collections.

BREWSTER COUNTY: with Larrea-Agave, 3000 ft., 4 mi. s. on Hot Springs turnoff from Park Rd. to Basin, Big Bend Nat. Park, April 29, 1948, #52; with Bouteloua, 4400 ft., Victor Pierce Ranch, in valley of Glass Mts., May 19, 1947, #126; 127; with Dasylirion-Agave ft. on gentle slope, ½ mil. se. of Crown Mt., Apr. 25, 1948, #266; with Bouteloua-Prosopis on clay soil, Sohl-Abbington (Lake) Ranch, w. of Rt. 67, May 14, 1948, #352; with Bouteloua-Yucca, 4400 ft., Sohl-Abbington (Lake) Ranch, w. of Rt. 67, May 14, 1948, #357; with Quercus-Juniperus 5100 ft., on low limestone outlier of Del Norte Mts., on Sohl Ranch, se of Alpine, May 22, 1948, #414; with Bouteloua-Juniperus, 5200 ft., west of Del Norte Mts., Sohl Ranch, May 28, 1948, #446; with Prosopis thicket along wash, 3700 ft., rd. from Rt. 67 in to Gilliland Canyon, June 4, 1948, #511; in tall grass along Rt. 90, w. of Sanderson, March 31, 1948, #211.

JEFF DAVIS COUNTY: with Bouteloua-Juniperus on open flat in Davis Mts., along Loop Drive, Aug. 24, 1948, #1050.

PECOS COUNTY: with Quercus-Juniperus, limestone soil, Allison Ranch, e. of Glass Mts., July 2, 1948, #683; with Quercus-Juniperus, 3 mi. n. of Allison Ranch house, July 3, 1948, #688; with Acacia, Fouquieria, and Leucophyllum n. of Sierra Madera along Marathon-Ft. Stockton rd., July 3, 1948, #693; with Pinus-Quercus, 4700 ft., Allison Ranch, e. of Glass Mts., July 4, 1948, #698.

PRESIDIO COUNTY: with Larrea on desert flat, 28 mi. s. of Marfa on Casa Piedra rd., Aug. 27, 1948, #1112; with Larrea along Rt. 17 to Marfa, Aug. 27, 1948, #1114.

Opuntia imbricata var. argentea var. nov. Similis formae typicae sed quam in forma typica articulus crassioribus; spinis vaginisque argenteis. Specimen typicum ex monte dicto "Mariscal Mountain, Big Bend National Park, Texas" siccatum conservatum est sub numero 280 in Herb. Univ. Mich. et vivum conservatum est sub numero 18830 in Hort. Mich.

PLANT a small, erect shrub, to 1.2 m. high, with crown to about 1 m. across; TRUNK up to 7.5 cm. in diameter; BRANCHES many, spreading to erect, ROOTS fibrous; JOINTS relatively large, up to 20 cm. long, 1.5-4 cm. in diameter; TUBERCLES 2 cm. long, 5-12 mm. wide and 5 mm.high, heavily glaucous, silvery green; LEAVES long-subulate, apiculate, 10-17 mm. long, 1.5 mm. wide, green; AREOLES relatively closely set, to 20 mm. apart, long-oval, 5-7 mm. long, 3-4 mm.wide; WOOL abundant, pale yellow, in age gray; SPINES 11-21 from all except lowermost areoles, subulate, elliptic, young spines white or pink with greenish base, older spines silvery with pinkish bases and silvery white sheaths, finally becoming gray, 6-14 central spines longer to 2 cm. long, spreading 5-7 radial spines shorter to 1.8 cm. long, spreading-deflexed; BRISTLES indistinguishable; GLOCHIDS inconspicuous in compact row along upper margin of areole, white with green bases when young, pale yellow in older areoles; scarcely 1 mm. long; FLOWER about 5 cm. long, and to 5 cm. across, with perianth segments in 4 whorls, outer segments pink with olive trace, apiculate, oblong to 1.8 cm. long and 1 cm. wide, inner segments reddish-purple, broadly spatulate, apiculate to 2.5 cm. long and 1.4 cm. wide; FILAMENTS magenta, 9 mm. long; STYLE bulbous just above base, and to 18 mm. long, stigma lobes 7-9, 5 mm. long; OVARY short conic, truncate, about 1.5 cm. long, and 1.5 cm. wide, with large, closely set areoles, uppermost ones bearing small subulate leaves, 3.5 mm. long, 1.5 mm. wide, abundant tawny wool, few minute white glochids and 1-2 long white bristles; FRUITS unknown; STOMATA of leaf averaging 37.0 u in length. TYPE LOCALITY: pediment east of Mariscal Mountain, Big Bend National Park, Brewster County, Texas. LOCAL DISTRIBUTION: Around Mariscal Mountain only, observed on northern and eastern slopes, eastern pediment and west of Solis Ranch in Prosopis thickets of Rio Grande Flood Plain, Big Bend Natl. Park.

This variety differs from typical <u>Opuntia imbricata</u> in lower stature, smaller tubercles bringing the areoles closer together, and spines which are silvery throughout; hence, the varietal epithet. Appearance in the field is chubby in comparison with the typical form. (Plate XIII).

A specimen transplanted from clay loam at the type locality, Mariscal Mountain, altitude 2300 feet, to loam soil on Victor Pierce Ranch in the Glass Mountains at 4300 feet survived the unusually cold winter of 1947-48, and was growing well when recollected. This adaptability augers well for its future spreading and establishment beyond the present small range of distribution.

Although most of the plants grow in the Larrea-Agave community, on gravel pediment and limestone detritus on the mountain, several plants were found with draw vegetation along drainage channels far from the main colony. The effect of torrential drainage in washing plants down to new localities is well illustrated here.

Flowers open early in April. Mature fruits were not obtained. Cacti associated with the main colony where the type specimens were collected were _Opuntia leptocaulis_, _O. phaeacantha_, _O. Schottii_, _Ariocarpus fissuratus_ (Engelm.) Schumann, _Echinocereus dasyacanthus_, and _Escobaria tuberculosa_. The living specimen at the Botanical Gardens has produced a number of new joints which are more abundant, arise at more acute angles, and are spinier than joints of the typical _Opuntia imbricata_ that is growing under the same conditions.

I am indebted to Dr. B. H. Warnock for telling me about the location of this population.

My description is based on five collections.

BREWSTER COUNTY: locally abund. with Larrea-Agave, ft., on pediment 4 mi. e. of Mariscal Mt., Big Bend Nat.Park, Apr. 7, 1947, #23, #150; rare, with Prosopis on sandy wash along Rio Grande, near Solis Ranch house, Big Bend Nat. Park, Apr. 28, 1948, #276; abundant with _Agave Lechuguilla_, 2500 ft., on n. end of Mariscal Mt., Big Bend Nat. Park, Apr. 29, 1948, #280; in Bouteloua-Juniperus association in transplant plot on Victor Pierce Ranch in Glass Mts., limestone soil, 4300 ft., (orig. from pediment e. of Mariscal Mt., Apr. 7, 1947), Sept. 12, 1948, #1163.

Opuntia Davisii. Engelmann & Bigelow, Pac. R. R. Rep. 4:49 1856.

Common names: "rat-tail", "sticker cactus", "Hosh-tit-say-yi" (Navajo).

PLANT a densely bushy, very spiny shrub, spreading to erect, much branched, to 7.5 dm. high and forming a wide crown 5-9 dm. across; TRUNK woody, to 40 cm. high and 3 cm. in diameter with closely-set areoles bearing a few white to gray spines, bark thin, yellowish brown; ROOTS fibrous; ultimate JOINTS very spiny, several verticillate at a node, readily detached, straight or curved through entire length, attenuate at base, terete, 6-15 cm. long, .6-2 cm. wide, strongly tuberculate, with laterally compressed, long linear-oblong TUBERCLES, 18-25 mm. long, 5-7 mm. wide, 6-7 mm. high, heavily glaucous, yellowish-green to grayish-green; TEXTURE dry and tough; LEAVES short-subulate, finely apiculate, 3.5-12 mm. long, 2 mm. wide, green; AREOLES at base of upper end of tubercle, relatively closely-set, as much as 15 mm. apart, oval, 5-7 mm. long, 3-4 mm. wide; WOOL abundant and tawny, becoming gray in age; SPINES mostly 5-10, fewer and shorter in lowermost areoles, flattened, slightly twisted, very unequal, annulately-marked, young spines reddish-brown with yellow tips, finally becoming gray, brittle and as many as 22 per areole; SPINES of two sorts, longer spines 5-7 to 5.3 cm. long, subulate, reddish-brown with yellow tips and very loose, strawy, yellow, persistent sheaths, spreading, shorter spines 2-4, only 1.4-2.7 cm. long, acicular, all yellow to straw-color, without sheaths, radially deflexed, from outer margin of areole; BRISTLES absent; GLOCHIDS inconspicuous, in dense tufts from upper margin of areoles, yellow when young, darkening with age, dull-yellow to gray, 4 mm. long; FLOWER BUDS from areoles at tips of terminal joints, 2-3 in a cluster; FLOWER up to 7 cm. long, 4.5 cm. across, with perianth segments in 4 whorls, outer segments green with deep pink entire margins, broadly spatulate, mucronate, inner segments pinkish-brown with pink trace, entire margin, spatulate, mucronate, 2.4-3.3 cm. long, 11-15 mm.wide; FILAMENTS pinkish-brown below, pink above, 9 mm. long, anthers bright yellow; STYLE white below, pink above, somewhat bulbous above base, 18 mm. long, stigma lobes 6-9, yellow-tan, 5 mm. long; OVARY tuberculate, spiny, conical, to 3.5 cm. long and 1.5 cm. in diameter, with large oval areoles, uppermost ones bearing large, subulate, apiculate scales, white wool, numerous yellow glochids, and 1-3 white bristles with deciduous sheaths, 7-27 mm. long; FRUIT dry, usually sterile, strongly tuberculate, shrunken, long-conical, 1.7-2.9 mm. long, to 1.3 cm. in diameter, pale green to tan with closely-set areoles bearing dense tufts of brownish-orange glochids to 3 mm. in length, occasionally a single, sheathless spine; UMBILICUS v-shaped, 10 mm. deep, and 10 mm. wide; SEEDS rare, 1-3 per fruit, pale yellowish-green, 3.5 mm. in diameter, 1.5 mm. thick, aril a thin line around edge; SEEDLINGS unknown; STOMATA of leaf relatively small, averaging 22.3 $\mu$ in length. TYPE LOCALITY: Upper Canadian River, about Tumcumcari Hills, near the Llano Estacado, New Mexico. GENERAL DISTRIBUTION: western Texas, eastern New Mexico and southwestern corner of Colorado. LOCAL DISTRIBUTION: grassland plains of northern Presido and Brewster counties.

Engelmann and Bigelow (30) named this Opuntia in honor of Jefferson Davis, the Secretary of War under whom the scientifically valuable Pacific railway surveys were made.

The erect shrub is conspicuous at some distance with its straw-colored, loosely-sheathed spines completely obscuring the stems. (Plate XV, Fig. 2) Upon closer inspection, one notices especially the very numerous spines which give the joints an untidy appearance. Hester (40) described a plant from this region otherwise resembling _Opuntia Davisii_, but with tuberous roots.

The flowering period is short, a few weeks in late June and early July. Fruits are mostly sterile; only a few seeds were obtained and these did not germinate. The large vascular gaps on old stems have a long, narrow, acutely-pointed shape in _Opuntia Davisii_. (Plate VIII, Fig. 1).

Individuals occur singly or as many as ten may be scattered locally. The species, in the Big Bend region, is restricted entirely to arid grassland associations, particularly in broad wash areas. Most commonly it occurs in extensive stands of the Bouteloua-Aristida association, but it was also found in Bouteloua-Yucca, Bouteloua-Prosopis, in a draw with Prosopis and Acacia, and in small stands of pure Acacia spp. Exposures are usually flat or only slightly sloping, and soil is a sandy loam. Opuntia Engelmannii and O. Pottsii were the only other cactus species found nearby.

Local distribution ranged from 4400 to 5000 feet; it is recorded at 5200 feet in the Guadaloupe Mountains.

SPECIMENS EXAMINED:

ARIZONA: 1870, D. E. Palmer 303 (MO); 1881, C. C. Parry (MO).

COLORADO: 7000 feet, southwestern Colorado, 1875, Brandegee (MO).

NEW MEXICO: Mara Visa, Quay Co., May 5, 1911, G.I. Fisher 99 (NY, US).

OKLAHOMA: dry hills near the Red River, Harmon Co., Dec. 16, 1933, G. J. Goodman and F.Barkley 2052a (US).

TEXAS: Lorraine, Sept. 14, 1909, C.R. Ball (US); desert grassland south of Sweetwater, 1934, F. Barkley (MO); Staked Plains, May 1899, W. L. Bray 418 (US, TEX); West Texas, 1877, G. Engelmann (MO); Abernathy, Hale Co., Dec. 1913, Mrs. Fritz Fuchs (US); occasional in mesquite 25 miles south of Sweetwater, Nolan Co., Aug. 5, 1934, G. J. Goodman 2255 (MO, NY).

My description is based on seven collections.

BREWSTER COUNTY: locally common in grassland, 4000 ft., 1.2 mi. s. of Marathon, w. of Rt. 227, Apr. 23, 1947, July 1, 1948 & Aug. 19, 1948, #60, 674, 1019; rare, in draw with Acacia & Prosopis, 3900 ft., 1 mi. s. of Haymond, July 8, 1948, #737.

CULBERSON COUNTY: grassland at 5200 ft., 10 mi. southeast of Pine Springs in foothills of Guadaloupe Mts., Sept. 15, 1948, B.H. Warnock (Anthony 1256).

PRESIDIC COUNTY: rare, Bouteloua-Yucca, 4900 ft., 10.1 mi. s. on Marfa-Ruidosa road, Aug. 26, 1948, #1060; rare, in Acacia stand, 5000 ft., 2 mi. along road s. from Paisano Pass, Sept. 11, 1948, #1147.

Opuntia tunicata (Lehman) Link & Otto, in Pfeiffer Enum. Cact. #170, 1837.

Cactus tunicatus Lehman, Ind. Sem. Hort. Hamb. 6 1827.
Opuntia stapeliae DeCandolle, Mem.Mus. Hist. Nat. Paris 17:117. 1828.
Opuntia hystrix Grisebach, Cact. Pl. Cub. 117. 1866.
Opuntia perrita Griffiths, Rep. Mo. Bot. Gard. 22:33. 1912.
Cylindropuntia tunicata Knuth. Kaktus A.B.C. 126. 1935.

Common names: "clavellina", "abrojo", "tencholote."

PLANT growing in low, spreading clumps to 5 dm.high and 7 dm. wide with conspicuous accumulation of dead stems; much branched at base and at terminus of each joint; TRUNK horizontal and half-buried, reaching 30 cm.in length and 6.3 cm. in width; main BRANCHES 50 to 60, erect, terete, relatively short, no more than 20 cm.high, and 5 cm. wide; ROOTS fibrous; 60 or more ultimate JOINTS at tips of main branches, readily detached, terete, to 9 cm. long and 2.5 cm. wide; strongly tuberculate with long, laterally compre ssed TUBERCLES, 30 mm. long, 3 mm. wide, 12 mm. high, dark bluish-glaucous TEXTURE soft-granular; LEAVES long-subulate, mucronate, 5 mm. long, 1 mm. wide, green, AREOLES at base of upper end of tubercles, relatively distant, 10-12 mm. apart, with drops of clear nectar secretion from upper half, long-triangular, relatively large, to 9 mm. long and 4 mm. wide, becoming slightly elevated and round in age;

WOOL very compact, white; SPINES 5, from lower end of all except lowermost areoles, acicular, all flattened dorso-ventrally, never twisted, nor curved, young spines white, older spines pale yellow with loose grayish white sheaths, finally becoming blackish, often with gray sheath still present; spines of several kinds, 1 spine to 5.2 cm. long, 2-4 spines shorter, 4.6-5.2 cm. long, spreading, 1-2 spines much shorter, only reaching 3 cm. in length, triangular in cross-section, often lower one deflexed; BRISTLES frequently present, 2, thin, much deflexed, short, to 8 mm. long, not persistent; GLOCHIDS cream-colored with pale yellow base, inconspicuous in narrow bands along upper margin of areole, very stiff, short, only 2.5 mm. long; FLOWER BUDS from areoles toward tips of ultimate joints, to 7 in a cluster; entire FLOWER reaching 5.5 cm. in length and 5.5 cm. across with perianth segments loosely arranged in 3 whorls, outer segments green with entire, white margins, short spatulate, mucronate, to 1.7 cm. long and 1 cm. wide, inner segments yellow, long spatulate, mucronate, 3 cm. long, 1 cm. wide; FILAMENTS greenish-white, 10 mm. long, anthers dark yellow, 2 mm. long; STYLE white below, greenish above, slightly bulbous above base, to 18 mm. long, stigma lobes 6, yellowish green, 4 mm. long; OVARY strongly tuberculate, obconic, 2.6 cm. long, 1.5 cm. wide with oval areoles, uppermost ones bearing small, mucronate leaves 2 mm. long, abundant white wool, numerous pale yellow glochids, up to 3 white bristles with white sheaths, reaching 18 mm. in length;

FRUIT at first fleshy, finally dry, often sterile, capable of proliferation on or off plant, oblong with somewhat tapering base, to 4.3 cm. long, and 2 cm. wide when mature, grayish yellow with small areoles, bearing dense tufts of yellow glochids, bristles and spines absent; UMBILICUS brown to black, v-shaped, oval, 7 mm. deep; SEEDS pale yellowish green, 3.2 mm. in diameter, 1.8 mm. thick, aril a thin line around the edge; SEEDLINGS with unequal cotyledons, 7-9 mm. long, 2.5 mm. wide, with blunt tips, occasionally with double embryos: size of leaf STOMATA relatively small, averaging 25.7 $\mu$ long, with no significant difference between stomata of dwarf and typical forms. TYPE LOCALITY: Mexico. GENERAL DISTRIBUTION: Mesa Central and Highlands of central Mexico; locally in Glass Mountains, Big Bend Region of Texas; Ecuador, Peru; Chile. LOCAL DISTRIBUTION: In an area of about one-half square mile on the southeastern slope of an outlier of the Glass Mountains, in southwestern Pecos County, Texas. First known scientific observation of this locality was by Dr. B. H. Warnock, Chairman, Department of Biology, Sul Ross State Teachers College, Alpine, Texas, who very kindly brought it to my attention.

The specific epithet from "tunicatus" L. refers to the sheaths which clothe the spines and are very conspicuous.

In "Las Cactaceas de Mexico by Helia Bravo, 1937 ( 7 ) page 131, Opuntia tunicata is described as "distributed abundantly throughout the Mesa Central and as far as South America." The plants are of striking appearance with low to ascending habit and red or white, sheathed spines. (Plate XIV, Fig. 2). The joints are extremely fragile, readily detached and soon root wherever they fall. The colony's limited distribution, guided by a cliff barrier, suggests dissemination by grazing animals which brush off joints and carry them along in the pelage. None of these plants approached the five to six decimeter height recorded for Mexican collections; frequent disturbance by grazing stock, as well as by wild animals, may account for such low stature.

A dwarf form is common among these low-growing plants. Dwarfs develop from detached proliferating terminal joints and fruits, and from natural seeding. No dwarf plants bearing fruits were found. Whole branches which are broken off give rise to the larger typical form. Further research with living material will be carried out to determine the complete origin of both forms and significance of their relationship.

The typical plants often develop a thick, woody, half-buried base which creeps along the ground, sending up branches, and which may attain a length of 30 cm. and a width of 6.3 cm. The clumps with papery-white sheaths almost obscuring the stems catch the eye as shining patches, even at some distance. Each clump has accumulated debris of old branches among the green ones, and myriads of ants are attracted by glandular secretions from the living areoles.

The dwarf form is distinguished by its miniature size, mostly 7 cm. high and shorter, more bristle-like spines.

The creeping stem is 10 cm. long, 1.5 cm. wide, and there is a short erect trunk. Joints are short-obovate and clavate, 3.5 cm. long and 1 cm. wide. Areoles measure 2.5 cm. long at most, and contain 1-2 spines, 2.4 cm. long or less, and 2.4 bristles, strongly deflexed, to 5 mm. long. (Plate XV, Fig. 1).

In 1948, the flowering period extended from about June 24th to early July, the fruits maturing in two months. Of 15 seeds planted at the Botanical Gardens, only 1 germinated, in twenty-two days and with a double embryo.

Britton and Rose (11) give the following description, in part: "very variable, sometimes low and spreading from the base and forming broad clumps, at other times 5-6 cm. high, with a more or less definite woody stem and numerous lateral branches .... spines reddish, normally 6-10 ... flower 3 cm. long, the joints, which break off easily, rarely grow to their full size."

Grisebach (36) and Carabia (13) list _O. tunicata_ in Oriente, in Cuba, as does Lenée in the herbarium specimens cited. The possible means of migration of this species from its other locations in Mexico and the West Indies offer interesting speculations. Since the intervening regions are not well explored it is possible that the distribution is actually more continuous than it appears. Grazing animals may have played an important role in carrying fragments of plants along from place to place.

Near the line between Pecos and Brewster counties (Lat. 30° 25') on the southeastern slope of a part of the Glass Mountains, *Opuntia tunicata* has become well established. The small colony, only one-half square mile in extent, has spread horizontally just below the dipping limestone cliffs in Plate XIV, Fig. 1. Relatively few scattered specimens were found above those cliffs and further up the main hill.

Vegetation on these slopes at about 4050 feet altitude is pine-oak woodland with *Pinus cembroides*, *Quercus grisea*, *Juniperus monosperma*, *Yucca Thompsoniana* Trel., *Dasylirion leiophyllum*, *Larrea divaricata*, *Acacia constricta* Benth., *Acacia Greggii* Gray, and *Microrhamnus eridoides*. The cacti thrive in full southeastern exposure to sun and in shade under low-branched *Pinus cembroides*. Growing with *Opuntia tunicata* are *Opuntia Engelmannii*, *O. imbricata*, *Echinocereus stramineus*, and *Epithelantha micromeris* (Engelm.) Web.

Situated in the rain-shadow east of the mountains, this area, at the time of study, had endured drought conditions for at least 14 months.

The soil has a pH of 8.0, is dark brown in color, of silty clay loam texture and belongs to the Reagan Series. It is derived from the Paleozoic limestone rock common throughout the Glass Mountains.

SPECIMENS EXAMINED:

ARIZONA: Tucson 1904 (cultivated at the University ) Herb. no. 1223520 (US).

CUBA: abund., Oriente, July 1924. *Brother Lenee* 24.422 (US): near Banacoa, Oriente, July-August, 1924, *Brother Lenee* 12035 (US).

COAHUILA: Saltillo, 1904, Dr. E. Palmer 239, 273, 246 (US); Parras, C. A. Rupus (US); Cerro del Puebla, Saltillo, July 9, 1907, W. E. Stafford 1289 (US).

HIDALGO: June 16, 1896, E. W. Nelson 3879 (NY).

MEXICO: Pedregal de San Angel, Feb. 3, 1914, A. Brovard (US); near Tlalpam, valley of Mexico, 1905, J. N. Rose, J. H. Painter, J. S. Rose 8426 (US); Pedregal near San Angel, W. E. Safford (US).

MEXICO, D. F.: Ilalpam, C. G. Pringle (US).

PUEBLA: Esperama, 2263 m., Aug. 16, 1905, H. Dittier (US); near Tehuacan, Aug. 30 - Sept. 8, 1905, J. N. Rose, J. H. Painter, J. S. Rose 10281 (US).

SAN LUIS POTOSI: end of May to end of June, 1880, Barrocte (MO); common from Agua Nueva to San Luis Potosi, 1848, J. Gregg (MO); Hac. Peotillos, May 1915, E. Palmer (US); May 24, 1905, E. Palmer 612 (NY, US); May 1878, C. C. Parry (MO); (chiefly) in the region of San Luis Potosi, 6000-8000 ft., 1878, C. C. Parry, E. D. Palmer 282 (US); near San Luis Potosi, H. von Schrenk 736 (photo) (US); 1912, Herb. no. 1928175, no. 1928178 (US); 1913, Mrs. Vera (NY); n. of San Luis Potosi, Oct. 1866, A. Weber (MO).

ZACATECAS: Casualidad, 7000 ft., April 28, 1892, M. E. Jones 248 (US); F. E. Lloyd 24, 190 (US); 1908, F. E. Lloyd 46 (photo) (US).

UNCLASSIFIED: May 1905, A. B. Case (US); Cerro de los Banos, June 7, 1865, E. Bourgeau (MO); D. Griffiths (MO), from Botanical Gardens, Harvard University, E. Palmer 282 (MO).

My description is based on three collections.

PECOS COUNTY: in Pinus-Quercus Woodland, 4050 ft., on se. slope of outlier of Glass Mts., June 27 and July 1, 1948, #649, #650, #676.

Opuntia Kleiniae De Candolle Mem. Mus. Hist. Nat. Paris 17:118 1828.

O. Wrightii Engelm. Proc. Amer. Acad. 3:308. 1856.
O. caerulescens Griffiths, Rep. Mo. Bot. Gard. 20:86 1909.
Cylindropuntia Kleiniae Knuth. Kaktus A.B.C. 123, 1935.

Common name: "tasajillo"

PLANT bushy, large, to 2.5 m. high to 2.7 m. wide, profusely branched; TRUNK woody, often several, 1.4-7.5 cm. thick with inconspicuous areoles bearing 1-3 dull brown spines to 3.9 cm. long; BARK tan to black with yellow wood showing in patches; BRANCHES ascending at angles somewhat less than 90° with stem often verticillate with 4 per node; ROOTS fibrous; ultimate JOINTS stubby, very readily detached, arising at right and acute angles from branches, curving upwards, attenuate at base, to 25 cm. long but mostly 7.5 cm. long, 7-15 mm. in diameter, slightly tuberculate with linear oblong, poorly defined tubercles, 12-23 mm. long, 2-3 mm. long, 2-3 mm. wide, 3 mm. high, glaucous, pale gray green with purple tinge around areoles or entire ventral surface dark purple; TEXTURE dry, tough; LEAVES long-subulate, curving upwards, finely apiculate, terete, 8-12 mm. long, 1.5 mm. wide, green; AREOLES distant, 10-12 mm. apart, bearing glands, not elevated, elliptic to oval, relatively large and conspicuous, 4-6 mm. long, 3-5 mm. wide, becoming spinier in age; in youth filled with with creamy-colored WOOL, becoming tan and less dense later; SPINES usually more than 1, up to 9, from all areoles or all except lower-most areoles, acicular, not twisted, terete, young spines reddish-brown with horn-colored tips and golden-orange, tight-fitting sheaths, older spines dark brown with lighter tips, mostly without sheaths, finally becoming dull brown, and more abundant, 1-2 spines longer, 2.6-5 cm. long, porrect or spreading downward, 1-3 spines shorter to .8 cm. long, deflexed, at lower margin of areole; BRISTLES several, grayish purple, deflexed, short, to 6 mm. long; GLOCHIDS inconspicuous, short, but in thick tufts in upper margin of areole, reddish brown, to 2.5 mm. long, more abundant in age; FLOWER BUDS from areoles near tips of younger joints, conic, 1.6 cm. long; FLOWER 4.0 cm. long, 3.5 cm.wide, with parts in 4 whorls, outer perianth segments olive green, obovate, apiculate, margins entire, 10 mm. long, 8 mm. wide, inner perianth segments dull rose, long and narrowly obovate, mucronate, margins entire, 2 cm. long, 1 cm. wide; FILAMENTS green below, pink above, 8 mm. long, anthers yellow; STYLE white below, pink above, slightly bulbous far above base, to 20 mm. long, stigma lobes 5-6, feathery, cream-colored, 2.5 mm. long; OVARY naked, obconic to oblong with slightly tapering base, 1.7-2.5 cm. long, 1.3 cm. in diameter, with closely set, conspicuous circular areoles, uppermost ones bearing narrowly subulate leaves, abundant cream-colored wool, numerous orange to reddish-brown glochids with yellow bases, occasionally a white bristle to 8 mm. long, no spines; FRUIT long-persistent, at first fleshy, finally dry, capable of proliferation on or off plant, obconic or clavate to long-oblong with slightly tapering base, weakly tuberculate, reddish-orange becoming brownish-orange, 2.3-2.5 cm. long, 1.2 cm. wide, with small, wooly, prominent areoles, these densely packed with orange to reddish-brown glochids at upper margin, spines 0-2; umbilicus v-shaped, 6 mm. deep; SEEDS to 14 per fruit, beaked, notched at hilum, relatively large, yellow and tannish yellow, to 5 mm. in diameter, 2 mm.

thick, aril .2-.5 mm. in a thickening along edge; SEEDLINGS with thick equal-sized cotyledons, to 15 mm. long and 7 mm. wide, with obtuse tips; leaf STOMATA relatively small, averaging 23.3 µ in length; TYPE LOCALITY: in Mexico. GENERAL DISTRIBUTION: southern New Mexico, western Texas, Coahuila, Sonora and states in central Mexico. LOCAL DISTRIBUTION: thickets along mountain canyons and occasional in arroyos on desert flats, along Rio Grande River from Presidio to Pecos River.

DeCandolle gave the specific epithet to emphasize the resemblance to members of the genus Kleinia, a succulent group well represented in Africa.

This much-branched bush is difficult to discern at a distance, since it is usually growing with other tall shrubs. There are two types of ultimate joints in _Opuntia Kleiniae_, _O. leptocaulis_, and the hybrid between them. The majority of the joints are short, in _O. Kleiniae_ about 7 cm. long and spineless. The others are highly variable in length, in _O. Kleiniae_ from 8 to 25 cm. long.

Both types of ultimate joints in _Opuntia Kleiniae_ arise at angles somewhat less than 90° to the main branch and curve gently upwards. Joints are readily detached and spines strongly barbed. Several main branches arise from the base of the plant whereas _O. leptocaulis_ typically has only one main trunk. (Plate XVI, Fig. 1; Plate XIX, Fig. 2).

The flowering period lasts from late May to late August, with the plant flowering prolifically. Mature fruits are developed within two months. Under adverse conditions or if detached while they are still green, these fruits readily proliferate, producing shoots and roots and may serve for vegetation reproduction. Seedlings are frequently found in thickets of these bushes. Five seeds out of 25 planted germinated in 17 days. Plumules have relatively closely set areoles, few hairs, and many short, white bristles. The skeletal pattern is characterized by oval gaps, which are relatively short and wide. (Plate VIII, Fig. 1).

Distribution of O. Kleiniae is very spotty but it occurs consistently along drainage channels, either broad washes or arroyos. In Musquiz Canyon at 4800 feet, in Jeff Davis County, these plants form thickets of large bushes, (Plate XVI, Fig. 2) associated with Acacia constricta, Opuntia Engelmannii, O. imbricata, O. leptocaulis, O. Lindheimeri, O. Pottsii and O. tortispina. Elsewhere individuals are rare and usually solitary.

In Sunny Glen at grassland altitudes, O. Kleiniae occurs infrequently in pure Juglans rupestris association on gravel and on sandy soil in dense shade. At Ruidosa, Presidio County, and Santa Elena Canyon, (Plate IV) Brewster County, mature plants were found in a draw in the Larrea-Agave association on loam soil, with Opuntia phaeacantha. Plants were also found along the flood plain of the Rio Grande on fine sand, with Baccharis at Santa Elena Canyon and with Prosopis near the Solis Ranch-house.

Judging from these samples, preferred soils range from silt-loam to loam, and altitude tolerance from 1900 to 4800 feet.

SPECIMENS EXAMINED:

NEW MEXICO: cactus garden at Agricultural College, 1910, J. N. Rose, P. C. Standley, and P. G. Russell 15193 (MO, US); near Agricultural College, July 7, 1911, P. C. Standley (US).

TEXAS: Davis Mts., A. P. Dodd 49 (US); Marfa, 1924, C. R. Orcutt 341 (MO); frequent from Presidio del Norte towards the Pecos, 1851-52, C. Wright (MO).

MEXICO: ZACATECAS - Lloyd 1 (MO)

HILDALGO - near Ixmiquilpan, J. N. Rose, J. H. Painter, J. S. Rose 8917 (US).

UNCLASSIFIED: 1862, Monell (MO #899110); C. Wright 490 (MO).

My description is based on eleven collections.

BREWSTER COUNTY: With Larrea-Flourensia, 4300 ft., about 5 mi. ne. of Rt. 90 on Victor Pierce Ranch, May 13, 1947, #119; with Prosopis on sandy soil, 1900 ft., just w. of Solis ranch-house near Rio Grande River, Big Bend Nat. Park, April 28, 1948, #275; with Juglans rupestris along stream bed on sandy soil, 4400 ft., Sunny Glen, nw of Alpine, June 17, 1948, #595, #596; in draw and on flats with Larrea n. of Ste. Elena Canyon on loam soil, 2100 ft., Sept. 14 & 16, 1948, #1188 and #1199.

JEFF DAVIS COUNTY: with Acacia-Prosopis on silt loam, 4800 ft., along Musquiz Creek bottomland, east of Mitre Peak, June 4, Aug. 24, Sept. 22, 1948, #512, #1043, #1250.

PRESIDIO COUNTY: in large draw with Juglans, Celtis, Prosopis, Acacia in Chinati Mountains, on silt loam, 14.8 mi. n. of Ruidosa on rd. to Marfa, Aug. 26, 1948, #1065; with Prosopis in draw, 2700 ft., 1.8 mi. along rd. from Ruidosa nw to Candelaria, Aug. 26, 1948, #1076.

Opuntia leptocaulis De Candolle Mém. Mus. Hist. Nat. Paris 17:118 1828.

O. ramulifera Salm-Dyck, Hort. Dyck. 360. 1834.
O. gracilis Pfeiff. Enum. Cact. 172 1837.
O. fragilis frutescens Engelm. Bost. Journ. Nat. Hist. 5: 245. 1845.
O. virgata Link and Otto in Forster, Handb. Cact. 506. 1846.
O. vaginata Engelm. in Wislizenus, Mem. Tour. North. Mex. 100. 1848.
O. californica Engelm. in Emory, Mil. Reconn. 158. 1848.
O. frutescens Engelm. Bost. Journ. Nat. Hist. 6:208. 1850.
O. frutescens brevispina Engelm., Proc. Amer. Acad. 3:309. 1856.
O. frutescens longispina Engelm., Proc. Amer. Acad. 3:309. 1856.
O. leptocaulis brevispina S. Watson, Bibl. Index. 1: 407. 1878.
O. leptocaulis vaginata S. Watson, Bibl. Index 1:407. 1878.
O. leptocaulis stipata Coult., Contr. U. S. Nat. Herb. 3:456. 1896.
O. leptocaulis longispina Berger, Bot. Jahrb. Engler 36:459. 1905.
Cylindropuntia leptocaulis Knuth. Kaktus A.B.C. 122, 1935.

Common names: "garambullo", "tasajilla", "tesajo", "Christmas cactus".

PLANT densely bushy, spreading, ascending to erect, not exceeding 1.8 m. in height and 2.1 m. in width; TRUNK definite, single, woody, up to 2 cm. in diameter; BARK scarcely 2 mm. thick, peeling in large scales yellow brown to black; main BRANCHES arising from near the ground, several to many, of pencil thinness; ROOTS fibrous; ultimate JOINTS equally thin, terete, with slightly attenuate bases, ascending at angles from 35° to 60° to the branches, curving upward sharply, very readily detached, some joints 4-9.5 cm. long but most 1-4 cm. long and spineless, 5-6 mm. in diameter, faintly tuberculate, not glaucous, yellow-green to dull-green, with dark purple blotches below areoles; TEXTURE dry, tough; LEAVES long-subulate, apiculate, 4-7 cm. long, 1 mm. wide, bright green; AREOLES at upper ends of faint linear protuberances, 7-12 mm. apart, broad-elliptic, relatively large, to 4 mm. long, and 2 mm. wide; WOOL abundant, very short, cream-colored becoming tan with age; SPINES solitary except in oldest areoles bearing 2-3 spines, lowermost areoles sometimes naked, spines acicular, elliptic to terete in cross-section mostly at right angles to stem, a few pointed somewhat upward or downward, sheaths closely fitting, long-persistent, finally splitting off, young spines purplish-brown with white to horn-colored tips and sheaths yellow or grading into white at tips, older spines lavender with white bases, yellow tips, and yellow to yellowish-brown sheaths, 3.9-5.1 cm. long; BRISTLES 2, caducous; GLOCHIDS in small tufts, usually in upper part of areoles, relatively short, to 4 mm., reddish-brown with yellow bases, gray and fewer in old areoles; FLOWER BUDS from areoles on terminal half of joint; FLOWER small only open in afternoon and most of the night, inconspicuous, to 2.2 cm. long and 2 cm. wide, periant segments loosely arranged in 3 whorls, outer segments broadly ovate, apiculate, recurved, 7 mm. long, 4 mm. wide, inner segments lemon yellow, broadly spatulate, mucronate, recurved, 6-11 mm. long, 5 mm. wide; FILAMENTS pale yellowish-green, 6 mm. long, anthers pale yellow; STYLE creamy, slightly bulbous just above base, 8-11 mm. long, stigma lobes 3-4, cream-colored, 1 mm. long; perianth persistent; OVARY spineless, obconic with truncate base, 8-19 mm. long, and to 7 mm. in diameter, with many, closely set, circular areoles, uppermost ones bearing narrowly-subulate leaves to 3 mm. long, abundant tan wool, few, inconspicuous reddish-brown glochids and no spines; FRUIT dry, usually fertile, capable of proliferation, long-persistent with lingering perianth, orange finally becoming dull red, short-obovate to clavate, with tapering base, small, 10-19 mm. long, 4-11 mm. in diameter when mature, abundant tan wool in small circular areoles; tufts of many, short, reddish-brown glochids to 1 mm. long; spines absent; umbilicus tan, sharply v-shaped, to 3 mm. deep by 4 mm. wide at top, small amount of yellowish-green granular flesh; SEEDS few in each fruit, beakless but notched at hilum, irregularly-shaped, twisted, angular, brownish yellow and tan, relatively large, 3-4 mm. in diameter, 1 mm. thick, aril, .2 mm. wide; SEEDLINGS with very unequal, clear-green cotyledons, 9-18 mm. long, to 6 mm. wide, with acute tips; tricotyledons rare; leaf STOMATA 23.6 µ long on average. TYPE LOCALITY: in Mexico. GENERAL DISTRIBUTION: Arizona, New Mexico, Texas, northern states of Mexico (Chihuahua, Coahuila, San Luis Potosi). LOCAL DISTRIBUTION: in grassland and desert associations of Brewster, Presidio and Jeff Davis counties. This plant with pencil-thin joints is aptly named. Of widespread occurrence throughout Brewster and Presidio counties, the species varies in form from a low bush with numerous primary branches (Plate XVII, Fig. 2) to an erect, almost arborescent bush with one or two main trunks branched about eight centimeters above the ground. (Plate XVII, Fig. 1).

The majority of ultimate joints are spineless and three centimeters long. The remainder are more variable in length, from three to nine and one half centimeters long. In contrast to Opuntia Kleiniae, O. leptocaulis has more of the very short joints which usually arise at right angles. These and the longer joints curve up sharply unlike the gently upward-curving ones of Opuntia Kleiniae. Joints of Opuntia leptocaulis are of yellow-green color; those of O. Kleiniae are gray-green. When diseased, the joints of the plant proliferate prodigiously, producing a "witches broom" effect.

Flowers arise along the terminal half of longer joints, and in contrast to those of other Opuntiae do not open until late afternoon, closing late at night. The blooming period extends from the middle of June to as late as September. Fruits are long persistent, often remaining a year or longer. A high percentage of seeds germinated in fourteen days. Only one tricotyledonous seedling was seen. The young plumules have distant areoles with few long, appressed hairs, one long brown spine and several white bristles with rufous bases.

The vascular gaps in old wood are relatively small, mostly short and oval with much thick wood between.

Many varieties have been described, but the only evident variant in the Big Bend Region was var. brevispina.

The latter is further discussed on page 102. The species is reported by Britton and Rose (11), to hybridize with *Opuntia imbricata*. I found no such hybrids, although the two species occur together frequently and their flowering periods overlap. A hybrid between *Opuntia leptocaulis* and *O. Kleiniae* was collected. (See page 103).

Plants of *Opuntia leptocaulis* occur singly or very abundantly, depending upon edaphic conditions. Where there are broad desert flats of clay loam , *Opuntia leptocaulis* may grow adjacent to almost every Larrea bush to form a community which has little else in it. (Plate XVIII, Fig. 1). Many of the plants are completely entangled with stems of Larrea, and thereby derive both support for their sprawling branches and protection for seedlings which are succulent tidbits for desert animals. Sometimes the plants grow similarly among low Prosopis branches. By process of elimination, more seedlings under bushes are apt to survive to maturity than those unprotected. These Larrea-Opuntia communities were encountered at locations marked by black circles on Map II.

The plants are common on the Chisos Flats with *Larrea divaricata*, *Agave Lechuguilla*, *Opuntia Engelmannii*, *O. Grahamii*, *O. imbricata*, *O. macrocentra*, *O. phaeacantha*, *Echinocereus dasyacanthus*, *E. stramineus*, and *Mammillaria* (*meiacantha*?).

In arid grasslands this species is found associated with stands of Flourensia with a few plants of *Opuntia*

Engelmannii. It prefers well-drained soil. Only one specimen was ever found above 5000 feet, in the encinal belt.

SPECIMENS EXAMINED:

ARIZONA: sacaton flat near Mud Springs, Chiricahua Mts., Dec. 10, 1906, J. C. Blumer 1982 (US); east side of Tucson Mts., 2500 ft., May 23, 1908, J. C. Blumer 2410 (US); Salviro Cañon, Tucson, W. A. Cannon (US); 1906, W. A. Cannon and Lloyd (US); Coon Creek, near Salt River, May 20, 1929, A. Eastwood (NY); Gleason, Cochise Co., July 12, 1940, R. S. Ferris 10013 (DS); Mule Mts., 1913, L. N. Gooding 1427 (NY, US); southwestern Tucson Mts., 2500 ft., July 2, 1927, H. W. Graham (NY); 4 mi. northwest of Tucson, April 1916, D. T. MacDougal (US); road from Roosevelt Dam to Payson, near Oxbow Hill, Feb. 25, 1929, S. D. McKelvey 764 (US); road to Coon and Cherry creeks in Sierra Ancha, May 20, 1929, S.D. McKelvey 1094 (NY); near Oracleon road to Tucson, May 25, 1929, S. D. McKelvey 1126 (US); 30 mi. east of Tucson near base of Sierra Santa Catarina, Nov. 28, 1872, P. F.Mohr,Jr. (US); sandy river flats between Roosevelt Dam and Tonto Basin Store, May 15, 1935, A. Nelson & R. A. Nelson 1935 (NY); vicinity of Tucson, April 25, 1908, J. N. Rose 11919 (US); vicinity of Benson, March 3, 1910, J. N. Rose, P. C. Standley, and P. G. Russell 12341 (US); ¼ mi. from east bank of Gila River, half way between Dripping Spring Valley and Christmas, June 11, 1922, G. P. Ross #G (US); Klondyke, July 1, 1922, R. C. Ross 19 (US); Ft. Lowell, Tucson, Dec. 1904, Oak Creek, Ariz. Terr., May 1883, H. H. Rusby (MICH); Oak Creek, June 1883, H. H. Rusby 123 (US); high mesas, San Francisco Mts. April 1, 1881, H.H. Rusby 146 (NY, MICH, US); near Chandler, March 11, 1915, H. L. Shantz (US); W. J. Swingle 149 (US); Sacatan, Pinal Co., 1912, F. Thackery (NY, US); Tucson, June 1894, var. longispina, J. W. Toumey (US); Tucson, Feb. 2, 1895, J. W. Toumey (US); Benson, March 1881, G. R. Vasey, 428 (US); Pinery Creek, Chiucahua Mts., Aug. 1896, B. E. Vernon (US); La Posa Plains 16 mi. s. of Quartzsite, Yuma Co., March 25, 1933, I. L. Wiggins 6629 (MICH).

NEW MEXICO: Hachita, July 17, 1908, E. A. Goldman 1314 (US); Socerro, Aug. 17, 1909, E. A. Goldman 1636 (US); 1880, E. L. Greene, (US-64697); Feb. 1880, E. L. Greene (NY); Mesilla Valley, Dona Ana Co., June 13, 1905, E. O. Wooton (US); 10 mi. east of Hillsboro, 1904, E. O. Wooton 3003 (MO); between Hillsboro and Hopkins Mill, 1904, E. O. Wooton (US); Nusa, Mesilla Parks, E. O. Wooton, 3090 (US);

OKLAHOMA: exposed cliffs of limestone bluff, Arbuckle Mts., near Turner Falls State Park, Garvin Co., July 29, 1933, E. Palmer 42055 (NY).

TEXAS: San Antonio, August 1907, C. R. Ball (US); 10 mi. south of Sweetwater, 1934, F. Barkley (MO); sandy upland south of Cotulla, LaSalle Co., Sept. 19, 1943, F. A. Barkley 13776 (TEX); roadside near Hueco Tanks, El Paso Co., July 21, 1946, Berkman and Lee 23 (TEX); Laredo, 1828, Berlandier 1455 (US); Lambshead Ranch, Throckmorton Co., June 11, 1947, W. F. Blair 19 (TEX); northern Jeff Davis Co. on volcanics, Aug. 2, 1947, J. Burnett 2 (TEX); Oldham Co., Aug. 1891, M. A. Carleton 410 (US); near Austin, 1904, F. V. Coville 1833 (US); mesa plain near Walker Tank, 25 mi. sw of Spur, Crosby Co., June 28, 1925, C. O. Erlanson 1207 (MICH); El Paso 1891, W. H. Evans (US); var. brevispina Travis Co., 1902, A. M. Ferguson (TEX); Finlay Station, Hudspeth Co., July 3, 1921, F. S. Ferris and C.D. Duncan 2466 (NY); Jino Ranch, Eagle Pass, May 11-13, 1904, D. Griffiths 6347 (US); Victoria, R. F. Griggs 11070 (US); rocky hills, Austin, May 18, 1872, E. Hall 232 (NY, US); Waco, McLennan Co., March 2, 1894, A. A. Heller 1375 (NY, US); Rio Grande near Chinati Mts., Aug. 1936, L. C. Hinckley (TEX); about 1½ mi. south of Ruidosa on Ruidosa-Presidio road, 850 m. common over the desert area, Aug. 11, 1936, L. C. Hinckley 811 (NY); 1½ mi. southwest of Rimrock hill, Candelaria-Valentine road, Presidio Co. June 29, 1941, L. C. Hinckley 1531 (TEX); Comanche Springs, New Braunfels, 1851, F. Lindheimer 828 (NY, US); New Braunfels, Oct. 1904, O. Locke (US); Ft. Clark, Kinney, Co., Dec. 3, 1892, E. A. Mearns 1221 (US); Harts Ranch, near El Paso, March 8, 1852, Mexican Boundary Survey (NY); rare, Victoria Co., March 4, 1912, J. D. Mitchell (NY, US); Smithwick Shale east of Rock Creek crossing, San Saba Co., June 25, 1943, F. B. Plummer and F. A. Barkley 13098 (TEX); sandy chapparal, Brownwood, July, J. Reverchon 342 (NY, US); Langtry, March 27, 1908, J. N. Rose 11603 (US); vicinity Laredo, Oct. 21, 1913, J. N. Rose 18032 (US); vicinity of El Paso, Oct. 10, 1913, J. N. Rose and W. R. Fitch 17878 (NY, US); near Laredo, Aug. 6-7, 1906, J. N. Rose and J. S. Rose 11066 (US); vicinity of Big Spring, Feb. 23, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12204 (NY, US); vicinity of Sierra Blanca, Feb. 24, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12235 (MO, NY); border of thicket, Cleburne, Aug. 19, 1913, A. Ruth 414 (US); in sandy waste ground, Garzaloo, Oct. 3, 1923, E. Ruth 1 (US); Tillia, Swisher Co., 1911, N. Standley (US); common on mesas, vicinity of El Paso, 1911, E. Stearns 107 (US); near Laredo, Jan. 30, 1911, W. T. Swingle 7175 (US); Paladuro Cañon, Randall Co., Sept. 5, 1910, K. H. Townsend 1679 (US); Dove Creek, Tom Green Co., 1880, Tweedy, (MBG); El Paso, March 1881, G. R. Vasey (US); mountains near El Paso, 1846, Wislizenius, type of leptocaulis var. vaginata (MO).

MEXICO: CHIHUAHUA - vicinity of Aldama, May 15-17, 1908, E. Palmer 256 (NY, US); Juarez, June 1912, E. Stearns 334 (US);

COAHUILA - 20 km. north of junction of Torreón and Monclova roads, 1120 m. Feb. 11, 1939, L. H. Harvey 1105 (MICH); about 25 mi. east of Americanos, Aug. 22, 1937, F. L. Wynd 750 (US);

HIDALGO - Ixmiguilpan, T. N. Rose and J. H. Painter 9012 (US);

SONORA - Carbo to Noria, April 11, 1932, L. R. Abrams 13369 (S); sandy flat, 16 mi. east of Kino Bay between Hermosillo and Kino Bay, Sonoran Desert, Aug. 27, 1941, I. L. Wiggins and R. C. Rollins 156 (DS).

TAMAULIPAS - San Fernando, Nov. 2, 1927, J. N. Rose and Russell 24323 (US).

UNCLASSIFIED: Dutch Charley's Ranch near Monument no. 88, Aug. 13, 1893, E. A. Mearns 1852 for International Boundary Commission (US); Valley of the Rio Grande, below Doñana, C. C. Parry, J. M. Bigelow, C. Wright, and A. Schott for Mexican Boundary Survey (US).

My description is based on seventeen collections.

BREWSTER COUNTY: with Prosopis, sandy soil, 1900 ft., just w. of Solis Ranch house near Rio Grande, Big Bend Nat. Park, Apr. 28, 1948, #277; with Bouteloua-Yucca, 4000 ft., along Four-Mile Crossing rd. se of Marathon, July 7, 1948, #723; with Larrea, on sandy soil, 2800 ft., Tornillo Flats just ne of Grapevine Hills, Big Bend Nat. Park, July 30, 1948, #857; with Larrea-Flourensia on limestone soil, 3200 ft., Dagger Flats, Big Bend Nat. Park, Aug. 2, 1948, #897; with Larrea-Flourensia, on sandy soil, 2600 ft., 25 mi. along rd. to Reagan Canyon, Aug. 14, 1948, #969; with Prosopis, 2200 ft., where rd. enters Reagan Canyon, Aug. 14, 1948, #994.

CULBERSON COUNTY: with Larrea-Prosopis on sandy soil, 10 mi. along rd. from Rt. 62 to Kent, Aug. 10, 1948, #967.

JEFF DAVIS COUNTY: with Acacia along rt. 17, e. of Wild Rose Pass, June 23, 1948, #622.

PECOS COUNTY: with Larrea-Flourensia, near line bet. Pecos and Reeves counties, just s. of Rt. 290, June 23, 1948, #646.

Opuntia leptocaulis var. brevispina Engelmann in Proc. Amer. Acad. 3:309, 1856. This short-spined variety of the well-defined species occurs commonly throughout the southwest and has long been recognized by taxonomists. It is characterized by shorter spines (6-28 mm. long), these lacking sheaths or with closely-fitting fugacious sheaths, and fewer of the long ultimate joints. (Plate XVIII, Fig. 2). Spines often spread downward instead of at right angles as in the typical form. It sometimes occurs with the typical O. leptocaulis.

My description is based on 6 collections.

BREWSTER COUNTY: with Juniperus on limestone ridge, 4400 ft., Victor Pierce Ranch on Glass Mountains, May 13, 1947, #109; with Juglans rupestris in draw, 3800 ft., along road to Gilliland Canyon (Glass Mts.), June 4, 1948, #507; with Larrea-Flourensia and Prosopis on flats e. of Glass Mts., 3900 ft., along Marathon-Ft. Stockton rd., June 27, 1948, #648; with Bouteloua-Yucca on low hill along Four-Mile Crossing rd. se of Marathon, 4000 ft., July 7, 1948, #720; with Larrea and Hilaria mutica, 3100 ft., along Chalk Draw rd. just north of Nine-Point Mesa, Aug. 3, 1948, #907; from transplant plot in Bouteloua-Juniperus on Victor Pierce Ranch, 4400 ft., (original spec. from Chilicotal Mt. in Big Bend Park on Apr. 3, 1947), Sept. 12, 1948, #1161.

Opuntia Kleiniae x leptocaulis hyb. nov. Erecta, usque ad 1.5 m. alta; articulis plerisque 5 cm. longis, 8 mm. diametro, paulum tuberculatis; areolis elevatis 2 mm.; spina 1, paululum deflexa, spinis setosis absentibus; floribus 3.2 cm. longis, 1.5 cm. latis, magnitudine intermediis inter parentes, interioribus segmentibus fusci-rubellis; fructibus 1.4 - 1.8 cm. longis, 1 cm. latis; seminibus 4 mm. diametro. Specimen typicum secus rivulum dictum "Musquiz Creek", prope montem "Mitre Peak", Jeff Davis Co., Texas, siccatum conservatum est sub numero #513 in Herb. Univ. Mich. et vivum sub numero 19215 in Hort. Mich.

PLANT a densely-branched bush to 1.5 m. high, and 2 m. across; TRUNK present, to 5 cm. in diameter; BRANCHES ascending; ROOTS fibrous; JOINTS intermediate in size, ascending at acute angles, more like O. Kleiniae, short joints mostly 5-7 cm. long, to 8 mm. diameter, somewhat tuberculate with protuberances to 2 mm. high, glaucous, like O. Kleiniae in gray-green color; LEAVES subulate, short mucronate, 3-7 mm. long, 1.5 mm. wide, green; **AREOLES** distant, about 12 mm. apart, bearing glands, obovate, small, to 4.5

mm. long and 3 mm. wide, becoming larger, elevated in age; WOOL abundant yellow or tan; SPINES 1, from uppermost areoles, strong, at right angles to stem or directed slightly downward, short joints spineless, young and mature spines white or purplish-brown with yellow tips, sheath white with long orange tip, persistent, finally becoming gray and shaggy in age; BRISTLES 2-4 caducous; GLOCHIDS inconspicuous in small dense tufts in upper end of areoles, bright orange with yellow bases, to 15 mm. long in older areoles; FLOWER of intermediate size, about 3.2 cm. long, and 1.5 cm. across, with perianth segments in 4 whorls, outer segments short-oblong mucronate, not recurved, to 5 mm. long and 5 mm. wide, inner segments pale pinkish brown with darker trace, broadly spatulate, mucronate, to 1.3 cm. long, 8 mm. wide; FILAMENTS greenish white below, pink above, 5 mm. long, anthers yellow; STYLE white below, pink above, bulbous above base, long and thin, to 12 mm. in length, stigma lobes 4, creamy yellow, 2.5 mm. long; OVARY long conic with tapering base, to 2 cm. long, 1 cm. in diameter, with distant areoles bearing minute, subulate leaves, tawny wool, dense tufts of reddish-orange glochids; bristles and spines absent; FRUIT small, drying to orange, narrowly obconic, with attenuate base, mostly sterile, to 1.8 cm. long and 1.0 cm. in diameter when mature, with minute areoles; short reddish-orange glochids; no spines; UMBILICUS v-shaped, 5 mm. deep; SEEDS yellow, beakless, faintly notched at hilum, relatively large 4 mm. in diameter, to 2 mm. thick, aril .5 mm. wide; SEEDLINGS with short, very broad, thinnish cotyledons, 14 mm. long, 3 mm. wide with obtuse tips; STOMATA of leaf averaging 23.2 μ in length. TYPE LOCALITY: with Acacia and Prosopis in thickets along silt loam bottomland of Musquiz Creek just south of Davis Mountains and east of Rt. 118, Jeff Davis County, Texas. DISTRIBUTION: found only at type locality.

This hybrid was found only on alluvial silt loam bottomland at 4400 feet, along Musquiz Creek in Jeff Davis County with dense thickets of Acacia. Both parents were locally abundant.

In most respects the plants resemble O. Kleiniae more closely than the smaller parent. (Plates XIX and XX). But size of the entire plant is somewhat smaller, the short joints characteristically curve up more sharply, tubercles are less evident and bear smaller areoles, areoles usually have only one long spine which points downward, bristles are absent on mature plants, and seedlings have somewhat less heavy cotyledons.

Flowering coincides with that of the parents, both of which bloom from June to August. Young fruits were collected in late September. At the Botanical Gardens only a low percentage of seeds germinated in 19 days, with one tricotyledonous seedling. The other seeds rotted.

The pattern of the wood is characterized by long narrow gaps.

*Opuntia Engelmannii*, *O. imbricata*, *O. Lindheimeri*, *O. Pottsii*, and *O. tortispina* also occurred with the hybrid, but the parentage is surely as indicated. The most remarkable divergence of the hybrid from the parent species is in the walls of the epidermal cells. In the hybrid the walls are not lobed, whereas in *O. leptocaulis* they are somewhat lobed and in *O. Kleiniae* they are deeply lobed, as most species. Since the hybrid in this characteristic lies not within but outside the rangeof the parent species, its peculiarity may possibly be interpreted as a result of interacting genetic factors, one derived from each parent. The smaller stature of the hybrid may arise from some disparity in chromosome numbers of the parents. The peculiar color of the flowers may conceivably be interpreted as a purely visual effect of the inheritance of yellow pigment in certain cells (probably sub-epidermal) from one parent and purple (probably in epidermal cells) from the other, the combined effect being brownish, but this hypothesis remains to be verified when cultivated plants come into flower.

My description is based on four collections.

JEFF DAVIS COUNTY: *infreq. with *Acacia* and *Prosopis* in thickets along bottomland of Musquiz Creek, e. of Mitre Peak, along Rt. 118, 4400 ft., on silt loam, June 4, 1948, #513, #514; Aug. 24, 1948, #1044; Sept. 22, 1948, #1377 a & b.

Opuntia Grahamii Engelmann Rep. U. S. & Mex.Bound Surv. II, Pt. I P.55. 1859.

Corynopuntia Grahamii Knuth Kaktus A.B.C. 116, 1935.

PLANT prostrate, spreading, rooting from areoles of branches, forming low mounds to 7.5 cm. high and 3 dm. wide, usually infected with fungus at base and in middle of clump; no definite TRUNK; BRANCHES many, short, usually with three main joints linearly arranged giving rise to secondary branches curved and ascending toward tips; ROOTS mostly fibrous, occasionally with single or fascicled, fusiform tubers to 6 cm. long, about 1 cm. wide; terminal JOINTS clavate to short oblong, readily detached, 4.5-7 cm. long, 2-2.7 cm. wide, weakly tuberculate with broadly diamond-shaped protuberances, 18 mm. long, 5 mm. wide and 4 mm. high, glaucous, dull yellowish green; TEXTURE soft; LEAVES broadly subulate, relatively short, mucronate, 3-4 mm. long, .5 mm. wide, bright green, persistent; AREOLES 11-15 mm. apart, not elevated, circular to horizontally oval, to 4 mm. in diameter; WOOL conspicuous in younger areoles thick, white; SPINES 1-15, from areoles on upper half of joint, acicular, scabrous, mostly terete, occasionally with longest ones somewhat flattened above, not twisted, young spines yellow-orange to orange-red, rarely with evanescent white sheath, 4-6 central spines longer 2-6 cm., spreading, dull red with dark reddish-brown bases and yellow tips, 2-6 radial spines shorter to 13 mm. deflexed, white; BRISTLES indistinguishable; GLOCHIDS stiff, strong, to 5 mm. long and spreading in age, pale yellow with dark orange bases and yellow tips, finally becoming gray; FLOWER BUDS reddish-pink, from areoles at tips of ultimate joints; FLOWER large, 6.5 cm. long, 5 cm. broad, with perianth segments in 3 whorls, outer segments olive-brown and red-tipped, ovate, apiculate, to 1.9 cm. long, 1 cm. wide, inner segments pale yellow tipped with red, long, obovate, mucronate, fimbriate, to 3.2 cm. long and 2.1 cm. wide; FILAMENTS purplish-red, 10 mm. long, anthers yellow; STYLE scarcely thicker above base, 16-26 mm. long, stigma lobes 5, green, 3 mm. long; perianth persistent; OVARY bristly, long-obconic, to 4.5 cm. long, 2.2 cm. in diameter, with large, distant areoles, bearing short, thick leaves 4 mm. long, 2 mm. wide, long, thick, pale tan, crinkly wool, few white glochids and several white bristles; FRUIT dry, oblong-ovoid, 3-4.5 cm. long, with numerous areoles bearing conspicuous crinkly white wool, long white glochids and bristles, crowned with dry perianth; UMBILICUS v-shaped, about 5 mm. deep; SEEDS pale yellow, relatively large, beaked, notched angular, 5 mm. in diameter, 2.5 mm. thick, aril only a line around edge; STOMATA of leaf averaging 22.6 µ in length. TYPE LOCALITY: sandy bottoms near El Paso, Texas. GENERAL DISTRIBUTION: southern New Mexico, western Texas, and adjacent parts of Mexico, in Chihuahua. LOCAL DISTRIBUTION: desert associations in southern Brewster and Presidio counties.

Colonel James D. Graham was for a time head of the scientific corps of the United States and Mexican Boundary

Commission. He was responsible for much botanical material being sent to Engelmann who gratefully named this cactus in honor of the colonel.

A species that occurs only in the desert shrub belt and more commonly on limestone soils, Opuntia Grahamii is an inconspicuous but frequent component of the more barren associations from 1900 to 3400 feet.

As the branches creep along the ground, fibrous roots develop from the basal areoles of each joint. Tuberous roots are generally found near the center of the clump where roots are older and better established. Tubers in Opuntia Grahamii are smaller and less abundant than in O. Schottii. The oldest joints are apparently always infected with fungus and tend to disintegrate, leaving numbers of small independent plants around a central mass of dead and dying stems. It may be that the older parts of the plants die naturally, and that fungus infection is secondary. Terminal joints also break off easily to form new plants. Clumps are often found around the bases of Larrea bushes; either fragments blow and lodge there, or they are less disturbed and therefore have more chance to develop. The mounds with a tangle of creeping branches are nuclei of deposition for wind-carried debris and soil particles so the oldest joints are usually covered by soil and the mound grows upwards as well as outwards. (Plate XXI, Fig. 1).

Few flowers are formed, these in March and early April, although Engelmann (29) gives the flowering period as June.

It may vary with the rains. Flowers are often as long as the joints themselves. The species hybridizes with O. Schottii, Page 111. By September, a few mature dry fruits are present, non-edible, and most of them sterile.

The species is of more common occurrence than Opuntia Schottii, being found at every collection station within its range. Individuals occur mostly on flat areas, gently sloping ridges and steep rocky slopes of cuestas, with Larrea, Fouquieria, Acacia, Larrea-Flourensia, Dasylirion-Agave, Larrea-Agave, and Prosopis-Acacia associations on soils of all textures.

Other cacti most commonly found with O. Grahamii are O. Engelmannii, O. leptocaulis, O. macrocentra, O. phaeacantha, O. Schottii; Coryphantha echinus (Engelm.) Britt. & Rose, Echinocactus horizonthalonius Lemaire, Echinocereus dasyacanthus, E. enneacanthus, E. stramineus, and Escobaria tuberculosa.

SPECIMENS EXAMINED:

TEXAS: Sierra Blanca, 1924, C. R. Orcutt 477 (US); El Paso, April 5-9, 1908, J. N. Rose 11720 (US); vicinity of El Paso, Oct. 8-9, 1913, J. N. Rose and W. R. Fitch 17823, 17865 (NY, US); Franklin Mts. vicinity of El Paso, Feb. 26, 1910, J. N. Rose, P. C. Standley, and P. G. Russell 12276 (US); about 1½ miles west of San Vicente, Brewster Co. April 13, 1941, O. E. Sperry 1908 (ARIZ); El Paso, July 1896, J. W. Toumey (US); El Paso, May 20, 1896, J. W. Toumey & C. R. Orcutt (NY, US); Sierra Blanca, 1913, J.N. Rose (US--38960); El Paso, at approx. 3700 ft., Aug. 24, 1909, E. O. Wooton. (US).

MEXICO: CHIHUAHUA - vicinity of Santa Rosalia, about 1200 m., June 13-15, 1908, E. Palmer 386 (NY, US).

UNCLASSIFIED: *1851, C. Wright, Opuntia #10, (MO).

My description is based on ten collections.

BREWSTER COUNTY: occasional on rocky hills with Bouteloua, Fouquieria, and Jatropha, 2100 ft., 1 mi. se of Castolon, Big Bend Nat. Park, Mar. 31, 1947, #11; abund. on limestone ridges with Larrea-Agave, 1950 ft., 2 mi. ne of Solis Ranch, Big Bend Nat. Park, Apr. 8, 1947, #27, #31; occasional on desert flats with Larrea-Agave, 3600 ft., base of Lone Mt., Big Bend Nat. Park, July 27, 1948, #827; infreq. in draw vegetation with Acacia n. of Rosillos Mts., July 30, 1948, #858; abund. in Dasylirion-Agave, 3300 ft., on slopes above Dagger Flats, Big Bend Nat. Park, Aug. 2, 1948, #892; on flats with Larrea-Flourensia, 2500 ft., near Dog Canyon, Big Bend Nat. Park, Aug. 2, 1948, #902; in Larrea-Flourensia along rd. to Reagan Canyon, Aug. 14, 1948, #977; in sandy wash through Larrea-Flourensia 3900 feet, along rd. to $O_2$ ranch, s. of Mitchell Mesa, Sept. 24, 1948, #1258.

Opuntia Schottii Engelmann, Rep. U. S. & Mex. Bound. Surv. II. Pt I. p. 54

Corynopuntia schottii Knuth. Kaktus A.B.C. 114. 1935.

Common name: "clavellina".

PLANT prostrate, spreading, rooting from areoles of branches, forming low mounds, to 16 cm. high and 15 dm. wide; definite TRUNK absent; BRANCHES many, usually curving and ascending toward tips; ROOTS mostly fibrous occasionally with tubers to 7 cm. long and 1.5-2 cm. wide; terminal JOINTS long-clavate, readily detached, 2.5-9 cm. long, 2.8 cm. wide, definitely tuberculate with long diamond-shaped protuberances, reaching 20 mm. in length, 6 mm. in width, and 10 mm. in height; glaucous, yellow-green, blue-green or gray-green; with purple on tubercles; TEXTURE soft; LEAVES broadly-subulate, relatively short, mucronate, 5-8 mm. long, 2.5 mm. wide, green or bronze-purple, AREOLES 12-15 mm. apart, conspicuous, round or oval, to 8 mm. long and 7 mm. wide, becoming larger and elevated in age; WOOL thick, persistent, white to straw-colored; SPINES 1-12, from areoles on upper two-thirds of joint, especially longest at tip of joint, acicular or shorter and subulate, scabrous; young spines red or yellow with yellowish-orange tips, sometimes with evanescent white sheath, older spines white mottled with black, or grayish-brown with white margins, reddish-brown bulbous bases and yellow tips, finally becoming dark-brown or gray, splintery and shaggy with dull-brown tips, 2-5 central spines longer 3.5-7.3 cm. long, up to 2 mm. wide, flat above, convex below, not twisted, spreading, ascending, 1-4 spines lower in areole, shorter often with 1 deflexed, 5-8 radial spine, very short to 2.3 cm., subulate, flat, white, deflexed; BRISTLES indistinguishable; GLOCHIDS conspicuous, yellow when young, pale reddish-brown or white with orange or rufous bases, in age loosely scattered, abundant, white to gray and to 8 mm. long in elevated tufts; FLOWER BUDS rare, few from areoles at tips of younger joints; FLOWERS 6 cm. long and 5 cm. across, sometimes as long as joint, with perianth segments in 3 whorls; outer segments wide-lanceolate, acuminate, yellowish-brown, to 2 cm. long, 8-10 mm. wide, inner segments pale-to burnt-yellow, long-obovate, mucronate, to 3.2 cm. long and 2 cm. wide; FILAMENTS brownish below, pinkish-red above, 10 mm. long, anthers yellow; STYLE creamy, scarcely bulbous above base, to 22 mm. long, stigma lobes 7-10, light green, 5 mm. long; perianth persistent; OVARY short-obconic with truncate base, to 2.7 cm. long and 2 cm. in diameter, with conspicuous areoles bearing thickly-subulate, apiculate scales, to 7 mm. long and 3 mm. wide, abundant, crinkly, white wool and, numerous white glochids, uppermost areoles with 1-4 flexible, white bristles to 6 mm. in length; FRUIT dry, persistent for several months, tuberculate and much wrinkled, long-obconic, to 3 cm. in length and 1 cm. in diameter, glaucous, greenish-yellow becoming black, with large, oval areoles, conspicuous, crinkly, white wool and, long, pale-yellow glochids, uppermost areoles with 1-4 porrect pinkish bristles to 9 mm. in length; UMBILICUS v-shaped, 15 mm. deep; FLESH yellow, dry, granular; SEEDS yellow, beaked and notched at hilum, 4-5 mm. in diameter, to 3 mm. thick, aril a thin line around margin; SEEDLINGS with long, tapering, unequal, very thick cotyledons, 9-18 mm. long, 5 mm. wide, with long tapering blunt tips; STOMATA of leaf averaging 30.0 µ in length. TYPE LOCALITY: "abundant on the arid hills near the Rio Grande, between the San Pedro and Pecos rivers" (TEXAS). Wright, Schott. GENERAL DISTRIBUTION: southern and western Texas, and northern Mexico, San Luis Potosi.

LOCAL DISTRIBUTION: desert associations in southern Brewster and Presidio counties.

Arthur Schott was an active botanical collector with the United States and Mexican Boundary Survey of 1851-53 and sent many species of cacti, both described and undescribed, to Engelmann.

In its most typical form, this species is easily distinguished from _O. Grahamii_ by the stronger, broadly-flattened spines, larger joints, and more prominent and elongate tubercles. The mounds are of the same general formation but larger than in _Opuntia Grahamii_. (Plate XXIV, Fig. 1). Joints have a very spiny appearance, and attach themselves readily to passing animals.

Flowers are uncommon; the species seems to be losing the ability to reproduce sexually, while becoming highly successful with asexual means of propagation. A few flowers appear from the middle of April to early May, and may be as long as the joints. Hybridization between this species and _O. Grahamii_ is discussed on page 117. Fruits are dry, shrunken, with abundant bristles, often sterile, and mature about a month after flowering. Rarely, a fruit may metamorphose directly into a joint. The few seeds that germinated under cultivation did so in twenty-one days. The young plumule has closely set areoles with a few white bristles and several pink spines.

Plants were found most commonly with Larrea, occasionally with Larrea-Flourensia, Larrea-Agave and Prosopis thickets usually on clay loams. A local community of Opuntia Schottii with Coryphantha macromeris (Engelm.) Lemaire and Echinocereus enneacanthus has developed northeast of Solis Ranch (Big Bend National Park) in a broad clay wash. (Plate XXIII). No other vegetation is present, probably because the light, shallow soil is subject to much blowing.

Near Reagan Canyon clumps are abundant and sometimes cover an area of 1.5 square meters between and among Larrea bushes on silty clay loam, adjacent to a Prosopis association. Clumps are much less frequent and extensive on the higher gravelly benches with Larrea-Agave, where Opuntia phaeacantha is the dominant cactus on sandy loam. (Plate XXIIO). Soil preference is evidently toward a clayey texture. Other cacti usually occurring with Opuntia Schottii, are O. Engelmannii, O. leptocaulis, O. macrocentra, O. phaeacantha, Coryphantha macromeris, Echinocactus horizonthalonius, Echinocereus stramineus, and Escobaria tuberculosa. Local range in altitude is from 1500 feet at Reagan Canyon to 3800 feet along the Jordan Gap road. A plant survived the cold 1947-48 winter at 4400 feet in the transplant plot in Glass Mountains about 43 miles out of range.

SPECIMENS EXAMINED:

TEXAS: cultivated at Capt. Alrich farm, Travis Co., July 24, 1943, F. A. Barkley 13422B (TEX). growing in clumps, near village of Tabasco, Hidalgo Co., Jan. 14, 1934, E.U. Clover 1884 (DS, TEX, MICH); just south of Badlands, Lower Capote Creek valley, Presidio Co., May 29, 1941, L. C. Hinckley 1536 (TEX); Laredo, June 27, 1905, J. N. Rose 8225 (US); vicinity of Langtry, March 27, 1908, J. N. Rose 11602 (NY, US); vicinity of Laredo, Oct. 21, 1913, J. N. Rose

18038 (US); near Laredo, June 27, 1905, J. N. Rose, J. H. Painter, T. S. Rose 8225 (NY, US); near Brownsville, Dec. 29, 1920, R. Runyon (US); *dry arid hills, Rio Bravo, near mouth of Pecos and San Pedro, A. Schott, (MO); rocky banks near mouth of Pecos, Oct. 13, 1852, no name nor number (NY).

MEXICO: NUEVO LEON - Monterrey, 1924, C. R. Orcutt. (US).

My description is based on 21 collections.

BREWSTER COUNTY: with Larrea on low rocky hill, 2600 ft., igneous soil, southern foot of Chilicotal Mt., Big Bend Nat. Park, Apr. 5, 1947, #21; with Larrea on limestone ridges, 1950 ft., 1 mi. n. of Solis Ranch, near Rio Grande, Big Bend Nat. Park, Apr. 15, 1947, #31c; #34; in draw just n. of Talley Mt., limestone rock, 2500 ft., Big Bend Nat. Park, May 4, 1947, #84; with Coryphantha macromeris and Echinocereus enneacanthus as only other vegetation in clayey wash, 1900 ft., one half mi. n. of Solis Ranch, Big Bend Nat. Park, Apr. 28, 1948, #273; with Larrea on sandy soil, 3200 ft., in Chalk Draw, n. of Nine-Point Mesa, Aug. 3, 1948, #910; with Larrea-Flourensia in sandy clay soil, along road to Reagan Canyon, Aug. 14, 1948, #981; with Larrea-Agave, 1500 ft., just sw of mouth of Reagan Canyon, along Rio Grande, Aug. 16, 1948, #1005; from transplant plot on Victor Pierce Ranch, in Bouteloua-Juniperus, 4400 ft., (originally from 1 mi. ne of Solis Ranch), Sept. 12, 1948, #1157; in Larrea-Flourensia on sandy silt, 43 mi. s. on Alpine - Terlingua rd., Sept. 14, 1948, #1174; in Bouteloua-Prosopis, on sandy silt, 3800 ft., 3 mi. nw on $O_2$ ranch rd. to Marfa, Sept. 25, 1948, #1263; in Larrea-Flourensia, 3400 ft., 1 mi. w. on Cheosa Water hole rd., Sept. 30, 1948, #1304.

PRESIDIO COUNTY: with Larrea-Prosopis on gravel benches near Rio Grande, 2700 ft., 3½ mi. n. of Ruidosa, Aug. 26, 1948, #1074; with Larrea, 2600 ft., 20 mi. se on Ruidosa-Presidio rd., Aug. 26, 1948, #26, 1948.

Opuntia Grahamii x Schottii hyb. nov. Prostrata; articulis 5-6.3 cm. longis, 1.5-2.5 cm. latis, grandioribus quam in O. Grahamii, eis O. Schottii fere aequalibus; tuberculis magnis, augustioribus quam in O. Grahamii; spinis 3-9, subcompressis; floribus flavis, segmentis perianthii; exterioribus longis, angustis. Specimen typicum ex loco dicto "Hot Springs, Big Bend National Park, Texas" siccatum conservatum est sub numero 856 in Herb. Univ. Mich. et vivum conservatum est sub 19605 in Hort, Mich.

PLANT forming low mound about 10 cm. high and 6 dm. wide; TRUNK absent; BRANCHES creeping, ascending at tips; ROOTS mostly fibrous, occasionally with several tubers to 10 cm. long and 1 cm. wide; JOINTS clavate or short obovate, 5-6.3 cm. long, 1.5-2.3 cm. wide; TUBERCLES broad, to 8 mm. long, 4-5 mm. wide, and 5-7 mm. high, glaucous, apple green, purplish on tubercles; LEAVES short-subulate, apiculate, to 7 mm. long and 2 mm. wide, purplish-green; AREOLES 10-15 mm. apart, circular, large, to 4 mm. in diameter; WOOL abundant, white; SPINES 1-10, from all but lowermost areoles, scabrous, subulate, flat above, convex below with bulbous bases, young spines white with pinkish base and pale yellow tips, older spines purplish-brown with white edges, 3-4 spines longer, to 4.6 cm., spreading, 1-5 spines shorter, to 1.9 cm., spreading, 2-4 radial spines, short to 1.7 cm. long, terete, deflexed, white; BRISTLES indistinguishable; GLOCHIDS conspicuous, pale yellow when young, white to gray and up to 12 mm. long and spine-like in older areoles; FLOWER about 7 cm. long and 5 cm. across with perianth segments in 4-5 whorls, outer segments long lancedate to narrow conic, green tipped with pink, to 2 cm. long and 1.1 cm. wide inner segments bright yellow, spatulate, apiculate slightly fimbriate, to 2.8 cm. long and 1.8 cm. wide; FILAMENTS red, 8 mm. long; STYLE creamy, narrow, long to 25 mm. long, stigma lobes 5 green, 5 mm. long; OVARY thin-obconic, to 4.5 cm. long, and to 1.1 cm. in diameter, with large areoles, bearing subulate leaves, 4-6 mm. long, 2 mm. wide, abundant white wool, numerous white glochids, several white bristles near rim of ovary; immature FRUIT, as in Opuntia Schottii, areoles with abundant white glochids, many long white bristles; UMBILICUS v-shaped, to 10 mm. deep; STOMATA of leaf averaging 34.6 μ in length. TYPE LOCALITY: sandy upper reaches of Tornillo Creek, northeast of Grapevine Hills, Big Bend National Park, Brewster County, Texas. DISTRIBUTION: desert shrub belt in southern Brewster and Presidio counties, Texas.

Joints of this hybrid are smaller with shorter and narrower spines than those of Opuntia Schottii, but the spines are more flattened and tubercles are stronger than in Opuntia Grahamii. (Plate XXI, Fig. 2).

Flowers are sparse, a characteristic of this group, and appear in April. Only immature fruits were available.

Distribution of these plants is approximately the same as that of the parents, throughout southern Brewster and Presidio counties. They were collected in Larrea, Larrea-Dasylirion, and Larrea-Prosopis communities and in draw vegetation. It occurs in clayey and sandy soils, but particularly on limestone detritus at altitudes from 1950 feet, northeast of Solis Ranch, to 3200 feet east of Nine-Point Mesa along Chalk Draw road.

<u>Opuntia</u> <u>Grahamii</u>, <u>O</u>. <u>leptocaulis</u>, <u>O</u>. <u>macrocentra</u>, <u>O</u>. <u>phaeacantha</u>, <u>O</u>. <u>Schottii</u>, <u>Coryphantha</u> <u>echinus</u>, <u>Echinocereus</u> <u>dasyacanthus</u> and <u>Escobaria</u> <u>tuberculosa</u> are commonly associated with this hybrid.

My description is based on ten collections.

BREWSTER COUNTY: abund. with Larrea-Agave on limestone ridges, 1950 ft., 2 mi. ne of Solis Ranch, Big Bend Nat. Park., Apr. 15, 1948, #31 b; *abund.with Larrea on limestone flat n. of Hot Springs, 2000 ft., Big Bend Nat. Park, Apr. 18, 1947, #37a; occas. in draw n. of Talley Mt., ft., Big Bend Nat. Park, May 4, 1947, #83; *abund. in Larrea 2800 ft., on Tornillo Flats, Big Bend Nat. Park, #856; abund. with Larrea, e. of Nine-Pt. Mesa, 3200 ft., Aug. 3, 1948, #909; common in Larrea, 15 mi. n. of Terlingua, along rd. to Alpine, Sept. 14, 1948, #1181; common in Larrea-Fouquieria, 2200 ft., flats just n. of Ste. Elena Canyon, Big Bend Nat.Park, Sept. 15, 1948,

#1246; with Larrea, 3400 ft., just s. of Nine-Pt. Mesa, Sept. 26, 1948, #1267; abund. with Dasylirion-Agave and some Larrea along Dabney-Moody ranch rd. in to Nine-Pt. Mesa, 3700 ft., Sept. 28, 1948, #1283.

VAL VERDE COUNTY: locally common, 6 mi. w. of Pecos River, Mar. 31, 1948, #205.

PLATYOPUNTIA

O. linguiformis Griffiths

A complete description cannot be made because my one collection has neither flowers nor fruits. (Plate XXIV, Fig. 2). Introduction of these plants is discussed on page 41 .

SPECIMENS EXAMINED:

ARIZONA: Cactus garden, Univ. of Ariz., Tucson, Sept., 1902, D. T. MacDougal 472 (NY, US); same locality, Apr. 26, 1910, J. N. Rose, P. C. Standley, P. G. Russell, 15159 (NY, US).

TEXAS:

BREWSTER COUNTY: in grassy opening in Prosopis thicket w. bank of Tornillo Creek, 1 mi. above Hot Springs, in abandoned Mexican garden, not indigenous, 1800 ft., Big Bend Nat. Park, Apr. 9, 1948, #233 (MICH).

Opuntia spinosibacca sp. nov. Robusta, diffusa, plerumque erecta; ramis adscentibus; radicibus fibrosis; saepe basi caule sublignoso teretique; articulis planis, longiobovatis, basi attenuatis, superficie paullum tuberculatis, glaucis, viridibus, ad areola purpureis; areolis ellipticis, remotis, magnis, fulvilanosis et seta colore flavida vel rufida gerentibus, plerisque armatis; spinis 2-5 validis, teretibus, superioribus ascendentibus divergentibus, inaequalibus, junioribus albidis, rufescentibus, aetate grisei-nigris; infima brevi, deflexa; alliis inferioribus lateralibus 1 vel 2 setosis, deflexis, grisis, longis, conspicuis; pallida floribus 5.5 cm. longis, 5 cm. latis, flavis, intus rubellis, segmentis perianthii 5-seriatis, exterioribus obovatis, longe-apiculatis, interioribus spatulatis; filamentis flavis; stylo flavo, stigmatis lobis 7, flavidi-viridibus; ovario obconico, areolis magnis, remotis, setis flavidirufis, superioribus areolis 1-3 spina valide, alba, basi rufa, gerentibus; bacca immatura succosa matura sicca, etuberculata, longe oblonga, prolifera, areolis superioribus 1-4 spina valida, rufa et alba gerentibus; seminibus magnis, 6 mm. diametro, commissura lineari distincta, late marginatis. Specimen typicum vivum ex loco dicto "Boquilla, Big Bend National Park", Brewster County, Texas." conservatum est sub numero 19109 in Horto. Botanico Universitatis Michiganensis et siccatum sub numero 236 in Herb. Univ. Mich.

PLANT a tall, massive bush, to 1.8 m. high, and 1.5 m. wide; sometimes with definite TRUNK 6 dm. high, 18 cm. in diameter; BRANCHES somewhat spreading but more ascending; ROOTS fibrous; JOINTS obovate to long ovate with attenuate base, 2-24 cm. long, 7.5-11 cm. wide, 7-12 mm. thick, heavily glaucous, green with purple around areoles; TEXTURE dry granular; LEAVES long-subulate, mucronate, green to pink with bronze tips; areoles elevated on small protuberances, relatively distant, 30-40 mm. apart, oval, large, to 6 mm. in length and 3 mm. in width; WOOL tawny or gray; SPINES 2-5, from all but lowermost areoles, subulate, mostly elliptic, slightly twisted, young spines white with rufous bases, older spines reddish-orange to dark reddish-brown with paler tips, finally becoming gray in age, 1-4 spines long, 3.5-7 cm. porrect, spreading 1 spine from base of areole, very short to 2 cm., much deflexed, gray; BRISTLES 2, deflexed from base of areole, rufous or gray, to 1.2 cm. long; GLOCHIDS in upper margin of areole, yellow to rufous, mostly 4 mm. long, some to 7 mm. long; FLOWER about 5.5 cm. long and 5 cm. across with perianth segments in 5 whorls, outer segments with yellow margins, pinkish-green trace, obovate, long-apiculate, to 1 cm. long and .5 cm. wide, inner segments yellow with red base, long obovate, apiculate, to 2.5 cm. long and 1.8 cm. wide; FILAMENTS yellow, to 11 mm. long, anthers white or yellow; STYLE white or yellow, bulbous above base, 18 mm. long, stigma lobes 7, yellowish-green, 4 mm. long; OVARY tuberculate, obconic with tapering base, reaching 3 cm. in length and 1.5 cm. in diameter, with relatively large and distant areoles, uppermost ones bearing subulate, apiculate leaves, dense tan wool, numerous yellow to rufous glochids and 1-3 subulate spines, rufous below, white above; FRUIT dry, shrunken, tuberculate, capable of proliferation or transformation into joint, long-oblong, with truncate base, to 3.5 cm. long and 1.5 cm. in diameter when mature, glaucous-pale purple with distant areoles, long yellow or orange glochids, areoles on upper half with 1-4 rufous and white subulate spines; UMBILICUS v-shaped, 10 mm. deep; FLESH dry, granular, creamy; SEEDS few per fruit, large, rough, yellow with green embryo, beakless, deeply notched at hilum, reaching 6 mm. in diameter, 2 mm. in thickness, aril 1-1.5 mm. wide. TYPE LOCALITY: with Larrea-Agave and _Jatropha spathulata_ on slopes of limestone hill just east of ranger's quarters, Boquillas, Big Bend National Park, Brewster Co., Texas. DISTRIBUTION: locally abundant around Boquillas, especially on rocky slopes from Boquillas west half way to Hot Springs, in Larrea-Agave association on limestone formations.

The species name is given to emphasize the most distinctive character - that of spiny fruits.

These large bushes with definite trunks and ascending branches are very conspicuous around Boquillas, especially in the most arid situations. Unlike any other of the Platypuntia species in the region, they reach 1.5 meters in height. Branches are definitely more ascending than spreading; joints are consistently long-obovate; ovary of the flower is decidedly spiny, and fruit is tuberculate, dry when mature, and spiny. (Plate XXV).

In the key by Britton and Rose (11), these characteristics bring it into the series Phaeacanthae near _Opuntia angustata_ and _O. phaeacantha_. _Opuntia angustata_ differs in having prostrate to suberect habit, spines shorter, more or less white, and no mention of tuberculate joints. _Opuntia phaeacantha_ agrees in having somewhat conspicuous bristles, reddish-spines and similar flowers, but differs in its more spreading habit, short-obovate to orbicular smooth joints, and juicy naked fruit.

This population has either migrated across the Rio Grande River at Boquillas from Mexico or is just beginning to spread from its center of origin there, or is a relict population.

Flowering period is from April to about the middle of May, with fruits maturing a month after the flowers. Fruits are readily proliferous. (Plate V, Fig. 1). A few seedlings with very long white spines (to 6.5 centimeters) becoming reddish-brown, were found near the parent plants.

Restricted to a small area, this species is found only in Larrea-Agave at altitudes from 1850 to about 2300 feet, with such associated plants as _Hechtia scariosa_ L. B.Smith, _Jatropha spathulata_, _Opuntia Grahamii_, _O. leptocaulis_, _O. rufida_, _Echinocactus horizonthalonius_, _Echinocereus enneacanthus_, _E. stramineus_, and _Escobaria tuberculosa_. It is especially abundant on steep, rocky hills, on northwest, west, southwest and southern exposures.

My description is based on six collections.

BREWSTER COUNTY: Big Bend National Park: locally abund. with Larrea-Agave, and _Jatropha spathulata_, at 2250 ft., on rocky limestone slopes e. of rangers' headquarters at Boquillas, Apr. 17, 1947, #36; Apr. 11, 1948, * #236, #238, #241, #243; infreq. with Larrea-Agave 1850 ft., along rd. from Hot Springs to Boquillas, Apr. 11, 1948, #235.

<u>Opuntia</u> <u>azurea</u> Rose Contr. U. S. Nat. Herb. 12:291 1909.

PLANT a low shrub to 1.2 m. high, and 1.5 m. across; definite TRUNK absent; BRANCHES spreading and ascending; ROOTS fibrous; JOINTS flat-orbicular or obovate, to 10.5 cm. long, 11.5 cm. wide, and 8 mm. thick, relatively thick; glaucous, whitish green, purple around areoles; TEXTURE dry, granular; LEAVES long-subulate, mucronate, to 14 mm. long, and 2.5 mm. wide, pinkish-green; AREOLES closely set, 20-35 mm. apart, long-oval, large, 6-7 mm. long, 3-5 mm. wide, becoming very spiny in age; WOOL tan, becoming grayish-black; SPINES 3-4, from areoles on all but lowermost part of joint, subulate, mostly elliptic, slightly twisted, young spines white with orange -red tips and bases, older spines yellow to orange with reddish-brown bases, finally becoming brown to black with brownish-yellow tips, 5-6 per areole; 1 spine very long, 5.7-6.3 cm., porrect, 1-3 spines shorter, attaining a length of 4.7 cm., spreading, 1 spine very short to 2.1 cm. long, dark gray to black, spreading downward; BRISTLES 0 to 2, gray, 9-11 mm. long; GLOCHIDS conspicuous in dense tufts, whitish-yellow with reddish-brown bases when young, yellow, finally becoming gray-brown, to 15 mm. long and spine-like in older areoles; FLOWER resembling that of <u>O. macrocentra</u>, 6 cm. long, 6 cm. across with perianth segments in 4 whorls, outer segments lanceolate, mucronate, yellowish-green, inner segments spatulate, winged, mucronate, pale yellow with light pink base, fading white on 2nd day; FILAMENTS 15 mm. long; STYLE bulbous above base, to 22 mm. long, stigma lobes 6, yellowish-green, 3 mm. long; OVARY obconic with truncate base, to 2.4 cm. long, and 1.5 cm. in diameter, bearing closely set areoles, uppermost ones with subulate leaves, 6 mm. long, 2 mm. wide, tan wool, numerous long yellow glochids and 1 to several yellow bristles; mature FRUIT unknown, not available. TYPE LOCALITY: northeastern Zacatecos, Mex.; DISTRIBUTION: Zacatecas and Durango in Mexico, and along Rio Grande River in the Big Bend National Park, in southern Brewster County, Texas. LOCAL DISTRIBUTION: locally abundant on barren limestone ridges one mile northeast of Solis Ranch, in the Big Bend National Park.

Britton and Rose (11) describe the spines of these plants as only 2 to 3 centimeters long and flowers fading pink, but the plants in Texas have spines which were mostly 6 centimeters in length and flowers which fade white on the second day. The specific epithet refers to the blue-green color of the joints. Successive joints of three years' growth show a striking contrast between young creamy white spines, mature bright yellow spines and the old black spines. (Plate XXVI).

Observed superficially, the species resembles Opuntia Lindheimeri in having spreading and ascending habit and orbicular to short obovate joints with yellow spines, but it differs in having occasional bristles, marked contrast in spine color and yellow flowers with red centers. Flowering period lasts from early to late April. Mature fruits were not available.

Plants were only found at this one station, and very locally there, on limestone cuestas sloping gently north with Larrea-Agave. Soil is a silty clay loam. Altitude is about 1900 feet.

Opuntia Grahamii, O. macrocentra, O. phaeacantha, Coryphantha echinus, Echinocactus horizonthalonius, and Echinocereus dasyacanthus were also common at this locality.

My description is based on four collections.

BREWSTER COUNTY: locally abundant with Larrea-Agave on low north-sloping limestone cuestas, 1900 feet, 1 mi. ne of Solis Ranch house, Big Bend Nat. Park, Apr. 15, 1947, #33 a & b; Apr. 27, 1948, #270 & #271.

Opuntia phaeacantha Engelmann in Gray, Mem. Amer. Acad. 4:52. 1849.

O. phaeacantha brunnea Engelm. Proc. Amer. Acad. 3:293. 1856.
O. phaeacantha major Engelm. ibid:293. 1856.
O. phaeacantha nigrans Engelm. ibid:293. 1856.
O. camanchica Engelm. & Big. ibid:293. 1856.
O. chihuahuaensis Rose. Contr. U.S.N.H. 12:291. 1909.
O. Toumeyi Rose. ibid. 12:402. 1909.
O. Blakeana Rose, ibid:402. 1909.
O. zuniensis Griffiths Bull. Torr. Club 43:86 1916. (from the descript).

PLANT a low bush, densely branched, 3-15 dm. high, 18 (rarely 27) dm. across; occasionally with short, thick TRUNK to 12.5 cm. long, and 5 cm. in diameter; BRANCHES many, spreading, somewhat ascending; ROOTS fibrous; JOINTS obovate, short-elliptic or orbicular, 10-22 (rarely 30) cm. long, 9-15 cm. (rarely 19) cm. wide, 4-25 mm. thick, thinly to thickly glaucous, yellow-green to gray-green purple around areoles; TEXTURE mealy, granular; LEAVES subulate, terete, tips recurved, mucronate, 7-13 mm. long, 1.5-2.5 mm. wide, pale green with purplish tinge; AREOLES distant, 20-45 mm. apart, not elevated but prominent, oval or elliptic, 5-10 mm. long, 3-5 mm. wide, becoming slightly larger in age; WOOL abundant, pale tan, brown or gray; SPINES 2-10, mostly 3-4, from areoles on upper one-third to four-fifths of joint, especially from margins, usually subulate, elliptic to terete in cross-section, twisted, straight, annulately colored young spines pale to dark reddish-brown, much paler toward tip, older spines reddish-brown, more or less streaked with white, with darker bases and orange tips, finally becoming speckled gray to brownish-black; 1-4 spines longer, some to 7 cm., others 3-4 cm., often twisted, spreading,1 spine shorter, 1-2.7 cm., white to gray, deflexed; BRISTLES 0-2, white, orange or gray with horny tips, deflexed, to 13 mm. long; GLOCHIDS abundant and conspicuous in upper ends of areoles, reddish-brown with yellow bases when young, becoming yellow, orange or reddish-brown with yellow bases, finally gray and reaching 19 mm. in length in old areoles; FLOWER relatively small, to 6.5 cm. long and 6 cm. across, with perianth segments in 4 whorls, outer segments green with yellow edges, and purplish tips, minutely toothed, obconic, apiculate, to 1.5 cm. long, inner segments yellow often with red bases, obcordate, apiculate, somewhat fimbriate to 3.5 cm. long and 3 cm. wide; FILAMENTS yellow or pinkish, 15 mm. long, anthers white; STYLE yellow, white or pink, short, thick, to 5 mm. in diameter just above

2.7-4 cm. long, 1-2 cm. in diameter, with conspicuous, distant areoles, uppermost ones bearing subulate leaves, all with abundant brown wool, few inconspicuous reddish-brown glochids with yellow bases, often a few scattered rufous and white bristles to 17 mm. long, up to 3 per areole; FRUIT somewhat juicy, pyriform, oblong or obovate with attenuate base, 2.7-4.5 cm. long, small, distant 1-3 cm. in diameter, glaucous, dull reddish-purple to rosy-red with small, distant areoles, bearing few glochids and no bristles; umbilicus U-shaped, to 10 mm. deep; flesh dull red; SEEDS abundant, beakless and deeply notched at hilum, yellow to yellow-orange with green embryo, rough, irregularly-shaped, large, 3.5-7 mm. long, to 6 mm. wide and 3 mm. thick, aril broad, 1-2 mm. wide; STOMATA of leaves averaging 29.5 µ in length. TYPE LOCALITY: "on the rocky hills about Sante Fe and on the Rio Grande" (New Mexico). GENERAL DISTRIBUTION: California, southern Utah, Arizona, southeastern and western Colorado, New Mexico, western Texas, and Mexico in Chihuahua. LOCAL DISTRIBUTION: In desert shrub, arid grassland and encinal belts of Brewster, Jeff Davis and Presidio counties.

O.phaeacantha (brown-spined) is an apt name for this common species of the southwest.

Usually a low, spreading bush, but extremely variable in most characteristics, Opuntia phaeacantha is one of the most difficult species in the Big Bend to identify with certainty. After study in the field, many distinct forms can be recognized, each differing in subtle variations of habit, spine number and spine arrangement, but intergrading to defy definition. Moreover, under cultivation many of these differences may not be apparent. Therefore, the group has here been broadly defined, ranging from spreading plants, with a few spines in the marginal areoles, to larger, more ascending bushes with very spiny joints. (Plates XXVII, XXVIII, XXIX). Thickness of joints on different individuals varies from 7 millimeters, which is relatively thin, to 15 millimeters, which is relatively thick. Bristles are consistently present in some forms, absent in others. The species hybridizes with Opuntia Engelmannii as discussed on page 136, and there may have been persistance of specially adapted segregates from hybridized populations in many localities.

Flowers of Opuntia phaeacantha are characteristically shorter, with a stouter ovary, than those of O. macrocentra. Other differences in floral structure include a short, thick style, usually bulbous at the base rather than above it, stigma lobes short and heavy instead of long and thin, outer perianth segments broadly conic, perianth not longer than ovary and frequently shorter, areoles distant on the ovary; flowers fading to a pale tan color, rather than pink as in Opuntia macrocentra. The flower is smaller altogether than that of O. Engelmannii. Flowers are sparse and open from early April to early July. Mature fruits were collected beginning in the middle of July.

Opuntia phaeacantha occurs commonly throughout desert grassland and encinal associations from 1600 feet to 5500 feet on all types of soil, but reaches its greatest development on the sandy loam of desert plains in southern Brewster and Presidio counties.

At Reagan Canyon, the species is the most abundant Opuntia on the gravel plains (Plate XXII), but is of occasional occurrence only on the precipitous limestone slopes of the canyon itself where O. rufida is dominant (Plate XXXIX, Fig. 2). On igneous slopes at somewhat higher altitudes, however, as at Lone Mountain, 3600 feet, Opuntia phaeacantha is the dominant cactus and no O. rufida is found. (Plate XXVIII, Fig. 1).

Opuntia Davisii is the only species of Opuntiae that was never found with O. phaeacantha.

SPECIMENS EXAMINED:

ARIZONA: lava 3 mi. northeast of the Clifton Junction, 4000 ft. Graham Co., Gila River Watershed, June 12, 1939, L. Benson 9475 (ARIZ); flat sandy land in the juniper belt, 5 mi. s. of Ashfork, Yavapai Co., June 16, 1939, L. Benson 9669 (ARIZ); Colossal Cave barbeque area, 4000 ft. Rincon Mts., Pima Co., Oct. 9, 1939, L. Benson 9812 (ARIZ); Tucson Mt., Park Headquarters, Dec. 1, 1939, L. Benson 9876 (ARIZ); east of Chem. Bldg., Tumamoc, Tucson, April 23, 1932, C. B. Carter (ARIZ); near irrigation ditch at foot of talus, Havasupai Canyon, Coconino Co., July 13, 1940, E. U. Clover 5065 (MICH); growing immediately around the Desert Laboratory, Tucson, Oct. 15, 1907, D. T. McDougal (US); Sierra Ancha, road to Carr's ranch and Pleasant Valley, May 7, 1929, S. D. McKelvey 943 (US); road to Coon and Cherry creeks in Sierra Ancha, May 10, 1929, S. D. McKelvey (US); foothills of Four Peaks in Mazatzal Range, May 12, 1929, S. D. McKelvey 1006 (NY) 1008 (US); Beach Ranch 3700 ft., 10 mi. n. of Helvetia, Jan. 1 & 8, 1940, A. A. Nichol (ARIZ); 5500 ft. tall grass and oaks, Tumacacori Mts., A. A. Nichol (ARIZ), Jan. 3, 1940; 1867 Parry (MO) vicinity of Tucson, April 12, 1908, J. N. Rose 11753 (US); northern end of Tucson Mts., April 22, 1908, J. N. Rose 11863 (US); vicinity of Benson, March 2, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12314, 12316, 12318, (US); cactus garden, Univ. Ariz., Tucson, April 26, 1910, J. N. Rose, P. C. Standley, and P. G. Russell 15151 (US); cactus garden, Univ. Ariz. - #508 from Tucson, J. N. Rose, P. C. Standley, P. G. Russell 15152, 15163 (US); cactus garden Univ. Ariz. April 26, 1910, J.N. Rose, P. C. Standley, P. G. Russell 15166 (#223 from Prescott), 15171, 15172. (US); dry hills, Navajo Indian Reservation, about the northern end of Carrizo Mts., July 30, 1911, P. C. Standley 7457 (US); Tucson, April 27, 1894, J. W. Toumey (US); Benson, April 30, 1895, J. W. Toumey (US); Tucson, May 5, 1895, J. W. Toumey (US); Sulphur Springs Valley, May 20, 1897, J. W. Toumey (US); garden specimen "original specimens from San Pedro valley," Sept. 30, 1898, J. W. Toumey (US); Bowie, Dec. 1896, J. W. Toumey, Aschmun (US); rocky slope 6 mi. west of Tucson on Ajo road, Pima Co., March 4, 1937, I. L. Wiggins 8674 (DS).

COLORADO: Trinidad, Aug. 26, 1896, Biltmore Herb. Colorado Expedition 1 942 (NY, US); vicinity La Junta, Sept. 16, J. N. Rose and W. R. Fitch 17051 (US).

NEVADA: Wilson's Ranch, sandy hills, Larrea belt, 1120 M. Charleston Mts., Clark Co., June 7, 1938, I. W. Clokey 8031 (ARIZ); low sandy hills, 1180 m. Wilson's Ranch, Clark Co., June 16, 1939, I. W. Clokey 8431 (AHLA, MO, TEX); rocky ground, juniper belt, 1350 m., mouth of Pine Canyon, Charleston Mts., Clark Co., May 21, 1940, I. W. Clokey 8656 (NY, AHLA, TEX).

NEW MEXICO: San Rapel, April 1, 1897, Aschmun (US); * type of O. phaeacantha var. major. 4 mi. east of Sante Fe, 1846, A. Fendler, (with photo) (MO); mesa, San Antonio, Socarro Co., June 22, 1921, R. S. Ferris & C. D. Duncan 2315 (MO, NY, DS); White Water, Grant Co., June 3, 1892, E. A. Mearns 81 for Mex. Bound. Surv. (DS); Alamogordo, 4350 ft., April 7 - May 24, 1902, Rehn and H. L. Viereck (NY); vicinity of Lordsbury, April 1908, J. N. Rose 11730, (NY); vicinity of Raton, Sept. 27, 1913, J. N. Rose, W. R. Fitch 17534 (US, NY); between Las Vegas and Anton Chico, Sept. 29, 1913, J. N. Rose and W. R. Fitch 17626 (US); between Anton Chico and mouth of Gallinas River, Sept. 30, 1913, J. N. Rose, W. R. Fitch 17632, 17633 (NY, US); vicinity of Sante Fe, Oct. 1913, J. N. Rose, W. R. Fitch 17774 (NY, US); vicinity of Sante Fe, Oct. 4, 1913, J. N. Rose, N. R. Fitch 17775 (US, NY); vicinity of Sante Fe, Oct. 3, 1913, J. N. Rose, W. R. Fitch 17778 (NY, US); vicinity of Albuquerque, Oct. 6, 1913, J. N. Rose, W. R. Fitch 17785, 17789 (NY, US); vicinity of Albuquerque, Oct. 6, 1913, J. N. Rose, W. R. Fitch 17790 (NY, US); Sante Fe Canyon, Oct. 3, 1913, J. N. Rose, J. H. Parkhust 17779, (NY, US); Tortugas Mt., Feb. 28, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12253 (NY, US); cultivated, collected by E. O. Wooton (#3117) 4 mi. sw of Killip, July 7, 1906, J. N. Rose, P. C. Standley, P. G. Russell 12264 (US); cultivated, collected by E. O. Wooton in nw New Mexico in 1904, J. N. Rose, P. C. Standley, P, G. Russell 12265 (US); Tortugas Mt., Feb. 28, 1910, J. N. Rose, P. C. Standley, Russell 12270, 12271, 12272 (MO, US); mesa west of Organ Mts. 4200 ft., June 1906, P. C. Standley 533 (US); Organ Mts., approx. 5600 ft. Dona Ana Co., June 1906, P. C. Standley 539, 540 (US); same locality, June 10, 1906, P. Standley 538 (US); same locality June 11, 1906, P. C. Standley (US); dry hills vicinity of Sante Fe, about 2225 m., July 6, 1911, P. C. Standley 6485 (US); Stein's Pass, May 12, 1895, J. W. Toumey (US); Gallup, Oct. 20, 1896, Toumey, Aschmun (US); Tortugas Mts., se of Las Cruces, Dona Ana Co., May 22, 1892, E. O. Wooton (US); Head of Seco, July 14, 1904, E. O. Wooton 3005 (US); Durfey's Well, July 20, 1904, E. O. Wooton 3007, (US); 5 miles southwest of Ancho, Aug. 28, 1904, E. O. Wooton 3025 (US); 4 mi. west of Kelley's, July 7, 1906, E. O. Wooton 3117 (US).

OKLAHOMA: grassy valley of Salt Fork River, Woods Co., Stevens 682½ (MO).

TEXAS: Llano Estacado, 1853, J. M. Bigelow, (MO); Davis Mts., Jeff Davis Co., July 1936, L. C. Hinckley (TEX); Langtry, March 27, 1908, J. N. Rose 11601 (US); vicinity of El Paso, April 1908, J. N. Rose 11723 (US); vicinity of Trinidad, Sept. 26, 1913, J. N. Rose, W. R. Fitch 17519 (NY); vicinity of El Paso, Oct. 8, 1913, J. N. Rose, W. R. Fitch 17822, 17877 (NY); vicinity of Sierra Blanca, Feb. 24, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12229 (NY, US); cultivated, from Marathon, collected in vicinity of Agricultural College, N. M., Feb. 28, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12267 (NY); in Rio Grande Valley 5 mi. below El Paso, Feb. 26, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12283 (NY, US); Franklin Mts., vicinity of El Paso, Feb. 26, 1910, J. N. Rose, P. C. Standley, P. G.Russell 12293 (NY) and 12297 (US); garden specimen, "original specimen collected in the vicinity of El Paso by Orcutt in 1894," Sept. 20, 1898, J. W. Toumey (US); sand hills of Rio Grande bottom. 1852, C. Wright (MO).

UTAH: Uinta Basin, Graham 9143 (MBG); St. George, Oct., 1909, E. W. Nelson 156 (US).

MEXICO: CHIHUAHUA - in Sierra Madre, June 21-July 29, 1899, E. W. Nelson 6080 (US); vicinity of Chihuahua about 1300 m., April 8 - 27, 1908, E. Palmer 69 (NY, US); vicinity of Chihuahua, Santa Eulalia Mts., April 4, 1908, J. N. Rose 11675 (US).

My description is based on 125 collections.

BREWSTER COUNTY: with Larrea-Agave, 2700 ft., sw slope of Chilicotal Mt. Big Bend Nat. Park, Apr. 3, 1947, #15; with Larrea-Agave, 2100 ft., on pediment e. of Mariscal Mt., Big Bend Nat.Park, Apr. 7, 1947, #22; with mixed desert shrub, 1950 ft., 1 mi. ne of Solis Ranch, Big Bend Nat.Park, Apr. 15, 1947, #35; with Larrea-Agave, 2000 ft., on limestone ridges n. of Hot Springs, Big Bend Nat. Park, April 18, 1947, #37; with Larrea-Agave 3100 ft. on desert flats s. of Hays Ridge, Big Bend Nat. Park, Apr. 30, 1947, #56; with Juniperus on limestone ridges, Victor Pierce Ranch, w.of Glass Mts., May 13, 1947, #120; with Prosopis 1800 ft., in wash at Boquillas, Big Bend Nat. Park, Apr. 11, 1948, #244; with Quercus-Juniperus, 5100 ft., on Sohl Ranch, w. of Del Norte Mts., May 30,1948, #473; with Bouteloua-Juniperus and in Juglans rupestris along draw, Kuntz Ranch, e. of Del Norte, Aug. 28 & 31, 1948, #1113, 1116; with Pinus-Quercus, along Kuntz Ranch rd. into Del Nortes, Sept. 3, 1948, #1123; 1124; with Acacia and Larrea, 2100 ft., near se. mouth of Ste. Elena Canyon, Big Bend Nat. Park Sept. 17, 1948, #1214; with Larrea-Prosopis in flats in Christmas Mts., Sept. 18, 1948, #1238; with Larrea-Prosopis, 3400 ft., 11 mi. w. on rd. in to Fizzle Flats, nw of Agua Fria Mt., Sept. 30, 1948, #1314; in oak grove, 1½ mi. e. of Hess Canyon, Glass Mts., Oct. 5, 1948, #1332.

(Specimens of large-jointed form) with Juniperus on low limestone hill, Victor Pierce, Glass Mts., May 13, 1947,

#115; with Larrea-Agave, 2000 ft., hill e. of Boquillas, Big Bend Nat. Park, Apr. 11, 1948, #240; with Bouteloua-Juniperus, 4000 ft., in Santiago Mts., where Marathon rd. passes through, May 9, 1948, #339; with Acacia on chert slopes of Pena Blanca Mts., se of Marathon, July 8, 1948, #728; with Larrea-Flourensia, 3200 ft., in Dagger Flats, Big Bend Nat. Park, Aug. 1, 1948, #865; with draw vegetation, 2100 ft., in Reagan Canyon, Aug. 15, 1948, #1000; with Dasylirion-Agave, 2300 ft., 4 mi. n. on Reagan Canyon-Bullis Gap rd., Aug. 16, 1948, #1007; with Bouteloua-Prosopis on flat on Gage Estate e. of Del Nortes, Aug. 21, 1948, #1039; with Larrea-Prosopis, 2200 ft., 3½ mi. n. of Ste.Elena Canyon, Big Bend Nat.Park, Sept. 16, 1948, #1209; with Larrea-Prosopis, 2400 ft., in sandy silt, 6½ mi. s. of Terlingua, Sept. 17, 1948, #1219; with Larrea-Prosopis on bank of draw, 10 mi. w. on rd. to Fizzle Flat, n.of Agua Fria Mt., Sept. 30, 1948, #1312; with Larrea-Flourensia, 3½ mi. e. of Santiago Mts. on Pope Ranch, Oct. 6, 1948, #1340.

CULBERSON COUNTY: with Yucca-Agave, 4½ mi. w. of Van Horn, Aug. 8, 1948, #940; with Larrea-Flourensia, 3 mi. s. on rd. from Rt. 62 to Kent; Aug. 10, 1948, #965;

EL PASO COUNTY: common on flats e. of Franklin Mts. with O. Engelmannii, Aug. 8, 1948, #946; with Larrea-Agave, along Scenic Drive on s. end of Franklin Mts., Aug. 9, 1948, #947; with Prosopis, 21 mi. e. of El Paso, along Rt.62, Aug. 9, 1948, #955.

HUDSPETH COUNTY: 8½ mi. w. of Van Horn, Aug. 8, 1948, #943; 42 mi. w. of Van Horn, Aug. 8, 1948, #945.

JEFF DAVIS COUNTY: with Bouteloua-Yucca, along Loop Drive in Davis Mts., Aug. 24, 1948, #1051.

PECOS COUNTY: with Pinus-Quercus, on limestone ridge e. of Glass Mts., n.of Marathon, July 2, 1948, #685.

PRESIDIO COUNTY: with Bouteloua-Yucca, 10 mi. s. on Marfa-Ruidosa rd., Aug. 26, 1948, #1061; in Chinati Mts., 34 mi. s. on Marfa-Ruidosa rd., Aug. 26, 1948, #1064; with Prosopis and Jatropha, 4000 ft., 9½ mi. ne. of Ruidosa, Aug. 26, 1948, #1071; with Jatropha, Condalia, Acacia, 9½ mi. n. Ruidosa, Aug. 26, 1948, #1072; with Dasylirion-Agave, 6 mi. n. of Ruidosa on Marfa rd., Aug. 26, 1948, #1073; with Larrea on gravelly hill, 1.8 mi. nw on Ruidosa-Candelaria rd., Aug. 26, 1948, #1078; with Larrea on flat, 2700 ft., 1 mi. se on Ruidosa-Presidio rd., Aug. 26, 1948, #1080; with Dasylirion-Agave, 1 mi. s. of Shafter along Rt. 67, Aug. 27, 1948, #1100.

VAL VERDE COUNTY: with Larrea and other desert shrubs on w. side of Pecos Canyon, Mar. 31, 1948, #204.

*Opuntia Engelmannii* x *phaeacantha* hyb. nov. Magnitudine parentibus similis; areolis remotis, elevatis, plerisque armatis; spinis 2-5, subcrompressis, subdeflexis, retrorsum divergentibus, junioribus spinis subnigris, rufescentibus floribus... flavus, intus rubellis, frutibus longis, obovoide; seminibus magnis, late marginatis. Specimen typicum ex montibus dictis "Glass Mountains, Brewster Co., Texas" siccatum conservatum est sub numero 113 in Herb. Univ. Mich. et vivum conservatum est no. 18906 in Hort. Mich.

PLANT a large but low bush, attaining a height of 7.5 dm. and a width of 18 dm.; TRUNK rarely present; BRANCHES spreading, only slightly ascending; ROOTS fibrous; JOINTS orbicular, obovate or ovate, from 15-45 cm. long, from 12-40 cm. wide, 7-13 mm. relatively thick; glaucous, purple around areoles; TEXTURE granular; LEAVES subulate, with curved tip, mucronate, 5-15 mm. long, 1-3 mm. wide, green to purplish-pink; AREOLES relatively distant, 30-45 mm. apart, elevated, prominent, oval, elliptic to orbicular, large, 9-10 mm. long, 4-7 mm. wide; WOOL abundant, tan or reddish-brown, becoming gray in age; SPINES 2-5, from areoles on upper 2/3 to 4/5 of joint, especially on margin, subulate, more or less flattened, twisted, sometimes curved, young spines white or reddish-brown, with black bases and orange tips, older spines reddish-brown or more often black with orange or reddish-brown tips, finally becoming gray and 7-8 per areole, 1 spine longer, reaching 5.1 cm. in length, terete, porrect, 2 spines shorter, 2.5-3 cm. long, spreading, 1 spine very short, 1.7-2.5 cm. long, white or gray, flattened, usually deflexed; BRISTLES 0-2, spreading, gray, to 7 mm. long; GLOCHIDS abundant, long, scattered in areole, orange when young, yellow, orange or dark reddish-brown with yellow bases in older areoles, finally becoming gray and to 17 mm. long; FLOWER reaching 7.5 cm. in length and 6 cm. across, with perianth segments in 4 whorls, outer segments green with pinkish tip and yellow margins, obcordate, inner segments bright yellow sometimes with pink to red bases, short obcordate, emarginate, slightly fimbriate, 3.5 cm. long and 2.9 cm. wide; FILAMENTS mostly green, sometimes yellow or white above, 11-14 mm. long, anthers yellow; STYLE white to pinkish, to 5 mm. thick just above base and to 19 mm. long, stigma lobes 6-10, pale green, or yellowish green, 4.5 mm. long; OVARY long conic, curved, 3-4.5 cm. long, 1.5-2.3 cm. in diameter, with distant, small areoles bearing a few subulate leaves, yellow or reddish-brown glochids and a few bristles; FRUIT purple, long obovate, reaching 3.5-5 cm. in length and 2.5 cm. in diameter, with small, distant areoles bearing few glochids and no spines; UMBILICUS v-shaped, 5 mm. deep; SEEDS yellow, rough, irregularly-shaped, beakless, deeply notched at hilum, large, 6 mm. long, 4.5 mm. across, 2 mm. thick, aril 1 mm. wide; SEEDLINGS with thick, short, very unequal cotyledons, 10-16 mm. long, 6 mm. wide, and 8 mm. long, 6 mm. wide, with blunt tips. TYPE LOCALITY: low limestone hill on Victor Pierce Ranch just west of Glass Mountains, Brewster County, Texas. DISTRIBUTION: desert shrub, arid grassland and encinal belts in Big Bend Region.

Flowers, fruits and seeds of this hybrid most closely resemble the Opuntia phaeacantha parent but the massive habit, orbicular joints, somewhat elevated and distant areoles and more or less flattened spines suggest O. Engelmannii. (Plate XXX, Fib. 1; Plate XXXI). Young spines are usually dark reddish-brown to black - a characteristic unique in this form.

The hybrid shows little restriction in distribution but is more common in the Glass Mountains and grassland areas than in the desert shrub life belt. (Plate XXX, Fig. 2). It is associated with all the other common cacti, often on sandy soils.

SPECIMENS EXAMINED:

ARIZONA: on sand hills, vicinity of Benson, Mar. 2, 1910. J. N. Rose, P. C. Standley, P. G. Russell 12311 (US).

My description is based on 53 collections.

BREWSTER COUNTY: with Prosopis on gravelly plain, 14 mi. s. of Marathon, w. of Rt. 227, Apr. 29, 1947, #49; * with Juniperus on low limestone hill, 4400 ft., Victor Pierce Ranch, just w. of Glass Mts., May 13, 1947, #112; #113; with Bouteloua-Prosopis, in Glass Mts., on Victor Pierce Ranch, May 19, 1947, #122; with Larrea-Agave, on limestone hill n. of Terlingua, 3000 ft., May 9, 1948, #326; with Juniperus and grass, in Santiago Mts., 4000 ft., along rd. to Marathon, May 9, 1948, #340; with Juniperus on low limestone hill and Larrea-Flourensia below, 3900 ft., on Parr Ranch w. of Glass Mts., May 19, 1948, #365; 366; with Bouteloua-Juniperus, on Sohl Ranch, w. of Del Norte Mts., May 22, 1948, #448; in draw with Juglans rupestris along rd. from Rt. 67 in to Gilliland Canyon, Glass Mts., June 4, 1948, #508; with Juniperus and Dasylirion-Agave, on limestone along Gilliland Canyon rd., in Glass Mts., June 5, 1948, #524; with Yucca, Agave, other desert shrubs, on slopes of chert cuesta, Pena Blanca Mts., se of Marathon, July 8, 1948, #727;

with Larrea-Leucophyllum along Chalk draw, n.of Nine-Pt. Mesa, Aug. 3, 1948, #912; with Larrea-Flourensia on flat, 20 mi. ne from Reagan Canyon on Bullis Gap rd., Aug. 17, 1948, #1012; with Bouteloua-Yucca and Acacia, 4000 ft., sw of Marathon at old Post, Aug. 21, 1948, #1034; in Prosopis thicket, 4000 ft., sw of Marathon near The Post, Aug. 21, 1948, #1036; with Bouteloua-Prosopis, 4400 ft., Sohl-Abbington Ranch, e. of Rt. 67, Sept. 4, 1948, #1134; with Juniperus on low limestone hill, 4 mi. ne of Rt. 90 on Victor Pierce ranch rd., Sept. 12, 1948, #1154; with Larrea-Agave and Fouquieria, on north slope, Christmas Mts., Sept. 18, 1948, #1241; with Larrea-O. leptocaulis, 3400 ft., on sandy flat, s. of Nine-Pt. Mesa, Sept. 26, 1948, #1270; with Larrea-Agave, 3600 ft., se base of Nine-Pt. Mesa Sept. 26, 1948, #1278; with Bouteloua on plains, 3½ mi. ne Hess Ranch house, Glass Mts., Oct. 5, 1948, #1323; with Quercus-Juniperus on slope, ½ mi. nw Hess Ranch house, Glass Mts., Oct. 5, 1948, #1324; with Larrea-Flourensia, 3000 ft., ne of Persimmon Gap and just e. of Santiago Mts., Oct. 6, 1948, #1335.

CULBERSON COUNTY: with Yucca-Agave, 4½ mi. w. of Van Horn, Aug. 8, 1948, #942.

PECOS COUNTY: with Quercus-Juniperus and draw vegetation e. slopes of Glass Mts., Allison Ranch, 24 mi. n. of Marathon, July 2, 1948, #682; with Juniperus on limestone hill, 15 mi. s. of Ft. Stockton, July 3, 1948, #694; with Bouteloua-Prosopis, 13½ mi. w. of Sanderson, along Rt. 90, July 9, 1948, #744.

PRESIDIO COUNTY: with Prosopis on sandy flat, 2600 ft., 8½ mi. se. of Ruidosa on rd. to Presidio, Aug. 26, 1948, #1083, #1084.

VAL VERDE COUNTY: with Prosopis on overgrazed rangeland, 31 mi. nw. of Del Rio, Mar. 31, 1948, #201.

Opuntia Engelmannii Salm-Dyck in Engelm., Bost. Jour. Nat. Hist. 6:207. 1850.

O. Engelmannii cyclodes Engelm. Proc. Amer. Acad. 3:291, 1856.
O. Lindheimeri cyclodes Coult., Contr. U.S. Nat. Herb. 3:422. 1896.
O. Dillei Griffiths Rep. Mo. Bot. Gard. 20:82. 1909.
O. arizonica Griffiths Rep. Mo. Bot. Gard. 20:93. 1909.
O. Wootonii Griffiths, Rep. Mo. Bot. Gard. 21:171. 1910.
O. cyclodes Rose, Contr. U.S. Nat. Herb. 13:309. 1911.
O. Gregoriana Griffiths, Rep. Mo. Bot. Gard. 22:26. 1912.
O. valida Griffiths, Proc. Biol. Soc. Wash. 27:24. 1914.
O. confusa Griffiths, Proc. Biol. Soc. Wash. 27:28. 1914.
O. magnarenensis Griffiths, Proc. Biol. Soc. Wash. 29:9. 1916.
O. expansa Griffiths, Proc. Biol. Soc. Wash. 29:14. 1916.
O. Engelmannii discata C.Z. Nelson, Trans. Ill State Acad. Sci. 12:124. 1919.

PLANT a large, compact bush to 18 dm. high and 18-24 cm. in diameter; sometimes with definite TRUNK to 23 cm. high and 17 cm. in diameter, often with long, white hairs still persisting in areoles; BRANCHES many, spreading and ascending, massive; ROOTS fibrous; JOINTS extremely variable in shape, elliptic, long obovate, with tapering base, orbicular, or reniform (19x21 cm.) occasionally expanded in three dimensions, 10.5-45 cm. long, 10.5-33 cm. wide, 6-40 mm. thick, thinly to thickly glaucous, yellowish green to blue-green, sometimes purple around areoles; TEXTURE soft, mucilaginous; LEAVES long subulate, long apiculate, terete or somewhat flattened, with recurved tip, 5-14 mm. long, 1-3 mm. wide, green to bronze with purple tinge; AREOLES distant, 25-55 mm.

apart, occasionally with glands, flat to elevated, short obovate to round, large, 5-12 mm. long, 3-8 mm. wide, becoming longer and more prominent in age; WOOL dense, tan to rufous, persistent; SPINES 0-10 in areole, usually from lower part of areole, occasionally from upper part, from all but lowermost areoles or any degree less, some joints spineless, young spines white with reddish-brown bases and horn-orange tips, older spines more abundant, subulate, white, orange or reddish-brown with dark reddish-brown to black bases and dark yellow tips, finally becoming gray-white with blackish yellow tips more numerous and papery; 2-3 spines longer, much flattened, sometimes twisted, more or less spreading downward or 1-2 deflexed, 3.3-5.0 cm. long, 1-3 spines, from lower in areoles, shorter, flattened, deflexed, .8-2.5 cm. long; often 1-2 bristles, white to yellow, deflexed, to 8 mm. long; GLOCHIDS numerous and in dense tufts in upper ends of areoles, reddish-brown or yellow when young, becoming dull orange to yellow with reddish-brown bases, finally gray in age, becoming very conspicuous and up to 14 mm. long in apical areoles of old joints; FLOWER BUDS from areoles along upper edge of joint, occasionally from areoles in middle of joint, long conic; FLOWER large, to 7.8 cm. long and 7.5 cm. across, with perianth segments in 4 whorls, outer segments yellowish-green to greenish-tan with pinkish tips, short-spatulate long diamond-shape or obovate with entire margins, apiculate, inner segments yellow streaked with orange or yellow with rose bases, obovate, obcordate or spatulate with entire margins, apiculate, 3-3.9 cm. long, 2.3-3 cm. wide; FILAMENTS yellow to white, to 16 mm. long, anthers white to yellow; STYLE white or pink below, greenish-white above, or yellow below and pink above, thick, bulbous at base or just above it, to 20 mm. long, stigma lobes 7-9, greenish-yellow, 2-6 mm. long; OVARY curved, conic, oblong or long-pyriform with tapering base, 2.5-5.5 cm. long, to 2 cm. in diameter, with small, distant areoles, uppermost ones bearing large, bronze leaves to 8 mm. long and 3 mm. wide, dense tan to rufous wool, numerous yellow to orange glochids with reddish-orange bases, few to many yellow or orange, subulate bristles; FRUIT extremely juicy, edible, short-elliptic to pyriform, 3.5-6.5 cm. long, 1.6-4.1 cm. in diameter when mature, plum-purple with inconspicuous, distant, elliptic areoles, bearing tan to white wool, few to no glochids and no spines; UMBILICUS shallow, U-shaped, 5-6 mm. deep, 15-26 mm. across at top; flesh abundant and plum-purple; SEEDS many, beakless but notched at hilum, grayish yellow, relatively small and smooth, 2.5-4 mm. in diameter, 1-2 mm. thick, aril yellow, to 1 mm. wide; SEEDLINGS with large, very unequal, long-subulate cotyledons, 9-15 mm. long, 4-5 mm. wide, with acutely pointed tips, young stem with hairy base, hairs white to 2 cm. long, lower areoles on first young joints with hairs and some glochids; STOMATA of leaves averaging 30.8 $\mu$ in length. TYPE LOCALITY: "from El Paso to Chihuahua". GENERAL DISTRIBUTION: southeastern Arizona, southern New Mexico, western Texas, Mexico in Chihuahua, Durango, Nuevo Leon and Sonora. LOCAL DISTRIBUTION: Occurs in all grassland and desert associations throughout Brewster, Jeff Davis and Presidio counties.

This large and well-known prickly pear is deservedly named after one of the earliest and greatest authorities on cacti, (particularly those from the Trans-Pecos region), Dr. George Engelmann, the brilliant German physician who worked on the many specimens sent to him by early biologists with the government surveys.

Opuntia Engelmannii is the least restricted and most abundant cactus in the Big Bend. (Plate XXXII). The usual habit is a massive bush with large, heavy pads, although low, spreading forms are encountered. Joints may be spineless or with spines in a few areoles or in all except the lowermost areoles. (Plate XXXI, Fig. 2). The joints, especially on plants in the Chisos Basin, have a tendency to expand in three planes, - a possible reversion to cylindrical form. This tendency was also evinced on one specimen of O. macrocentra and one of O. Lindheimeri. (Plate XXXVII, Fig. 2).

Flowering is prolific from late April in the desert belt to late July in the arid grassland belt. There is considerable variation in flower color, ranging from clear yellow to yellow heavily streaked with orange, and with yellow to green stigma lobes. The species hybridizes with O. phaeacantha. (Page127). Mature fruits are formed by the middle of May and are eaten by many animals. Seedlings are easily identified in the field by the hairy bases. Only a few seeds of a large planting at the Botanical Gardens sprouted in 27 days. Hairs on the plumules of these seedlings measured up to 2 centimeters long. Hairs are also present in the lowermost areoles of the first young pads.

The species is most abundant on Larrea-Agave flats, overgrazed rangeland at grassland belt altitudes (Plate XXXII, Fig. 2) and north, east, and south slopes of chert cuestas. Less at home on limestone than on gravelly sandy loam flats, O. Engelmannii is however, common throughout the Glass Mountains. In altitude the species ranges from 2100 feet at Castolon to 6700 feet in a high "laguna"[1] of the Chisos Mountains.

All the other species of Opuntiae except O. polyacantha are found associated with O. Engelmannii.

SPECIMENS EXAMINED:

ARIZONA: Desert Laboratory, Tucson, April 4, 1932, L. R. Abrams, 13392 (DS); Tonto Natl. Monument, Dec. 20, 1940, E. C. Alberts 69 (ARIZ); lava desert, 3600 ft. 3 mi. ne. of the Clifton Junction, Graham Co., Gila River Watershed, June 12, 1939, L. Benson 9472 (ARIZ); Colossal Cave barbeque area, 4000 ft. Rincon Mts., Pima Co., Oct. 9, 1939, L. Benson 9814 (ARIZ); Gates Pass, Tucson Mts., Dec. 1, 1939, L. Benson 9872 (ARIZ); vicinity of Kingman, Mohave Co., May 1927, Selma Braem (S-187374); open rocky slopes back of Ceinf, Chiricahua Nat. Monument, June 21, 1939, O. M. Clark 8163 (ARIZ); 1937, Cutler 1089 (MO); foothills of Four Peaks in Mazatzal Range, May 12, 1929. S. D. McKelvey 1007 (US); Fish Creek on Apache Trail, May 14, 1929, S. D. McKelvey 1031 (NY); Apache Trail, May 21, 1929, S. D. McKelvey 1111 (NY); Beach Ranch, 3700 ft. 10 mi. n. of Helvetia, Jan. 2, 1940. A. A. Nichol (det. Benson) (ARIZ); 1877, D. E. Palmer 3 (MO); Swift Trail, 3700 ft. Panalemo Mts., Graham Co., Oct. 10, 1939, R. H. Peebles 14537 (US); vicinity of Tucson, May 12, 1908, J. N. Rose 11751, 11751a (US); vicinity of Benson, March 2, 1910, N. J. Rose, P. C. Standley & P. G. Russell 12337, 12338 (NY, US); Oak Creek, June 21, 1883, H. H. Rusby 625, 626 (MICH, NY); Tucson, April 30 - Aug. 1, 1894, J. W. Toumey (MO, NY); Sabino Canon, Santa Catalina Mts., April 23, 1895, J. W. Toumey (US); Santa Catalina Mts., April 27, 1896, J. W. Toumey (NY); Tucson, Aug. 20, 1896, J. W. Toumey (US);

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[1] A "laguna" in local usage is not a lake (there are none) but a high grassy meadow. This usage is illustrated in the place-name Laguna in the Chisos Mountains.

Tucson, 1897, J. W. Toumey (US); gravelly slopes, 36 mi. w. of Tucson, Pima Co., March 5, 1937, I. L. Wiggins (US).

NEW MEXICO: White Water, Grant Co., June 3, 1892, E. A. Mearns 275 (US); Dog Spring, 1892, E. A. Mearns 310 (MO); 1895, Mulford 1392 (MO); between Anton Chico and Las Vegas, Oct. 1, 1913, J. N. Rose & W. R. Fitch 17630 (NY, US); Anton Chico and mouth of Gallinas River, Sept. 30, 1913, J. N. Rose & W. R. Fitch 17631 (US); vicinity of Albuquerque, Oct. 6, 1913, J. N. Rose & W. R. Fitch 17787, 17788 (NY, US); collected from cactus garden, Feb. 28, 1910, J. N. Rose, P. C. Standley, & P. G. Russell 12243 (NY); vicinity of Agricultural College, Feb. 28, 1910, J. N. Rose, P. C. Standley & P. G. Russell 12244 (NY); near Alamogordo, type locality, Feb. 28, 1910, J. N. Rose, P. C. Standley, & P. G. Russell 12247 (NY); Tortugas Mt., vicinity Agricultural College, Feb. 28, 1919, J. N. Rose, P. C. Standley, & P. G. Russell 12272, 12252 (NY, US); Organ Mts. June 11, 1906, P. C. Standley (US); Durfey's Well, 1904, E. O. Wooton 3007 (MO); Organ Mts., E. O. Wooton 3027, 3028 (MO, US); Organ Mts., Jan. 31, 1905, E. O. Wooton 3073 (var. cycloides) (ARIZ); Hachet, June 18, 1906, E. O. Wooton (US); between Rockweek and Limpia, 1852, C. Wright 473 (MO).

TEXAS: desert plains, Nolan Co., 1934, F. Barkley (MO); scrubland 8 mi. w. of Santa Maria, Hidalgo Co., May 25, 1946, F. Barkley 16T446 (TEX); Eagle Pass, J. M. Bigelow (MO); 6 mi. n. of McAllen on Old Depot road, Hidalgo Co., July 13, 1937, C. E. R. Cameron C-1, C-6 (TEX); Fresno Canyon, 1938, H. C. Cutler 1899 (MO); Goat Canyon, Jeff Davis Co., July 1936, L. C. Hinckley (TEX); Franklin Mts., near El Paso, Oct. 9, 1913, J. N. Rose & W. R. Fitch 17860 (MO, NY); vicinity of Sierra Blanca, Feb. 24, 1910, J. N. Rose, P. C. Standley & P. G. Russell 12231 (NY, US); Franklin Mts., vicinity of El Paso, Feb. 26, 1910, J. N. Rose, P. C. Standley & P. G. Russell 12295, 12296 (NY, US); desert scrub areas south and east of the Chisos Mts., most frequent along arroyos and washes, Brewster Co. (with photo) April 13, 1941, O. E. Sperry 1914 (ARIZ); Green Co., west Texas, Tweedy (MO); El Paso, 1852, C. Wright 329 (MO).

MEXICO: CHIHUAHUA - vicinity Chihuahua, about 1300 m., April 8-27, 1908, E. Palmer 123 (NY, US); near Colonia Garcia in the Sierra Madres, 7400 ft., June 2, 1899, C.H.T. Townsend & C. M. Narber 75 (NY, US).

COAHUILA - collected at Saltillo, state of Coahuila and vicinity, April 15-30, 1898, E. Palmer 95, 96 (NY, US).

NUEVO LEON - Monterey, 1909, E. Rodriquez (US).

My description is based on 84 collections.

BREWSTER COUNTY: with Larrea-Agave on slopes of low hill, 4 mi. s. on Hot Springs turnoff from rd. to Basin, Big Bend Nat. Park, Apr. 30, 1947, #55; with Prosopis in wash, 3200 ft. n. base of Chicotal Mt., May 30, 1947, #57, #58; with Juniperus and grass along Green Gulch rd., Chisos Mts., Big Bend Nat. Park, May 2, 1947, #65, #67; with Larrea-Agave along rd. to Glenn Springs, May 3, 1947, #73; with Quercus on igneous hills sw. of Alpine, Lane Ranch, May 9, 1947, #103; with Juniperus, 4300 ft., on low limestone ridge, Victor Pierce Ranch, w. of Glass Mts., May 13, 1947, #116; in draw with Celtis, Victor Pierce Ranch, in Glass Mts., May 19, 1947, #124; with Juniperus, Victor Pierce Ranch in Glass Mts., May 19, 1948, #129; with Bouteloua-Prosopis in Stroud Pasture, w. of Glass Mts., May 25, 1948, #431; in a wash between Chilicotal Springs and Glenn Springs, Big Bend Nat. Park, Apr. 27, 1948, #269; with Dasylirion-Agave, 4400 ft., on northwestern talus slopes of Ward Mt., Chisos Mts., Big Bend Nat. Park, May 8, 1948; #299; with Quercus-Juniperus along lower Cattail canyon, below Ward Mt., Big Bend Nat. Park, May 8, 1948, #312; with Bouteloua-Yucca, 4400 ft., Sohl-Abbington (Lake) Ranch, w. of Rt. 67, May 14, 1948, #346; with Prosopis, along rd. from Rt.67 to Gilliland Canyon, w. of Glass Mts., June 5, 1948, #525; with Hilaria mutica 3600 ft., on Neal Ranch, w. of Glass Mts., June 11, 1948, #542; with Prosopis, Juniperus, Bouteloua, 1 mi. w. Allison Ranch house, Glass Mts., July 4, 1948, #695; in draw with

Agave, s. of Pena Blanca cuestas, July 8, 1948, #734; with Bouteloua-Prosopis, 3900 ft., just w. of Haymond, July 8, 1948, #736; with canyon vegetation along Window Trail, Big Bend Nat. Park, July 12, 1948, #768; with Pinus-Quercus s. of Pullman Bluffs, Big Bend Nat. Park, July 13, 1948, #773; in meadow s. of Pulliam Bluffs, Big Bend Nat. Park, July 14, 1948, #775; with _Pinus ponderosa_, _Juniperus flaccida_, _Arbutus texana_, Quercus in Pine Canyon, Chisos Mts., Big Bend Nat. Park, July 15, 1948, #797; with Pinus-Quercus, 5500 ft., in Basin of Chisos Mts., Big Bend Nat. Park, July 27, 1948, #824; with draw vegetation in lower Green Gulch of Chisos Mts., Big Bend Nat. Park, July 27, 1948, #825; with Larrea-Flourensia, 3900 ft., bet. Burnham Ranch and Hot Springs turnoff, Big Bend Nat. Park, July 31, 1948, #863; with Larrea on silty clay, 7 mi. s. of Terlingua, Sept. 14, 1948, #1186; with Larrea and _O. leptocaulis_, 2 mi. n. of Ste. Elena Canyon, Sept. 16, 1948, 1205; with Pinus-Quercus in Chisos Basin, Sept. 17, 1948, #1225; with Quercus and Acer on slopes north of Hess Canyon, Glass Mts., Oct. 5, 1948, #1333.

CULBERSON COUNTY: with Yucca-Agave, 4½ mi. w. of Van Horn along Rt. 90, Aug. 8, 1948, #941.

JEFF DAVIS COUNTY: with Acacia, east of Wild Rose Pass, and Davis Mts., along Rt. 17, June 23, 1948, #621.

PRESIDIO COUNTY: with Prosopis on sandy soil, 1 mi. nw on Ruidosa-Candelaria rd., Aug. 26, 1948, #1079.

UVALDE COUNTY: with Prosopis on overgrazed range, 10 mi. w. of Uvalde, Mar. 30, 1948, #183.

Opuntia Engelmannii var. Wootonii (Griffiths) nov. comb.

O. Wootonii Griffiths, Rep. Mo. Mot. Gard. 21:171 1910.

PLANT somewhat ascending, to 6 dm. high, spreading to 12 dm. diameter; TRUNK absent; BRANCHES much subdivided; ROOTS fibrous; JOINTS long-ovate or obovate, often attenuate at both ends, from 14.5 - 25 cm. long and 10-15 cm. wide, relatively thin, 6-8 mm.thick, heavily glaucous, green; TEXTURE granular; AREOLES distant, 30-40 mm. apart, short ovate, large, to 10 mm. long and 7 mm. wide; WOOL pale tan; SPINES 4-7, from areoles on upper 2/3 to 4/5 of joint, subulate, twisted, young spines mostly black with paler tips, older spines pinkish-white with reddish black bases and horny yellow tips, becoming red throughout when wet, finally becoming grayish-black, annulately marked; 1 spine very long, to 7.3 cm., usually flattened, porrect or spreading downward, 2-3 spines shorter to 5.5 cm. long, elliptic to flattened, twisted, spreading, 1 spine, very short, to 2.3 cm. long, elliptic, deflexed; BRISTLES 0-2, white with yellow or orange tips, reaching 5 mm. in length; GLOCHIDS yellow, orange, or reddish-brown, reaching a length of 12 mm. in older, upper areoles; FLOWER and FRUIT not observed; TYPE LOCALITY: Organ Mountains of New Mexico; LOCAL DISTRIBUTION: scattered, few plants in desert shrub vegetation on Tornillo Flats and locally abundant in Christmas Mountains.

Griffiths (34), p. 171, described Opuntia Wootonii as a new species, from collections made by Prof. E. O. Wooton in the Organ Mountains of New Mexico. Unlike the plants in his description, with joints attenuate at both ends, these west Texas representatives have mostly obovate joints which are only occasionally attenuate at the base. (Plate XXXIII, XXXIV).

In contrast to the typical _Opuntia_ _Engelmannii_ with its massive habit, mostly orbicular joints, and spines to about 5 centimeters in length, _O._ _Engelmannii_ var. _Wootonii_ has a more spreading habit, elongate-obovate joints and conspicuous long white spines, reaching 7.3 centimeters in length and little flattened. These spines have a white bloom which is easily penetrated by water so that the spines darken to red when wet.

Individuals were not abundant, but one extensive population was well established on desert plains within the Christmas Mountains. A few scattered specimens were found elsewhere, almost always with _Larrea-Prosopis_ association, so it is probable that local edaphic conditions of greater moisture have contributed to development of this race.

It may represent a separate evolutionary development along parallel lines to the plant of the Organ Mountains, possibly disjunct and never part of the same population. Nevertheless I have hesitated to give it a distinct name on a chiefly geographic basis. There is no reason why parallel evolution should not take place in remote centers, giving rise to almost indistinguishable taxonomic entities that might mingle if brought together in the same area. Closely related species with disjunct distribution may have originated in such varieties. If I have been too conservative in considering the Big Bend population to be essentially the same as Griffiths' O. Wootonii, the most important matter is to point out the existence of similar evolutionary trends in isolated areas. It will be interesting later to cultivate them side by side and to hybridize them.

My description is based on seven collections.

BREWSTER COUNTY: with Prosopis on sandy clay, 1900 ft., near Solis Ranch-house along Rio Grande, Big Bend Nat. Park Apr. 28, 1948, #274; with Larrea-Flourensia and Agave lechuguilla, 3200 ft., in Dagger Flats, Big Bend Nat. Park, Aug. 2, 1948, #873; with Larrea-Prosopis on silty clay soil, 12 mi. n. of Terlingua on rd. to Alpine, Sept. 14, 1948, #1182; with Larrea-Prosopis, 2900 ft., just ne of Terlingua, Sept. 17, 1948, #1224; with Prosopis, 4.1 mi. along rd. into Christmas Mts. ne of Study Butte, Sept. 18, 1948, #1231; with Larrea-Prosopis on flat valley in Christmas Mts., Sept. 18, 1948, #1236; * with Larrea-Prosopis, near end of rd. in Christmas Mts., Sept. 18, 1948, #1244.

Opuntia tenuispina Engelmann Rep. U. S. & Mex. Bound. Surv. II, Pt. I, p. 50. 1859.

O. minor C. Mueller in Walpers, Ann. Bot. 5:50. 1858.

PLANT low, spreading, only terminal joints ascending, much branched, 5-6 dm. high, 15-21 dm. wide; definite TRUNK absent; ROOTS fibrous; JOINTS long-oval to short-obovate, often with attenuate base from 16-27.5 cm. long and to 13 cm. wide, 5-11 mm. thick, relatively thin, very glaucous, yellow-green to glaucous-green, purple around areoles; TEXTURE mealy;

LEAVES slender, subulate, long-apiculate, reaching 6 mm. in length and 1 mm. in width; AREOLES relatively remote, 25-35 mm. apart, mostly long-oval, some short-obovate, relatively small, to 7 mm. in length and 3 mm. in width, becoming conspicuous with yellow glochids in age; WOOL tan; SPINES 1-5 per areole, from areoles on upper half or less of joint, especially marginal areoles, elliptic in cross-section with flattened base, often annulately colored, acicular, young spines terete with orange or black bases becoming paler toward orange tip, older spines white with black bases and yellowish-orange tips, finally becoming gray with darker tips; 1 spine very long, to 6.6 cm. sometimes deflexed, 1-2 spines shorter 3.3-4.5 cm., twisted, spreading, deflexed; 1 spine often very short to 2 cm. terete, mostly white, usually deflexed; BRISTLES absent; GLOCHIDS conspicuous, yellow or reddish-brown with yellow tips and bases, becoming longer in older areoles; FLOWER reaching 9 cm. in length and 6-8 cm. across, with perianth segments in 4 whorls, outer segments bluish-green with purplish tips and yellow lateral margins, obovate, apiculate, to 1.4 cm. long and .9 cm. wide, inner segments clear yellow with faint rosy blush at base, spatulate, somewhat fimbriate, mucronate, to 5.2 cm. long, and 3.5 cm. wide; FILAMENTS greenish-white below, white above, 14 mm. long, anthers white; STYLE creamy, 6 mm. wide just above base, 21 mm. long, stigma lobes 6-8, creamy with green edges, 4.5 mm. long; OVARY obconic, with truncate base, to 3 cm. long and 1.8 cm. in diameter, with small, distant areoles, somewhat elevated to 2 mm. high, upper ones bearing subulate, mucronate leaves, 8 mm. long, 2 mm. wide and numerous reddish-brown glochids; FRUIT juicy, long-oblong, obovate or pyriform, relatively small, 2.7-4.2 cm. long, 1.8-2.7 cm. in diameter when mature, rosy-red to light reddish-purple with many minute, prominent, elevated areoles bearing few yellow or reddish-brown glochids; UMBILICUS v-shaped, to 6 mm. deep; FLESH pale purple; SEEDS relatively small, smooth, beakless and notched at hilum, 5 mm. in diameter, 1.5-2.0 mm. thick, aril 1 mm. wide; SEEDLINGS with long, broad, unequal cotyledons, bronze green with pink blush, 13-18 mm. long, 7-8 mm. wide with obtuse tips; STOMATA of leaves averaging 43.2 $\mu$ in length; TYPE LOCALITY: sand hills on the Rio Grande near El Paso, Texas. GENERAL DISTRIBUTION: Arizona, Zion Nat. Park, Utah, New Mexico, southwestern Texas, northern Chihuahua in Mexico. LOCAL DISTRIBUTION: frequent in desert life belt in southern and eastern Brewster County, occasionally in grassland belt, frequent in encinal life belt in Chisos Mountains and on Nine-Point Mesa.

A translation of "tenuispina" give "slender spines" which characterizes these plants, in addition to a low spreading habit, long-obovate joints, spines in upper areoles only, and usually 1 to 3 terete spines per areole. It closely resembles Opuntia phaeacantha and can only be well distinguished by thinner joints, fewer spines per joint and seeds with more narrow aril. Low bushes of O. Engelmannii also may be confused with O. tenuispina, but have larger areoles and flatter spines. Flowers are very sparse; a few mature fruits were collected by early August. A low percentage of seeds germinated in thirty-three days. The young plumule bears areoles with a few short, white radial bristles.

Plants of O. tenuispina tend to form large colonies in local sandy areas, and are most commonly associated with desert shrub vegetation, as Larrea-Flourensia. (Plate XXXV). However, individuals are also found in Bouteloua-Prosopis, in Quercus-Juniperus on Nine-Point Mesa and with Pinus-Juniperus in the Chisos Mountains. (Plate XXXVI). Occasionally, O. tenuispina occurs on tobosa flats, although it is more common on silty to sandy loams.

Opuntia Engelmannii, O. Engelmannii x phaeacantha, O. Grahamii, commonly occur with O. tenuispina.

SPECIMENS EXAMINED:

ARIZONA: in valley usually in adobe soil, vicinity of Benson, March 2, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12312 (NY); sand hills, vicinity Benson, March 2, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12316 (NY). vicinity of Benson, March 2, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12318 (NY);

NEW MEXICO: Mesilla Park, 1908, J. N. Rose 11707 (US); Mesilla valley, June 1906, P. C. Standley (US).

TEXAS: vicinity of El Paso, July 1912, E. Stearns, 333 (US); garden specimen cultivated in Arizona, (original specimen from El Paso,) May 1, 1896, J.W. Toumey (US); *sandy hillocks below El Paso, 1852, C. Wright 332, (MO).

MEXICO: CHIHUAHUA - Juarez, June 1912, E. Stearns (NY, US).

My description is based on 32 collections.

BREWSTER COUNTY: with grass in Basin, near Window, 4600 ft., Chisos Mts., Big Bend Nat. Park, July 12, 1948, #764; in grassy meadow south of Pulliam Bluffs, Chisos Mts., Big Bend

Nat. Park, July 14, 1948, #778; with Larrea and Fouquieria, 2800 ft., sandy loam soil, Tornillo flats, east of Paint Gap Hills, Big Bend Nat. Park, July 18, 1948, #823; with Larrea, Prosopis, Fouquieria, and Jatropha, sandy soil 3800 ft., along Chalk Draw rd., ne. of Nine-Point Mesa, Aug. 3, 1948, #908; with Larrea-Flourensia sandy clay loam, along Reagan Canyon rd., Aug. 14, 1948, #976; with Larrea at 2500 feet on open flat, 28 mi. n. of Reagan Canyon along Bullis Gap rd., Aug. 17, 1948, #1014; with Acacia, Bouteloua, Yucca, 4000 ft., sw. of Marathon at old Post, Aug. 21, 1948, #1035; with Bouteloua-Juniperus, on silt loam, 4000 ft., Kuntz ranch rd. into Del Norte Mts., Sept. 3, 1948, #1128; with Larrea-O. leptocaulis, 2200 ft., 2 mi. n. of Ste. Elena Canyon, Big Bend Nat.Park, Sept. 16, 1948, #1204; with Larrea, on desert flat in Christmas Mts., Sept. 18, 1948, #1233; with Bouteloua-Prosopis, ft., 4½ mi. nw. of $O_2$ ranch rd. to Marfa, Sept. 25, 1948, #1266; with Larrea-Flourensia, sandy soil 3400 ft., s. of Nine-Pt. Mesa, Sept.26, 1948, #1273; 1274; with Quercus-Juniperus on sandy loam, 5100 ft. top of Nine-Pt. Mesa, Sept. 29, 1948, #1290; 1376; With Hilaria mutica, 3000 ft., bet. Pope and Martin ranch houses, e. of Santiagos, Oct. 6, 1948, #1345.

JEFF DAVIS COUNTY: with Prosopis, along Rt. 17 toward Toyahvale, June 23, 1948, #623;

TERRELL COUNTY: with Bouteloua-Prosopis, w.of Sanderson, July 9, 1948, #739, 742.

Opuntia Lindheimeri Engelmann, Bost. Jour. Nat. Hist. 6:207. 1850.

O. dulcis Engelm. Proc. Amer. Acad. 3:291. 1856.
O. Lindheimeri dulcis Coult., Contr. U. S. Nat. Herb. 3:42. 1896.
O. Engelmannii dulcis Schum. Gesamtb. Kakteen 725. 1898.
O. cacanapa Griffiths & Hare, N. M. Agr. Exp. Sta. Bull. 60:47. 1906.
O. ferruginispina Griffiths, Rep. Mo. Bot. Gard. 19:267. 1908.
O. tricolor Griffiths, Rep. Mo. Bot. Gard. 20:85. 1909.
O. texana Griffiths, Rep. Mo. Bot. Gard. 20:92. 1909.
O. subarmata Griffiths, Rep. Mo. Bot. Gard. 20:94. 1909.
O. alta Griffiths, Rep. Mo. Bot. Gard. 21:165. 1910.
O. Gomei Griffiths, Rep. Mo. Bot. Gard. 21:167. 1910.
O. Sinclairii Griffiths, Rep. Mo. Bot. Gard. 21:173. 1910.
O. cyanella Griffiths, Rep. Mo. Bot. Gard. 22:30. 1912.
O. gilvoalba Griffiths, Rep. Mo. Bot. Gard. 22:35. 1912.
O. convexa Mackensen, Bull. Torr. Club 39:290. 1912.
O. Griffithsiana Mackensen Bull. Torr. Club 39:291. 1912.
O. reflexa Mackensen Bull. Torr. Club 39:292. 1912.
O. deltica Griffiths, Bull. Torr. Club 43:84. 1916.
O. laxiflora Griffiths, Bull. Torr. Club 43:85. 1916.
O. flexispina Griffiths, Bull. Torr. Club 43:87. 1916.
O. squarrosa Griffiths, Bull. Torr. Club 43:91. 1916.

PLANT a large bush, occasionally arborescent, 9-12 dm. high, (2.4 m. high near Devil's River), to 18 dm. wide; definite TRUNK rare, to 7 cm. long and 2 cm. in diameter; BRANCHES massive, spreading and ascending; ROOTS fibrous; JOINTS short-to-long-obovate, long-oval, orbicular, or wider than long, 12-33 cm. long, 16-24.5 cm. wide, 5-15 mm. thick, sometimes very glaucous, pale yellow-green or blue-green, purple around areoles; LEAVES long-subulate, apiculate, flattened, 7-11 mm. long, 1-3 mm. wide, green; AREOLES distant, 3.5-4.5 cm. apart, somewhat elevated and conspicuous, oval to round, large, 6-10 mm. long, 5 mm. wide, in age becoming larger, more spiny, to 4 mm. high with numerous dark divergent glochids; WOOL abundant, reddish-brown; SPINES 0-5, from areoles on upper two-thirds or all of joint, subulate, annulate, flattened, somewhat curved, young spines rufous or yellow with rufous bases, older spines reddish-brown to yellow with short reddish-brown bases and yellow tips, finally becoming gray, brown or black; 1-4 spines longer, 4-6 cm. not usually twisted, spreading downward, 0-2 spines lower in areole, shorter to 1.2 cm., usually deflexed; BRISTLES absent; GLOCHIDS especially conspicuous in marginal areoles, 8-15 mm. long, bright yellow when young, becoming reddish-brown, orange, or yellow with reddish-brown bases, finally gray in older areoles; FLOWER BUDS usually from marginal areoles; FLOWER large, 7.5-9.5 cm. long, to 7 cm. wide, with perianth segments in 3 whorls, outer segments olive green with yellow margins, obovate, apiculate, to 2 cm. long and 1.2 cm. wide, inner segments yellow to orange-red, broadly-spatulate, mucronate, 3.3-5.5 cm. long, 2.3 cm. wide; FILAMENTS pink below, yellow above, to 16 mm. long, anthers pale-yellow; STYLE short, thick, pink, bulbous above base, to 21 mm. long, stigma lobes 8-12, green, 5-7 mm. long; OVARY long-obconic, 3.5-4.5 cm. long, 2 cm. in diameter, with small, distant areoles, uppermost ones bearing long-subulate leaves to 8.5 mm. long and 2 mm. wide, brown wool, numerous brown to yellow glochids and few yellow bristles; FRUIT abundant, sometimes proliferous, glaucous, pyriform with tapering base, 6-7 cm. long, 3-4 cm. in diameter, plum-purple, with small, distant, circular areoles, few yellow glochids, no spines; UMBILICUS very shallow, saucer-shaped, 4-8 mm. deep; flesh purple, very juicy; SEEDS pale grayish yellow, beakless, scarcely notched at hilum, irregularly shaped, relatively small, 2-4 mm. long, 3 mm. wide, 1-2 mm. thick, aril 1 mm. wide; SEEDLINGS often with hair in basal areoles; STOMATA of leaves averaging 29.3 $\mu$ in length. TYPE LOCALITY: "about New Braunfels" (Texas). GENERAL DISTRIBUTION: southwestern Louisiana, reported in southern New Mexico by Tidestrom (66), southeastern to southwestern Texas, Mexico, in northern Tamaulipas. LOCAL DISTRIBUTION: rare in grasslands of northern Brewster County.

Ferdinand Lindheimer collected actively in southeastern Texas from 1843 to 1852, and this cactus was named by Engelmann in his honor.

The bush resembles O. Engelmannii closely, but is distinguished by consistently yellow spines, lack of bristles in areoles, and relatively large seeds. The flowering period is from the middle of May to early June. Fruits ripen within about six weeks and are as juicy and edible as those of O. Engelmannii.

From San Antonio, west to Del Rio and north to Devil's River, many specimens were noted but further west it becomes rare and forms less massive bushes; in the Big Bend a few isolated specimens of the type were found in encinal and grassland associations at about 4500-4600 feet. (Plate XXXVII). A rare one or two were collected in desert scrub. None of these achieve the massive size of specimens farther east; often the habit is more spreading than ascending. It has given rise to an endemic variety in the Big Bend area, O. Lindheimeri var. chisosensis, page 160.

The type form of the species usually occurs with O. Engelmannii, O. Pottsii, and Echinocereus viridiflorus in

Prosopis thickets, Bouteloua Prosopis and Quercus-Juniperus associations.

SPECIMENS EXAMINED:

NEW MEXICO: Mangas Springs approx. 4700 ft. 18 mi. northwest of Silver City, Grant Co., Sept. 24, 1903, O. B. Metcalfe (ARIZ).

TEXAS: Travis Co., F. A. Barkley 16T237 (TEX); Kingsville, Nueces Co., 1904, J. M. Ferguson (NY, US); San Antonio, 1905, J. Jermy (NY, US); * New Braunfels, 1845, Lindheimer, (MO); Braunfels, 1904, O. Locke (NY, US); Rockport, Dec. 26, 1910, W. L. McAtee 1980 (US); Matagorda, Dec. 28, 1910, W. L. McAtee 1991 (NY, US); Kerrville, Aug. 7, 1909, B. Mackensen (US); San Antonio, Sept. 15, 1909, B. Mackensen (US); San Antonio, 1910, O. Lindheimeri x macrorhiza, B. Mackensen (NY); San Antonio, 1911, B. Mackensen (NY, US); near San Antonio, Aug. 6, 1906, J. N. Rose 11005 (US); vicinity of Laredo, Oct. 21, 1913, J. N. Rose 18029, 18030 (US); valley of the Rio Grande, 1913, J. N. Rose (US); Laredo, 1913, J. N. Rose (NY); Brownsville, 1913, J. N. Rose (NY); Loma Alta near Brownsville, 1913, J. N. Rose (NY); vicinity of Corpus Christi, Oct. 24, 1913, J. N. Rose 18093 (NY, US); near Laredo, June 27, 1905, J.N. Rose, J. H. Painter, J. S. Rose 8223, 8235 (US); Laredo, Aug. 6-7, 1906, J. N. and J. S. Rose 11008 (US); Mustang Island, 1908, F. Weinbarg (US); Industry 1905, Wurzlow (NY).

MEXICO: SAN LUIS POTOSI - Charcas, Venado road, Charcas, July-August 1934, C. L. Lundell 5795 (MICH).

My description is based on 26 collections.

BELL COUNTY: with Prosopis and grass, Rt. 81, 5 mi. no. of Jarrell, Mar. 25, 1948, #153.

BREWSTER COUNTY: with Quercus, 4700 ft., igneous hills 2 mi. sw. of Alpine on Lane Ranch, May 9, 1947, #106; with Fallugia and Bouteloua, 4900 ft., Kuntz Ranch, e. of Del Norte Mts., Aug. 31, 1948, ANTHONY 1117; with Larrea, 2700 ft., 15 mi. n. along Bullis Gap rd. from Reagan Canyon, Aug. 16, 1948, #1010.

HAYS COUNTY: with Prosopis, Quercus and grass, along Rt. 81 bet. Austin and San Antonio, Mar. 26, 1948, #154.

JEFF DAVIS COUNTY: with Acacia and Prosopis, 4400 ft., on silt loam, east of Mitre Peak, along Musquiz Creek bottomland, June 4, 1948, #515; #516; with Acacia and Juniperus on west slopes of lava-capped mesa, 4500 ft., along Rt. 118 as it enters Davis Mts., June 23, 1948, #618; with Pinus-Quercus along Loop Drive through Davis Mts., Aug. 24, 1948, #1049.

MEDINA COUNTY: with Prosopis and grass, along Rt. 90, 5 mi. past Hondo, Mar. 30, 1948, #178.

TOM GREEN COUNTY: with Prosopis and grass, 19 mi. e. of San Angelo, Oct. 9, 1948, #1354.

UVALDE COUNTY: with Prosopis and grass, 5 mi. w. of Uvalde, Mar. 30, 1948, #181; with Prosopis, 10 mi. w. of Uvalde, Mar. 30, 1948, #185; with Prosopis on overgrazed rangeland, 18 mi. w. of Uvalde, Mar. 30, 1948, #186; #189; #342.

WILSON COUNTY: with Prosopis and grass on Rt. 87 bet. Stockdale and LaVernia, Mar. 28, 1948, #176.

*Opuntia Lindheimeri* var. *chisosensis* var. nov. Robusta; articulis plerisque orbiculatis; areolis obovatis, spinis 1-5, seape curvatis, paullum compressis; floribus ignotis; fructibus subglobosis, 3.3-4.5 cm. longis, 3.5 cm. latis; seminibus 5 mm. diametris. Specimen typicum ex loco dicto "Basin, Chisos Mountains, Big Bend National Park, Texas" siccatum conservatus est sub numero 810 in Herb. Univ. Mich. et vivum conservatum est sub numero 19606 in Hort, Mich.

PLANT a large bush, reaching about 1 m. in height, and 2.5 m. in diameter; TRUNK absent; BRANCHES spreading and ascending arise from short, thickened base; ROOTS fibrous; JOINTS usually 6 per branch, mostly orbicular, some short-obovate with attenuate base, from 16-29 cm. long, 13-22 cm.wide and 6-15 mm. relatively thick, heavily glaucous, yellow-green to gray-green; TEXTURE mealy; AREOLES relatively distant, 30-35 mm. apart, short oval to circular, 7-8 mm. long, 5-6 mm. wide, becoming larger and elevated in age; WOOL abundant, tan; SPINES 1-5, from areoles on upper 2/3 to all of joint, subulate, annulate, elliptic in cross-section, often curved, spreading downward, young spines bright yellow with paler tips, older spines all yellow or reddish-orange with yellow bases and yellow tips; 1 spine very long to 6.7 cm. flattened, 1-4 spines shorter, about 5.5 cm. not twisted, annulate, curved, spreading; 1 spine very short, up to 2 cm., much deflexed; BRISTLES absent; GLOCHIDS in dense tufts, yellow throughout, to 20 mm. long and conspicuous in older areoles; FLOWER not observed; FRUIT juicy, reddish purple, glaucous, small, short-oblong with truncate base to globose, 3.3-4.5 cm. long and 3.5 cm. in diameter when mature, with small, inconspicuous, distant areoles, bearing only a few yellow glochids; UMBILICUS saucer-shaped, to 9 mm. deep; FLESH purple; SEEDS yellow, beakless but notched at hilum, relatively large, 5 mm. long, 4 mm. wide, 2 mm. thick, aril 1 mm. wide; TYPE LOCALITY: Basin of Chisos Mountains, Big Bend National Park, Brewster County, Texas. In Quercus-Juniperus, Quercus-Pinus and _Pinus ponderosa-Pseudotsuga taxifolia_ associations at altitudes from about

5200 feet (about 4400 at lower Cattail Falls) to 6500 feet. DISTRIBUTION: encinal belt in Chisos Mountains, Big Bend National Park, Brewster County, Texas.

The varietal name is derived from the type locality, namely the Chisos Mountains. Bushes of these plants are compact, usually less than one meter high, and colorful with yellow, sometimes red, spines against a glaucous-green background. (Plate XXXVIII). The red-spined form is about as common as the yellow-spined form, but does not occur at as high altitudes above the Basin. *Opuntia Lindheimeri* var. *chisosensis* flowers heavily in May, and the deep red fruits are ripe by the middle of July. Areoles are smaller and less elevated, and spines more spread out than in the typical *O. Lindheimeri*. Unlike the large pyriform fruit of the typical form, the fruit of this variety is relatively small and almost globose with very shallow umbilicus and large seeds. These seeds did not germinate at all in nine months.

This variety is the most conspicuous and abundant cactus in encinal and montane belts from Upper Green Gulch all through the Basin and up the slopes of the higher peaks of the Chisos Mountains. (Plate II). Plants are especially abundant where natural vegetation is disturbed, occurring near Park Headquarter buildings with *O. imbricata* and around the campgrounds with *O. Engelmannii* and *O. tenuispina*. It is the only Opuntia associated with Transition Zone flora at 6500 feet and above. It favors grassy lagunae over shade of the forest and occurs abundantly with O. Engelmannii on open northwest-facing slopes.

Approaching the lower slopes of the Chisos Mountains from the northwest at Oak Springs and Cattail Falls, one finds an occasional specimen of this variety and its associate Echinocereus triglochidiatus which have doubtless been washed down along the waterways.

My description is based on seventeen collections.

BREWSTER COUNTY: *with Quercus-Pinus-Juniperus on very sandy soil, 5500 ft., Basin of Chisos Mts., Big Bend Nat. Park, April 8 & July 17, 1948, #223 and #810 (#811), (#813); with Pseudotsuga taxifolia and Cupressus arizonica in Upper Juniper Canyon, near Boot Springs, 6500 ft., Chisos Mts., Big Bend Nat. Park., Apr. 18, 1948, #253, #254; with Quercus, Staphylea, and grasses 4400 ft. at lower Cat-tail Canyon (nw base of Ward Mt.) Big Bend Nat.Park, May 8, 1948, #314; in grassy meadow southwest in Pulliam Peak, 5200 ft., Chisos Mts., Big Bend Nat. Park, July 14, 1948, #776; with Pinus-Quercus, along Lost Mine Trail, Chisos Mts., Big Bend Nat. Park, July 15, 1948, #791, #794.

Opuntia rufida Engelmann, Rep. U. S.& Mex. Bound.Surv. II, Pt. I, p. 51. 1859.

Common name: "blind pear".

PLANT large, bushy, 9-18 dm. high, 7.5-15 dm. wide, occasionally with definite TRUNK 15 cm. high, 10 cm. in diameter; BRANCHES ascending, somewhat spreading; ROOTS fibrous; JOINTS short to long obovate, to 16.5 cm. long, and 12 cm. wide, 5-8 mm. thick, old joints larger and thicker, pubescent, glaucous, yellowish green to grayish green with purple tinge around areoles; LEAVES very narrowly subulate, long-apiculate, 4-6 mm. long, .5 mm. wide, dark green with pink tip; AREOLES 10-17 mm. apart, elevated, prominent, oval to circular to 5 mm. in diameter, becoming much elevated and worm-like to 4 mm. high in age; WOOL tan, abundant; SPINES and BRISTLES always absent; GLOCHIDS flexible, reddish-brown, to 8 mm. long; FLOWER BUDS prolific, pink; FLOWER 3.5-8 cm. long, 4-4.5 cm. wide, perianth segments in 3 whorls, outer segments pinkish tan, lanceolate, apiculate, to 22mm. long, 6-8 mm. wide, inner segments yellow, fading to pinkish-orange, broadly spatulate, mucronate, 2-3 cm. long, to 2.3 cm. wide; FILAMENTS yellow, to 12 mm. long, anthers pale yellow; STYLE yellow, short and thick, bulbous and 5 mm. wide just above base, 13-17 mm. long, stigma lobes 9-10, dark green, 3 mm. long; OVARY oblong, obconic or obovate, to 2.3 cm. long and 1 cm. in diameter, areoles closely set, small but conspicuous, few with subulate leaves, these to 4 mm. in length, very abundant pale tan, long, thick wool, numerous reddish brown glochids to 4 mm. long, a few reddish brown, porrect bristles to 8 mm. long; FRUIT not observed.[1] STOMATA of leaf averaging 32.2 $\mu$ in length. TYPE LOCALITY: "about Presidio

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[1]Griffiths (34) p.82 ," usually the greater part of the fruit is greenish with only a blush of red on one side."

del Norte on the Rio Grande," Texas. GENERAL DISTRIBUTION: Texas and northern Mexico. LOCAL DISTRIBUTION: desert flats south from approximately latitude 30° in southern Brewster and Presidio counties, characteristically on steep, rocky walls along the river and in canyons.

The specific epithet refers to conspicuous reddish-brown tufts of glochids on the spineless pads. This is the only Opuntia in the Big Bend with pubescent and consistently spineless joints. (Plate XXXIX, Fig. 1).

One form of Opuntia rufida, which I am naming O. rufida var. tortiflora, has joints short-obovate to elliptic, relatively remote areoles, and outer perianth segments which are swirled in imbrication and twisted sideways when the flower is open. (Plate XL, Fig. 1). In contradistinction, the typical form has obovate to long-obovate joints, areoles not as distant and outer perianth segments not swirled in imbrication nor curved on the flower.

Flowering period for both is in April, although Engelmann records the species as blooming in May, from Presidio, Texas into Chihuahua. Fruits require a long period to mature and consequently were not observed.

The species occurs in great abundance on steep limestone cliffs along the Rio Grande and lower parts of its tributaries in the United States (Plate XXXIX, Fig. 2) on rocky cuestas with Larrea-Agave. community, and on the gravelly desert plains with the same but denser vegetation at 2900 feet and lower south and southeast of the Chisos Mountains. O. Engelmannii,

O. Grahamii, O. macrocentra, O. phaeacantha, Echinocereus dasyacanthus, E. enneacanthus and E. stramineus are often associated with O. rufida.

From the Chisos Mountains northward, however, specimens are of sporadic occurrence only, indicating that this is the northern limit of the range. The most northern specimen found in Brewster County was near Yellow House Peak, at about 2800 feet. In Presidio county an isolated plant was seen northwest of Ruidosa on a gravel bench with Larrea and Jatropha at about 2800 feet. No plants of this species were found in desert country adjoining the highlands to the east, north and west.

The species favors Boquillas brown limestone as well as the chalky white limestone, and is abundant there with O. macrocentra. Local range in altitude for O. rufida is from 1600 feet at Reagan Canyon to 4100 feet on Chilicotal Mountain. Soil tolerance ranges from silty clay loam to sand.

SPECIMENS EXAMINED:

TEXAS: Boquillas, Brewster Co. May 1901, V. Bailey 187 (NY, US); *Presidio del Norte, 1852, J. M. Bigelow (MO); 1847, Gregg (MO) western Texas, 1925, E. Mortengan 10 (US).

My description is based on seven collections.

BREWSTER COUNTY: Big Bend Nat. Park: infrequent with *Larrea-Agave, 4100 ft., among igneous rocks on s. slope of Chilicotal Mt., Apr.3, 1947, #17; very abund. with Larrea-Agave on steep limestone slopes, 2000 ft., just nw of Hot Springs, Apr. 18, 1947, #39 a & b; very abund. in Larrea-Agave, ft., on steep n. & w. slopes of hill just e. of Boquillas, Apr. 11, 1948, #242; infreq. with Larrea and Prosopis along Tornillo Flats, in badland area ne of Grapevine Hills, 2800 ft., July 28, 1948, #835; common in Dasylirion-Agave, 3300 ft., on steep limestone cuesta slopes w. of Daggar Flats, Aug. 2, 1948, #898.

PRESIDIO COUNTY: infreq. in Larrea-Jatropha, 2800 ft., along rd. from Ruidosa to Candelaria, Aug. 26, 1948, #1077.

*Opuntia rufida* var. *tortiflora*. Articulis ellipticis breviter obovoideis; areolis remotis; segmentis perianthii exterioribus tortis. Specimen typicum ex loco dicto "Hot Springs, Big Bend National Park" siccatum conservatum est sub numero 39c, in Herb. Univ. Mich.

HABIT and ROOTS as in type form; JOINTS short-obovate, elliptic to short oval, from 13-24 cm. long, 10.5-14 cm. wide, to 11 mm. thick, pale blue-green to gray-green, with purple around areoles; AREOLES remote, 10-15 mm. apart, long elliptic, less elevated, to 3 mm. long, becoming worm-like in age; pale tan becoming darker; GLOCHIDS rufous; FLOWER BUD with segments swirled in imbrication; FLOWER 3.5 cm. long, 5.5 cm. across with perianth segments in 4 whorls, outer segments reddish bronze with green trace, long-lanceolate narrow, twisted, to 2.5 cm. long and 1.7 cm. wide, inner segments yellow, fading to pink,tan base obovate, mucronate, to 3.5 cm. long and 2.3 cm. wide; FILAMENTS 13 mm. long, STYLE yellow, 6 mm. in diameter, 23 mm. long, stigma lobes 8, green; OVARY oblong, to 2.4 cm. long and 1.5 cm. in diameter with large, closely set areoles.

My description is based on six collections.

BREWSTER COUNTY: Big Bend Nat. Park: occas. in Larrea-Agave among igneous rocks, 4100 ft., south slope of Chilicotal Mt., Apr. 3, 1947, #16; *very common with Larrea-Agave on steep limestone slopes nw of Hot Springs, 2000 ft., #39c, (d) and (e); abund. with Larrea-Agave on steep nw slope of hill e. of Boquillas, 2000 ft. Apr. 11, 1948, #237; occas. in Dasylirion-Agave on slopes of brown limestone hills just s. of Dagger Flats, Aug. 2, 1948, #899.

<u>Opuntia macrocentra</u> Engelmann Rep. U. S. & Mex. Bound. Surv. II pt. I, 1859.

PLANT a low-growing bush, to 6 dm. high, and 6 dm. wide, rarely with definite TRUNK, to 7.5 cm. high, 5 cm.wide; BRANCHES spreading, and somewhat ascending; ROOTS fibrous; JOINTS short-elliptic, obovate, orbicular or wider than long, often twisted, 9-26 cm. long, 7.5-17 cm. wide, relatively thin, only 4-10 mm. thick, glaucous, young joints reddish, or turquoise, becoming yellow-green, gray-green on blue-green, purple around areoles or throughout; LEAVES narrowly subulate, apiculate, 5-8 mm. long, 1-1.5 mm. wide, green or blue-green with reddish tips, AREOLES closely set, 1.5-4 cm. apart, relatively small, narrow, 8-11 mm. long, 2-5 mm. wide, scarcely larger in age; WOOL reddish brown to tan; SPINES 0-7 mostly 2-3 per areole, from areoles on upper one fifth to one half of joint, marginal ones particularly, acicular, flexible, flattened or terete, often twisted, curved or straight, annulately colored, young spines white, yellow or red, with yellow tips, older spines reddish-brown to black, occasionally almost white, with reddish-brown bases and pale yellow tips, finally becoming gray-white; 2-3 spines longer, 3.5-14 (mostly 8-9) cm. porrect and spreading, 1 spine lower in areole, shorter 2.5-3.8 cm. white to gray with brown tip, deflexed; BRISTLES absent; GLOCHIDS abundant, conspicuous, long, rufous when young, yellow or rufous in age and becoming 7 mm. long; FLOWER BUDS yellowish green with pink tips, from areoles along upper margin; FLOWER 6.5-8.5 cm. long, 4-6 cm. across, with perianth segments in 4 whorls, outer segments with yellow margins and olive green to reddish-brown trace, short-obovate, apiculate, to 1.5 cm. long and 1.1 cm. wide, inner segments pale to dark yellow with rose bases and white tips, fading to salmon pink or burnt orange, obcordate, fimbriate, apiculate, 4-5.2 cm. long, 3.2 cm. wide; FILAMENTS green below, white above or green throughout, 10-18 mm. long, anthers yellow; STYLE white to green, bulbous and 5 mm. in diameter just above base, 17-30 mm. long, stigma lobes 7-9, yellow or pale green, 3-5 mm. long; OVARY bristly at rim, long obconic to oblong, 3.5-4.3 cm. long, 1-2 cm. in diameter, with small distant areoles, occasionally with narrowly subulate scales, all with abundant tan wool, numerous, long, reddish brown to yellow glochids, uppermost areoles with 1-3 yellow to rufous bristles reaching 14 mm. in length; FRUIT juicy, rarely proliferating, short-oblong to long-obovate with attenuate base, 2.5-4.3 cm. long, .6-3 cm. in diameter, reddish purple with small, inconspicuous wooly areoles, few reddish-brown glochids, bristles and spines lacking; UMBILICUS v-shaped, 4-8 mm. deep and 9 mm. across top; flesh purple; SEEDS abundant, beakless, deeply notched at hilum, yellow to tan, rough, relatively large, 2-6 mm. long, 3-6 mm. wide, 1 mm. thick, aril 1 mm. wide; STOMATA of leaf averaging 22.6 $\mu$ in length. TYPE LOCALITY: sandy ridges in the bottom of the Rio Grande near El Paso, also on the Limpia River, Texas. GENERAL DISTRIBUTION: south central and southeastern Arizona, southern New Mexico, western Texas, Mexico, in Chihuahua. LOCAL DISTRIBUTION: occasional in grasslands and common desert flats in Brewster and Presidio counties.

The name "macrocentra" means large central spines, a feature which distinguishes this species in its typical form immediately. Usually spines are confined to areoles along the upper margins of joints. (Plate XLI). Three or four spines are generally present per areole, with at least one longer than the two intermediate spines, and one very much shorter and deflexed. The species is well segregated from _Opuntia phaeacantha_ by the thinner and usually orbicular joints, slender leaves, smaller and closely set areoles, lack of bristles, more acicular spines, and more elongate flowers with narrower outer segments. _O. setispina_, alike in orbicular joints, closely set areoles, and large flower, always has thicker joints with spines spreading downward, while _O. macrocentra_ has porrect, upward-spreading spines.

Unlike _O._ _setispina_, individuals in sheltered habitats are frequently spineless. (Plate XLI, Fig. 1).

Joints of _O._ _macrocentra_ are peculiarly subject to becoming purple, especially in dry years and in sunny summers more than in the winter. Young joints are a beautiful reddish or blue-green.

_O._ _macrocentra_ is one of the earliest cacti in the region to begin flowering. Buds open from April to the middle of May. Flowers may be almost as long as the joint, and sometimes the perianth is twice as long as the ovary.

The many fertile fruits ripen by early July. (Plate XLI, Fig. 2). Seeds are large but with narrower arils than on seeds of _O._ _phaeacantha_.

_O._ _macrocentra_ is a conspicuous element in the Larrea-Agave association on desert flats around the Chisos Mountains, on tobosa flats south and west of the grassland belt (i.e., west of Nine Point Mesa, and northwest of Valentine in Jeff Davis County) on local areas of sandy Boquillas limestone, sometimes with _O._ _rufida_, and on bare rocky hills with the Bouteloua-Yucca community in grassland. (Plate XXX, Fig. 2).

The species has a wide range of distribution from Larrea-Agave vegetation at 1900 feet on limestone ridges along the Rio Grande to less frequent occurrence with Quercus-Juniperus in the encinal belt at 4750 feet. Its soil tolerance ranges from sandy to clay loam. Hence it occurs with a variety of other cacti, having been found with all except _Opuntia_ _Davisii_, _O._ _polyacantha_, _O._ _strigil_, _O._ _trichophora_ and _O._ _tunicata_.

SPECIMENS EXAMINED:

ARIZONA: cactus garden, Univ. of Ariz. Dec. 5, 1939, L. Benson 9878 (ARIZ); Thompson Ranch 4500 ft. Perilla Mts., 10 mi. east of Douglas on road to San Bernardino, Cohise Co., scattered along canyon bottom, June 16, 1945, R. A. Darrow 2586 (ARIZ); Mt. Graham, July 1922, C. R. Orcutt (US); vicinity of Benson, May 15, 1908, J. N. Rose 11961 (US); vicinity of Benson, March 2, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12321 (NY, US); San Pedro valley, July 28, 1894, J. W. Toumey (US); Bowie, Oct. 20, 1896, J. W. Toumey (NY); Safford, Oct. 20, 1896, J. W. Toumey (US); Nogales, Nov. 10, 1896, J. W. Toumey and Achmun (US); Bowie, Dec. 1896, J. W. Toumey and Achmun (US); gravelly slopes at northern end of Coyote Mts., 40 mi. west of Tucson on Tucson-Ajo road, Pima Co., March 5, 1937, I. L. Wiggins 8680 (DS, US).

NEW MEXICO: White Water, Grant Co., June 3, 1892, E. A. Mearns 81 (US); Dog Spring, June 13, 1892, E. A. Mearns 311 (US); Lordsburg, April 1908, J. N. Rose 11730 (US); cactus garden Agricultural College, April 30, 1910, J. N. Rose, P. C. Standley, P. G. Russell 15206 (US); mesa west of Organ Mts. approx. 4000 ft., Dona Ana Co., July 1906, P. C. Standley 493 (US); between Strauss and Anapra, July 1912, E. Stearns 371 (US); Steins Pass, May 12, 1895, J. W. Toumey (US); 1851-52, C. Wright I (NY).

TEXAS: Ft. Davis, Jeff Davis Co., June 6, 1902, W. L. Bray (TEX); 26 mi. east of Castolon, 1937, Cutler 763, Dog Gap, Santiago Mts., H. C. Cutler 768 (MO); Fresno Canyon, 25 mi. north of Lajitas, Presidio Co., May 29, 1938, H. C. Cutler 1907 (MO, NY, S); Juniper Canyon, Chisos, 1937, H. C. Cutler 960 (MO); 2 mi. west of Castolon, H. C. Cutler 1034 (MO); Alpine, Sept., 1909, B. Mackensen (US); Sierra Blanca, 1891, Nealley & Evans (US); vicinity of Pecos City, Oct. 14, 1913, J. N. Rose and W. R. Fitch 1790 (NY, US); vicinity of Sierra Blanca, Feb. 24, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12230 (NY, US); Franklin Mts., vicinity of El Paso, Feb. 26, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12295 (NY, US); desert scrub areas east and south of the Chisos Mts., Brewster Co., April 12-13, 1941, with excellent photographs, O. E. Sperry 1906, 1911, 1915, 1916 (ARIZ); *low hills in Rio Grande bottom near El Paso, 1852 C. Wright (MO).

MEXICO: CHIHUAHUA - Candelaria, 50 mi. south of Juarez, E. Stearns (US).

UNCLASSIFIED: Monument no. 40, Mexican Boundary Line, May 9, 1892, E. A. Mearns 246 (US).

My description is based on 54 specimens.

BREWSTER COUNTY: with Jatropha spathulata and Fouquieria splendens on rocky hills 1 mi. se of Castolon, 2100 ft., Big Bend Nat. Park, Mar. 31, 1947, #12; with Larrea-Agave on rocky southern slopes of Chilicotal Mt., 2600 ft., Big Bend Nat. Park, April 5, 1947, #18; 20; with Larrea-Agave on limestone cuesta, 1900 ft., 1 mi. ne Solis Ranch house, near Rio Grande, Big Bend Nat. Park, April 8, 1947, #26, 29 a- q; with Dasylirion-Agave 3100 ft., on north slope of Chilicotal Mt., Big Bend Nat. Park, May 1, 1947, #61; with Larrea-Agave 3200 ft., along abandoned rd. toward Chilicotal Springs, Big Bend Nat. Park, May 1, 1947, Apr. 26, 1948, #62, #267; with Bouteloua-Aristida 4750 ft. on "A" hill just south of Alpine, May 6, 1947, #86; with Quercus-Juniperus, 4700 ft., Lane Ranch, sw of Alpine, May 9, 1947, #102; with Prosopis in thicket, 3600 ft., along rd. from Rt. 67 in toward Gilliland Canyon, June 4, 1948, #510; with Larrea, 2800 ft., on low hills w. of Dead Horse Mts., Big Bend Nat. Park, July 28, 1948, #841; with Larrea-Flourensia, 3400 ft., bet. Burnham Ranch and Hot Springs turnoff, July 31, 1948, #862; with Hilaria mutica on broad clayey flat, 3200 ft., west of Santiago Peak, Aug. 3, 1948, #935; on bank of draw 8½ mi. along rd. from Study Butte into Christmas Mts., Sept. 18, 1948, #1240; with Larrea, 3900 ft., 6 mi. w. on rd. in to $O_2$ Ranch, s. of Mitchell Mesa, Sept. 24, 1948, #1261.

EL PASO COUNTY: with O. arenaria and Larrea-Prosopis association on open sandy flat, 2½ mi. west of Smeltertown, Aug. 9, 1948, #950.

PRESIDIO COUNTY: with grass along railroad tracks, 4800 ft., 5 mi. e. of Marfa, June 1, 1948, #487.

Opuntia macrocentra var. minor var. nov. Diffusa; paucis ramis erecte ascendentibus; articulis quam in forma typica minoribus breviter obovatis; areolis remotioribus; spinis 2-7, varie divergentibus; floribus fructibusque ignotis. Specimen typicum ex loco dicto "Ruidosa, Presidio Co., Texas" siccatum conservatum est sub numero 1081, in Herb. Univ. Mich. et vivum conservatum est numero 19607 in Hort. Mich.

PLANT mostly spreading much branched; some branches vertically ascending; TRUNK absent; ROOTS fibrous but sometimes with fleshy taproot; JOINTS short obovate, from 6 cm. and 5 cm. wide to 10 cm. long and 7 cm.wide, to 8 mm. thick, heavily glaucous, young joints blue-green, older joints glaucous green; LEAVES subulate, apiculate, 4-6 mm. long, 1.5 mm. wide, green; AREOLES 15-20 mm. apart, large, ovate to circular, 3-6 mm. long, 2-4 mm. wide, becoming larger in age; WOOL tan to gray; SPINES 2-7 mostly (3-4), from areoles on upper half of joint, acicular, twisted, angular, young spines rufous below, becoming white with orange tips, older spines rufous with orange tips, finally becoming all brown; 1-3 spines longer, mostly 4.5 cm., a few to 6 cm., spreading, 1-4 spines shorter, mostly 2.5 cm., spreading, 1 spine short 2.2 cm. always deflexed, rufous below, white toward tip; BRISTLES absent; GLOCHIDS abundant, conspicuous, bright orange when young, yellow and rufous with yellow bases and to 12 mm. long in older areoles; FLOWERS unknown; FRUIT unknown; STOMATA of leaf averaging 22.6 µ in length. TYPE LOCALITY: along road from Ruidosa, 1.4 miles southeast toward Presidio, on sandy soil, with Larrea, Presidio County. LOCAL DISTRIBUTION: in Larrea and Larrea-Prosopis associations on sandy flats along the Rio Grande River, from 2100-2700 feet, Ruidosa and Presidio, Pres. Co., and north of Santa Elena Canyon in Big Bend Nat. Park, Brewster Co.

The small-jointed, spreading and very spiny *Opuntia macrocentra* var. *minor* was evident in two very sandy, open and flat localities at about 2200 to 2700 feet. (Plate XL, Fig. 2). Neither flowers nor fruits were found.

Tap roots on one plant were definitely fleshy. The spreading branches form an extensive clump among the Larrea bushes; occasional erect branches, three to four joints long, give an average height of three decimeters. Spines are rufous throughout, unlike those of the typical *O. macrocentra*, with the terminal half paler or white. (Plate XLII, Fig. 1).

Cacti associated with this variety are *Opuntia Engelmannii*, *O. leptocaulis*, and *O. phaeacantha*.

My description is based on two collections.

BREWSTER COUNTY: with Larrea-Prosopis on sandy soil, 2200 ft., 4.8 mi. n. Ste. Elena Canyon, Big Bend Nat. Park, Sept. 16, 1948, #1211.

PRESIDIO COUNTY: with Larrea on sandy flats, 2700 ft., 1.4 mi. along rd. from Ruidosa to Presidio, Aug. 26, 1948, #1081.

PLANT spreading and ascending; ROOTS fibrous; JOINTS obovate, to 20 cm. long, 15 cm. wide and 7-12 mm. thick, heavily glaucus, gray-green purple around areoles; LEAVES subulate, 8 mm. long, 2 mm. wide, AREOLES distant, 20-35(mostly 22) mm. apart, ovate, relatively small, to 6 mm. long and 4 mm. wide, in age becoming 9 mm. long and 6 mm. wide; WOOL brown; SPINES 1-6 from areoles on upper half of joint, acicular, terete to elliptic, twisted, usually curved, young spines yellow with darker bases, older spines grayish yellow; 5 spines longer, 4-7.7 cm. spreading, 1 spine shorter, to 1.8 cm. deflexed; BRISTLES absent; GLOCHIDS yellow, up to 13 mm. long in older areoles; FLOWER 5.5 cm. long, with perianth segments in 4 whorls, outer segments sagittate, apiculate, to 1.2 cm. long and .6 cm. wide, inner segments yellow, spatulate, apiculate, to 3 cm. long and 2 cm. wide; FILAMENTS greenish yellow or greenish white, 15 mm. long; STYLE creamy, bulbous above base, 18 mm. long, stigma lobes 7, yellow, 5 mm. long; OVARY obconic, 3 cm. long, 2 cm. in diameter, with distant areoles, uppermost ones bearing subulate leaves, numerous rufous glochids, no bristles nor spines; FRUIT unknown; STOMATA of leaf averaging 34.0 $\mu$ in length. DISTRIBUTION: In Glass Mountains, southwest of Old Blue Mountain.

This plant most closely resembles Opuntia macrocentra with a few long spines in each areole along the upper margin of the joints. (Plate XLII, Fig. 2). But the spines are yellow rather than dark reddish-brown, areoles are relatively distant rather than closely set and the flowers are yellow throughout.

The plant therefore suggests a hybrid between _O. Lindheimeri_ and _O. macrocentra_. Continued observation of specimens under cultivation will be necessary to substantiate this hypothesis.

My description is based on two collections.

BREWSTER COUNTY: with Bouteloua-Juniperus valley in Glass Mts., on Victor Pierce Ranch, May 19, 1947, #125; on low limestone hill with Pinus-Quercus, Yates Ranch, Glass Mts., June 3, 1948, #506.

_Opuntia setispina_ Engelmann in Salm-Dyck, Cact. Hort. Dyck. ~~1849. 239, 1850.~~

PLANT a low bush with dense divergent branching, 2.5-6 dm. high, 7.3-12 dm. across, rarely with short, spiny TRUNK; ROOTS fibrous; JOINTS mostly 5 per branch, short to long obovate or orbicular, sometimes with attenuate base, often twisted, from 12-25 cm. long, 11-17 cm. wide, 6-12 mm. relatively thick, old joints thicker, more spiny, slightly glaucous, yellowish-green or gray to dark green, often purplish around areoles; TEXTURE granular; LEAVES thick-subulate, mucronate, terete, 5-8 mm. long, 1-2 mm. wide, purplish-green, AREOLES relatively closely set, 13-20 mm. apart, neat-looking, elevated, long narrow-elliptic, small, to 6 mm. long and 4 mm. wide, becoming rounder, larger, with more abundant orange glochids in age; WOOL yellow to reddish-brown; SPINES 1-10 (mostly 2-4) per areole on upper one or two thirds of joint, especially along margin, acicular, some angular or flattened dorso-ventrally, others terete, young spines blackish brown and white with orange tips, older spines brown to gray with darker bases and red tips, finally becoming gray; 1 spine longer, 4.5-6.4 cm. long, porrect, 2 spines shorter, twisted, only 1 of these porrect, other slightly deflexed, 1 spine shorter to 2 cm., always much deflexed; BRISTLES absent; GLOCHIDS inconspicuous, in high, dense circular tuft, filling the areole, reddish-orange with yellow bases when young, yellow, orange or reddish brown with yellow bases in older areoles, to 12 mm. long; FLOWER 5-7 cm. long, 6 cm. wide, with perianth segments in 4 tight whorls, outer segments olive green with yellow, entire margins and purple tips, narrowly subulate to obovate, apiculate, to 2.2 cm. long and 1.2 cm. wide, inner segments yellow with long rose-colored bases, long obovate, fimbriate, mucronate, 3-4.5 cm. long, 2.2-3 cm. wide; FILAMENTS greenish below, pale yellow above, 11-13 mm. long, anthers yellow to white; STYLE creamy below, pinkish above, bulbous and 6 mm. in diameter at or above base, 18-20 mm. long, stigma lobes 7-8, yellow with green margins, 4-6 mm. long, perianth persistent; OVARY wrinkled, short to long-obconic with truncate base, 2.5-3.5 cm. long, to 1.8 cm. in diameter, relatively closely set minute areoles, with many, long subulate scales, 7-10 mm. long, abundant tan wool, numerous small reddish-brown glochids with yellow bases, bristles and spines lacking; FRUIT pinkish purple to lavender, wrinkled when dry, long-elliptic, oblong, obovate or pyriform, with long tapering base, 3-5 cm. long, 2.2-3 cm. fruit occasionally with double or even triple, fusion of ovaries, abundant minute inconspicuous areoles; conspicuous reddish-brown short glochids, no spines; umbilicus tan, U-shaped, to 9 mm. deep, 13x15 mm. across flesh purple; SEEDS yellow and brown, beaked, notched at hilum, large, 5 mm. in diameter, 2 mm. thick, aril to 1 mm. wide; SEEDLINGS with very unequal, long-oblong cotyledons, 8-14 mm. long, 5-6 mm. wide with obtuse tips; STOMATA of leaf averaging 28.7 $\mu$ in length. TYPE LOCALITY: "Pine woods in the mountains west of Chihuahua, Mexico." GENERAL DISTRIBUTION: Western Texas to western Chihuahua, in Mexico. LOCAL DISTRIBUTION: grassland associations of northern Brewster county.

The relatively thin, acicular spines explain the name "seti" (L) bristle, and "spina" (L) spines.

This grassland and encinal species resembles O. macrocentra, but has thicker, usually orbicular joints, with spines spreading downward. (Plate XLIII, Fig. 1). Some specimens also resemble O. tenuispina with acicular spines, but the latter species has a more creeping habit, usually long obovate joints with fewer and less flattened spines, often only in marginal areoles.

When plants of O. setispina are in flower, from the middle of May to the middle of July, one notices particularly the very numerous and minute areoles on the somewhat tuberculate ovaries, equally evident on the fruits which mature from the earliest flowers by late June. Occasionally mature fruits show fusion of two and even three ovaries on otherwise normal individuals. No flowers with this tendency were seen. Seeds within these typical fruits were perfectly normal and well formed. In the laboratory only a few of any of the seeds germinated after fifty-five days.

One plant that looked like a hybrid between _O. setispina_ and _O. tortispina_ was found in eastern Brewster County. (Plate XLV, Fig. 2). Further observations on the living specimen which has not yet flowered, will be necessary to confirm this supposition.

_O. setispina_ occurs in the Big Bend region at altitudes from about 3400 feet northwest of the Glass Mountains to 5000 feet east of Hess Canyon in the Glass Mountains. Individuals are most abundant on tobosa flats, within these altitudes, where they grow deep in grass; _O. tortispina_ is equally common in that association with a few plants of _O. imbricata_ and _O. phaeacantha_. (Plate XLIII, Fig. 2).

_Opuntia setispina_ appears occasionally in all other grassland communities and up through Quercus-Pinus association in the montane belt, on clay to loam soils.

SPECIMENS EXAMINED:

MEXICO: CHIHUAHUA - vicinity of Minaca, April 1, 1908, _J. N. Rose_ 11640 (NY, US).

UNCLASSIFIED: * 1846, _A. Wislizenius_, (MO).

My description is based on sixteen collections.

BREWSTER COUNTY: with Juniperus on low limestone ridge, 4200 ft., on Victor Pierce Ranch, May 13, 1948, #108; with

Bouteloua-Prosopis-Opuntia, on clay soil, Sohl-Abbington (Lake) Ranch, nw of intersection of Rts. 67 & 90, May 14, 1949, #343; with Larrea-Flourensia on silty clay loam, 3800 ft., on Parr Ranch, e. of Rt. 67, May 18, 1948; #364; with Hilaria mutica, 3400 ft., on clay soil, Neal Ranch, e. of Rt. 67, June 9, 1948, #536; #541; with Bouteloua-Aristida and Microrhamnus ericoides, 4500 ft., along rd. in to Sunny Glen, nw of Alpine, June 17, 1948, #555; with Bouteloua-Juniperus on silt loam, 4600 ft., at entrance to Sunny Glen, nw of Alpine, June 27, 1948, #654; with Hilaria mutica, on loam, 4000 ft., along Four-Mile Crossing rd., se of Marathon, July 7, 1948, #712, 1028, 1029, 1031; with Bouteloua-Prosopis on sandy silt, 4000 ft., 1½ mi. s. of Marathon on Rt. 227, Aug. 19, 1948, #1020; with Bouteloua-Juniperus, 5000 ft., Kuntz ranch road into Del Norte Mts., Sept. 3, 1948, #1129; with Bouteloua-Prosopis on open flat, 4400 ft., Sohl-Abbington Ranch e. of Rt. 67, Sept. 4, 1948, #1133; with Pinus-Quercus, about 5000 ft., 1½ e. of Hess Canyon, Glass Mts., Oct. 5, 1948, #1331.

PRESIDIO COUNTY: with grass along rr. tracks, 5 mi. e. of Marfa, 4800 ft., June 1, 1948, #485.

Opuntia strigil Engelmann Rep. U. S. & Mex. Bound. Surv. II, Pt. I p. 47. 1859.

O. strigils Engelm. Schum. Gesamt. Kakteen p. 713. 1897 - 1899.

PLANT forming a very dense bush, 1.2 m. high, 1-1.2 m. wide, sometimes with short TRUNK 8-12.5 cm. long, 4-10 cm. wide, with very large areoles, these densely crowded with glochids and spines; BRANCHES spreading, some joints ascending; ROOTS fibrous; JOINTS short to long oval, sometimes orbicular, large, 10-19 cm. long, 9-16 cm. wide, 5-6 mm. thick, old joints with large spiny areoles, glaucous, yellowish green to glaucous green, LEAVES acicular, acuminate, 6-8 mm. long, 1 mm. wide, green, tipped with bronze; AREOLES very closely set, 8-10 mm. apart, slightly elevated, broadly elliptic, small, 3-5 mm. long, 2.5-4 mm. wide, becoming prominent, elevated, 15 mm. apart larger and worm-like to 4 mm. high, in age; WOOL pale tan, gray or brown; SPINES 2-7 from areoles on upper two-thirds to all of joint, fewer and shorter in lowermost areoles, terete, young spines white to orange-yellow with reddish-brown bases, older spines dark reddish-brown with reddish-black bases and yellow tips, in age becoming stouter and gray to black; 1, rarely 2, spines longer, 2.3-4 cm. lower in areole, acicular, more yellow with less reddish-brown, radially deflexed; BRISTLES indistinguishable; GLOCHIDS abundant, conspicuous, to 3 mm. long, yellow with orange bases, longer ones scattered and spreading from periphery of areole, in age becoming 15 mm. long; FLOWER BUDS prolific along upper margin of pad; FLOWER to 6 cm. long and 7 cm. wide with perianth segments in 4 whorls, outer segments russet to vinaceous brown, conic to diamond-shape, apiculate, to 1.8 cm. long and .8 cm. wide, inner segments pale lemon yellow with slight tinge of pink at base, broadly spatulate, fimbriate, mucronate, to 4.4 cm. long and 3.1 cm. wide; FILAMENTS cream, 14 mm. long, anthers yellow; STYLE cream, bulbous above base, 18 mm. long, stigma lobes 10, greenish yellow, 4 mm. long; OVARY obconic with truncate base, to 2 cm. long and 1.8 cm. in diameter, with minute remote areoles, few subulate leaves, reddish-brown wool, numerous yellow glochids, several yellow bristles in upper areoles; FRUIT dry, wrinkled, old rose-purple to plum color, short oblong, small, 1.7-2.5 cm. long, to 2.3 cm. in diameter when mature, with many minute wooly areoles, few creamy glochids, 2-3 thin, deflexed bristles per areole; UMBILICUS v-shaped, yellow, 4-8 mm. deep; SEEDS very abundant, yellow, beakless but notched at hilum, irregular shape, smooth, 3 mm. long, 2.5 mm. wide, 1.8 mm. thick, aril narrow, .5 mm. wide; STOMATA of leaf relatively small, averaging 20.1 $\mu$ in length. TYPE LOCALITY: in crevices of limestone rock, between the Pecos River and El Paso, Texas. GENERAL DISTRIBUTION: west of the Pecos River in Texas. LOCAL DISTRIBUTION: just south and east of Ft. Stockton on limestone hills, Pecos County.

The meaning of this specific epithet is more obscure than most. Translation of the Latin is "a scraper", instrument for scraping the skin as after a bath, or "one of a group of undulating flutings in Roman architecture". Perhaps it is a misnomer, meant to be strigosus N. L., which, botanically, means "set with stiff bristles".

At a distance this plant looks very much like <u>Opuntia rufida</u> with its bushy habit, short-obovate joints, and closely set but large areoles filled with conspicuous glochids.

However, closer inspection shows a very spiny joint, truly one of the most wickedly armed species among the Opuntiae under consideration here. (Plate XLVI, Fig. 1).

Flowering period is in early April. The flowers are surprisingly small with perianth longer than ovary. Mature fruits were collected early in July.

This species forms a monotypic Series (Strigiles), and is most easily identified with its relatively large, thick joints; red and yellow spines which are mostly deflexed; small, spiny fruits; and lack of variability.

Although _Opuntia strigil_ is very abundant west of Pecos River in Terrell County and on limestone ridges south and east of Fort Stockton in Pecos County, it was not found in the Big Bend counties although similar habitats are available. Perhaps this is a relatively newly developed species in its center of origin and has yet to spread, or it may be a relict population in its last stand. It might be highly specialized physiologically, restricting its occurrence to a few localities with certain edaphic conditions.

In Terrell County, _Opuntia strigil_ occurs with Larrea at approximately 2600 feet. In Pecos County it was growing with Acacia at about 3000 feet. _Opuntia Engelmannii_, _O. Engelmannii_ x _phaeacantha_, and _O. leptocaulis_ were found nearby.

SPECIMENS EXAMINED:

NEW MEXICO: 1851-52, _C. Wright_, (NY, US).

TEXAS: 1924, A. D. Dodd (US); frequent on limestone knolls 12 mi. east of Ft. Stockton, near highway, Pecos Co., April 19, 1946, B. H. Warnock, 46138 (MO, TEX). * Wright 374 (MO) (not available).

My description is based on three collections.

PECOS COUNTY: locally abund. with Acacia, Fouquieria & Leucophyllum n. of Sierra Madera, July 3, 1948, #692.

TERRELL COUNTY: locally abund. with Larrea, 44 mi. w. of Pecos River, along Rt. 90, Mar. 31,1948, #208, #209.

Opuntia tortispina Engelmann Pac. RR. Rep. 4:41. 1856.

O. tortisperma Engelm. Pac. R. Rep. 4: pl. 23, f. 1-5. 1856.
O. cymochila Engelm. Proc. Amer. Acad. 3:295. 1856.
O. cymochila montana Engelm. Proc. Amer. Acad. 3:296. 1856.
O. Rafinesquei cymochila Engelm. Proc. Amer. Acad. 3:295. 1856.
O. Rafinesquei cymochila montana Engelm. and Bigelow, Pac. R. Rep. 4:42. 1856.
O. mesacantha cymochila Coult. Contr. U. S. Nat.Herb. 3:430. 1896.
O. mesacantha greenei Coult. Contr. U. S. Nat. Herb. 3:431. 1896.
O. mesacantha oplocarpa Coult. Contr. U. S. Nat. Herb. 3:431. 1896.
O. Greenei Engelm. in Britton and Rose, Smiths. Misc. Coll. 50:523. 1908.
(?) O. sanguinocula Griffiths, Proc. Biol. Soc. Wash. 27:26. 1914.
O. spirocentra Hort.

PLANT low, spreading, much branched, ultimate joints ascending, reaching 5 dm. in height and 15 dm. in diameter; TRUNK absent, may have short thickened base; ROOTS fibrous but taproots often large and fleshy; JOINTS to 5 on a branch, often wrinkled, orbicular, short to long obovate or long oval, usually with attenuate base, 11.5 - 20.5 cm. long, 8 to 12 rarely to 20 cm. wide, relatively thin, 5-13 mm. thick, becoming 25 mm. thick in age, glaucous, yellowish green to blue green, purple around areoles; TEXTURE mealy-granular; LEAVES long-oblong to thick subulate with curved tips, long mucronate, terete, 6-10 mm. long, 1-2.5 mm. wide, green or purplish; AREOLES glandular, relatively close, 12-25 mm. apart, often elevated, very prominent, long elliptic, large, 5-8 mm. long, 3-5 mm. wide, becoming larger, with many scattered long glochids and more spines in age; WOOL abundant tan-rufous; SPINES 1-5, rarely to 10 in age, from all but lowermost areoles or occasionally with few spines in upper and marginal areoles only, spines subulate, mostly terete, some elliptic or angular, young spines a striking rusty red to burnt yellow annulately colored, with long yellow tips, older spines orange-red or white with red bases and yellow tips, finally becoming gray to white, with blackish-yellow tips; 1-4 spines longer, 5.9-7.2 cm., stouter, elliptic in cross-section, often much twisted, porrect and spreading downward, lower in areole 2-6 spines shorter, to 2.9 cm. thinner, white to gray, elliptic in cross-section, radially deflexed; BRISTLES 2, grayish white, deflexed, terete, to 7 mm. long; GLOCHIDS conspicuous in dense tufts, yellowish orange to orange-red with red bases, finally blackish-yellow to gray, and 11-19 mm. long in older areoles; FLOWER large, 5-7 cm. long, to 7 cm. across, with perianth segments in 4 whorls, outer segments rose to pinkish-olive, obovate, apiculate, to 1.5 cm. long and 1 cm. wide, inner segments sulfur yellow with faint to strong rosy-red bases, broadly spatulate, mucronate, to 3 cm. long and 2.2 cm. wide; FILAMENTS greenish white to pink with whitish base, 15 mm.

long, anthers cream to yellow; STYLE pinkish-white to white with yellow tip, bulbous from base, 7-16 mm. long, stigma lobes 6, green, 3-4 mm. long; OVARY smooth, obconic, 2.8 cm. long, 1.3 cm. in diameter, with many small, conspicuous areoles, a few uppermost ones bearing subulate, apiculate leaves to 6 mm. long, all areoles with abundant tan wool, numerous reddish-brown, short glochids to 5 mm. long, bristles and spines lacking; FRUIT very juicy, dull old rose to pinkish-purple, short to long obovate with pinched-in top and long tapering base; 3-6.5 cm. long, 2-3.2 cm. in diameter, with small remote areoles, few if any glochids and no spines; UMBILICUS v-shaped with central upward projection, 6-7.5 mm. to 15 mm. across deep; SEEDS abundant, orange-yellow to yellow and brown, irregular in shape, rough, beakless but slightly notched at hilum, large, 5-6 mm. long, 4.2-6 mm. wide, at least 3 mm. thick, aril 1.2-1.5 mm. wide; SEEDLINGS with very broad, thick, equal-sized cotyledons, to 11 mm. long and 6 mm. wide, with blunt tips; STOMATA of leaf relatively large, averaging 30.4 $\mu$ in length. TYPE LOCALITY: on the Comanchica Plains near the Canadian River, east of the Plateau of the Llano Estacado, Texas. GENERAL DISTRIBUTION: South Dakota, Kansas, Nebraska, southeastern Colorado, eastern Arizona, eastern and southeastern New Mexico, and Texas. LOCAL DISTRIBUTION: common in grassland and woodland associations in northern Brewster and Presidio counties, also in Jeff Davis county.

The twisted habit of the spines in this species is well emphasized in the name "tortis" (L) meaning twisted, and "spina" (L) meaning spines.

The typical form is very distinct with spreading habit, long obovate joints which are wrinkled when young, young spines a striking burnt-yellow, long central spines with shorter deflexed radials, and distinctive rose-purple fruits. (Plate XLIV). Atypical forms of Opuntia tortispina are most likely to be confused with O. phaeacantha, but can be distinctly identified by the closer areoles and dense tufts of conspicuous orange-red glochids.

Flowering is very heavy, commences about mid-May and continues into mid-July. The many fruits ripen in a month and are filled with juicy pulp and abundant seeds. These seeds showed a very low percentage of germination after thirteen days.

A possible hybrid between this species and O. setispina is discussed on page 181. (Plate XLV, Fig. 2).

This plains and mountain species, widely-distributed throughout the west, is also common in grassland, encinal and montane belts in the Big Bend Region. The occurrence of several plants in the 6700 feet-high Laguna, with Quercus, Stipa and other grasses, just northwest of Emory Peak in the Chisos Mountains, is of particular interest. Joints of these plants are thick, slightly wrinkled and bear relatively few white spines. (Plate XLV, Fig. 1).

The lowest altitude at which Opuntia tortispina was found was about 3800 feet at the eastern edge of Brewster County.

Specimens were collected on clay to sandy loam soils.

The species is associated most frequently with Opuntia Engelmannii, O. imbricata, O. Lindheimeri, O. macrocentra, O. phaeacantha, O. Pottsii, and O. setispina.

SPECIMENS EXAMINED:

ARIZONA: Ft. Collins, Sept. 10, 1895, J. W. Toumey (US); Sept. 1, 1898, J. W. Toumey (US).

ARKANSAS: June 1929, D. Demaru (US).

COLORADO: Hermosa, April 6, 1899, C. F. Baker 480 (NY); McElmo, 5200 ft., Montezuma Co., June 21, 1907, M. Cary 192 (US); plains 6000 ft. Colorado Springs, Sept. 19-21, 1895, Mrs. S. L. Clarke (NY); plains, Colorado Springs, Sept. 1895, S. L. Clarke 92 (NY); Boulder, 1912, T.D.A. Cockerell (NY,US); 2 mi. s. of Brighton, also 5 mi. east of Littleton, Dec. 1912, A. E. Holch (US); near Denver, 1911, A. Kuester (US); Yuma, July 1909, H. L. Shantz (US); Wray, 1910, H. L. Shantz (US); Yuma, Sept. 15, 1911 and 1912, H. L. Shantz (US); dry prairie, Ft. Collins, C. S. Sheldon 219 (US); in small clumps, vicinity of Trinidad, 1800-1950 m., June 17, 1911, P. C. Standley 6038, 6039 (US); Ft. Collins, Sept. 10, 1895, J. W. Toumey (US).

KANSAS: sand hills, Riley Co., Sept. 21, 1895, J. B. Norton 185 (NY); near Webb City, Jasper Co., Oct. 1, 1909, E. J. Palmer 2801 (US); Pratt, Sept. 23, 1912, J. N. Rose 17160 (NY); vicinity of Syracuse, Sept. 15, 1912, J. N. Rose & W. R. Fitch 17050 (US); vicinity of Liberal, Sept. 22, 1912, J. N. Rose & W. R. Fitch 17160 (NY, US); Minneola, Oct. 6, 1909, Westgate (US).

MINNESOTA: thin soil near rocks, Granite Falls, July 20, 1913, L. R. Moyer 362 (NY).

MISSOURI: dry rocky prairies, Webb City, Jasper Co., Oct. 12, 1909, E. J. Palmer 7 (NY); Columbia, Dec. 13, 1907, H. L. Shantz (US).

NEBRASKA: Denel Co.,July, 1890, P. A. Rydberg 124 (NY).

NEW MEXICO: Texas line at Mara Vista, Sept. 9, 1909, C. R. Ball 1584, Oct. 7, 1909, C. R. Ball 1585 (US); Silver City ?, Oct. 9, 1909, G. A. Pearson (US); Collected by E. O. Wooton in 1905 in Pecos Valley, Feb. 28, 1910, Lakewood, J. N. Rose, P. C. Standley, P. G. Russell 12268 (US); adobe flats in Mesilla Valley, 3850 ft. Dona Ana Co., May 1906, P. C. Standley (US); Lakewood, Aug. 3, 1905, E. O. Wooton 3101 (US).

OHIO: east of Cincinnati, Sept. 10, 1922, E. T. Wherry (escaped from cultivation (US).

SOUTH DAKOTA: on French Creek 15 mi. below Custer 4000 ft. Black Hills, July 23, 1892, P. A. Rydberg 716 (NY); Washabaugh Co., Pine Ridge Reservation, Aug. 22, 1911, S. S. Visher 2282 (NY).

TEXAS: Washburn, Aug. 29, 1892, V. Bailey (US); Amarillo, Oct. 1908, C. R. Ball 1282 (US); Aug. 12, 1909, C.R. Ball 1501 (US); 1909, C. R. Ball 1502 US); Aug. 12, 1909, C. R. Ball 1504, 1505, 1506 (US); Lorraine, Sept. 14, 1909, C. R. Ball 1558 (US); (common from Big Springs to Lubbock, from Tahoka) near Lamesa, Sept. 15, 1909, C. R. Ball 1561 (US); Amarillo, 1910, C. R. Ball 1677 (US); Plainview, Sept. 16, 1909, C. R. Ball (US); plains, Amerillo Aug. 22, 1910, C. R. Ball & Townsend 1616, 1617 (US); near Vigo Park, also Julia, Swisher Co., 1911, N. Standley (US).

My description is based on 58 collections.

BREWSTER COUNTY: with Bouteloua-Juniperus, 4700 ft., north slope of igneous hills, Paradise Canyon, w. of Alpine, May 7, 1947, #94; with Quercus Stipa and other grasses in Laguna, 6700 ft., along trail to South Rim, Chisos Mts., Big Bend Nat. Park, Apr. 18, 1948, #255; with Bouteloua-Prosopis, 4400 ft., Sohl-Abbington (Lake) Ranch, w. of Rt. 67, May 14, 1948, #344; with Quercus-Juniperus and Bouteloua-Juniperus 5000 ft., on Sohl Ranch, w. of Del Norte Mts., May 22, 1948, #383, #388; in grove of Quercus, in Gilliland Canyon, Glass Mts., June 5, 1948, #533; with Bouteloua-Juniperus, 5000 ft., on Merriweather Ranch, 10 mi. s. of Alpine, June 11, 1948, #544; with Bouteloua-Nolina 4650 ft., s. of Altuda, e. of Del Norte Mts., June 17, 1948, #564; with Bouteloua-Prosopis, 4500 ft., 5 mi. e. of Alpine, June 28, 1948, #657; with Bouteloua-Prosopis, 4400 ft., on Sohl-Abbington Ranch e. of Rt. 67, Sept. 1, 1948, #1135; with

Quercus-Juniperus, 4800 ft., in Sunny Glen, nw. of Alpine, Sept. 7, 1948, #1143; in oak grove, ½ mi. w. of Hess Canyon, Oct. 5, 1948, #1330.

CULBERSON COUNTY: with Prosopis and Flourensia, in sandy soil, 2 mi. s. on rd. from Rt. 62 to Kent, Aug. 10, 1948, #963; #964.

HUDSPETH COUNTY: with Bouteloua-Yucca, on sandy flat, 36 mi. e. of El Paso on Rt. 62, Aug. 9, 1948, #961; with Larrea-Flourensia, on sandy soil near Sierra Blanca, Aug. 8, 1948, #944.

JEFF DAVIS COUNTY: with Hilaria mutica on broad flat, 36 mi. w. of Marfa, Aug. 8, 1948, #939; with Prosopis and Acacia along Rt. 118 just s. of Musquiz Creek and e. of Mitre Peak, Aug. 24, 1948, #1045; with Pinus-Quercus, 6780 ft., just below Observatory on Mt. Locke, Davis Mts., Aug. 24, 1948, #1047; with Bouteloua-Prosopis, along rd. n. to Kent, in Davis Mts., Sept. 22, 1948, #1255.

PECOS COUNTY: with Bouteloua-Prosopis, 24 mi. n. of Marathon, e. of Glass Mts., July 2, 1948, #687;

PRESIDIO COUNTY: in grass along rr. track 4700 ft., 5 mi. e. of Marfa, June 1, 1948, Sept. 7, 1948, #484, 1145, 1146; with Bouteloua-Yucca on plains 10 mi. w. of Marfa along Rt. 90, Aug. 8, 1948, #937.

REEVES COUNTY: with Hilaria mutica, n. of Barilla Mts., 2 mi. e. of Balmorrhea along Rt. 290, June 23, 1948, #626.

TOM GREEN COUNTY: with Prosopis and grass, 18 mi. e. of San Angelo on Rt. 67, Oct. 9, 1948, #1355.

Opuntia polyacantha Haworth, Suppl. Pl. Succ. 82. 1819.

Cactus ferox Nutt. Gen. Pl. 1:296. 1818. Not Willdenow. 1813.
O. media Haw. Suppl. Pl. Succ. 82. 1819.
O. missouriensis DC Prodr. 3:472. 1828.
O. splendens Pfeif., Enum. Cact. 159. 1837.
O. missouriensis albispina Engelm. & Big. Proc. Amer. Acad. 3:300. 1856.
O. missouriensis microsperma Engelm. & Big, ibid:300. 1856. Not O. Rafinesquei microsperma Engelm. ibid:295. 1856.
O. missouriensis platycarpa Engelm. ibid:300. 1856.
O. missouriensis rufispina Engelm. & Big. ibid:300 1856.
O. missouriensis subinermis Engelm. ibid:300. 1856.
O. polyacantha albispina Coult. Contr. U.S.N.H. 3:437. 1896.
O. polyacantha borealis Coult. ibid:436. 1896.
O. polyacantha platycarpa Coult. ibid:436. 1896.
O. polyacantha watsonii Coult. ibid:437. 1896.
O. missouriensis watsonii Schum. Gesamtb. Kakteen 735. 1898.

Common names: "Hunger cactus", "starvation cactus".

PLANT low, procumbent, terminal joints and some short branches ascending, forming a clump 2.5 dm. high and 9 dm. wide; ROOTS fibrous; JOINTS short to long-obovate, 8-15 cm. long, 5.5-11 cm. wide, to 10 mm. thick, old joints becoming thicker, not glaucous, light green,somewhat tuberculate with diamond or linear hexagonal shaped elevations to 2 mm. high; LEAVES subulate, minute, AREOLES closely set, 6-8 mm. apart, circular to short-oval, small, 2 mm. long, 1 mm. wide, becoming larger and more elevated in age; WOOL abundant, pale tan; SPINES 1-3, from all areoles but fewer and shorter in lowermost areoles, spines longer in areoles along margins and mostly deflexed, elliptic in cross-section, not twisted, acicular, young spines white to reddish-brown with horn-colored tips, older spines mottled-gray with blackish-yellow tips, finally becoming dark gray; 1 spine longer to 3.6 cm., always deflexed, 2-7 radial spines shorter, to 1.3 cm. spreading, deflexed, white becoming gray; BRISTLES indistinguishable; GLOCHIDS conspicuous in dense tufts, scattered, pale yellow when young, dark yellow with darker bases and to 6 mm. long in older areoles; FLOWER to 6.4 cm. long and about 4.5 cm. across, with perianth segments in 4-5 whorls, outer segments green with yellow margins, spatulate-obovate, apiculate, inner segments yellow, obcordate, emarginate, fimbriate, 3-3.5 cm. long; FILAMENTS and anthers yellow; STYLE yellow, bulbous just above base, stigma lobes 8, green; OVARY spiny, obconic to short-oblong, 2.5-3.2 cm. long, with closely set areoles, bearing a few subulate, mucronate leaves near upper end, abundant white to tan wool, few white-cream glochids, and numerous short, red and white porrect spines; FRUIT dry, spiny, oblong with pinched top, to 2.6 cm. long and 1.5 cm. in diameter, yellow-green, with close and conspicuous wooly areoles, small tufts of pale yellow glochids, 1-6 white bristles, to 8 mm. long; UMBILICUS yellow, saucer-shaped, 4 mm. deep; FLESH cream-colored, granular; SEEDS yellow with green embryo, linear-oval, somewhat beaked, deeply notched at hilum, very large, 7 mm. long, 6 mm. wide, 2-2.5 mm. thick, aril 2 mm. wide; SEEDLINGS with thin, unequal, cotyledons, 11-15 mm. long, 5 mm. wide, with blunt tips; TYPE LOCALITY: arid situations on the plains of the Missouri River. GENERAL DISTRIBUTION: Panhandle plains and Davis Mountains of Texas, eastern and northern New Mexico, northern Arizona, southern Utah, throughout Colorado, arid situations on the plains of the Missouri, northwestern Oklahoma, Nebraska, North Dakota, Montana, Washington, north to the borderline of United States and into Alberta as far north as Peace River. LOCAL DISTRIBUTION: Occasional in Davis Mountains in montane belt, with Quercus-Pinus at 6780 feet on Mt. Locke, with _Pinus flexilis_ and _P. ponderosa_ on on Mt. Livermore above 7400 feet, and in Limpia canyon above 6000 feet.

Haworth named this species with reference to its "many spines", and it is one of the most distinct types of Opuntia in the Big Bend Region.

Distinguished from the closely related _Opuntia trichophora_ by a greater number of porrect spines, and lack of any hairs in basal areoles, _O. polyacantha_ is equally rare and likewise occurs in a montane association in the northern part of the area. (Plate XLVII, Fig. 1).

Flowering period begins in late May, and mature fruits were collected in the latter part of August. Several seedling were thriving in the forest litter. Only two out of fifty seeds germinated in fourteen days in the laboratory. The young plumule is very spiny, bearing areoles with many short, white bristles.

_Opuntia polyacantha_ is of sporadic occurrence in the Davis Mountains. W. L. Bray in 1902 collected the species in Limpia Canyon above 6000 feet. J. Ferris, 1925, collected one in the "Davis Mountains". L. C. Hinckley has collected material on Mount Livermore at 8382 feet, and with _Pinus ponderosa_ and _Pinus flexilis_ at about 7450 feet. I collected specimens on the north slope of Mount Locke at 6780 feet under shade of Quercus and Pinus trees on sandy loam.

In general, the species is widely distributed laterally and altitudinally, giving rise to diverse races, described under seven varieties, now all in synonymy. The form from the Davis Mountains falls into the albispina group.

These records from Trans-Pecos Texas mark the most southerly extent of Opuntia polyacantha known; perhaps the species is migrating south along the higher mountain chains.

SPECIMENS EXAMINED:

ARIZONA: pinon-juniper type, under sage, 6700 ft. 60 mi. n. of Holbrook, on road to Keam's Canon, June 8, 1940, R. A. Darrow (ARIZ); Little Colorado River between Concho and Holbrook, June 8, 1940, R. A. Darrow (ARIZ); Cane Springs 5000 ft., Coconino Co., eastern escarpment of Kaibab Plateau, Jan. 14, 1940, A. A. Nichol (ARIZ).

COLORADO: Colorado Springs June 18, 1896, Biltmore Herbarium Colorado Expedition 1 121 (NY, US); on base of Flagstaff Hill, Boulder, Nov. 1912, W. D. & T. D. A. Cockerell (NY, US); rocky slopes 6500 ft., Garden of the Gods, Manitou Springs, El Paso Co., June 12, 1939, J. H. Ehlers 7591.5 (MICH); sloping meadow 9000 ft., June 16, 12 mi. south of Westcliffe, Custer Co., June 16, 1926, E. W. Erlanson 1902 (MICH); Sugar City, Sept. 1921, A. A. Hansen (US); Denver and 5 mi. east of Middleton, Dec. 1912, A. E. Holch (US); vicinity of La Junta, Sept. 26, 1913, J. N. Rose & W. R. Fitch 17501 (NY, US); Walsenburg, 1800 m., June 5, 1900, P. A. Rydberg & F. K. Vreeland 5870 (NY); Colorado City, Dec. 1907, H. L. Shantz (US); Akron, July 6, 1912, H. L. Shantz 1137; (US); dry hills, growing in clumps, 1800-1950 m. vicinity Trinidad, June 17, 1911, P. C. Standley 6040, 6041 (US); plains and foothills near Boulder, 5000-600 ft., July 1902, F. Tweedy 5015 (NY).

IDAHO: abundant all over the Snake River plains of southern Idaho in the Upper Sonoran Zone. Dubois, Aug. 22, 1909, V. Bailey (NY, US); St. Anthony, Aug. 31, 1911, V. Bailey (US); dry barren hillside above Clearwater River near Lewiston, Nez Perces Co., July 18, 1919, R. S. Ferris & R. Duthie 1291 (det. Wiggins) (DS); dry hills 4400 ft. Kirtley Ranch, Aug. 25, 1895, L. F. Henderson 3818 (US); Spencer, July 10, 1916, common on low rocky ridges and plains, H. J. Rust 756 (US).

KANSAS: Leoti, Sept. 29, 1909, C. R. Ball 1577 (US); vicinity of Tribune, Sept. 17, 1912, J. N. Rose & W. R. Fitch 17072 (US).

MONTANA: on the plains, June 18, 1887, F. W. Anderson 2975, (NY); Hillsides along Yellowstone River, Gardiner, July 9, 1948, Y. Dawson 4965 (AHLA); on silty hillsides among Artimesia and buckwheat approx. 4000 ft., 17 mi. south of Toston, July 9, 1948, Y. Dawsen 4966 (AHLA); Sheridan, July 1897, Mrs. L. A. Fitch (NY); Townsend, July 11, 1921, J. S. Halmer (US); Horr (Yellowstone Nat. Park, July 18, 1902, E. A. Mearns (US).

NEVADA: Lower Lee Canyon, ridge, juniper belt, 2000 m., Charleston Mts., June 6, 1936, I. W. Clokey 7204 (DS); 1937, I. W. Clokey 7591 (TEX); infrequent, loose sandy soil, 12 mi. n. of Battle Mt., Lander, Elko Co., June 10, 1941, A. H. Holmgren 1071 (ARIZ); frequent, dry gravelly soil, A. H. Holmgren 1280 (ARIZ).

NEW MEXICO: near foothills, do not grow on open range, Cimarron, 1909, C. N. Ainslie (US); vicinity of Raton, Sept. 27, 1913, J. N. Rose & W. R. Fitch 17533 (NY, US); between Anton Chico and mouth of Gallinas River, Sept. 30, 1913, J. N. Rose & W. R. Fitch 17634 (US); vicinity of Sante Fe, Oct. 3, 1913, J. N. Rose & W. R. Fitch 17777 (NY); vicinity of Raton, Colfax Co., dry hills, 2100-2380 m., P. C. Standley 6256 (US); dry hills vicinity of Farmington 1550-1650 ft., San Juan Co., Aug. 20, 1911, P. C. Standley 7114 (US); prostrate on rocky hillside, Ute Park, Colfax Co., 2200-2900 m. Sept. 1, 1916, P. C. Standley 14118 (US); 5 mi. west of Tiznitzin, Aug. 6, 1904, E. O. Wooton 3015 (US).

NORTH DAKOTA: Bismark, Dec. 4, 1907, V. Bailey (US).

TEXAS: Amarillo, Sept. 2, 1910, C. R. Ball 1676 (US); Limpia Canyon, above 6000 ft., June 6, 1902, W. L. Bray (TEX); Davis Mts., Jeff Davis Co., 1925, J. Ferris 532A (US); Mt. Livermore, Jeff Davis Co., June 1936, L. C. Hinckley (TEX); on low hills, Oro Grande, on the E. P. and S. W. Ry. about 50 mi. north of El Paso, Oct. 1920, E. C. Prentiss (US).

UTAH: south of Moab, San Juan Co., June 15, 1938, E. U. Clover & M. L. Jotter 1990 (MICH); at Natural Bridge between Montecello and Moab, San Juan Co., June 15, 1938, E. U. Clover & M. L. Jotter 2016 (MICH); sandy bottom and talus slopes of sandstone gorge of Sevier River (Sevier Canyon) on highway to Provo, July 7, 1948, Y. Dawson 4954 (AHLA); Artemisia slope in Echo Canyon, 5900 ft. near Emory, northeastern Utah, July 8, 1948, Y. Dawson 4960 (AHLA); Wahsatch Mts., 7000 ft., northern Utah, July 1869, S. Watson 435, (NY, US).

WYOMING: Artemisia flats at Bridges Pass, about 7500 ft., July 8, 1948, Y. Dawson 4961 (AHLA); sand hills 10 mi. south of Big Piney, Wyo., July 8, 1948, Y. Dawson 4962 (AHLA); on gravel slopes covered with low Artemisia and other dwarf brush, 6800 ft., mesa 3 mi. north of Big Piney, July 9, 1948, Y. Dawson

4963 (AHLA); basalt cliffs and talus, 6300 ft., 3 mi. north of Jackson, July 9, 1948, Y. Dawson 4964 (AHLA); Tarn Creek, 5500 ft., near Bruce, Aug. 17, 1905, F. W. Johnson (US); Laramie River, July 12, 1897, E. Nelson 3365 (US).

My description is based on two collections.

JEFF DAVIS COUNTY: with Pinus-Quercus, 6780 ft. on loam, just below Observatory on north slope, Mt. Locke, Davis Mts., May 23, 1947 E. U. Clover 18893 ; Aug. 24, 1948, #1046.

Opuntia trichophora Engelm. Britton and Rose, Smiths, Misc. Coll. 50:535. 1908.

O. missouriensis trichophora Engelm. Proc. Amer.Acad. 3:300. 1856.
O. polyacantha trichophora Coult. Contr. U. S. Nat. Herb. 3:437. 1896.

Common names: "grizzly bear cactus", "wooly cactus".

PLANT growing in low, spreading clumps to 20 cm. high, and about 1 m. across; without a definite TRUNK; BRANCHES many, ascending or erect; ROOTS fibrous; JOINTS ovate to long-ovate, from 6-11 cm. long, 3-6 cm. wide, to 5 mm. thick, in age becoming woody, almost terete, glaucous, light yellow-green; TEXTURE tough, mealy; LEAVES narrowly subulate, apiculate, terete, 3 mm. long, .5 mm. in diameter, reddish-brown; AREOLES closely set, 6-7 mm. apart, elevated, elliptic, large, to 3 mm. long, 2 mm. wide, becoming prominent in age; WOOL dense, straw-colored, persistent; SPINES 8-30 or more from all areoles, covering surface at tips of joints strongly deflexed, giving a combed appearance, others spreading downward, spines very unequal, acicular, somewhat curved, flexible, setiform, young spines pale yellow with horn-colored tips, older spines more abundant, longer, white with yellow bases and tips, finally becoming gray with yellow tips, sometimes very long and hair-like in lowermost areoles 2-6 longer, 3-6.5 cm. much flattened, twisted, spreading, 6-23 shorter to 3 cm., flattened, spreading downward; BRISTLES indistinguishable; GLOCHIDS relatively few, in upper end of areole, pale yellow when young, yellow with reddish bases in older areoles, to 7 mm. long; FLOWER BUDS from areoles along upper edge of terminal joint, short conical; FLOWER large, 6 cm. long, 4-5 cm. wide, with perianth segments, in 4 whorls, outer segments reddish bronze, wide lanceolate, acuminate, to 1.5 cm. long, inner segments lemon yellow, obovate, apiculate, 2.5-3 cm. long, 1.5 cm. wide; FILAMENTS white, 10 mm. long, anthers yellow; STYLE white, bulbous just above base, 20 mm. long, stigma lobes 9-10, green, 2 mm. long; OVARY very spiny, oblong with tapering base, to 3 cm. long and 1 cm. in diameter, with many circular areoles, uppermost ones bearing bronze leaves, abundant cream-colored wool, numerous yellow glochids with red bases, up to 7 short to 17 mm. white, flexible bristles in each areole; TYPE LOCALITY: Mountains near Albuquerque, New Mexico. GENERAL DISTRIBUTION: Northeastern Arizona, western Colorado, eastern New Mexico, northern Texas, Oklahoma. LOCAL DISTRIBUTION: in grassy swale, Hidden Valley, in hills south of Lane Ranch buildings, just southwest of Alpine, Brewster County.

The characteristic of bearing, "phora" hairs, "tricho" from lower and older areoles, clearly distinguishes the species *Opuntia tricophora* from its close relative *O. polyacantha*. (Plate XLVII, Fib. 2).

Joints are almost obscured by spiny covering, giving a shaggy appearance to the creeping branches. Flowers open early in May; fruits were not collected.

Previous records had given the most southern, and only Texas station, as El Paso, Texas. In the Big Bend, the species is very rare, found only in a sheltered, grassy valley, at about 4900 feet, among igneous hills just southwest of Alpine. *Opuntia Engelmannii* and *O. macrocentra* were growing with oak scrub on rocky slopes nearby.

Joints grown at the Botanical Gardens since 1947 have produced new shoots with perfectly cylindrical cross-section, indicating considerable plasticity in the plant's response to environmental changes.

SPECIMENS EXAMINED:

ARIZONA: Black mesa, 7200 ft., Navajo Co., June 21, 1939, R. H. Peebles 14357 (US).

NEW MEXICO: San Rapel, April 1, 1897, Ashmun (US); near Albuquerque, May 28, 1908, J. N. Rose (US); between Las Vegas and Anton Chico, Sept. 29, 1913, J. N. Rose & W. R. Fitch 17623 (NY, US); between Anton Chico and mouth of Gallinas River, Sept. 30, 1913, J. N. Rose & W. R. Fitch 17635 (NY, US); Socorro, 1881, Vasey 432 (MO); hills west of Magdalena, 1904, E. O. Wooton, (MO); head of Horse Camp Draw, July 19, 1904, E. O. Wooton 3006 (US); 5 mi. west of Tiznitzin, July 6, 1904, E. O. Wooton 3015 (US).

OKLAHOMA: Cimarroneo, May 30, 1930, M. S. Lahman (US); on top of sandstone butte, near Kenton, May 15, 1913, G. W. Stevens 495 (NY).

My description is based on two collections.

BREWSTER COUNTY: rare, in grassy valley 4900 ft. surrounded by igneous hills with oak scrub, 2 mi. sw. of Alpine, on Lane Ranch, May 6, 1947, B. H. Warnock (Anthony 85), May 9, 1947, #104.

Opuntia Pottsii Salm-Dyck, Cact. Hort. Dyck. 1849. 236. 1850.

O. filipendula Engelm. Proc. Amer. Acad. 3:294. 1856.

PLANT small, inconspicuous ascending to 2.5 dm. high and 3 dm. across, with short terete base, 13 cm. long, 3 cm. in diameter; no definite TRUNK; ROOTS with 2-6 tubers, occasionally moniliform, 7-14.5 cm. long, 2.7-3 cm. in diameter, with milky juice; BRANCHES 1-3, short, somewhat spreading; JOINTS few, obovate, triangular or flattened orbicular, sometimes with attenuate base, from 6-12.5 cm. long, 4-10 cm. wide, mostly 10 cm. by 7 cm., 4-7 mm. thick, heavily glaucous, gray to pale blue green, purple around areoles; TEXTURE soft, pad often wrinkling with drying; LEAVES long subulate, apiculate, 5.5 mm. long, 1 mm. wide, green; AREOLES distant, 13-20 mm. apart, not elevated, long oval, conspicuous, 3.5-6 mm. long, 2-3 mm. wide, in age becoming larger, more densely wooly and spineless; WOOL abundant creamy-tan; SPINES 1-3, rarely 4, from areoles(mostly marginal) on upper one-fifth of joint, some joints spineless, spines terete, relatively long, acicular, young spines white, older spines reddish-brown and white or white speckled with black, with yellow tips, finally becoming gray with blackish yellow tips, 1-2 or rarely 3 spines longer, to 4.8 cm. elliptic in cross-section, very twisted, at least 1 porrect, others spreading downward, 1 spine shorter, to 1.6 cm., terete, usually deflexed, white with yellow tip; BRISTLES absent; GLOCHIDS conspicuous in dense tufts, yellow when young, yellow to orange with brown bases in older areoles and to 7 mm. long; FLOWER large, 7 cm. long, 5 cm. across with perianth segments in 3 whorls, outer segments tannish green with reddish margins, long obovate, long apiculate, to 1.4 cm. long and 1.1 cm. wide, inner segments orange-red with darker center, fimbriate, long spatulate, mucronate, to 3.3 cm. long and 1.9 cm. wide; FILAMENTS greenish yellow, 15 mm. long, anthers yellow; STYLE white with pinkish tip, slightly bulbous above base, 18-20 mm. long, stigma lobes 6-7, yellow, 3 mm. long; OVARY slender, long obconic, 3-5 cm. long, 1 cm. in diameter, with small, distant but conspicuous areoles, uppermost ones with subulate leaves, 7 mm. long, all areoles with abundant pale tan wool, few yellow glochids to 4 mm. long; bristles and spines absent; FRUIT juicy, smooth, long pyriform tapering abruptly at both ends, 3.5-4.5 cm. long, 1.5-2 cm. in diameter, pale dull purple, with remote, conspicuous areoles, bristles and spines lacking; UMBILICUS v-shaped, 5 mm. deep; flesh green; SEEDS beaked and notched at hilum, yellow, smooth, large, to 6 mm. in diameter, 3 mm. thick, aril 5 mm. wide, obtuse; STOMATA of leaf averaging 27.6 $\mu$ in length. TYPE LOCALITY: near Chihuahua City, Chihuahua, Mexico. GENERAL DISTRIBUTION: southern New Mexico, Trans-Pecos Texas, to central Chihuahua in Mexico. LOCAL DISTRIBUTION: occasional in grassland associations of Brewster, Jeff Davis and Presidio counties.

The specific epithet honors John Potts, an official in Chihuahua, who sent cacti to Kew Gardens between 1842 and 1850.

One of the least conspicuous species of the genus in the area, Opuntia Pottsii is strikingly different from any other discussed here in its large tuberous roots and pinkish-red flowers, which appear in the middle of May. The fruits too, collected from late August to October, are of distinctive long pyriform shape and a glaucous pink-purple color. None of the seeds planted at the Botanical Gardens germinated in eight months. Form of the joints is highly variable, being orbicular, obovate or sometimes almost triangular in shape. Rarely more than six to eight joints comprise a plant. (Plate XLVI, Fig. 2). The speeies must be relatively short-lived as there is no debris of dead joints around the base.

Plants are widely distributed, but nowhere abundant, throughout arid grassland and encinal belts, especially in Bouteloua-Juniperus association, Bouteloua-Aristida and alluvial bottom and with Prosopis and Acacia along Musquiz and Limpia Canyons. The species was found from 3000 feet in Terrell County to about 6000 feet in the Davis Mountains on soils ranging from clays to sandy loams, but more commonly on the latter. Individuals often grow in the shelter of Prosopis or other spiny bushes. Only one (from Terrell County) was found in a desert association, namely Larrea-Flourensia.

Most other grassland and encinal species of the genus occur with Opuntia Pottsii, including the rarer O. Kleiniae and O. Lindheimeri. Echinocereus viridiflorus and Coryphantha pectinata are other commonly associated cacti.

SPECIMENS EXAMINED:

ARIZONA: Bowie, Dec. 20, 1896, J. W. Toumey (NY); Deming, Dec. 1896, J. W. Toumey-Ashmun (US).

MEXICO: CHIHUAHUA - Mesquite Spring, May 16, 1892, E. A. Mearns 83 (US); vicinity of Chihuahua, about 1300 m. April 8-27, 1908, E. Palmer 70, (NY, US) 124 (NY); plains near Chihuahua, May 2, 1885, C. G. Pringle (NY, US).

NEW MEXICO: Carlsbad, 1924, W. J. Lee (US); Dog Springs, Grant Co., May 28, 1892, for Mex. Bound. Survey, E. A. Mearns 83 (S); collected by E. O. Wooton at Lakewood in 1905, Feb. 28, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12263 (US); Lakewood, Aug. 3, 1905, E. O. Wooton 3100 (US); Queen P. O. 5900 ft., top of Guadalupe Mts., Aug. 3, 1909 E. O. Wooton (US).

TEXAS: desert plains, divide between Colorado and Brazos rivers, Nolan Co., 1934, F. A. Barkley (MO); 1924, C. R. Orcutt (US); vicinity of El Paso, Oct. 10, 1913, J. N. Rose & W. R. Fitch 17880 (NY, US); vicinity of El Paso, Feb. 26, 1910, J. N. Rose, P. C. Standley, P. G. Russell 12294 (US); below El Paso on the Rio Grande, 1855, A. Schott (filipendula) (MO); in small bunches in Rio Grande bottom near San Elisario, also near El Paso, 1852, C. Wright 337 (MO).

My description is based on ten collections.

BREWSTER COUNTY: occas. in Bouteloua-Prosopis, 4500 ft., on Sohl-Abbington (Lake) ranch, nw. of Junction of Rts. 90 & 67, on clayey soil, May 14, 1948, #348; rare in Bouteloua-Juniperus, 4800 ft., Sunny Glen, nw. of Alpine, June 27, 1948, #655; rare in Bouteloua-Aristida, 4700 ft. Sunny Glen, nw. of Alpine, Sept. 7, 1948, #1140; infreq. in Bouteloua-Juniperus, 4800 ft., Sunny Glen, nw. of Alpine Oct. 3, 1948, #1319.

JEFF DAVIS COUNTY: infreq. in Prosopis-Acacia thickets ft., on alluvium along Musquiz Creek, Davis Mts., June 18, 1948, #597; rare in Pinus-Quercus about 6000 feet along rd. to Indian Lodge, in Davis Mts., Aug. 24, 1948, #1385; with Acacia along bottomland of Musquiz Creek, e. of Mitre Peak and Rt. 118, 4400 ft., Sept. 22, 1948, #1251.

PRESIDIO COUNTY: rare in Bouteloua-Yucca, 4900 ft., 31 s. on Marfa-Presidio rd., Aug. 26, 1948, #1062; infreq. in Bouteloua-Yucca, 4900 ft., 4 mi. s. on rd. from Paisano Pass, Sept. 11, 1948, #1151.

TERRELL COUNTY: rare in Larrea-Flourensia 3000 feet along Rt. 90, w. of Sanderson, July 8, 1948, #738.

## SUMMARY

1) The area studied encompasses Jeff Davis, Presidio, and Brewster counties, Texas, with the latter receiving the most detailed consideration.

2) Climate of the Big Bend Region is typically arid with high evaporation, low precipitation with the peak of the rainy season during the hottest months - July and August, and widely-fluctuating diurnal temperatures.

3) Altitude, with resultant effect on climate, and drainage are the two primary determining factors in the local distribution of species of Opuntia. Overgrazing, type of country rock, and texture of soil are secondary factors.

4) Local distribution of these cacti can be closely correlated with vegetative associations which in turn are an accurate index to topography and climatic conditions.

5) Great variety of topography and resultant localization of soil and moisture conditions produce a corresponding variety of habitats occupied by different types of vegetation. There are four associations in the desert life belt:

Larrea-Flourensia*
Dasylirion-Agave*
Larrea-Agave*
Draw vegetation*

at least two associations along the Rio Grande Flood Plain:

*Baccharis glutinosa**
*Prosopis glandulosa**

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*The Big Bend National Park includes examples of the starred associations.

six associations in the arid grassland belt:

Bouteloua-Aristida
*Hilaria mutica*
Bouteloua-Yucca
*Juglans rupestris*
*Populus Palmeri*

and four associations in the encinal and montane belts:

Bouteloua-Juniperus*
Quercus-Juniperus*
Pinus-Juniperus*
*Pinus ponderosa* with *Pseudotsuga taxifolia*, or *Pinus flexilis**

6) There are also numerous local variations, seven of which feature cacti, as follows:

Larrea and *Opuntia leptocaulis**

*Coryphantha macromeris* and *Opuntia Schottii**

*Agave Lechuguilla* and *Opuntia rufida**

*Hilaria mutica* and *Opuntia macrocentra*

Desert shrub life belt
arid grassland life belt

*Hilaria mutica*, *Opuntia setispina* and *O. tortispina*

*Acacia spp.* and *Opuntia Kleiniae*

Bouteloua and *Opuntia imbricata*

7) Occurrence of each vegetative type is determined by (a) altitude which affects local climatic conditions, (b) country rock, (c) degree and exposure of slope, (d) drainage and (e) soil characteristics, especially texture.

(8) High desert mountains, such as the Chisos group, offer examples of the effect of isolation in development of clear-cut varieties, i.e., *Opuntia Lindheimeri* var. *chisosensis*,

*The Big Bend National Park includes examples of the starred associations.

an almost spineless form of O. tortispina and a small form of Echinocereus triglochidiatus. They also demonstrate the effect of sharply increasing altitudes in determining change of vegetative types from desert shrub to montane elements and a corresponding change in species of cacti.

9) The ease of vegetative propagation among species of Opuntia is an important factor (1) in their rapid invasion and establishment in newly available habitats (2) in their general ubiquity, and (3) in their variety of forms.

10) Mammals act as disseminators for these cacti by fragmenting and carrying joints and eating fruits. Defecated seeds have been reported as more likely to germinate than those untouched. Birds and ants may be instrumental in spreading the seeds by eating the juicy fruits.

11) Woody vegetation is increasing and invading grassland in the Trans-Pecos as elsewhere because of severe overgrazing. Opuntia Engelmannii and O. imbricata are among the pioneer species to enter abused rangeland.

12) Human disturbance around habitations in the desert scrub life belt increases local numbers of prickly pear. Mexicans often introduce non-indigenous species by transplantation. This human factor is not to be ignored, since spontaneous crossing is very likely to produce a whole wild population in the course of time. There is no evidence yet of modification of the population by introduced species, but it is by no means unlikely to become an important factor in evolution.

13) Proximity of four adjacent biotic provinces has made the Big Bend Region a meeting ground for woodland, high plains, arid grassland and Mexican forms.

14) Most of the species of cacti with a small area of general distribution also have restricted distribution in the Big Bend Region.

15) _Opuntia_ _Engelmannii_, _O._ _phaeacantha_ and _O._ _tenuispina_ consist each of a polymorphous complex with intergrading variants within each group. These variants offer diverse material for race development in this region of severe climatic fluctuations and many physical barriers.

As populations of a genetically variable species spread out and adapt to more and more habitats, forming a number of clear-cut variants, the possibility grows that some fraction of a population will become modified enough or isolated enough that speciation will occur.

16) Differences between species are most evident in habit; distance between areoles; presence or absence of bristles; type of fruit as juicy versus dry and smooth versus spiny; size of seed and width of aril.

17) Variations within species are particularly expressed in the number of spine-bearing areoles on a joint, number of spines per areole, and the length and color of individual spines.

18) Complete descriptions are given for five varieties, four of them new, namely: _Opuntia_ _imbricata_ var. _argentea_, _O._ _Lindheimeri_ var. _chisosensis_, _O._ _macrocentra_ var. _minor_, and _O._ _rufida_ var. _tortiflora_. Each of these may be thought of as a potential source of new endemic types. Any especially adapted types which segregate out and attain dominance in a particular habitat are potential new species.

19) Three new hybrids are presented, namely: Opuntia Engelmannii x phaeacantha; O. Grahamii x Schottii; and O. Kleiniae x leptocaulis. Specimens which indicate possible hybridization of Opuntia setispina with O. tortispina and O. Lindheimeri with O. macrocentra are discussed.

20) Opuntia spinosibacca is newly described. This is the only endemic Opuntia of the Big Bend region which is considered to be of specific rank, because of its spiny fruit, tuberculate surface, and elongate joints. The Big Bend region is therefore not one marked by extreme endemism so far as the Opuntiae are concerned.

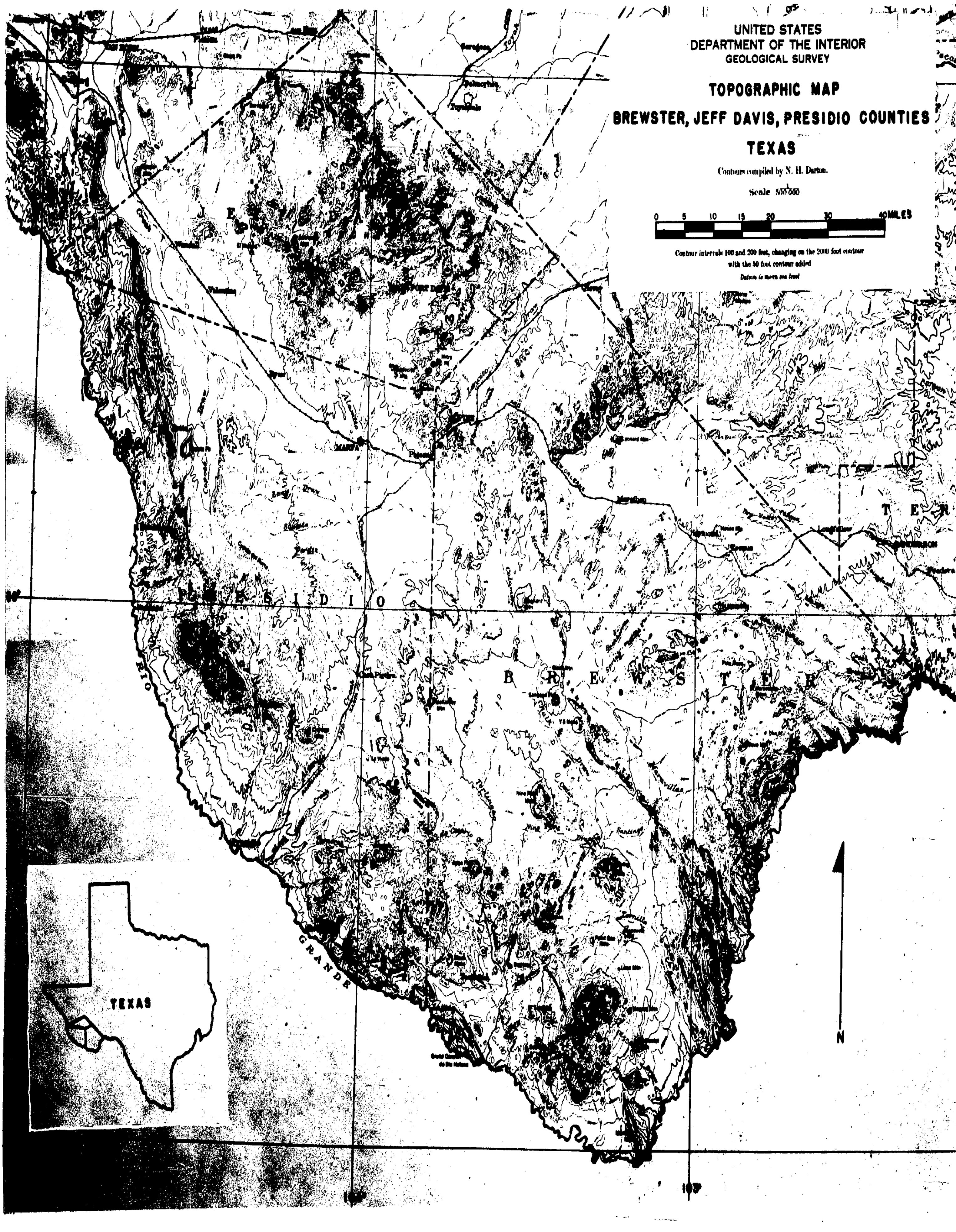
21) A full description of the genus precedes a key to the thirty-one species, varieties and hybrids found in the Big Bend Region.

22) Each species is described technically with citation of herbarium specimens examined and general remarks about the appearance and occurrence of the plants in the Big Bend Region.

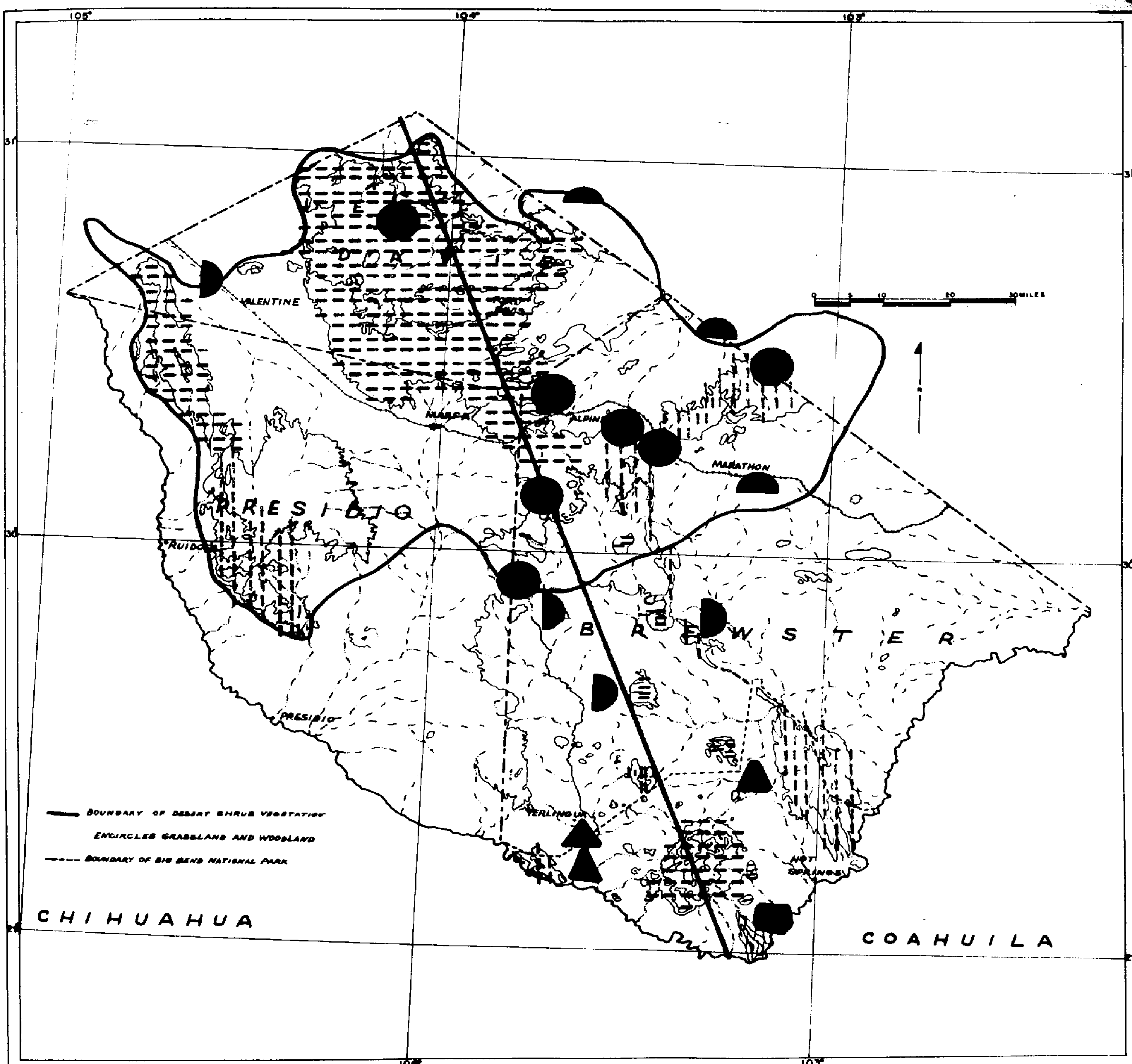
23) Opuntia tunicata is an example of disjunct distribution far from its closest recorded occurrence in Saltillo, Coahuila. Its dwarf and typical forms suggest perpetuation of somatic differentiation in vegetatively reproduced clones.

A P P E N D I X

MAP I


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
TOPOGRAPHIC MAP
BREWSTER, JEFF DAVIS, PRESIDIO COUNTIES
TEXAS
Contours compiled by N. H. Darton.
0 5 10 15 20 30 40 MILES
PRESIDIO
BREWSTER
RIO GRANDE
TEXAS
N

MAP II

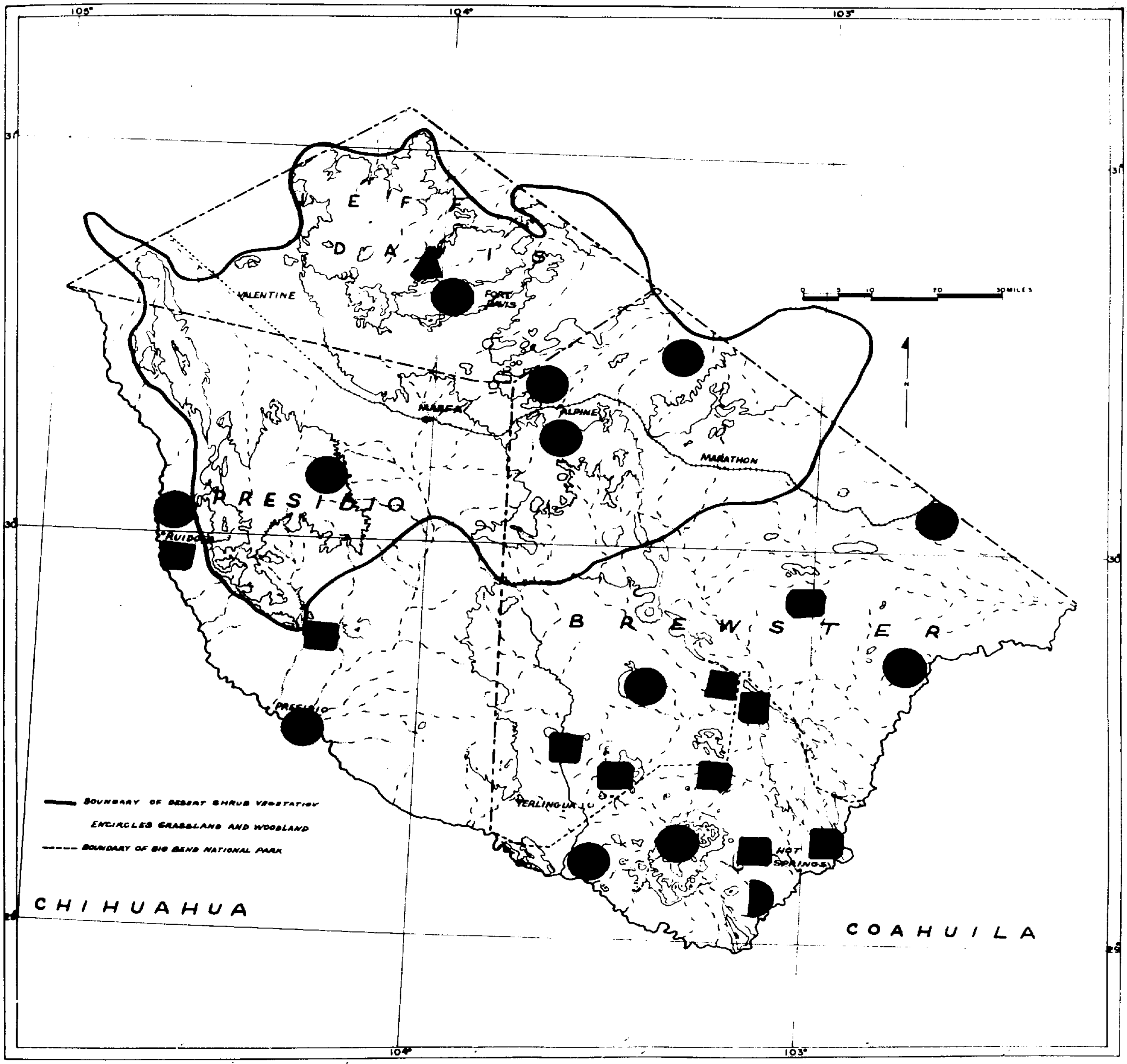



Approximate extent of igneous ---- and sedimentary |||| rocks.

Occurrence of local communities with species of Opuntia codominant:

- ● Bouteloua and O. imbricata
- Hilaria mutica, O. setispina and O. tortispina
- Hilaria mutica and O. macrocentra
- ▲ Larrea and O. leptocaulis
- ■ Coryphantha macromeris and O. Schottii

# MAP III



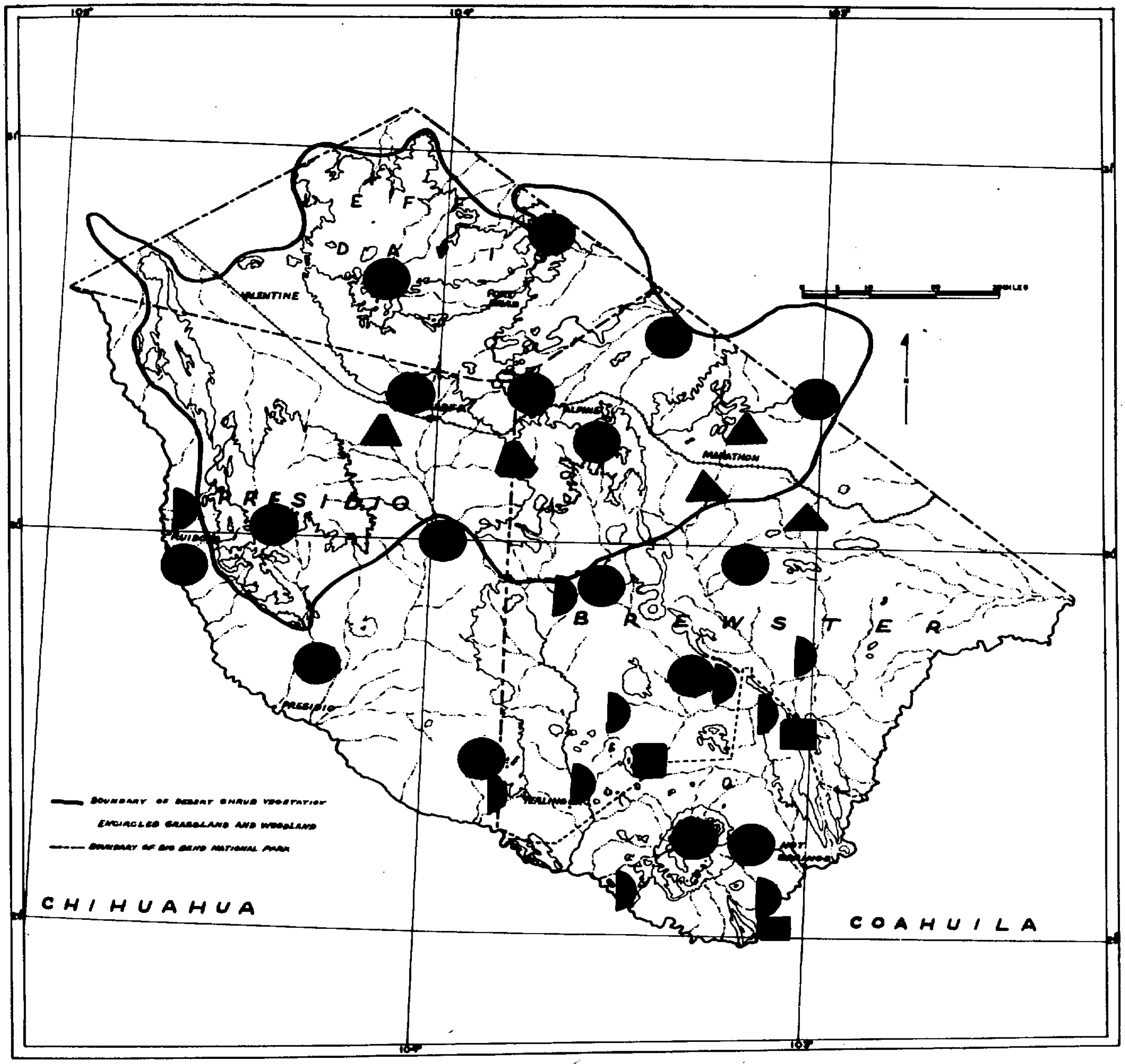

Sample occurrences of species of Opuntia to show extent of their local distribution: O. azurea

O. Engelmannii

O. polyacantha

O. rufida

MAP IV



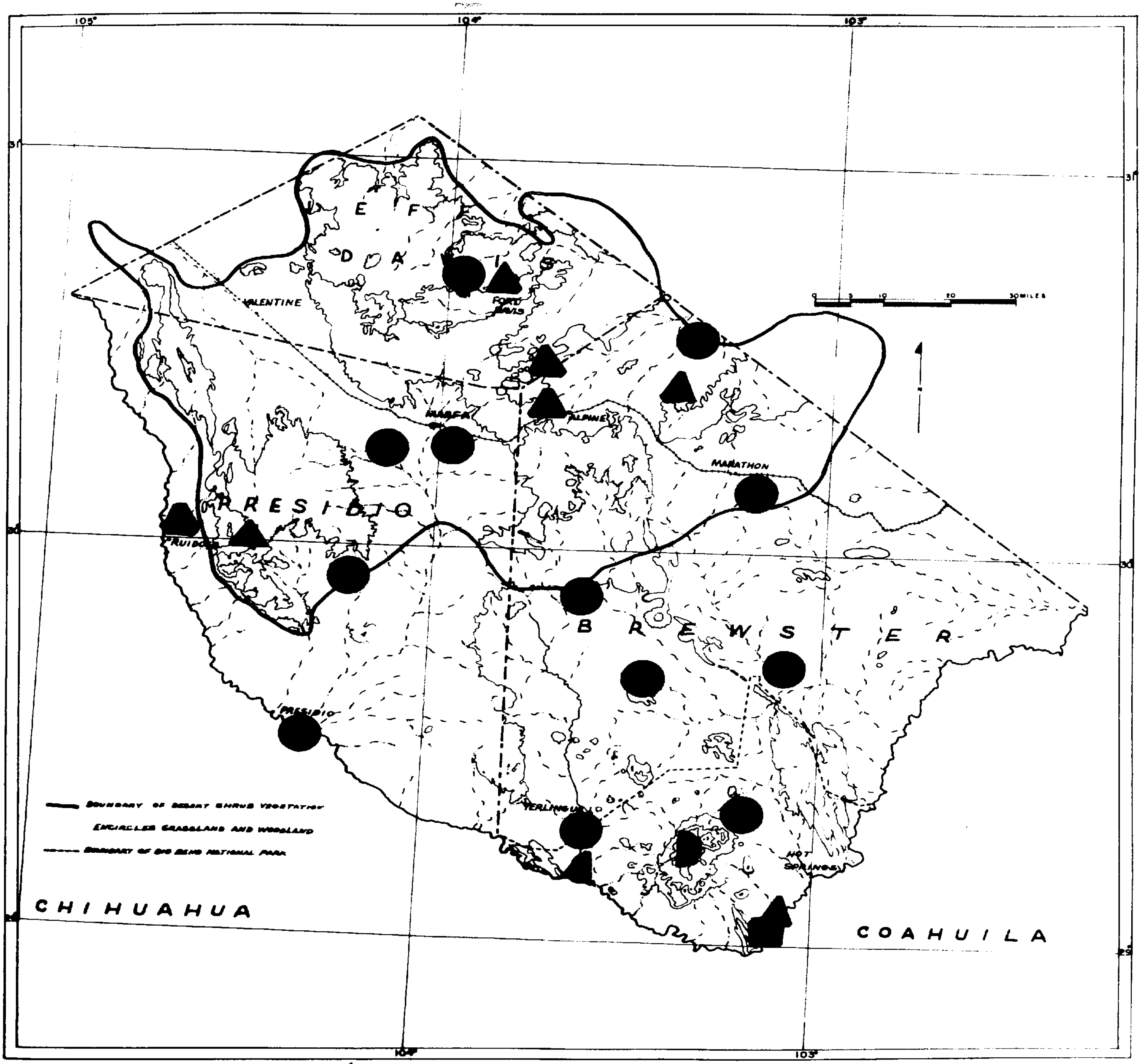

Sample occurrences of species of Opuntia to show extent of their local distribution: ▲ O. Davisii

■ O. Engelmannii var. Wootonii

◗ O. Grahamii

● O. imbricata

MAP V



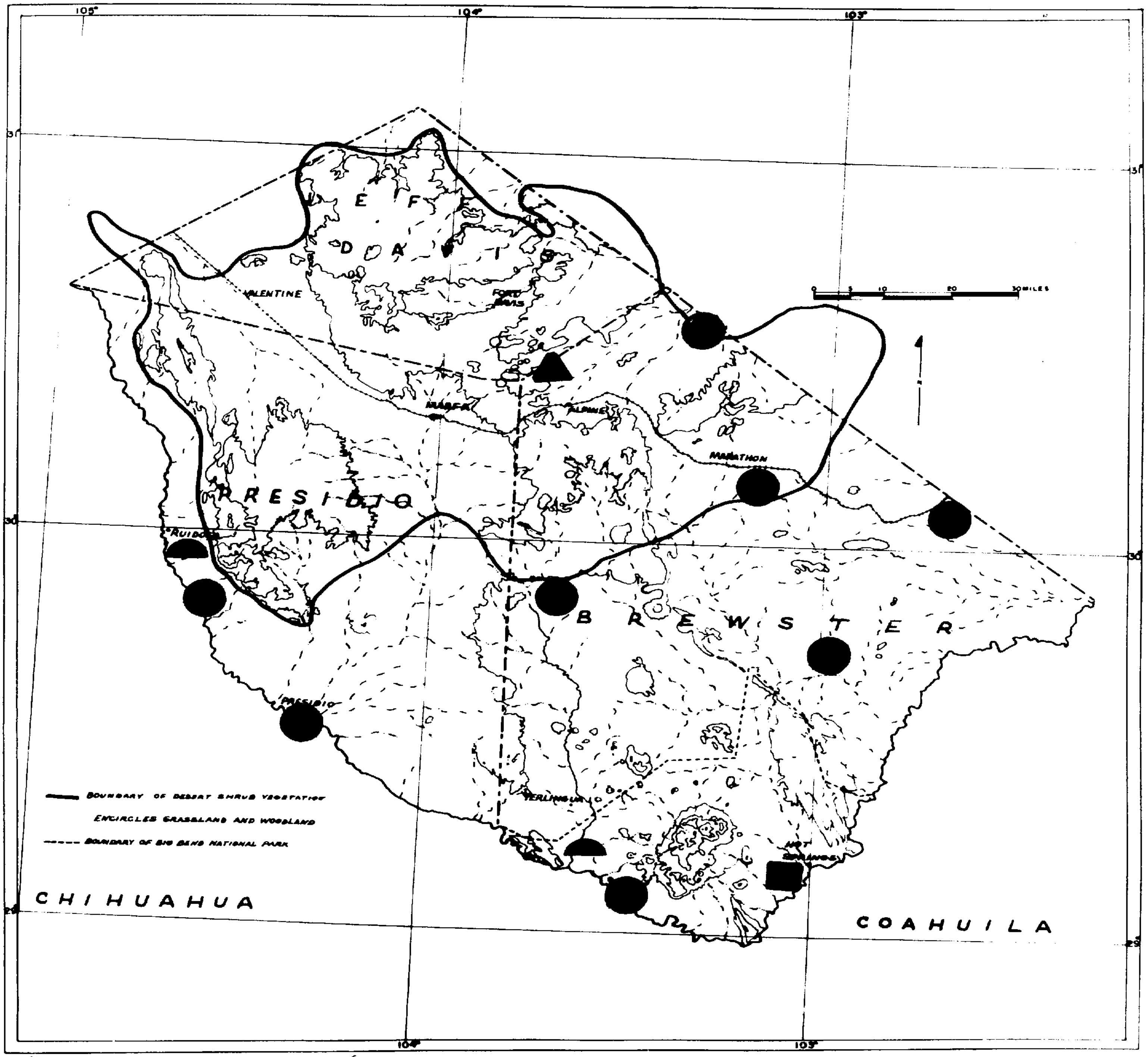

Sample occurrences of species of Opuntia to show extent of their local distribution: ■ O. imbricata var. argentea

▲ O. Kleiniae

◗ O. Lindheimeri var. chisosensis

● O. macrocentra

# MAP VI



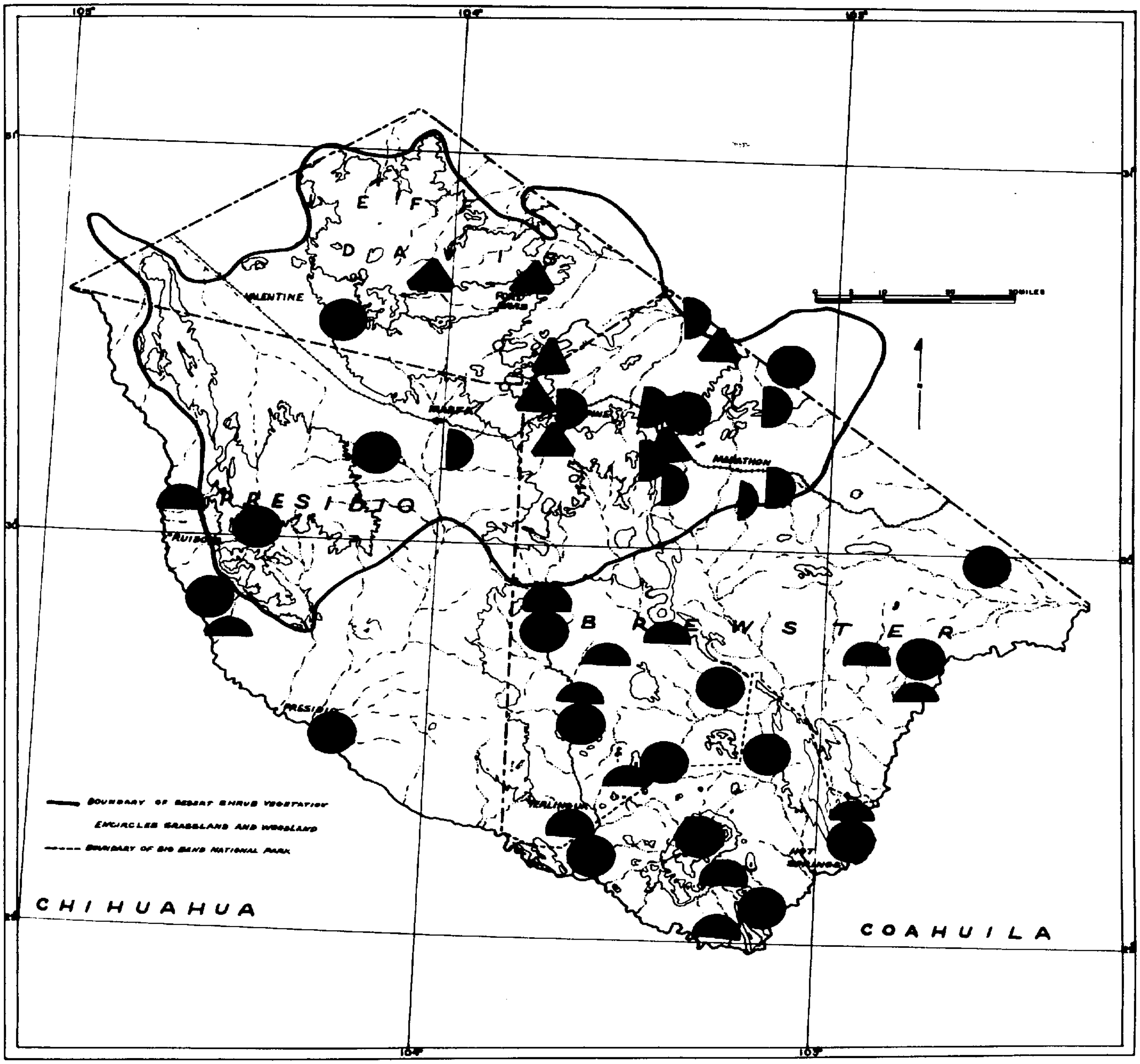

Sample occurrences of species of Opuntia to show extent of their local distribution: ■ O. Kleiniae x leptocaulis

▲ O. leptocaulis

◗ O. linguiformis

● O. macrocentra var. minor

# MAP VII



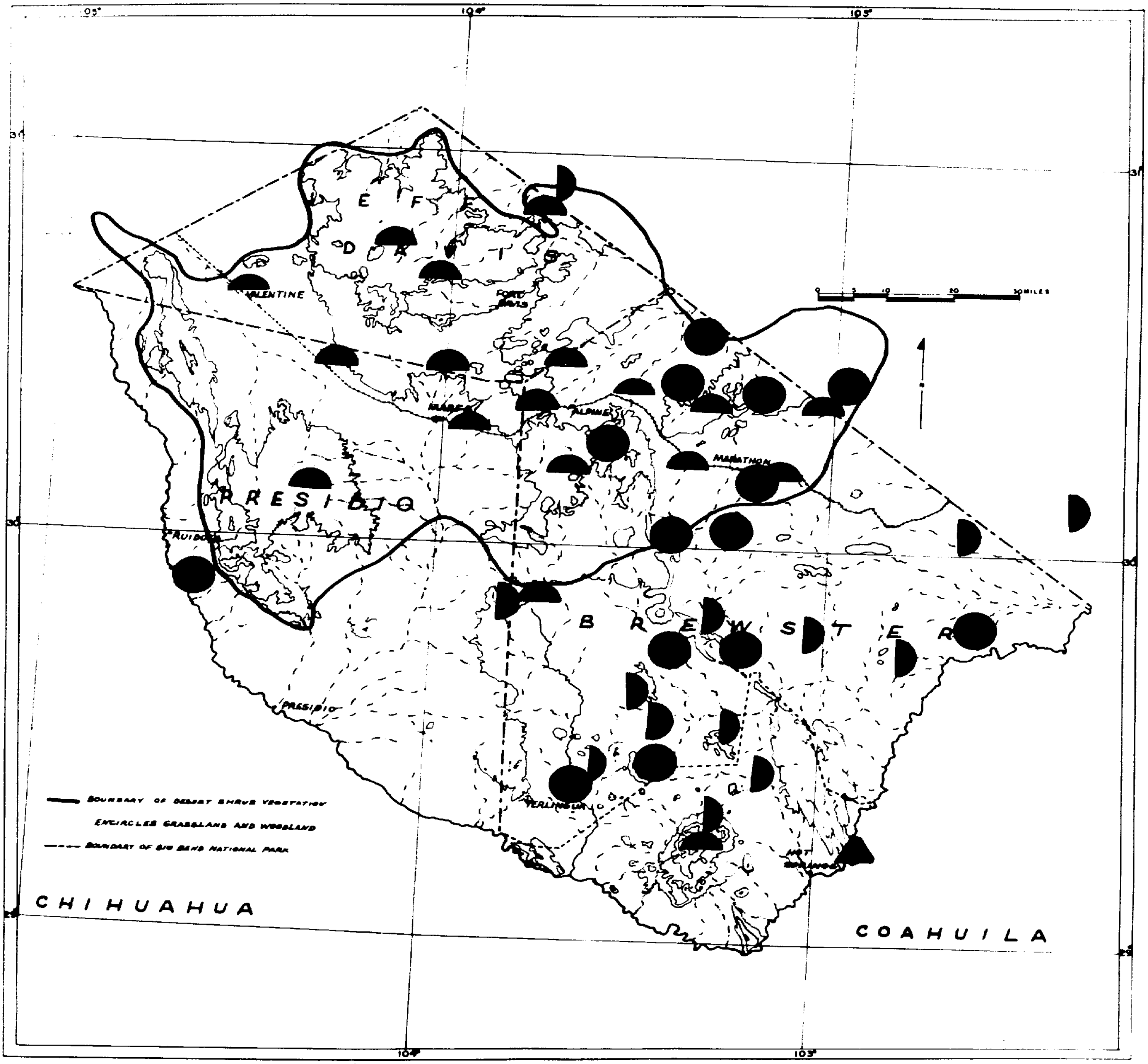

Sample occurrences of species of Opuntia to show extent of their local distribution: <u>O. Lindheimeri</u>

<u>O. phaeacantha</u>

<u>O. Schottii</u>

<u>O. setispina</u>

# MAP VIII



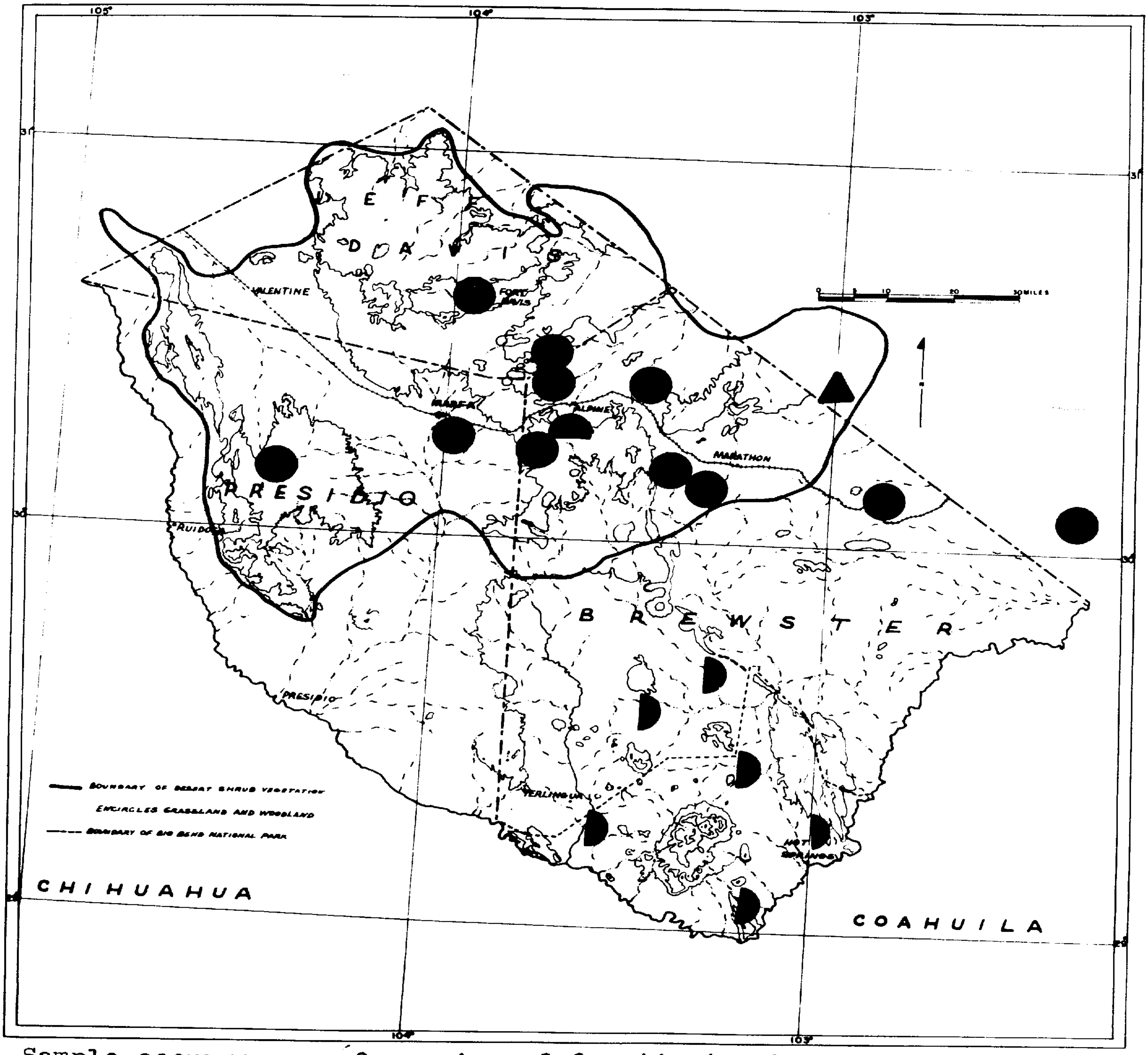

Sample occurrences of species of Opuntia to show extent of their local distribution: O. Engelmannii x phaeacantha

O. spinosibacca

O. tenuispina

O. tortispina

# MAP IX



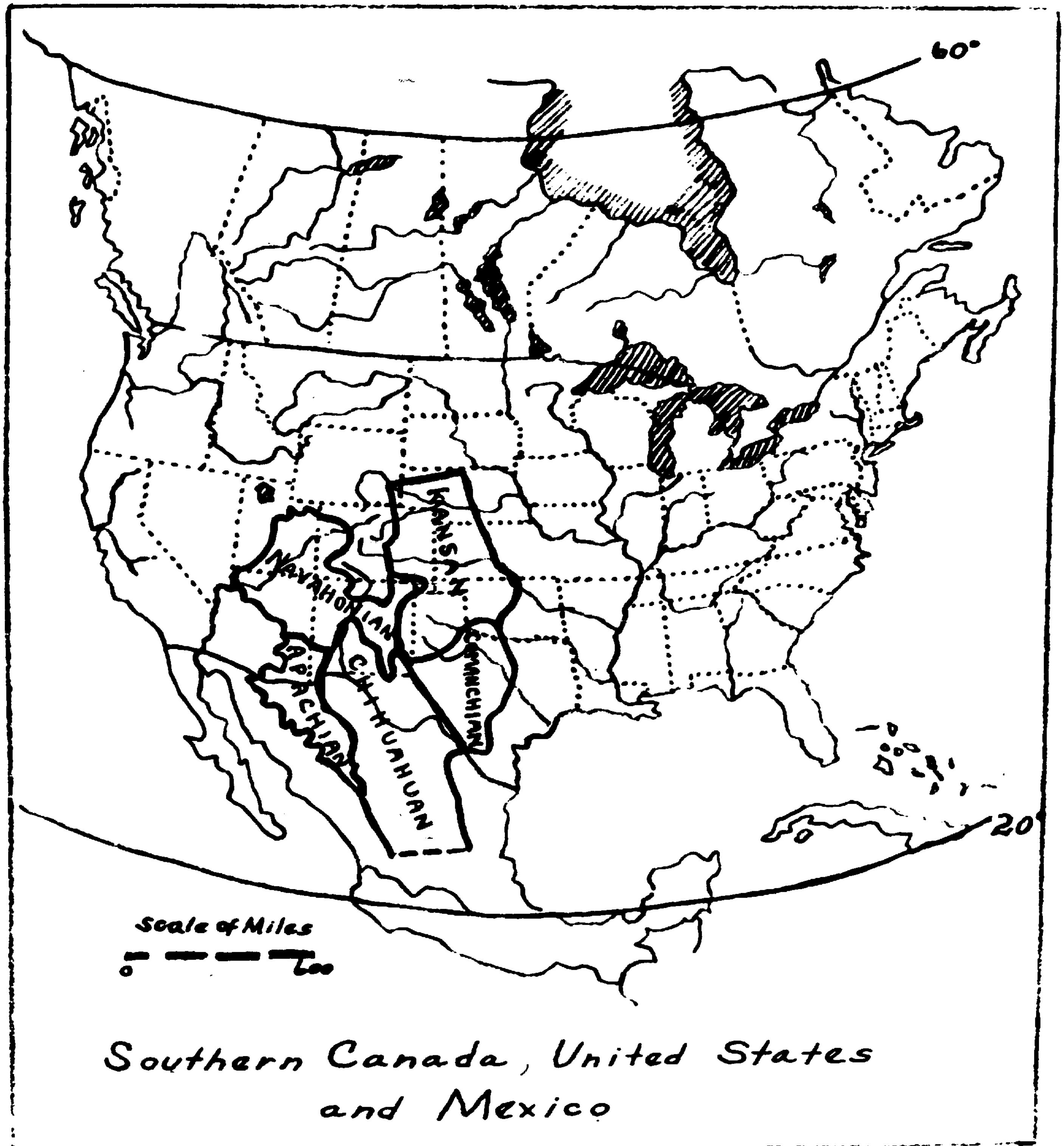

Sample occurrences of species of Opuntia to show extent of their local distribution: O. Pottsii

O. trichophora

O. tunicata

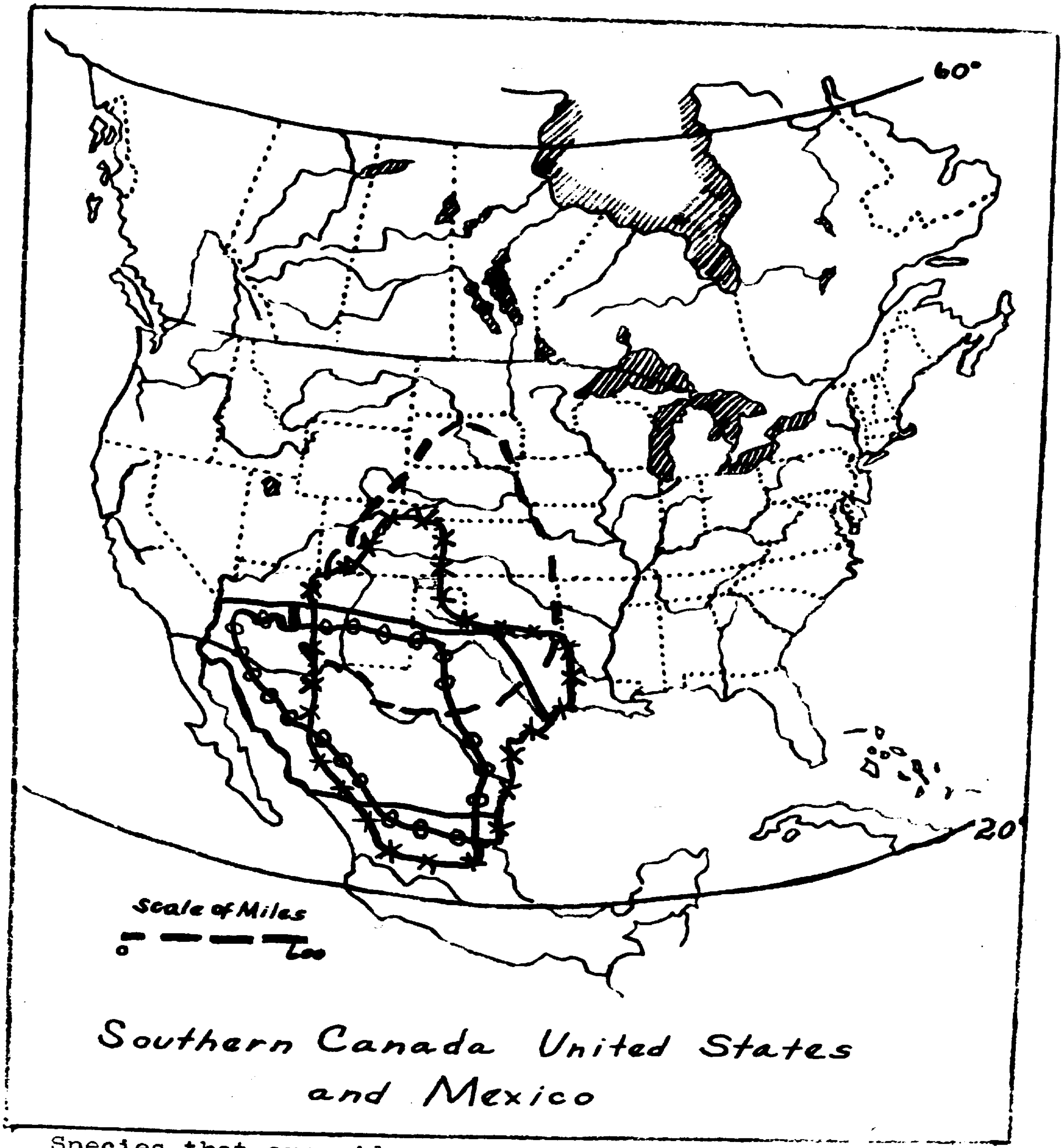
O. Grahamii x Schottii

MAP X




Biotic provinces which have floristic affinities with the Big Bend Region.

after Dice (23)




Species that are widespread throughout southwestern United States and are also common in many habitats in the Big Bend Region.

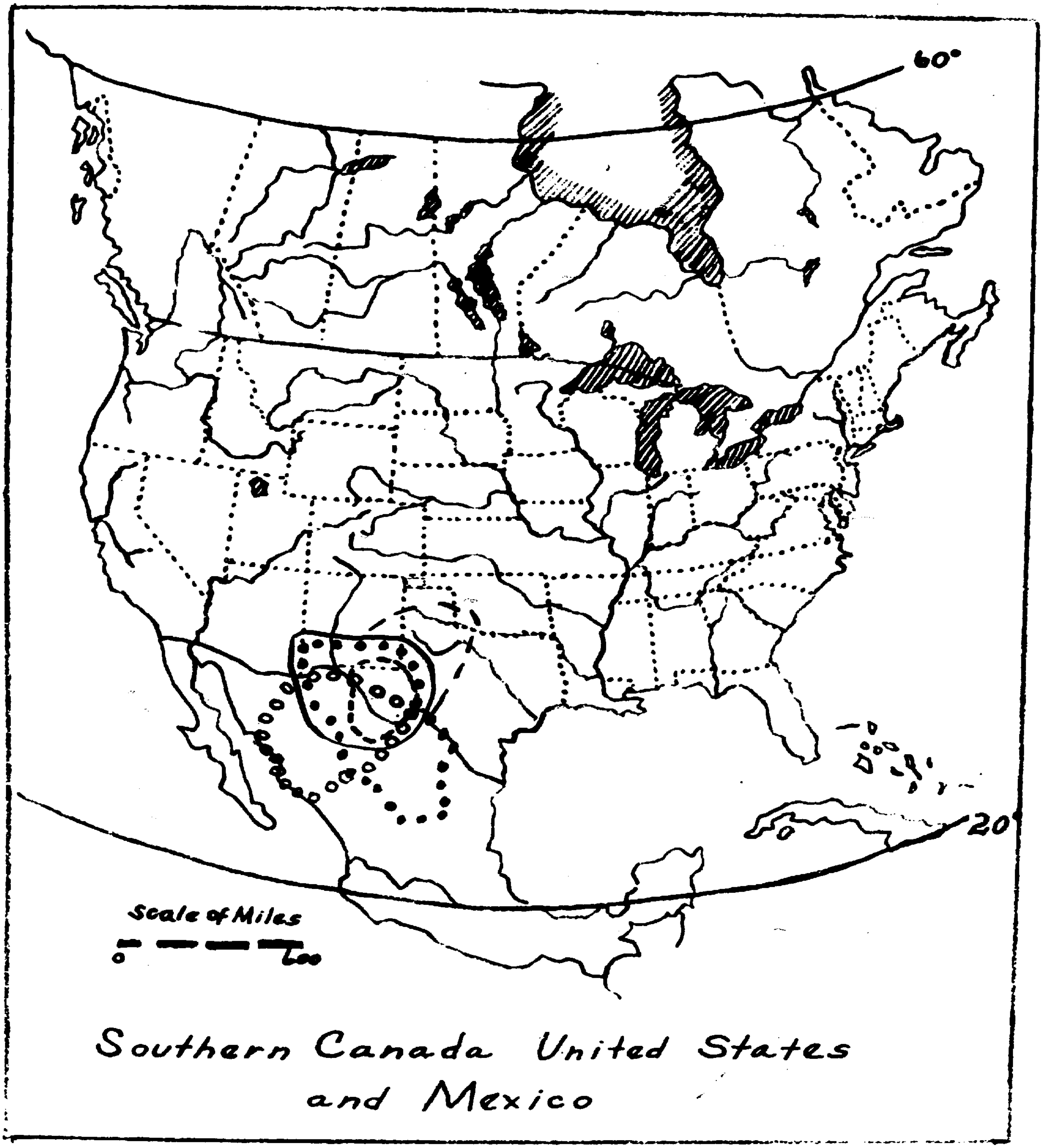
——— O. Engelmannii

-x-x- O. imbricata

-o-o-o- O. leptocaulis

— — — O. tortispina

MAP XII




Species with relatively small ranges of distribution and with more or less restricted occurrence in the Big Bend Region. ooo O. rufida ——— O. Davisii

----O. setispina ..... O. Kleiniae

——— O. Pottsii

| Species of *Opuntia* | Montane Life Belt | Encinal Life Belt | | Arid Brassland Life Belt | | |
|---|---|---|---|---|---|---|
| | PINUS -- PSEUDOTSUGA | PINUS -- JUNIPERUS | QUERCUS - JUNIPERUS | BOUTELOUA- JUNIPERUS | JUGLANS RUPESTRIS | BOUTELOUA-- YUCCA |
| azurea | | | | | | |
| Davisii | | | | | | R |
| Engelmannii | R | F | F | F | R | F |
| Engelmannii var. Wootonii | | | | | | |
| Engelmannii x phaeacantha | | R | R | O | | O |
| Grahamii | | | | | | |
| Grahamii x Schottii | | | | | | |
| imbricata | | F | F | F | R | F |
| imbricata var. argentea | | | | | | |
| Kleiniae | | | | | R | |
| Kleiniae x leptocaulis | | | | | | |
| leptocaulis | | | | R | | R |
| leptocaulis var. brevispina | | | | R | R | R |
| Lindheimeri | | | O | R | R | |
| Lindheimeri var. chisosensis | O | F | | | | |
| linguiformis | | | | | | |
| macrocentra | | R | F | R | | O |
| macrocentra var. minor | | | | | | |
| phaeacantha | | F | F | F | R | O |
| polyacantha | | R | | | | |
| Pottsii | | R | R | O | | O |
| rufida | | | | | | |
| rufida var. tortiflora | | | | | | |
| Schottii | | | | | | |
| setispina | | R | R | O | | O |
| spinosibacca | | | | | | |
| strigil | | | | | | |
| temuispina | | F | F | R | | R |
| tortispina | | F | F | F | | F |
| trichophora | | | R | | | |
| tunicata | | R | | | | |

**TABLE 1.**

Tables 1 -- 5. Frequency of occurrence of species, varieties and hybrids of Opuntia in associations and local communities. A -- Abundant, F -- Frequent, O -- Occasional, R -- Rare.

| Species of <u>Opuntia</u> | Arid Grassland Life Belt | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| | BOUTELOUA - PROSOPIS | BOUTELOUA ARISTIDA | BOUTELOUA - NOLINA | BOUTELOUA OPUNTIA | BOUTELOUA - ACACIA | ACACIA GREGGII |
| azurea | | | | | | |
| Davisii | R | R | | | | R |
| Engelmannii | F | O | | | | A |
| Engelmannii var. Wootonii | | | | | | |
| Engelmannii x phaeacantha | O | O | | R | | |
| Grahamii | | | | | | |
| Grahamii x Schottii | | | | | | |
| imbricata | F | O | R | A | | |
| imbricata var. argentea | | | | | | |
| Kleiniae | R | R | | R | R | |
| Kleiniae x leptocaulis | | | | | | |
| leptocaulis | O | R | | | | R |
| leptocaulis var. brevispina | | | | | | |
| Lindheimeri | O | | | | | |
| Lindheimeri var. chisosensis | | | | | | |
| linguiformis | | | | | | |
| macrocentra | F | O | | | | |
| macrocentra var. minor | | | | | | |
| phaeacantha | R | R | R | | R | |
| polyacantha | | | | | | |
| Pottsii | O | O | | R | | |
| rufida | | | | | | |
| rufida var. tortiflora | | | | | | |
| Schottii | | | | | | |
| setispina | O | O | R | R | | O |
| spinosibacca | | | | | | |
| strigil | | | | | | |
| temuispina | O | | | | | |
| tortispina | F | F | O | | | O |
| trichophora | | | | | | |
| tunicata | | | | | | |

TABLE 2.

| Species of Opuntia | Arid Grassland Life Belt | Desert Shrub Life Belt | | | | |
|---|---|---|---|---|---|---|
| | HILARIA MUTICA | HILARIA MUTICA | FLOURENSIA | LARREA - FLOURENSIA | LARREA | LARREA -- AGAVE |
| azurea | | | | | | R |
| Davisii | | | | | | |
| Engelmannii | O | | F | F | F | F |
| Engelmannii var. Wootonii | | | | O | | |
| Engelmannii x phaeacantha | | | | O | O | O |
| Grahamii | | | | F | F | F |
| Grahamii x Schottii | | | | F | F | O |
| imbricata | O | R | R | F | O | O |
| imbricata var. argentea | | | | | | R |
| Kleiniae | | | | R | R | |
| Kleiniae x leptocaulis | | | | | | |
| leptocaulis | R | | O | F | F | F |
| leptocaulis var. brevispina | | | | R | R | |
| Lindheimeri | | | | R | R | |
| Lindheimeri var. chisosensis | | | | | | |
| linguiformis | | | | | | |
| macrocentra | | A | | F | F | F |
| macrocentra var. minor | | | | | R | |
| phaeacantha | | | | F | F | F |
| polyacantha | | | | | | |
| Pottsii | R | | | R | | |
| rufida | | | | | F | F |
| rufida var. tortiflora | | | | | | O |
| Schottii | | | | F | F | F |
| setispina | A | | R | R | O | |
| spinosibacca | | | | | | R |
| strigil | | | | | | |
| temuispina | F | | | F | F | O |
| tortispina | A | | | R | | |
| trichophora | | | | | | |
| tunicata | | | | | | |

TABLE 3.

| Species of *Opuntia* | Desert Shrub Life Belt | | | | | |
|---|---|---|---|---|---|---|
| | LARREA - PROSOPIS | DASYLIRION- AGAVE | ACACIA- PROSOPIS | LARREA- FOUQUIERIA | LARREA - OPUNTIA | YUCCA - AGAVE |
| azurea | | | | | | |
| Davisii | | | R | | | |
| Engelmannii | F | F | F | O | R | O |
| Engelmannii var. Wootonii | O | | | | | |
| Engelmannii x phaeacantha | | O | O | | | O |
| Grahamii | | R | | R | | |
| Grahamii x Schottii | O | R | R | R | | |
| imbricata | R | O | | | | |
| imbricata var. argentea | | | | | | |
| Kleiniae | | | R | R | | |
| Kleiniae x leptocaulis | | | | | | |
| leptocaulis | F | O | O | R | A | |
| leptocaulis var. brevispina | | | | | | |
| Lindheimeri | | | | | | |
| Lindheimeri var. chisosensis | | R | | | | |
| linguiformis | | | | | | |
| macrocentra | O | O | | O | | |
| macrocentra var. minor | R | | | | | |
| phaeacantha | F | F | F | | | |
| polyacantha | | | | | | |
| Pottsii | | | | | | |
| rufida | R | F | | | | |
| rufida var. tortiflora | | O | | | | |
| Schottii | O | | | O | | |
| setispina | | | | | | |
| spinosibacca | | | | | | |
| strigil | | | | | | |
| tenuispina | O | | O | R | R | |
| tortispina | | | | | | |
| trichophora | | | | | | |
| tunicata | | | | | | |

TABLE 4.

| Species of Opuntia | Desert Shrub Life Belt | | Rio Grande Flood Plain | | Vegetation surrounding mountains | |
|---|---|---|---|---|---|---|
| | PROSOPIS ON DUNES | PROSOPIS THICKETS | BACCHARIS | HYMENOCLEA | GRASSLAND MOUNTAINS | DESERT MOUNTAINS |
| azurea | | | | | | |
| Davisii | | | | | | |
| Engelmannii | R | O | O | | F | F |
| Engelmannii var. Wootonii | | O | | | | |
| Engelmannii x phaeacantha | | O | | | F | |
| Grahamii | | | | | | |
| Grahamii x Schottii | | | | | | |
| imbricata | | | | | F | F |
| imbricata var. argentea | | R | | | | |
| Kleiniae | | R | R | | | |
| Kleiniae x leptocaulis | | | | | | |
| leptocaulis | O | O | | | | |
| leptocaulis var. brevispina | | | | | | |
| Lindheimeri | | | | | O | |
| Lindheimeri var. chisosensis | | | | | | O |
| linguiformis | | R | | | | |
| macrocentra | | O | | | O | |
| macrocentra var. minor | | | | | | |
| phaeacantha | R | O | O | R | F | F |
| polyacantha | | | | | R | |
| Pottsii | | | | | O | |
| rufida | | | | | | |
| rufida var. tortiflora | | | | | | |
| Schottii | | R | | | | |
| setispina | | | | | O | |
| spinosibacca | | | | | | |
| strigil | | | | | | |
| tenuispina | R | | | | | O |
| tortispina | | | | | F | R |
| trichophora | | | | | R | |
| tunicata | | | | | R | |

TABLE 5.

| Species of *Opuntia* | Type of Country Rock | | | | Texture of Soil | |
|---|---|---|---|---|---|---|
| | Chert | Sedimentary | Brown Limestone | Igneous | Clay | Clay Loam |
| azurea | | R | | | | R |
| Davisii | | | | | | |
| Engelmannii | A | F | | F | F | R |
| Engelmannii var. Wootonii | | O | | | | R |
| Engelmannii x phaeacantha | | O | | | | O |
| Grahamii | | F | | | O | O |
| Grahamii x Schottii | | F | | | | O |
| imbricata | F | O | | F | O | R |
| imbricata var. argentea | | R | | | | |
| Kleiniae | | | | O | | |
| Kleiniae x leptocaulis | | | | | | |
| leptocaulis | | F | | | F | F |
| leptocaulis var. brevispina | | R | | | | |
| Lindheimeri | | | | O | | |
| Lindheimeri var. chisosensis | | | | R | | |
| linguiformis | | | | | | |
| macrocentra | | F | F | F | O | O |
| macrocentra var. minor | | | | | | |
| phaeacantha | O | F | | F | O | O |
| polyacantha | | | | R | | |
| Pottsii | | | | O | O | |
| rufida | | A | O | O | O | F |
| rufida var. tortiflora | | F | O | O | O | F |
| Schottii | | F | | | O | O |
| setispina | | O | | O | F | |
| spinosibacca | | R | | | | |
| strigil | | R | | | | |
| tenuispina | | | | O | O | |
| tortispina | | | | A | | |
| trichophora | | | | R | | |
| tunicata | | R | | | | |

**TABLE 6.**

**Frequency of occurrence of species, varieties and hybrids of Opuntia correlated with type of country rock and texture of soil.** **(Continued on Table 7.)**

| Species of Opuntia | Textures of Soil | | | | | |
|---|---|---|---|---|---|---|
| | Silt Loam | Silty Clay Loam | Loam | Sandy Loam | Sand | |
| azurea | | | | | | |
| Davisii | | | R | | R | |
| Engelmannii | F | O | F | F | R | |
| Engelmannii var. Wootonii | | O | | | | |
| Engelmannii x phaeacantha | | | | O | | |
| Grahamii | R | F | O | | F | |
| Grahamii x Schottii | | | | O | | |
| imbricata | F | | F | F | R | |
| imbricata var. argentea | | | | R | | |
| Kleiniae | O | O | O | | O | |
| Kleiniae x leptocaulis | R | | | | | |
| leptocaulis | F | O | R | R | F | |
| leptocaulis var. brevispina | | | | | | |
| Lindheimeri | | | | O | | |
| Lindheimeri var. chisosensis | F | | O | O | | |
| linguiformis | | | | R | | |
| macrocentra | F | O | F | F | | |
| macrocentra var. minor | | | | | R | |
| phaeacantha | F | O | F | F | F | |
| polyacantha | | | R | | | |
| Pottsii | | O | | O | | |
| rufida | | O | | O | O | |
| rufida var. tortiflora | | | | | | |
| Schottii | | | | O | | |
| setispina | O | O | F | | | |
| spinosibacca | | | | | | |
| strigil | | | | | | |
| temuispina | O | | O | F | O | |
| tortispina | O | | F | O | | |
| trichophora | | | | | | |
| tunicata | | | | | | |

TABLE 7.

| Species of <u>Opuntia</u> | Local Distribution | | | General Distribution | | |
|---|---|---|---|---|---|---|
| | Desert Life Belt | Grassland Life Belt | Encinal Life Belt | Plains | Eastern Texas | Mexico |
| azurea | R | | | | | X |
| Davisii | | R | | X | | |
| Engelmannii | A | A | | | | |
| Engelmannii var. Wootonii | O | | | | | |
| Engelmannii x phaeacantha | O | A | O | | | |
| Grahamii | | A | | | | |
| Grahamii x Schottii | | A | | | | |
| imbricata | A | A | A | | | |
| imbricata var. argentea | R | | | | | |
| Kleiniae | R | R | R | | | X |
| Kleiniae x leptocaulis | | R | | | | |
| leptocaulis | A | O | | | | |
| leptocaulis var. brevispina | | O | | | | |
| Lindheimeri | | O | O | | X | |
| Lindheimeri var. chisosensis | | | A | | | |
| linguiformis | R | | | | | |
| macrocentra | A | A | O | | | |
| macrocentra var. minor | R | | | | | |
| phaeacantha | A | A | F | | | |
| polyacantha | | | R | X | | |
| Pottsii | | O | R | | | X |
| rufida | A | | | | | X |
| rufida var. tortiflora | A | | | | | X |
| Schottii | A | | | | X | X |
| setispina | | A | O | | | X |
| spinosibacca | R | | | | | ? |
| strigil | R | | | | | |
| tenuispina | O | O | O | | | |
| tortispina | | A | F | X | | |
| trichophora | | | R | X | | |
| tunicata | | | R | | | X |

**TABLE 8.**
**Local distribution of Opuntiae according to life belts.**
**Opuntiae which show affinities with adjacent areas.**

| Species of Opuntia | HABIT | | | | TRUNK | |
|---|---|---|---|---|---|---|
| | Erect Shrub | Large Bush | Low Bush Spreading | Prostrate | Present | Absent |
| azurea | | X | | | | X |
| Davisii | X | | | | X | |
| Engelmannii | | X | | | X | |
| Engelmannii var. Wootonii | | | X | | | X |
| Engelmannii x phaeacantha | | X | | | | X |
| Grahamii | | | | X | | X |
| Grahamii x Schottii | | | | X | | X |
| imbricata | arborescent | | | | X | |
| imbricata var. argentea | arborescent | | | | X | |
| Kleiniae | X | | | | X | |
| Kleiniae x leptocaulis | X | | | | X | |
| leptocaulis | X | | | | X | |
| leptocaulis var. brevispina | X | | | | X | |
| Lindheimeri | | X | | | X | |
| Lindheimeri var. chisosensis | | X | | | X | |
| linguiformis | X | | | | | X |
| macrocentra | | X | | | X | |
| macrocentra var. minor | | | X | | X | |
| phaeacantha | | X | | | | X |
| polyacantha | | | | X | X | |
| Pottsii | | | X | | | X |
| rufida | | X | | | | X |
| rufida var. tortiflora | | X | | | X | |
| Schottii | | | | X | X | |
| setispina | | X | | | | X |
| spinosibacca | X | | | | X | |
| strigil | | X | | | X | |
| tenuispina | | | X | | X | |
| tortispina | | | X | | | X |
| trichophora | | | | X | | X |
| tunicata | | | X | | X | |

TABLE 9.
Tables 9-17 contrast taxonomic characteristics of the species, varieties and hybrids of Opuntia.

| Species of Opuntia | ROOTS | | SHAPE OF JOINTS | | AREOLES | |
|---|---|---|---|---|---|---|
| | Fibrous | Tuberous | Mostly Orbicular | Mostly Obovate | Distant | Closely Set |
| azurea | X | | X | | X | |
| Davisii | X | | oblong | | | X |
| Engelmannii | X | | X | | X | |
| Engelmannii var. Wootonii | X | | X | X | X | |
| Engelmannii x phaeacantha | X | | X | | X | |
| Grahamii | | X | | clavate | X | |
| Grahamii x Schottii | | X | | clavate | X | |
| imbricata | X | | oblong | | X | |
| imbricata var. argentea | X | | oblong | | | X |
| Kleiniae | X | | oblong | | X | |
| Kleiniae x leptocaulis | X | | oblong | | | X |
| leptocaulis | X | | oblong | | | X |
| leptocaulis var. brevispina | X | | oblong | | | X |
| Lindheimeri | X | | X | | X | |
| Lindheimeri var. chisosensis | X | | X | | X | |
| linguiformis | X | | | X | | X |
| macrocentra | X | | X | | | X |
| macrocentra var. minor | X | | | X | | X |
| phaeacantha | X | | | X | X | |
| polyacantha | X | | | X | | X |
| Pottsii | | X | | X | | X |
| rufida | X | | | X | | X |
| rufida var. tortiflora | X | | | X | | X |
| Schottii | | | | clavate | | |
| setispina | X | | X | | | X |
| spinosibacca | X | | | X | X | |
| strigil | X | | X | | | X |
| tenuispina | X | | | X | X | |
| tortispina | X | | | X | | X |
| trichophora | X | | | X | | X |
| tunicata | X | | oblong | | X | |

TABLE 10.

| Species of Opuntia | SPINES | | DEFINITE BRISTLES | | INNER PERIANTH SEGMENTS | |
|---|---|---|---|---|---|---|
| | Spreading Downward | Spreading Outward | Present | Absent | Emarginate | Not Emarginate |
| azurea | | | | | | |
| Davisii | | X | X | | | |
| Engelmannii | X | X | X | | | |
| Engelmannii var. Wootonii | X | X | | X | | |
| Engelmannii x phaeacantha | | | | X | | |
| Grahamii | | X | | X | | |
| Grahamii x Schottii | | X | X | | | |
| imbricata | | X | X | | | |
| imbricata var. argentea | | X | | X | | |
| Kleiniae | | X | | X | | |
| Kleiniae x leptocaulis | | X | X | | | |
| leptocaulis | | X | | X | | |
| leptocaulis var. brevispina | X | X | | X | | |
| Lindheimeri | X | | | X | | |
| Lindheimeri var. chisosensis | | X | | X | | |
| linguiformis | X | | | X | | |
| macrocentra | | | | X | | |
| macrocentra var. minor | | X | | X | | |
| phaeacantha | | X | | X | | |
| polyacantha | X | X | X | | | |
| Pottsii | | | | X | | |
| rufida | | | | X | | |
| rufida var. tortiflora | | | | | | |
| Schottii | | | | | | |
| setispina | X | X | X | | | |
| spinosibacca | | | | X | | |
| strigil | X | X | X | | | |
| tenuispina | X | | | X | | |
| tortispina | X | | | X | | |
| trichophora | X | | X | | | |
| tunicata | | X | X | X | | |

**TABLE 11.**

| Species of *Opuntia* | STYLE | | STIGMA | | STAMENS | |
|---|---|---|---|---|---|---|
| | Short, thick | Long, thin | Green | Yellow | Yellow, White or Green | Other Colors |
| azurea | | | | | | |
| Davisii | | X | | | | |
| Engelmannii | X | | | pink-white | | pink-brown |
| Engelmannii var. Wootonii | X | | X | X | yellow-wh. | |
| Engelmannii x phaeacantha | | | | | | |
| Grahamii | X | | | X | gr.- wh. | |
| Grahamii x Schottii | | X | X | | | purple-red |
| imbricata | | X | X | | | purple-red |
| imbricata var. argentea | X | | | X | | magenta |
| Kleiniae | X | | | X | | magenta |
| Kleiniae x leptocaulis | | X | | creamy | | gr.-pink |
| leptocaulis | | X | | creamy | | gr.-pink |
| leptocaulis var. brevispina | | X | | creamy | gr.-ye. | |
| Lindheimeri | | | | | | |
| Lindheimeri var. chisosensis | X | | X | | | pink-ye. |
| linguiformis | | | | | | |
| macrocentra | | | | | | |
| macrocentra var. minor | | X | | X | gr.-ye. | |
| phaeacantha | | | | | | |
| polyacantha | X | | | X | yellow | |
| Pottsii | | | | | | |
| rufida | | | | X | gr.-ye. | |
| rufida var. tortiflora | X | | X | | yellow | |
| Schottii | | | | | | |
| setispina | | X | X | | | purple-red |
| spinosibacca | X | | | X | gr.-ye. | |
| strigil | X | | | X | yellow | |
| tenuispina | | | | X | creamy | |
| tortispina | | | | X | wh.-gr. | |
| trichophora | | | X | | | pink-wh. |
| tunicata | | | X | | white | |
| | | | | X | gr.-wh. | |

TABLE 12.

| Species of Opuntia | OVARY | | | FRUIT | | |
|---|---|---|---|---|---|---|
| | Relatively Long | Relatively Short | With Bristles | Naked | Dry | Juicy |
| azurea | | | | | | |
| Davisii | | X | X | | X | |
| Engelmannii | X | | | X | | X |
| Engelmannii var. Wootonii | | | | | | |
| Engelmannii x phaeacantha | X | | | X | | X |
| Grahamii | X | | X | | X | |
| Grahamii x Schottii | X | | X | | X | |
| imbricata | | X | X | | X | |
| imbricata var. argentea | | X | | | X | |
| Kleiniae | | X | | X | X | |
| Kleiniae x leptocaulis | | X | | X | X | |
| leptocaulis | | X | | XX | | |
| leptocaulis var. brevispina | | | | X | | |
| Lindheimeri | X | | | X | | X |
| Lindheimeri var. chisosensis | | | | X | | X |
| linguiformis | | | | | | |
| macrocentra | X | | | X | | X |
| macrocentra var. minor | | | | | | |
| phaeacantha | | X | | X | | X |
| polyacantha | X | | X | | X | |
| Pottsii | X | | | X | | X |
| rufida | | X | | X | | X |
| rufida var. tortiflora | | X | | X | | X |
| Schottii | X | | X | | X | |
| setispina | X | | | X | | X |
| spinosibacca | X | | X | | X | |
| strigil | | X | X | | | X |
| temuispina | X | | | X | | X |
| tortispina | X | | | X | | X |
| trichophora | X | | X | | | |
| tunicata | | X | | X | X | |

TABLE 13.

| Species of *Opuntia* | FRUIT | | UMBILICUS | | SEEDS | |
|---|---|---|---|---|---|---|
| | Sterile (mostly) | Fertile | v-shaped | u-shaped | Large | Small |
| azurea | | X | | | | |
| Davisii | X | | X | | X | |
| Engelmannii | | X | | X | | X |
| Engelmannii var. Wootonii | | | | | | |
| Engelmannii x phaeacantha | | X | X | | X | |
| Grahamii | X | | X | | X | |
| Grahamii x Schottii | X | | X | | | |
| imbricata | | X | | X | | X |
| imbricata var. argentea | | | | | | |
| Kleiniae | | X | X | | X | |
| Kleiniae x leptocaulis | X | | X | | | |
| leptocaulis | | X | X | | | X |
| leptocaulis var. brevispina | | | | | | X |
| Lindheimeri | | X | | X | | X |
| Lindheimeri var. chisosensis | | X | | X | X | |
| linguiformis | | | | | | |
| macrocentra | | X | X | | X | |
| macrocentra var. minor | | | | | | |
| phaeacantha | | X | | X | X | |
| polyacantha | | X | X | | X | |
| Pottsii | | X | X | | X | |
| rufida | | | | | | |
| rufida var. tortiflora | | | | | | |
| Schottii | X | | X | | X | |
| setispina | | X | X | | X | |
| spinosibacca | X | | X | | X | |
| strigil | | X | X | | | X |
| tenuispina | | X | X | | X | |
| tortispina | | X | X | | X | |
| trichophora | | | | | | |
| tunicata | X | | X | | | X |

TABLE 14

| Species of <u>Opuntia</u> | SEEDS | | | | ARIL | |
|---|---|---|---|---|---|---|
| | Beaked | Beakless | Deeply Notched | Scarcely Notched | Wide | Narrow |
| azurea | | | | | | |
| Davisii | X | | | | | X |
| Engelmannii | | X | X | | | X |
| Engelmannii var. Wootonii | | | | | | |
| Engelmannii x phaeacantha | | X | X | | X | |
| Grahamii | X | | X | | | X |
| Grahamii x Schottii | | | | | | |
| imbricata | X | | | X | | X |
| imbricata var. argentea | | | | | | |
| Kleiniae | X | | | | | X |
| Kleiniae x leptocaulis | | X | | X | | |
| leptocaulis | | X | | X | | X |
| leptocaulis var. brevispina | | | | | | |
| Lindheimeri | | X | X | X | | X |
| Lindheimeri var. chisosensis | | X | X | | X | |
| linguiformis | | | | | | |
| macrocentra | | X | X | | X | |
| macrocentra var. minor | | | | | | |
| phaeacantha | | X | X | | X | |
| polyacantha | | X | X | | X | |
| Pottsii | X | | X | | X | |
| rufida | | | | | | |
| rufida var. tortiflora | | | | | | |
| Schottii | X | | X | | | X |
| setispina | X | | X | | X | |
| spinosibacca | | X | X | | X | |
| strigil | | X | | | | X |
| tenuispina | | X | X | | X | |
| tortispina | | X | X | X | X | |
| trichophora | | | | | | |
| tunicata | | | | | | X |

TABLE 15.

| Species of <u>Opuntia</u> | STOMATA | WALLS OF EPIDERMAL CELLS | | HOW SPREAD | | |
|---|---|---|---|---|---|---|
| | Length of Stoma in µ | Straight | Lobed | Easily Fragmented | Abundant Fertile fruits | |
| azurea | 24.4 | | X | | | |
| Davisii | 22.3 | X | | X | | |
| Engelmannii | 30.8 | | X | | X | |
| Engelmannii var. Wootonii | | | | | | |
| Engelmannii x phaeacantha | 28.7 | X | X | | X | |
| Grahamii | 30.0 | | X | X | | |
| Grahamii x Schottii | 34.6 | | X | X | | |
| imbricata | 20.9 | X | | | X | |
| imbricata var. argentea | 36.9 | | X | | | |
| Kleiniae | 23.3 | X | X | X | | |
| Kleiniae x leptocaulis | 23.2 | X | | X | | |
| leptocaulis | 23.6 | X | | X | | |
| leptocaulis var. brevispina | | | | X | | |
| Lindheimeri | 29.3 | | X | | X | |
| Lindheimeri var. chisosensis | | | | | X | |
| linguiformis | | | | | | |
| macrocentra | | | | | X | |
| macrocentra var. minor | 22.6 | X | | | | |
| phaeacantha | 29.5 | | X | | X | |
| polyacantha | | | | | | |
| Pottsii | 27.6 | | X | | X | |
| rufida | 32.2 | | X | | | |
| rufida var. tortiflora | | | | | | |
| Schottii | 30.0 | | X | X | | |
| setispina | 28.7 | | X | | X | |
| spinosibacca | | | | | X | |
| strigil | 20.1 | | X | | X | |
| tenuispina | 43.2 | | X | | X | |
| tortispina | 30.4 | | X | | X | |
| trichophora | 26.3 | | X | | | |
| tunicata | 19.4 | X | | X | | |

TABLE 16

| Species of <u>Opuntia</u> | MONTHS | | | | | |
|---|---|---|---|---|---|---|
| | March | April | May | June | July | August |
| azurea | | XXXXXXX | | | | |
| Davisii | | | | | XXXXXXX | |
| Engelmannii | | XXX | XXXXXXXXXX | XXXXXXXXXX | XXXXXXXXXX | |
| Engelmannii var. Wootonii | | | | | | |
| Engelmannii x phaeacantha | | XXX | XXXXXXX | | | |
| Grahamii | XXX | XXXXXXXXXX | XXXXXXX | | | |
| Grahamii x Schottii | | XXXXXXXX | | | | |
| imbricata | | XX | XXXXXXXXXX | XXXXXXXXXX | XXXXXXXXXX | |
| imbricata var. argentea | | XXXXXXXXXX | | | | |
| Kleiniae | | | XXXXXXXXX | XXXXXXXXXX | XXXXXXXXXX | XXXXXXXXXX |
| Kleiniae x leptocaulis | | | X | XXXXXXXX | | |
| leptocaulis | | | | XXXXXXXX | XXXXXXXXXX | XXXXXXX |
| leptocaulis var. brevispina | | | | | | |
| Lindheimeri | | | XXXXXXXXX | XXXXX | | |
| Lindheimeri var. chisosensis | | | XXXXXXXXX | | | |
| linguiformis | | XXXXXXXX | | | | |
| <u>macrocentra</u> | | XXXXXXXXX | XXXXXXXX | | | |
| macrocentra var. minor | | | | | | |
| phaeacantha | | XXXXXXXXX | XXXXXXXX | | | |
| <u>polyacantha</u> | | | XXXXXXX | XX | | |
| Pottsii | | | XXXXXXXX | | | |
| <u>rufida</u> | | XXXXXXXX | | | | |
| rufida var. tortiflora | | XXXXXXXX | | | | |
| Schottii | | XXXXXXXX | | | | |
| <u>setispina</u> | | | XXXXX | XXXXXXXXXX | XXXXXXX | |
| <u>spinosibacca</u> | | XXXXXXXX | | | | |
| <u>strigil</u> | | XXXXXXXX | | | | |
| <u>tenuispina</u> | | | | XXXXXXXX | | |
| <u>tortispina</u> | | | XXXXXX | XXXXXXXXXX | XXXX | |
| <u>trichophora</u> | | | XXXXX | | | |
| tunicata | | | | XXXXX | X | |

**TABLE 17**

**FLOWERING PERIODS**

| Species of Opuntia | Species of Opuntia | | | | | |
|---|---|---|---|---|---|---|
| | azurea | Davisii | Engelmannii | Engel. var. Wootonii | Engelmannii x phaeacantha | Grahamii |
| azurea | | | | | | X |
| Davisii | | | X | | | |
| Engelmannii | | X | | | X | X |
| Engelmannii var. Wootonii | | | | | | |
| Engelmannii x phaeacantha | | | X | | | |
| Grahamii | | | X | | | |
| Grahamii x Schottii | | | X | X | | |
| imbricata | | | X | | X | X |
| imbricata var. argentea | | | | | | |
| Kleiniae | | | X | | | |
| Kleiniae x leptocaulis | | | X | | | |
| leptocaulis | | | X | | X | X |
| leptocaulis var. brevispina | | | | | | |
| Lindheimeri | | | X | | | |
| Lindheimeri var. chisosensis | | | X | | | |
| linguiformis | | | | | | |
| macrocentra | X | | X | X | X | X |
| macrocentra var. minor | | | | | | X |
| phaeacantha | | | X | | X | X |
| polyacantha | | | | | | |
| Pottsii | | X | X | | | |
| rufida | | | X | | | X |
| rufida var. tortiflora | | | X | | | X |
| Schottii | X | | X | X | | X |
| setispina | | | X | | | |
| spinosibacca | | | | | | X |
| strigil | | | X | | | |
| tenuispina | | | X | | | |
| tortispina | | | X | | | |
| trichophora | | | | | | |
| tunicata | | | X | | | |

TABLE 18.

Species of Opuntia that occur together.

Tables 18-22.

| Species of Opuntia | Species of Opuntia | | | | | |
|---|---|---|---|---|---|---|
| | Grahamii x Schottii | imbricata | imbricata var. argentea | Kleiniae | Kleiniae x leptocaulis | leptocaulis |
| azurea | | | | | | |
| Davisii | | | | | | |
| Engelmannii | X | X | | X | X | X |
| Engelmannii var. Wootonii | X | | | | | |
| Engelmannii x phaeacantha | | X | | | | X |
| Grahamii | X | | | X | | X |
| Grahamii x Schottii | | X | | | | X |
| imbricata | X | | | X | X | X |
| imbricata var. argentea | | | | | | X |
| Kleiniae | | X | | | X | X |
| Kleiniae x leptocaulis | | X | | X | | X |
| leptocaulis | X | X | X | X | X | |
| leptocaulis var. brevispina | | | | | | |
| Lindheimeri | | X | | X | X | X |
| Lindheimeri var. chisosensis | | X | | | | |
| linguiformis | | | | | | |
| macrocentra | X | X | | | | X |
| macrocentra var. minor | | | | | | X |
| phaeacantha | X | X | X | X | | X |
| polyacantha | | | | | | |
| Pottsii | | X | | X | X | X |
| rufida | | X | | | | X |
| rufida var. tortiflora | | X | | | | X |
| Schottii | X | X | X | | | |
| setispina | | X | | | | |
| spinosibacca | | | | | | X |
| strigil | | | | | | |
| temuispina | | X | | | | X |
| tortispina | | X | | X | X | X |
| trichophora | | | | | | |
| tunicata | | | | | | |

TABLE 19.

| Species of Opuntia | Species of Opuntia | | | | | |
|---|---|---|---|---|---|---|
| | leptocaulis var, brevisp. | Lindheimeri | Lind. var. chisosensis | lingui-formis | macro-centra | macrocentra var. minor |
| azurea | | | | | X | |
| Davisii | | | | | | |
| Engelmannii | X | X | X | X | X | X |
| Engelmannii var. Wootonii | X | | | | X | |
| Engelmannii x phaeacantha | | | | | X | |
| Grahamii | | | | | X | |
| Grahamii x Schottii | | | | | X | |
| imbricata | X | X | X | | X | |
| imbricata var. argentea | | | | | | |
| Kleiniae | | X | | | | |
| Kleiniae x leptocaulis | | X | | | | |
| leptocaulis | | X | | | X | X |
| leptocaulis var. brevispina | | | | | | |
| Lindheimeri | | | | | X | |
| Lindheimeri var. chisosensis | | | | | | |
| linguiformis | | | | | | |
| macrocentra | X | X | | | | X |
| macrocentra var. minor | | | | | X | |
| phaeacantha | | X | X | | X | X |
| polyacantha | | | | | | |
| Pottsii | | X | | | | |
| rufida | | | | | X | |
| rufida var. tortiflora | | | | | X | |
| Schottii | | | | | X | |
| setispina | X | | | | X | |
| spinosibacca | | | | | | |
| strigil | | | | | | |
| temuispina | | | X | | X | |
| tortispina | | X | | | X | |
| trichophora | | | | | | |
| tunicata | | | | | | |

TABLE 20.

| Species of *Opuntia* | Species of Opuntia | | | | | |
|---|---|---|---|---|---|---|
| | phaeacantha | poly-acantha | Pottsii | rufida | Schottii | setispina |
| azurea | | | | | X | |
| Davisii | | | | | | |
| Engelmannii | X | | X | X | X | X |
| Engelmannii var. Wootonii | X | | | | | |
| Engelmannii x phaeacantha | X | | | | | X |
| Grahamii | X | | | X | X | |
| Grahamii x Schottii | X | | | X | X | |
| imbricata | X | | X | X | X | X |
| imbricata var. argentea | X | | | | X | |
| Kleiniae | | | X | | | |
| Kleiniae x leptocaulis | | | X | | | |
| leptocaulis | X | | X | X | X | |
| leptocaulis var. brevispina | | | | | | X |
| Lindheimeri | X | | X | | | |
| Lindheimeri var. chisosensis | X | | | | | |
| linguiformis | | | | | | |
| macrocentra | X | | | X | X | X |
| macrocentra var. minor | X | | | | | |
| phaeacantha | | | | X | X | X |
| polyacantha | | | | | | |
| Pottsii | | | | | | X |
| rufida | X | | | | X | |
| rufida var. tortiflora | X | | | X | X | |
| Schottii | X | | | X | | |
| setispina | X | | X | | | |
| spinosibacca | X | | | X | | |
| strigil | | | | | | |
| temuispina | X | | | | | X |
| tortispina | X | X | X | | | X |
| trichophora | | | | | | |
| tunicata | X | | | | | |

TABLE 21.

| Species of *Opuntia* | Species of Opuntia | | | | | |
|---|---|---|---|---|---|---|
| | spinosi-bacca | strigil | tenuispina | tortispina | trichophora | tunicata |
| azurea | | | | | | |
| Davisii | | | | | | |
| Engelmannii | | X | X | X | | X |
| Engelmannii var. Wootonii | | | | | | |
| Engelmannii x phaeacantha | | X | X | X | | X |
| Grahamii | X | | X | | | |
| Grahamii x Schottii | | | | | | |
| imbricata | | | X | X | | X |
| imbricata var. argentea | | | | | | |
| Kleiniae | | | | X | | |
| Kleiniae x leptocaulis | | | | X | | |
| leptocaulis | X | | X | X | | |
| leptocaulis var. brevispina | | | | | | |
| Lindheimeri | | | | X | | |
| Lindheimeri var. chisosensis | | | X | | | |
| linguiformis | | | | | | |
| macrocentra | | | X | X | | |
| macrocentra var. minor | | | | | | |
| phaeacantha | X | | X | X | | X |
| polyacantha | | | | X | | |
| Pottsii | | | | X | | |
| rufida | X | | | | | |
| rufida var. tortiflora | X | | | | | |
| Schottii | | | | | | |
| setispina | | | X | X | | |
| spinosibacca | | | | | | |
| strigil | | | | | | |
| tenuispina | | | | X | | |
| tortispina | | | X | | | X |
| trichophora | | | | | | |
| tunicata | | | | X | | |

**TABLE 22.**

TABLE 23

## LEGEND

BACCHARIS and PHRAGMITES

AGAVE LECHUGUILLA

LARREA DIVARICATA

FOUQUIERIA SPLENDENS

JUNIPERUS MONOSPERMA

QUERCUS GRISEA

PINUS CEMBROIDES

PSEUDOTSUGA TAXIFOLIA

DASYLIRION LEIOPHYLLUM

FLOURENSIA CERNUA

PROSOPIS GLANDULOSA

NOLINA

PORLIERIA ANGUSTIFOLIA

BOUTELOUA and ARISTIDA

YUCCA

HILARIA MUTICA

POPULUS PALMERI

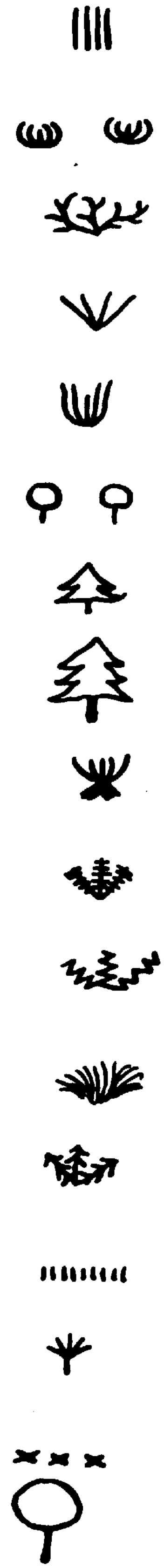
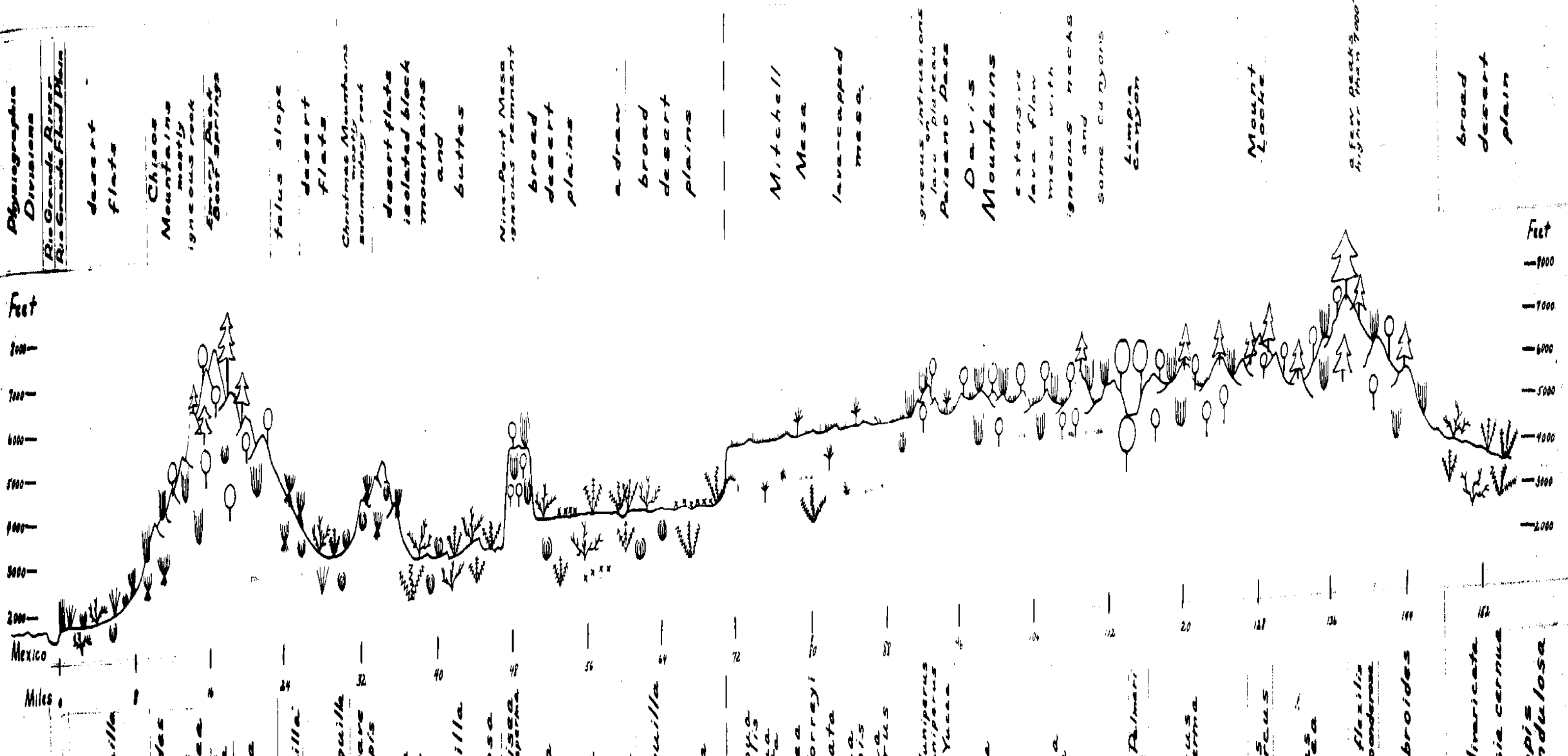


TABLE 23.




Topography, Dominant Vegetation and Cacti
with 155-mile profile northwest from Rio Grande River across Davis Mountains

| Species of <u>Opuntia</u> | Distribution of Opuntiae | | | | | |
|---|---|---|---|---|---|---|
| | New Records | Disjunct Distribution | | Widespread Gen, Distrib. | Restricted Gen. Distrib. | Restricted Distrib. Locally |
| azurea | X | X | | | X | X |
| Davisii | | | | X | | X |
| Engelmannii | | | | X | | |
| Engelmannii var. Wootonii | X | X | | | | X |
| Engelmannii x phaeacantha | X | | | | | |
| Grahamii | | | | | X | |
| Grahamii x Schottii | X | | | | | |
| imbricata | | | | X | | |
| imbricata var. argentea | X | | | | | X |
| Kleiniae | | | | X | | |
| Kleiniae x leptocaulis | X | | | | | X |
| leptocaulis | | | | | | |
| leptocaulis var. brevispina | | | | | | |
| Lindheimeri | X | | | X | | X |
| Lindheimeri var. chisosensis | X | | | | | X |
| linguiformis | X | X | | | X | X |
| macrocentra | | | | X | | |
| macrocentra var. minor | X | | | | | X |
| phaeacantha | | | | X | | |
| polyacantha | X | & | | X | | X |
| Pottsii | | | | | X | |
| rufida | | | | | X | |
| rufida var. tortiflora | X | | | | | |
| Schottii | | | | X | | |
| setispina | X | | | | X | |
| spinosibacca | X | | | | | X |
| strigil | | | | | X | X |
| tenuispina | | | | X | | |
| tortispina | | | | X | | |
| trichophora | X | X | | | X | X |
| tunicata | X | X | | X | | X |

TABLE 24

Distribution of Opuntiae, local and general.

PLATE I

Looking across desert plains of mixed xerophytic shrubs (Opuntia macrocentra, Larrea and Yucca), one sees cores of the Chisos Mountains, each with its steep talus slope. On the far left the Pinnacles are a jagged outline, Elephant Tusk leans to the southwest in center background; the table-top in left background is the promentory of South Rim. Protected canyons in those mountains shelter small populations of sub-mesophytic vegetation. (See Table 23).

PLATE I

Looking across desert plains of mixed xerophytic shrubs (Opuntia macrocentra, Larrea and Yucca), one sees cores of the Chisos Mountains, each with its steep talus slope. On the far left the Pinnacles are a jagged outline, Elephant Tusk leans to the southwest in center background; the table-top in left background is the promentory of South Rim. Protected canyons in those mountains shelter small populations of sub-mesophytic vegetation. (See Table 23).

PLATE I

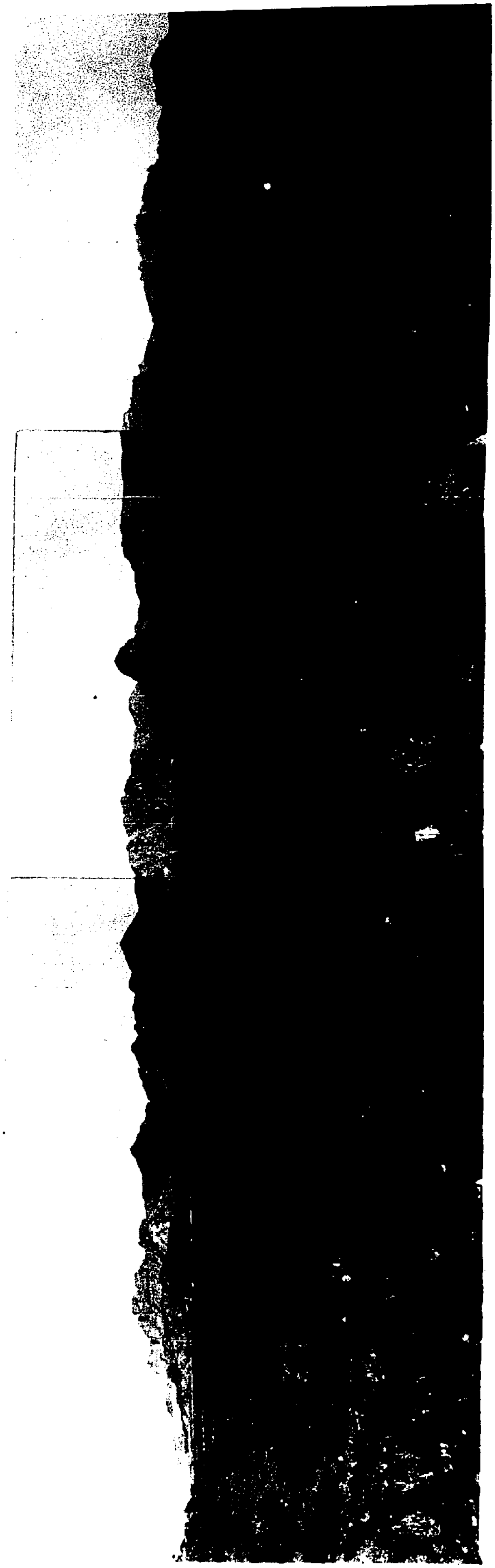


PLATE II

The Basin of the Chisos Mountains, present site of the Big Bend National Park headquarters, looks out through the Window to buttes of resistant rock on the desert flats which surround this high more mesophytic "island". Note contrast of Dasylirion-Agave association on southwest-facing slopes (right background) and Pinus-Quercus on northeast-facing slopes (left background). _Opuntia Lindheimeri_ var. _chisosensis_ and _O_. _Engelmannii_ are particularly conspicuous components of vegetation in the Basin, on the warmer, drier south slopes and open grassy portions swales of north-facing slopes. Drainage funnels down the Basin and out the Window to Oak Springs below. Some few specimens of this endemic race of _O_. _Lindheimeri_ were found washed down below, and established in the Dasylirion-Agave vegetation on north slopes. (See Table 23).

PLATE II

PLATE III

Fig. 1. View from South Rim, showing Basin and Range topography with steep slopes and flats of coarse detritus, affording ideal terrain for a rich and diversified cactus flora. The low fault block in the left background is Chilicotal Mountain. (See Table 23).

Fig. 2. Looking south from Nine-Point mesa one sees various erosion forms, including Corazones Peaks and Christmas Mountains (far right background). The north slopes of the Chisos Mountains appear through the haze in the distance. The vegetation with little grass in the foreground shows the effect of heavy overgrazing by sheep. (See Table 23).

PLATE III

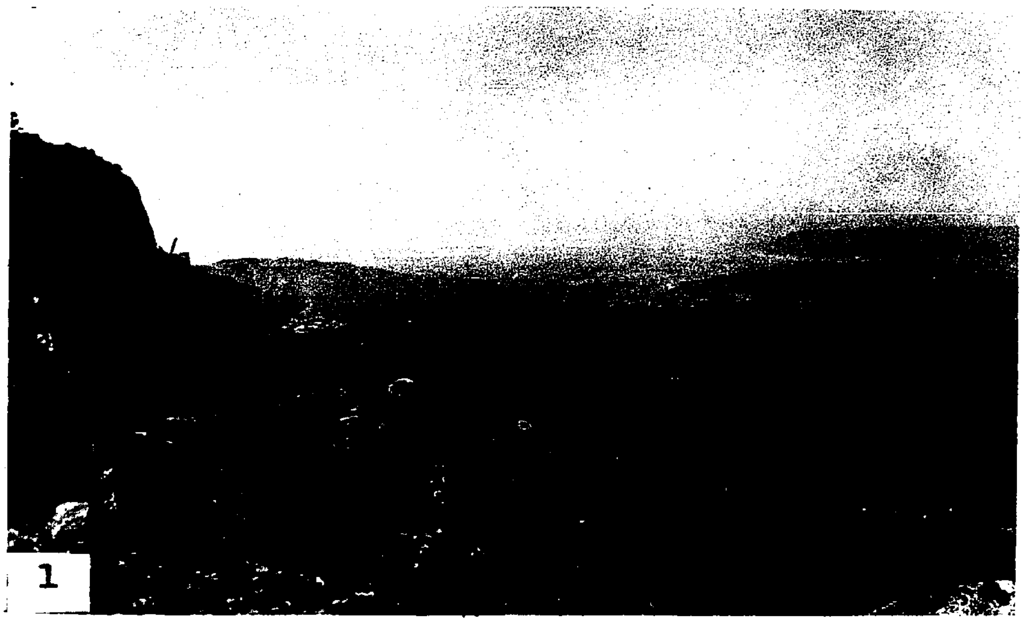


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PLATE IV

The Rio Grande River has carved Santa Elena Canyon 1800 feet deep through Mesa de Anguila, to the left in the background lies Mexico, the right portion of the mesa is on the United States side of the river. On the steep talus slopes of the mesa vegetation is composed of Larrea, Dasylirion, Fouquieria, _Opuntia Engelmannii_ and _O. rufida_. The sandy plain of the Rio supports Baccharis, and Prosopis with _Opuntia Kleiniae_, and _O. Engelmannii_. Larrea and Fouquieria make a sparce cover on the flats of silty clay loam in the foreground, associated with _Opuntia phaeacantha_, _O. leptocaulis_, _O. Grahamii_, _Mammillaria Pottsii_ and _Echinocereus enneacanthus_.

PLATE IV

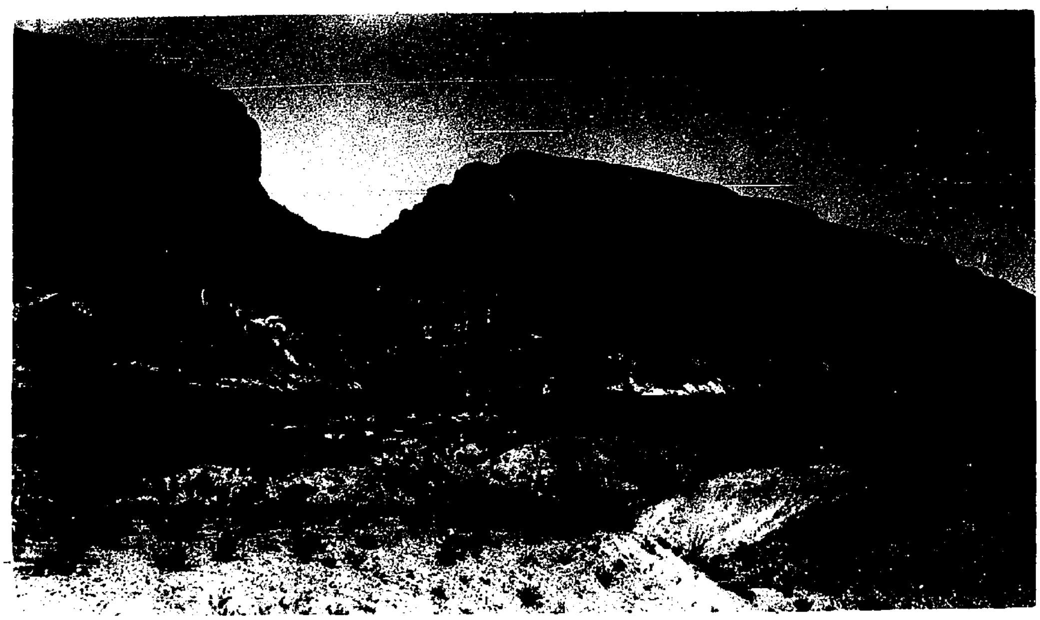

PLATE V

Fig. 1. In the center a fruit of Opuntia spinosibacca is forming a joint by proliferation - note the joint-like nature of the fruit. A pot of O. phaeacantha on either side shows the differences between the new species and its most closely-related forms. Note the striking differences in young spines on new joints, both of which developed under uniform conditions at the Botanical Gardens.

Fig. 2. A fruit of O. phaeacantha which has proliferated several joints is here cut open to show the locule with undeveloped ovules. A fragment of the woody base of O. strigil budded from an areole one month after collection.

PLATE V

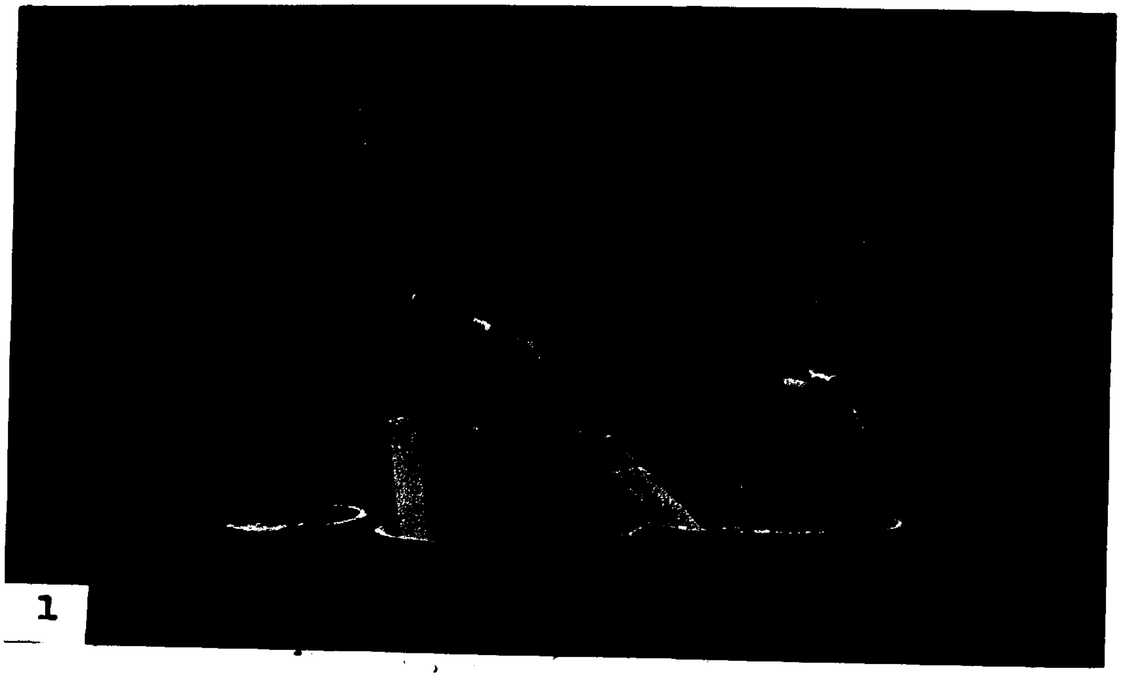

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PLATE VI

Fig. 1. Fungus disease on joints of _Opuntia Engelmannii_ distort spine formation so plants are difficult to identify.

Fig. 2. A joint of this infected plant of _Opuntia macrocentra_ grown at the Botanical Gardens produced two normal-appearing pads with acicular, straight spines. (See Plate XLII, Fig. 2).

# PLATE VI

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PLATE VII

Fig. 1. A typical areole, demonstrating arrangement of wool, spines, with shorter ones below longer ones, bristles deflexed from base of areole, and glochids in tuft at upper margin.

Fig. 2. A stoma with small accessory cells and somewhat lobed epidermal cells.

Fig. 3. The tuberculate fruit of Opuntia tunicata has a v-shaped umbilicus and long narrow locule.

Fig. 4. The typical seed of the Platyopuntiae in this study has a conspicuous aril and a deeply notched hilum.

Fig. 5. The Cylindropuntiae have seeds with less wide arils and are usually beaked as well as notched at the hilum.

Fig. 6. The angle between the flange of the aril and the body of the seed may be sharp ("rough" seed) or only a gentle gradation ("smooth" seeds).

PLATE VII

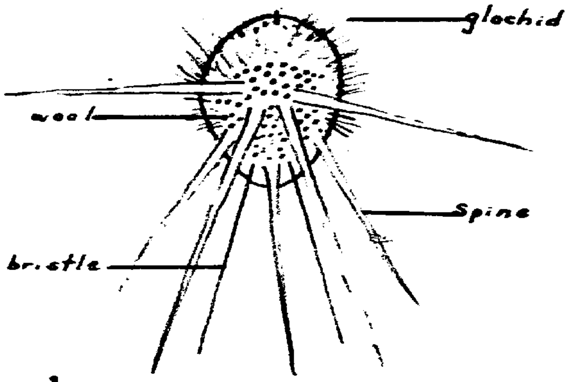



Fig. 1

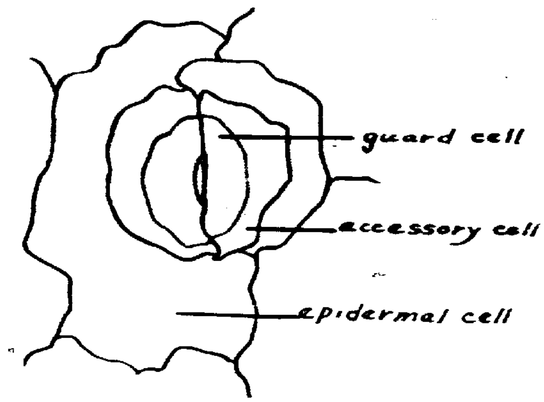



Fig. 2

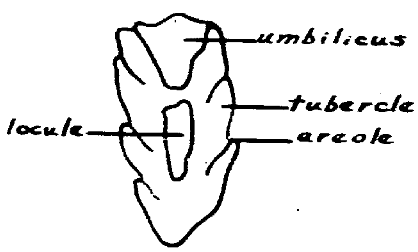



Fig. 3

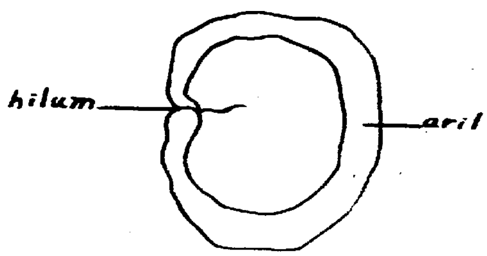



Fig. 4

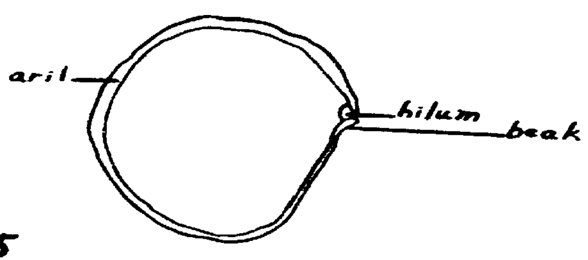



Fig. 5

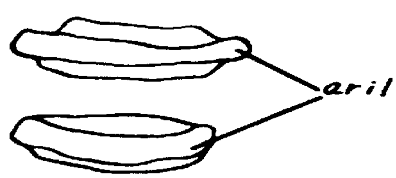


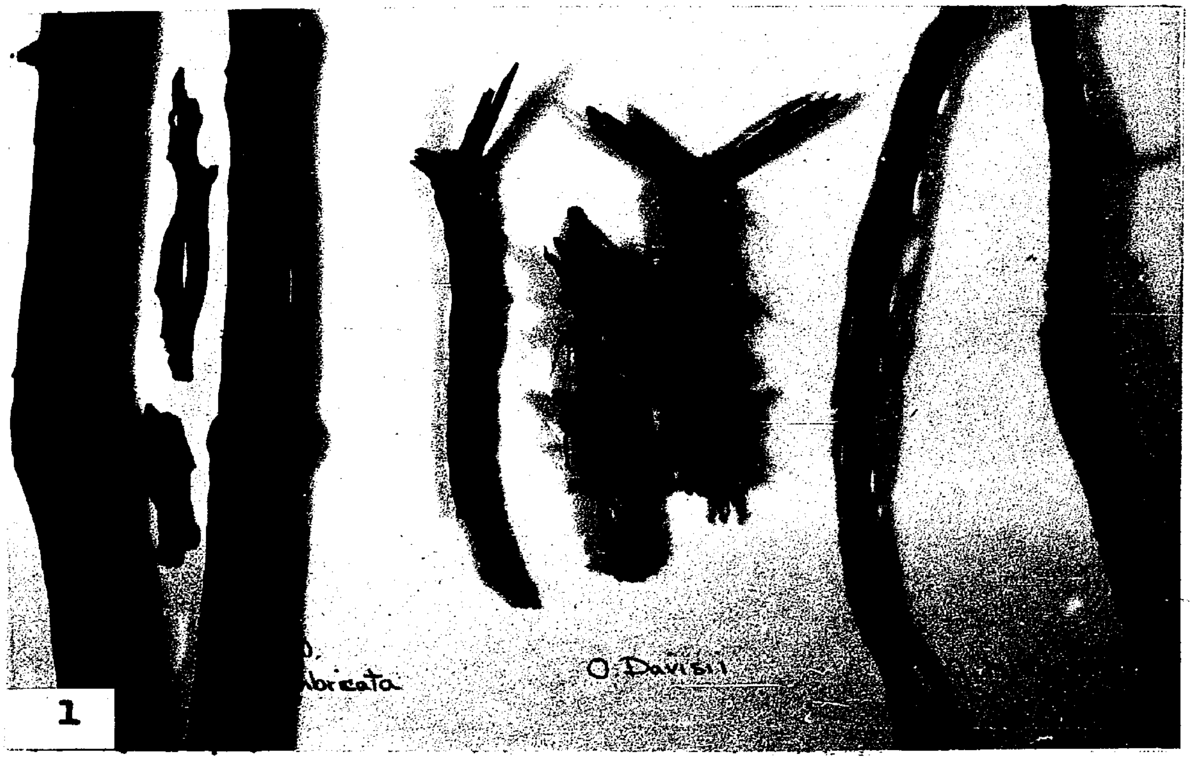

Fig. 6

PLATE VIII

Fig. 1. The vascular gaps in the dictyostele show clearly in dead branches of the shrubby Cylindropuntiae. Shape ranges from long and narrow in _O. Davisii_ to more or less short ovate in _O. Kleiniae_.

Fig. 2. _Opuntia tortispina_ is atypical with distant areoles and few spines, and hard to recognize as it grows in dense shade under _Juniperus monosperma_. Note the spinier, more typical original joint, near the ruler.

# PLATE VIII

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# PLATE IX

Fig. 1. Among the Cylindropuntiae in this study *O. Grahamii* and *O. Schottii* have tuberous roots. These form at the base of the creeping branches.

Fig. 2. Among the Platyopuntiae only *O. Pottsii* has tubers. These are much larger than those of the Cylindropuntiae shown above and they more frequently develop in moniliform rather than fasicle arrangement. Note relatively small mature pads.

PLATE IX

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PLATE X

Fig. 1. Although shape of cotyledon varies somewhat between species, the seedling stages cannot be used for specific distinctions. Cotyledons are usually of unequal length.

Fig. 2. Note differences in thickness of cotyledon and obtuse or acute tips.

PLATE XX

1


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Fig. 1. *Opuntia imbricata* may be arborescent with one main trunk or tall and bush-like with several trunks and more sprawling habit. Flowers are profuse from May through June.

Fig. 2. In a broad valley at the northern end of the Davis Mountains, trees of *O. imbricata* with species of Bouteloua make a distinctive local community adjacent to Bouteloua-Juniper on slopes in the distance. Jeff Davis County. (See Table 23).

PLATE XI

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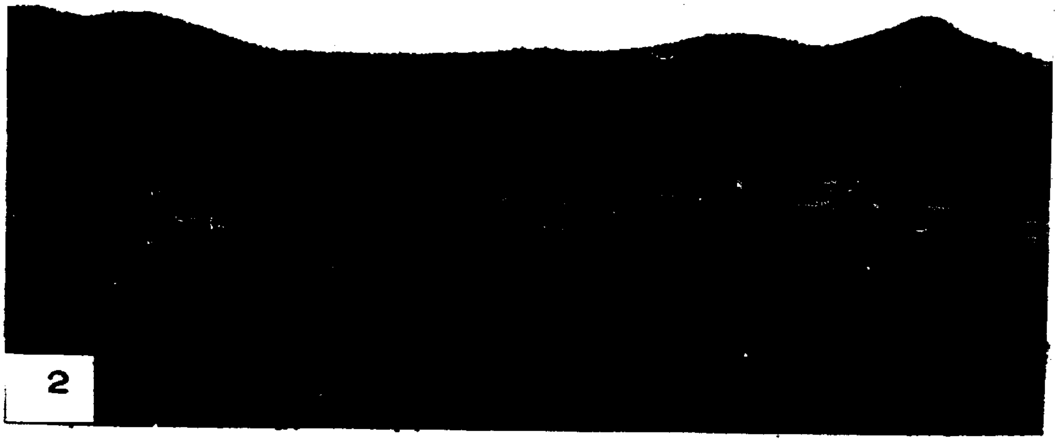

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PLATE XII

Fig. 1. *Opuntia imbricata* growing in a wash with Prosopis has more ascending branches, weaker tubercles, and fewer spines. Note the bird's nest among the verticillate branches.

Fig. 2. Occasional specimens of *O. imbricata* in desert scrub have drooping, less plump branches, bearing yellow spines and sheaths, yet there is no evidence of disease. Nearby plants of the same species are perfectly typical. Living specimens at the Botanical Gardens are developing completely normal shoots. (See Plate XIII, Fig. 2).

# PLATE XII

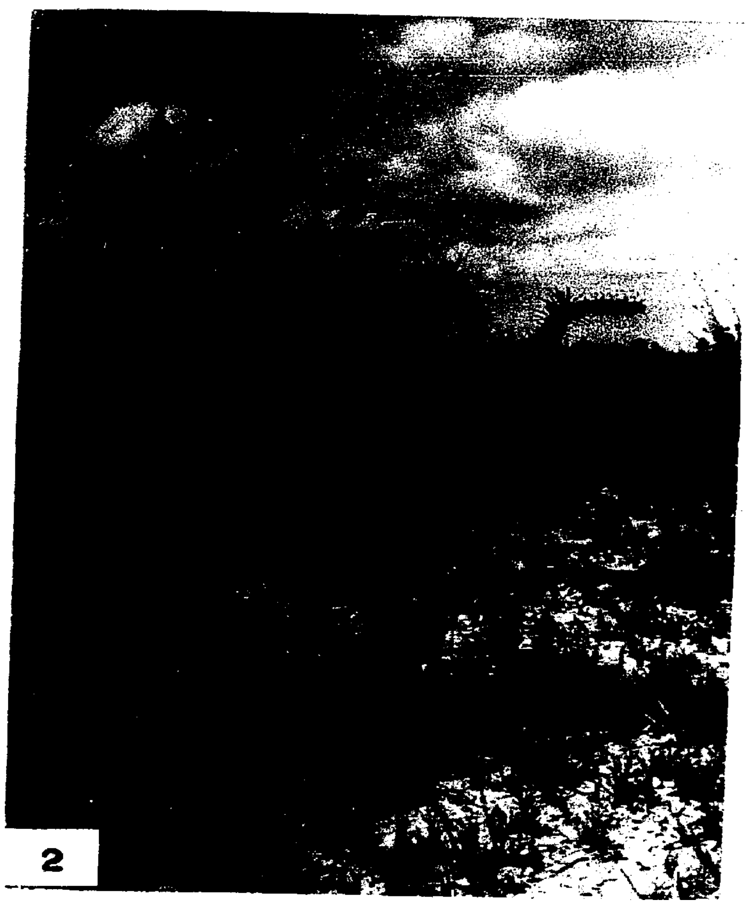

PLATE XIII

Fig. 1. Opuntia imbricata var. argentea has a chubby appearance as well as striking silver spines and sheaths.

Fig. 2. A joint of a typical O. imbricata on the left is contrasted with joints of the yellow-spined form in the middle and with the silver-spined variety on the right. New growth on the latter accentuates the differences in closeness of areoles and stubby appearance.

PLATE XIII

PLATE XIV

Fig. 1. The colony of Opuntia tunicata spreads horizontally just below the dipping limestone cliffs.

Fig. 2. A clump of Opuntia tunicata with several flowers and immature fruits.

PLATE XIV

PLATE XV

Fig. 1. The dwarf form of Opuntia tunicata, in the pot on the left, is about 1/3 the size of the typical form on the right. It has maintained this difference during a year of cultivation at the Botanical Gardens and has grown prolifically.

Fig. 2. Opuntia Davisii is an untidy-looking, much-spined bush found occasionally in grassland associations. Branches on far right bear a few tuberculate fruits.

PLATE XV

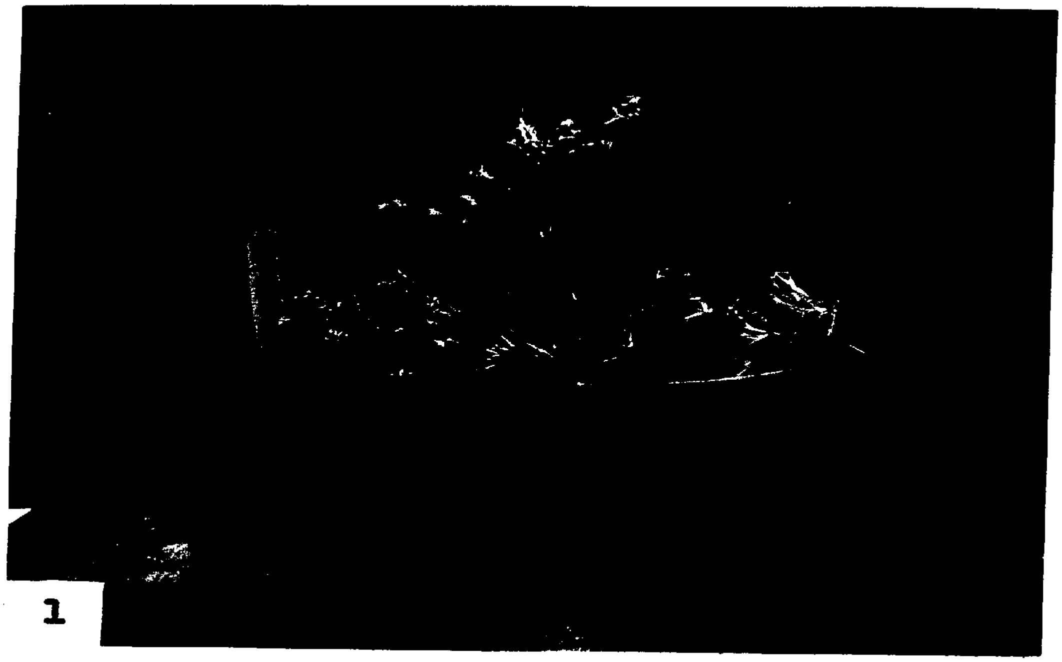

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PLATE XVI

Fig. 1. An isolated bush of Opuntia Kleiniae grows in Prosopis cover on sandy outwash near the Solis Ranch house, Big Bend National Park. This species was found in washes or along waterways exclusively.

Fig. 2. More typical habitat for O. Kleiniae is in Acacia thickets on silt loam along extensive bottomlands of Musquiz Creek in Jeff Davis County.

PLATE XVI

PLATE XVII

Fig. 1. The erect bush form of _Opuntia leptocaulis_, showing the numerous fruits, is common in Larrea-Flourensia on desert flats.

Fig. 2. The spreading, much branched form of the species is less frequently encountered. Here it occurs with Larrea in a gravelly wash.

PLATE XVII

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PLATE XVIII

Fig. 1. Stands of evenly-spaced Larrea bushes often develop on flat clay loam areas in the desert belt. Occasionally _Opuntia_ _leptocaulis_ is a co-dominant which grows entangled in the stems of the creosote. Tornillo Flats, Big Bend National Park.

Fig. 2. _O._ _leptocaulis_ var. _brevispina_ on the left has fewer and shorter spines than the type form on the right.

# PLATE XVIII

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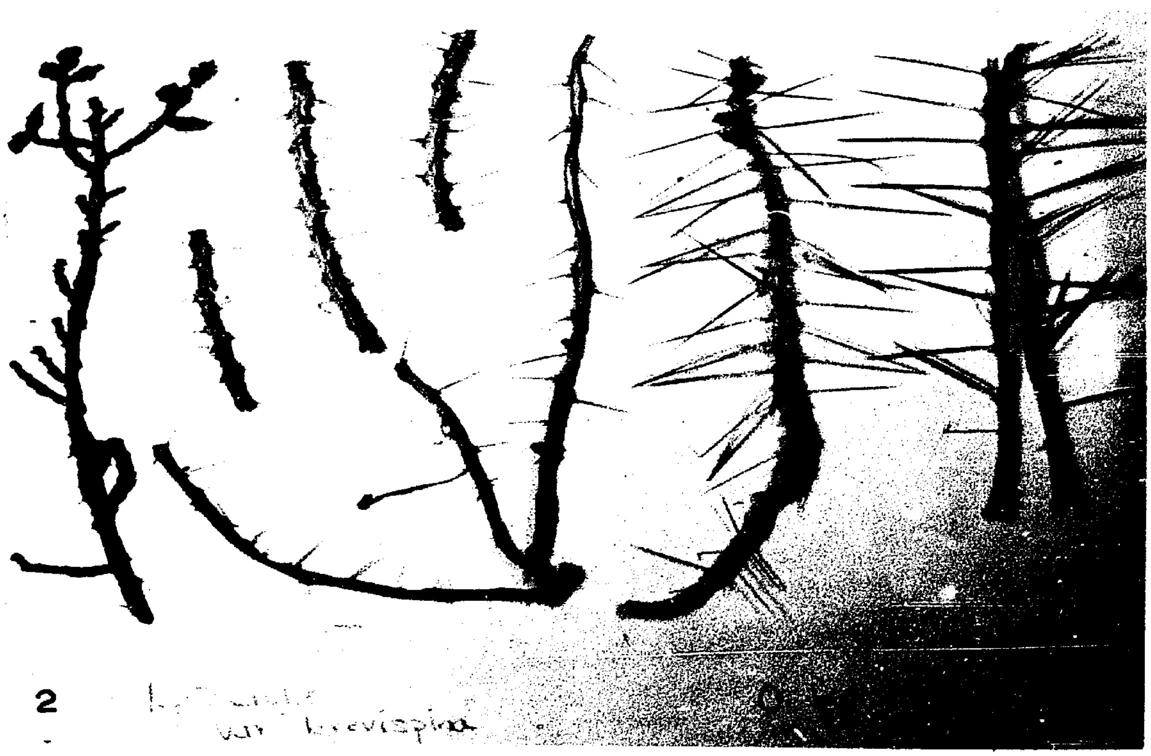

2 [illegible]
var brevispina

PLATE XIX

Fig. 1. Opuntia Kleiniae x leptocaulis is intermediate in size between both parents and grows entangled in an Acacia thicket along Musquiz Creek bottomland, Jeff Davis County.

Fig. 2. This mature bush of Opuntia Kleiniae bearing fruits is about 1.8 meter high and thrives in dense cover of Bouteloua and Acacia along Musquiz Creek. Note mesa formation of Davis Mountains in background. (See Table 23).

PLATE XIX

1

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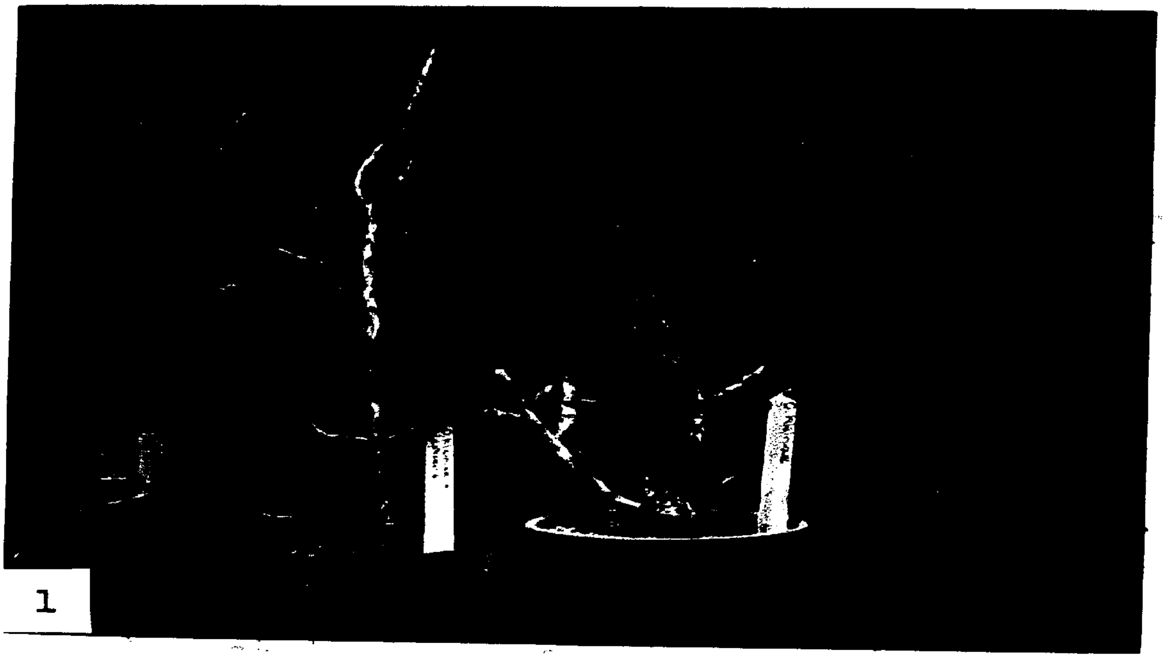
PLATE XX

Fig. 1. From left to right, _O. leptocaulis_, _O. Kleiniae_ x _leptocaulis_ and _O. Kleiniae_. Differences are particularly evident in diameter of joint and length of ultimate joints.

Fig. 2. The flowers of the hybrid (in the center) are intermediate in size and color between _O. Kleiniae_ (on the left) and _O. leptocaulis_ (on the right).

PLATE XX



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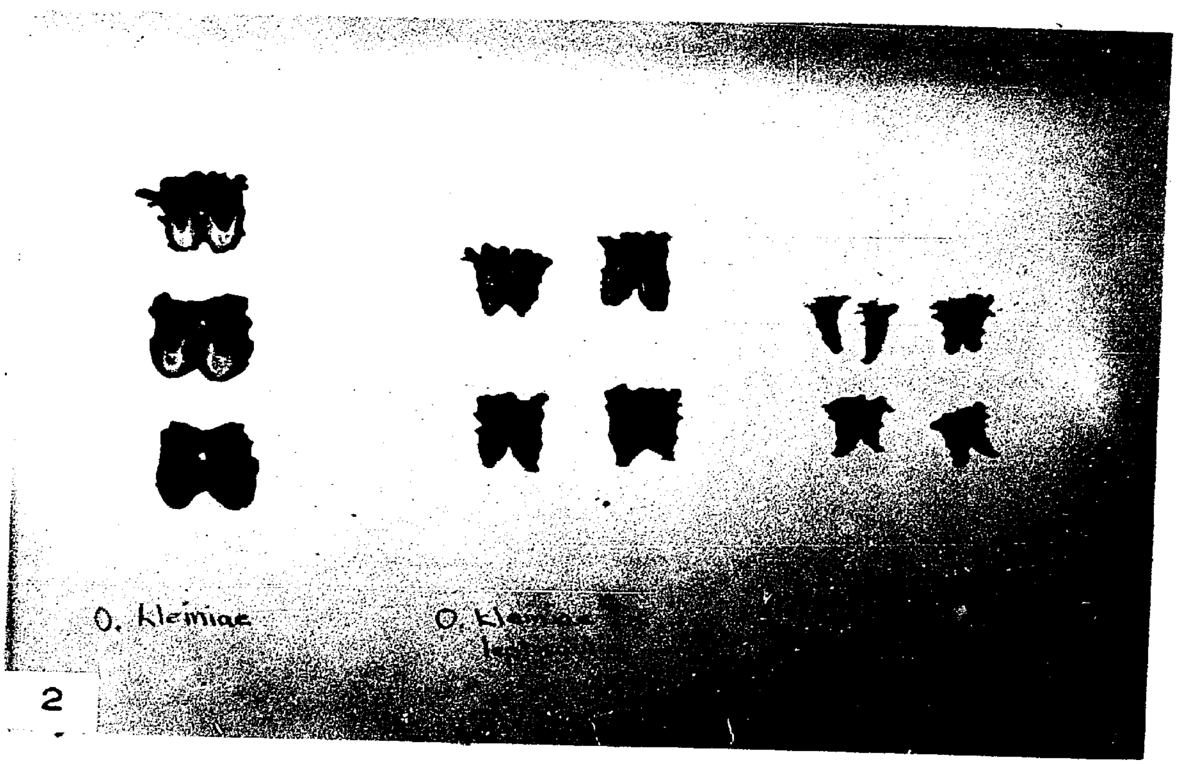


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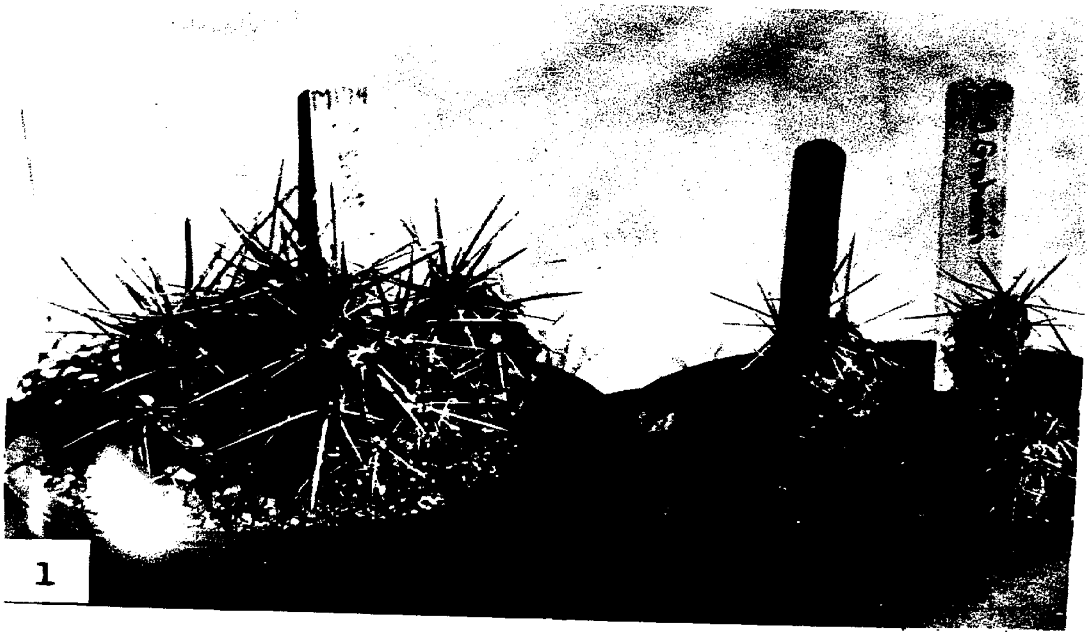
PLATE XXI

Fig. 1. Sharp differences in size of tubercles, number of spines and shape of spines are seen when typical plants of _Opuntia Schottii_ (on left) and _O. Grahamii_ (on right) are compared.

Fig. 2. Two plants of _O. Grahamii_ x _Schottii_ show the intermediate size of tubercles and spine arrangement between the two parents.

PLATE XXI



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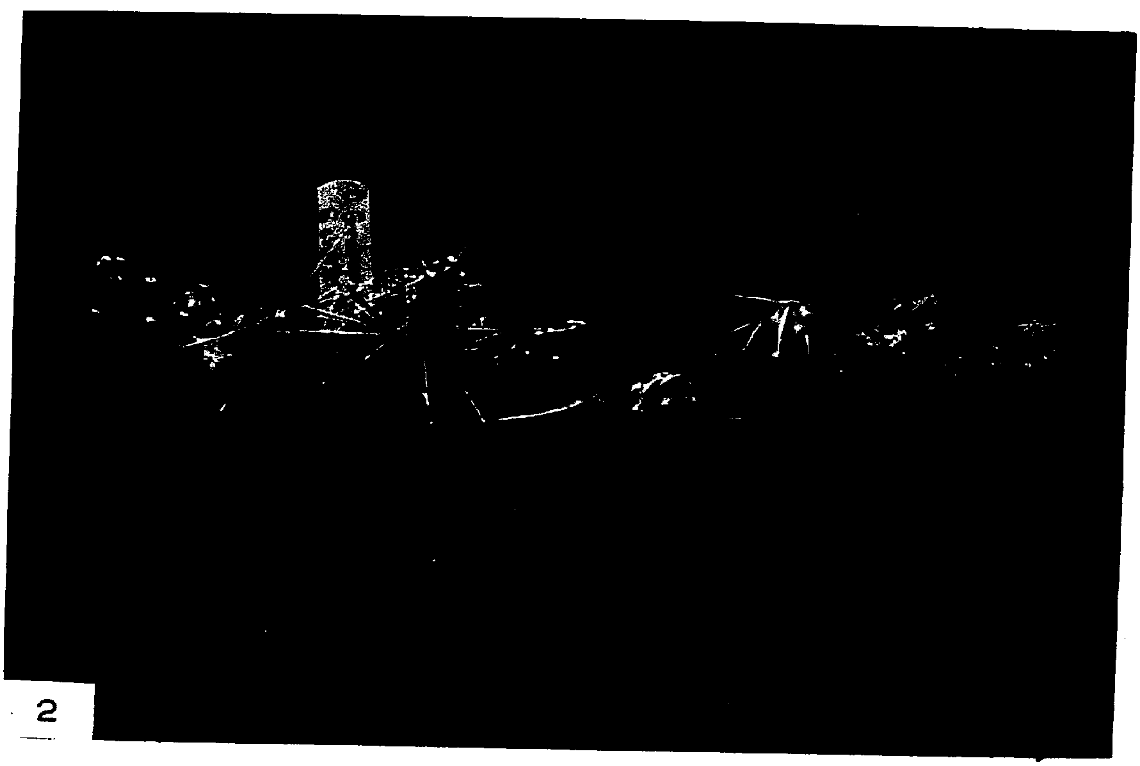

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PLATE XXII

Near the mouth of Reagan Canyon (southeastern Brewster County) the Rio Grande River flows past majestic cliffs in Mexico, thickets of Prosopis and higher desert gravel flats of Larrea-Agave in the United States. With Larrea on clayey outwash in the center of this photograph _Opuntia Schottii_ forms large mats; but it is of less frequent occurrence, in small clumps, on the higher gravelly benches. _Opuntia phaeacantha_ is the dominant cactus with Larrea-Agave on those benches, shown in the foreground and background. In the Prosopis thicket there was no other vegetation due to pure sandy soil and in part to the shade.

PLATE XXII

PLATE XXIII

On a broad clayey wash, east of the pediment of Mariscal Mountain, an unusual community of _Coryphantha macromeris_, _Opuntia Schottii_ and _Echinocereus enneacanthus_ is well established. The shallow, much blown soil limits invasion of other types of vegetation.

PLATE XXIII

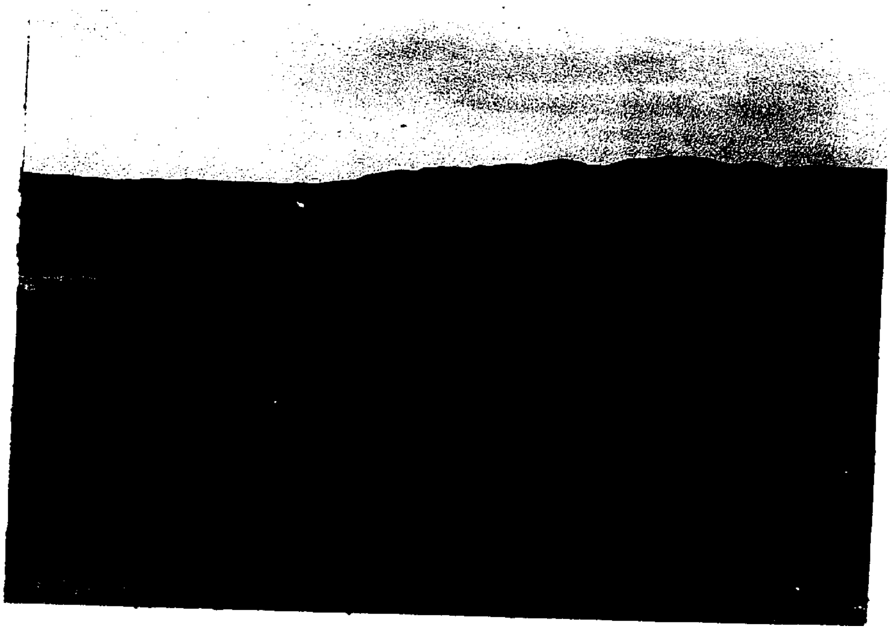

PLATE XXIV

Fig. 1. A low mound of Opuntia Schottii spreads beneath a Larrea bush. Numerous spines more or less obscure the joints.

Fig. 2. Several six-foot high bushes of O. linguiformis thrive in a Mexican garden, abandoned for at least five years.

PLATE XXIV

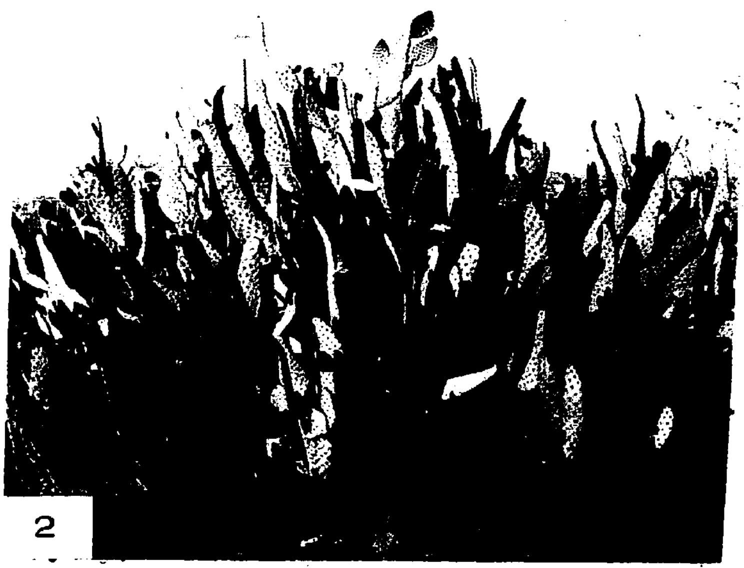

PLATE XXV

Fig. 1. One of the few Opuntiae bushes of this region with almost vertically ascending branches, Opuntia spinosibacca sp. nov. is also well-distinguished by long-obovate, somewhat tuberculate joints, conspicuous bristles and dry spiny fruits.

Fig. 2. The above mentioned characteristics are seen here in herbarium material of O. spinosibacca. Flowers are rather similar to those of O. macrocentra.

PLATE XXV

1

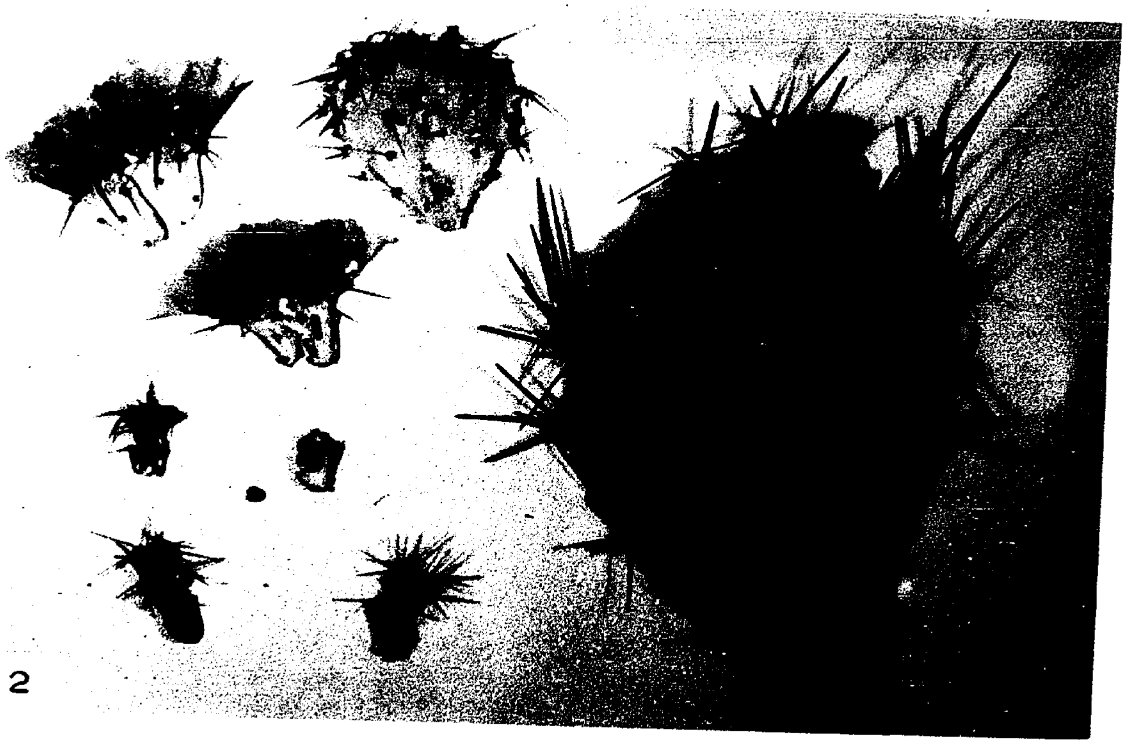

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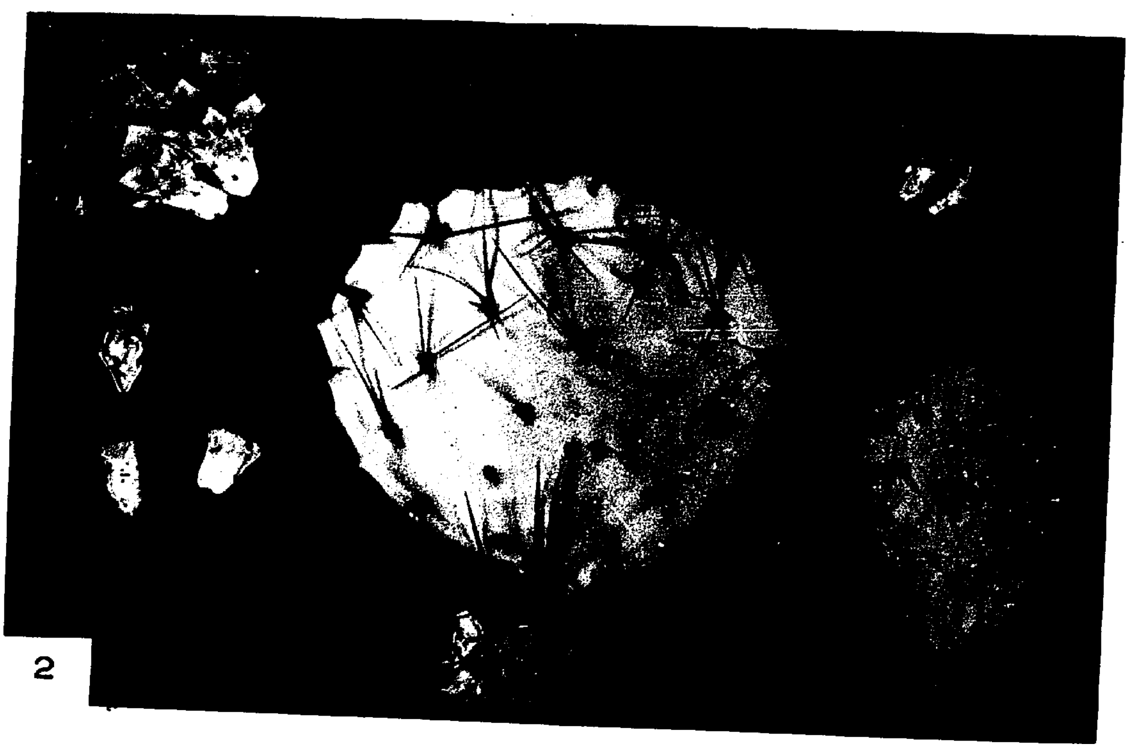
PLATE XXVI

Fig. 1. *Opuntia azurea* most closely resembles *O. macrocentra* in spreading, ascending habit and yellow flowers, with red toward the center; and *O. Lindheimeri* in yellow color of spines on mature joints.

Fig. 2. Herbarium material of *O. azurea* with young fruits. The perianth is decidedly longer than the ovary.

PLATE XXVI

1



2

Fig. 1. A typical plant of Opuntia phaeacantha on desert flats with Larrea has many rufous spines and conspicuous red glochids.

Fig. 2. In the Del Nortes, limestone mountains surrounded by arid grassland, with Quercus-Juniperus vegetation, O. phaeacantha is more spreading, with paler grayish spines and glochids. The commonly associated species, O. imbricata, appears in the background.

PLATE XXVII

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PLATE XXVIII

Fig. 1. In the foreground with Dasylirion-Agave are scattered plants of O. phaeacantha. O. Engelmannii, O. Grahamii, O. leptocaulis, O. imbricata, O. macrocentra, Echinocereus stramineus and E. dasyacanthus are common on desert flats below with Larrea and Flourensia. Note flower stalks of the dominants, sotol and lechuguilla. (See Table 23).

Fig. 2. At 5500 feet in the Basin of the Chisos Mountains with Pinus-Quercus vegetation, this specimen of O. phaeacantha is much reduced from the usual larger habit and greater number of spines. Fruits and seeds, however, are typical.

PLATE XXVIII

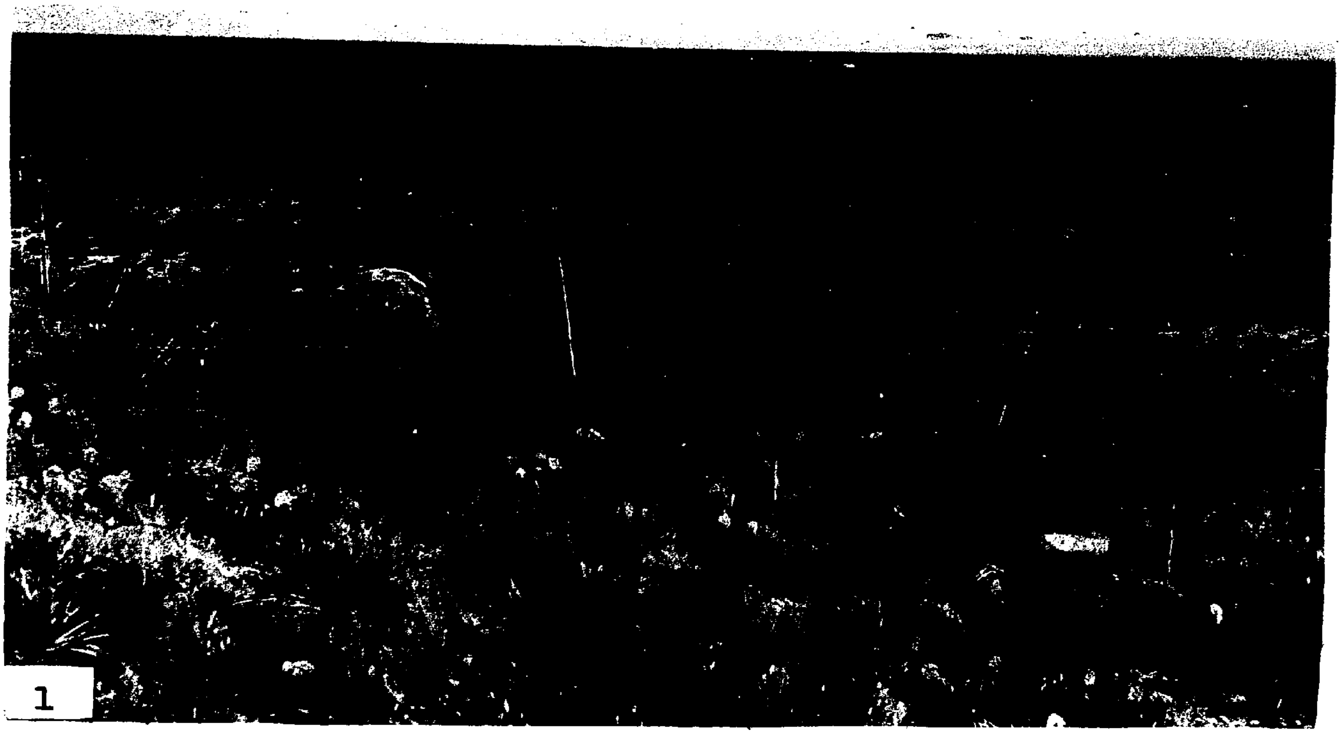

PLATE XXIX

Fig. 1. The plant in the center is the common large-jointed form of _O. phaeacantha_. Joints newly-formed under cultivation show great similarity.

Fig. 2. _Opuntia leptocaulis_, _O. phaeacantha_, _O. macrocentra_ var. _minor_ and _Echinocereus enneacanthus_ add to the sparce desert cover on sandy silt soil, as one looks north to Rattlesnake Hills from near Santa Elena Canyon, Big Bend National Park.

# PLATE XXIX

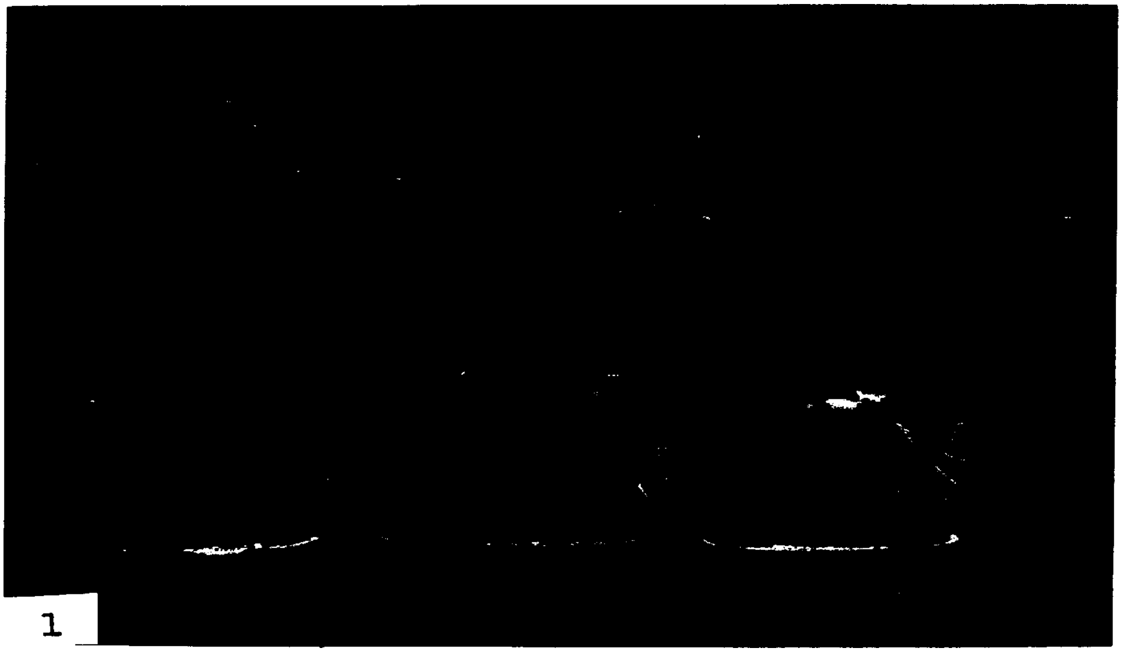

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PLATE XXX

Fig. 1. The hybrid between _Opuntia_ _Engelmannii_ and _O. phaeacantha_ resembles the latter parent more closely in spreading habit, dark spines and large seeds. An immature plant is growing here in Bouteloua-Juniperus association.

Fig. 2. Typical arid grassland habitats for _O. Engelmannii_ x _phaeacantha_ are the broad grassy flats of Bouteloua-Prosopis vegetation. _O. macrocentra_ is common on the rocky hill of Bouteloua-Yucca in the background. _O. imbricata_ is very abundant in a depression on top of this hill, indicating its usual preference for more moist localities. (See Table 23).

PLATE XXX

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PLATE XXXI

Fig. 1. The hybrid _O._ _Engelmannii_ x _phaeacantha_ (on the right) more closely resembles _O._ _phaeacantha_ (on the left) than the other parent, i.e. note the young short oblong fruit.

Fig. A typical joint of _O._ _Engelmannii_ with young pads developed under cultivation. These latter joints are more elongate than the original joint, but spine formation is similar.

PLATE XXXI

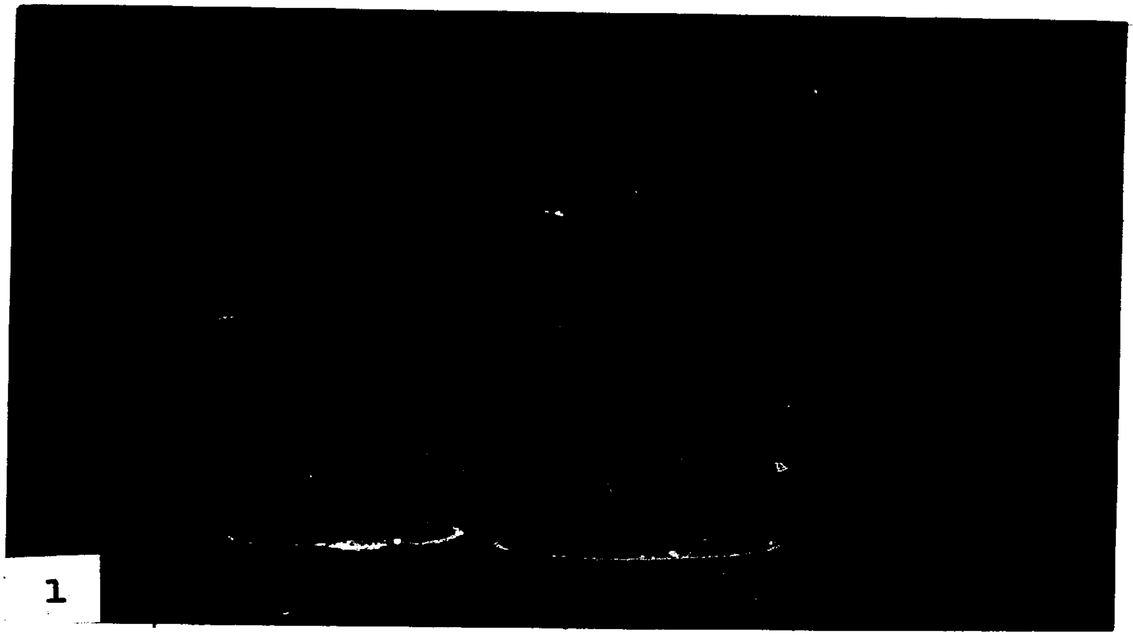

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PLATE XXXII

Fig. 1. The most ubiquitous large-jointed Opuntia in the Big Bend Region is O. Engelmannii. It flowers profusely during April, May, June and early July. Note the nesting material, probably of a mouse, among the joints of this specimen growing in Larrea-Agave association, Big Bend National Park.

Fig. 2. Massive bushes of Opuntia Engelmannii cascade down the rocky southern escarpment slopes of the Pena Blanca cuesta formation. Other vegetation on this chert outcrop is Yucca, Bouteloua and Acacia Greggii.

PLATE XXXII

1

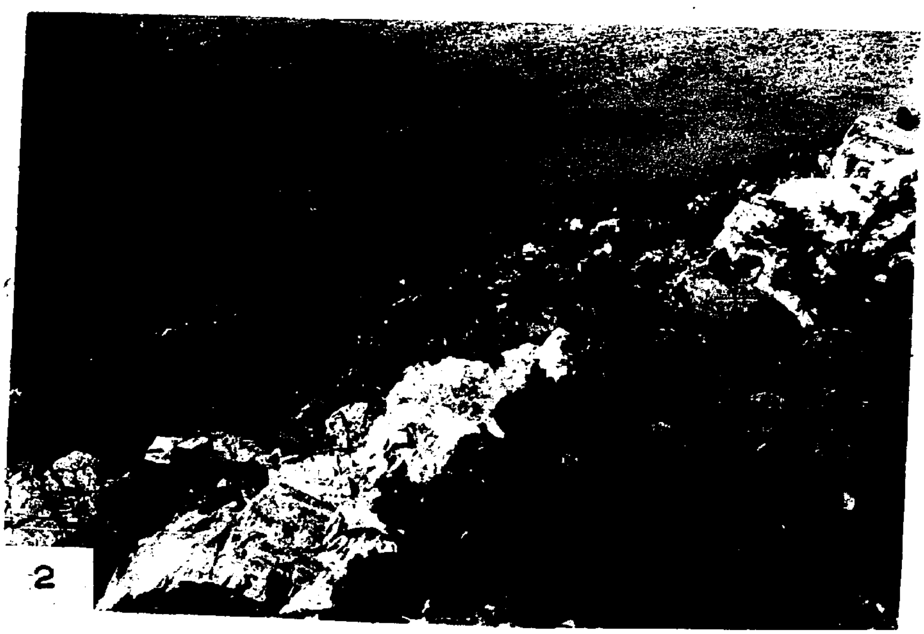

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PLATE XXXIII

Fig. 1. Just north of Santa Elena Canyon on sandy flats, bushes of (left to right) _Opuntia tenuispina_, (left) _O. phaeacantha_ (center) and _O. Engelmannii_ var. _Wootonii_ (right) flourish with Larrea and _O. leptocaulis_.

Fig. 2. Two joints of _O. Engelmannii_ var. _Wootonii_ show the long-spined character of this variant.

PLATE XXXIII

1

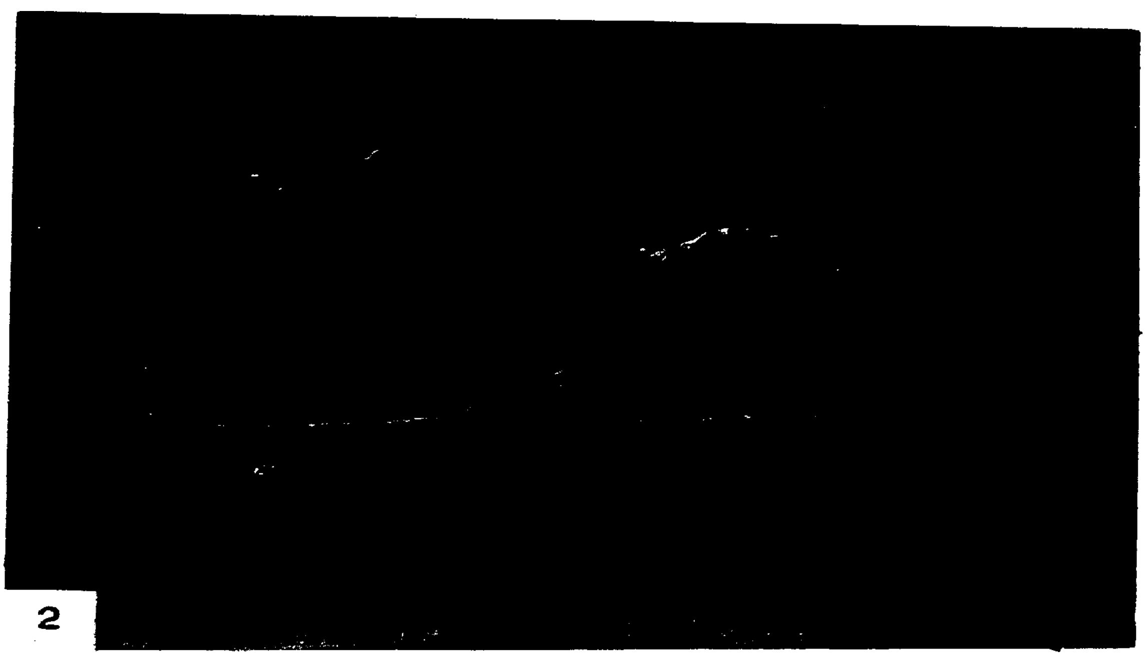

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PLATE XXXIV

*Opuntia* *Engelmannii* var. *Wootonii* with spreading habit, long spines and attenuate pads, forms a well-established race in sheltered valleys of the Christmas Mountains, with Larrea-Prosopis vegetation. A few scattered individuals occur elsewhere under similar edaphic conditions. (See Table 23).

PLATE XXXIV

PLATE XXXV

West of Sanderson in sandy soil with Prosopis, creeping bushes of Opuntia tenuispina form a veritable mat. Note elongate joints with spines mostly spreading downwards.

PLATE XXXV

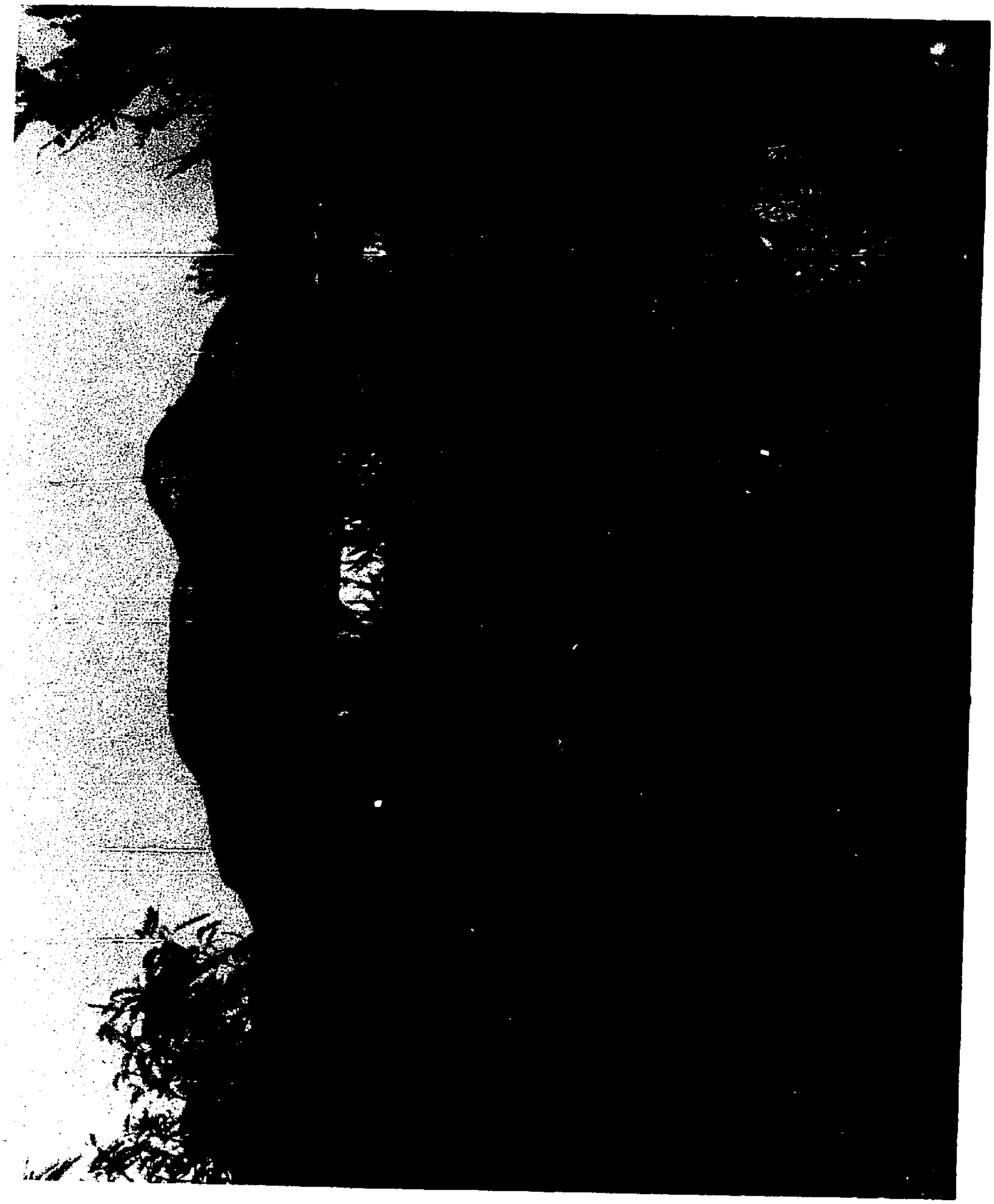


PLATE XXXVI

Fig. 1. Opuntia tenuispina is occasionally associated with O. Engelmannii and O. Lindheimeri var. chisosensis in Quercus-Pinus vegetation, Basin of Chisos Mountains, Big Bend National Park.

Fig. 2. Low bushes of Opuntia tenuispina are also a common constituent of the cactus flora on Nine-Point Mesa in Quercus-Juniperus association with O. Engelmannii and O. imbricata. (See Table 23).

PLATE XXXVI

Fig. 1. *Opuntia tenuispina* is occasionally associated with *O. Engelmannii* and *O. Lindheimeri* var. *chisosensis* in Quercus-Pinus vegetation, Basin of Chisos Mountains, Big Bend National Park.

Fig. 2. Low bushes of *Opuntia tenuispina* are also a common constituent of the cactus flora on Nine-Point Mesa in *Quercus-Juniperus* association with *O. Engelmannii* and *O. imbricata*. (See Table 23).

PLATE XXXVI

1

2

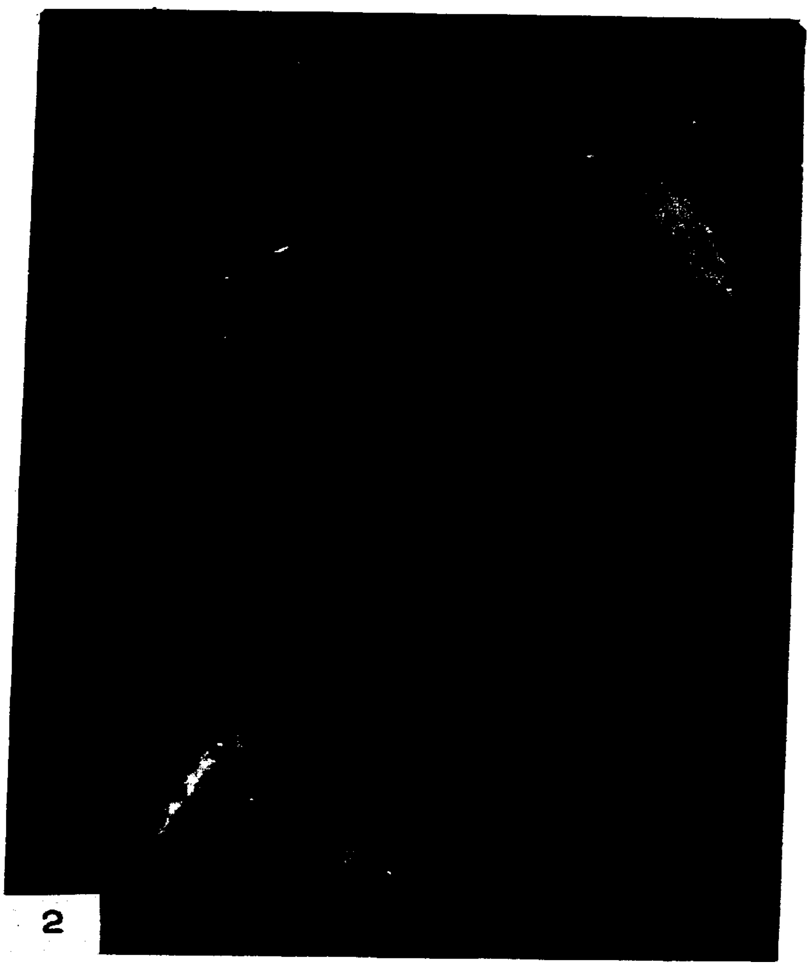
PLATE XXXVII

Fig. 1. A creeping plant of Opuntia Lindheimeri was encountered in Quercus-Juniperus woodland on igneous loam in Sunny Glen, Brewster County.

Fig. 2. O. Lindheimeri var. chisosensis (on the right) has less elevated areoles and smaller joints than the type form on the left. The tendency for occasional joints to expand in three directions is seen in O. Lindheimeri.

PLATE XXXVII

1



2

Fig. 1. With Pinus-Quercus in the Basin of the Chisos, at about 5500 feet, _Opuntia_ _Lindheimeri_ var. _chisosensis_ develops into a massive bush up to 1 meter high and 2.5 meters across.

Fig. 2. Some specimens of this variety have red spines, rather than yellow but are otherwise similar.

PLATE XXXVIII

1

2

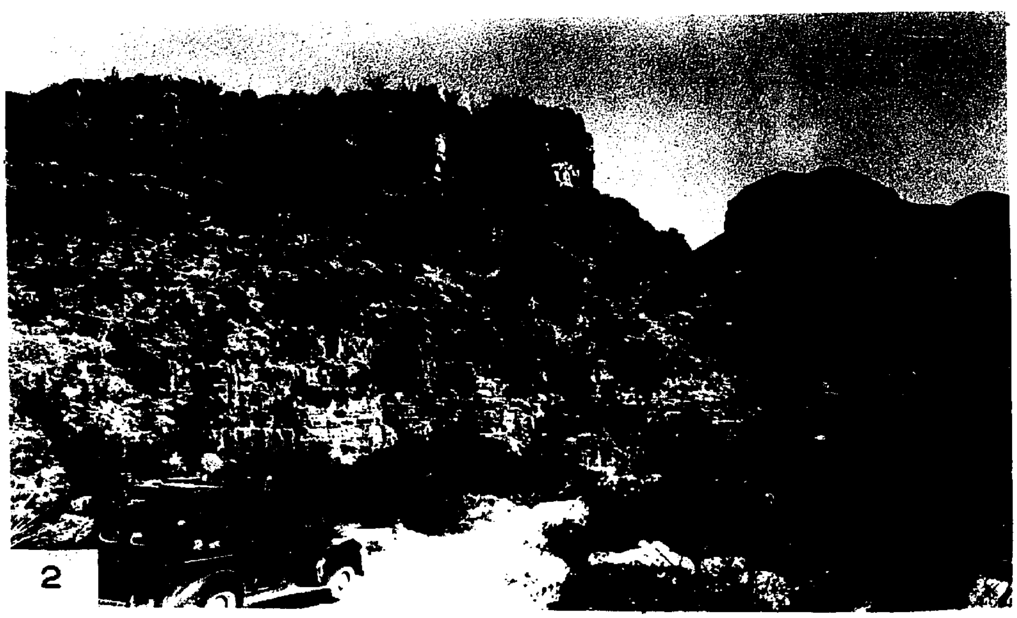
PLATE XXXIX

Fig. 1. Restricted to the most southern portion of Brewster and Presidio counties, Opuntia rufida, the only truly spineless prickly pear of the region, is locally conspicuous on desert flats of Larrea-Agave southeast of the Chisos Mountains, Big Bend National Park.

Fig. 2. The species reaches its highest development on steep talus slopes and amid fractures of limestone cliffs in deeply eroded country such as Reagan Canyon.

PLATE XXXIX

1



2

PLATE XL

Fig. 1. On the right herbarium material of O. rufida var. tortiflora shows the more shortly-obovate joints, distant areoles, and twisted outer perianth segments contrasted with a specimen of the typical form on the left.

Fig. 2. The creeping and abruptly ascending habit of O. macrocentra var. minor readily distinguishes it from the usual higher bush of the typical O. macrocentra. It is locally common in Larrea association on sandy soil.

PLATE XL

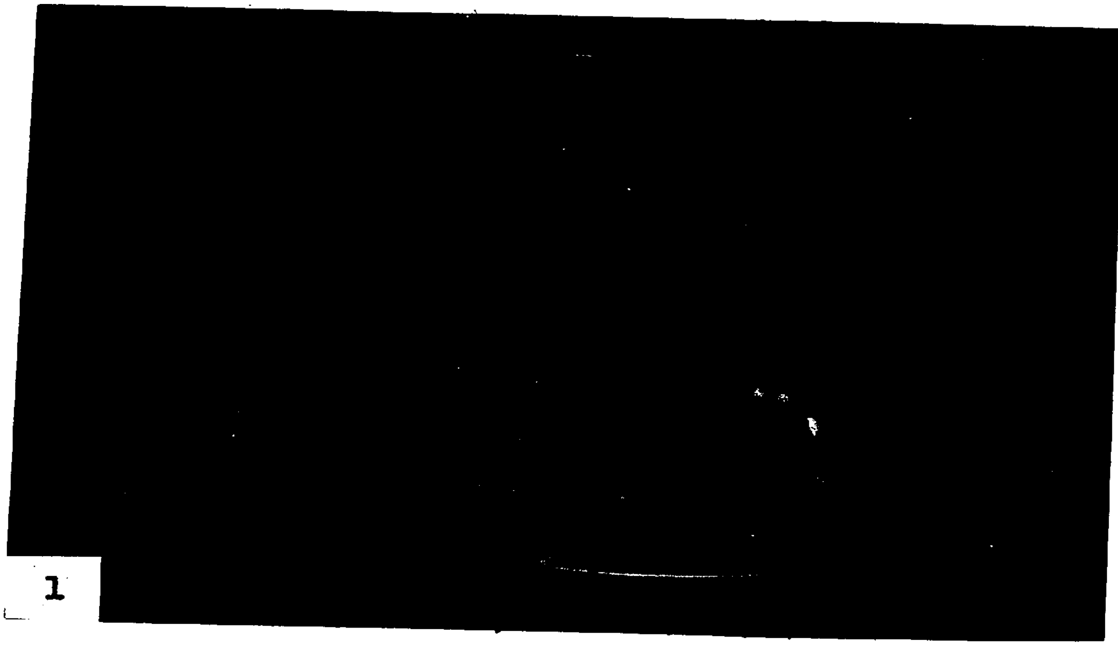
1

2

Fig. 1. In sheltered habitats of greater moisture content, joints of Opuntia macrocentra are entirely spineless, as in this Quercus-Juniperus association on igneous rock at about 4800 feet altitude. Note the typical long flower with narrow-conic ovary and scars on the pads, left by browsing animals.

Fig. 2. Fruits of O. macrocentra are mature by early July. The species is common in mixed desert scrub with Larrea-Agave at 3200-3500 feet, north and east of the Chisos Mountains.

PLATE XLI



1

2

PLATE XLII

Fig. 1. O. macrocentra var. minor on the left contrasts sharply with the larger, less spiny type form on the right. The lower or original joint of the latter has produced more typical new growth at the Botanical Gardens, showing that the stout and tortuous spines must be caused by local disease effect (See Plate VI, Fig. 2)

Fig. 2. This specimen of Opuntia spp. shows characteristics of O. macrocentra in the long acicular spines in marginal areoles only. Characteristics of O. Lindheimeri are shown in the yellow color of the spines and the remote areoles. The plant was growing in the Glass Mountains where both parents would be expected.

PLATE XLII

1

2

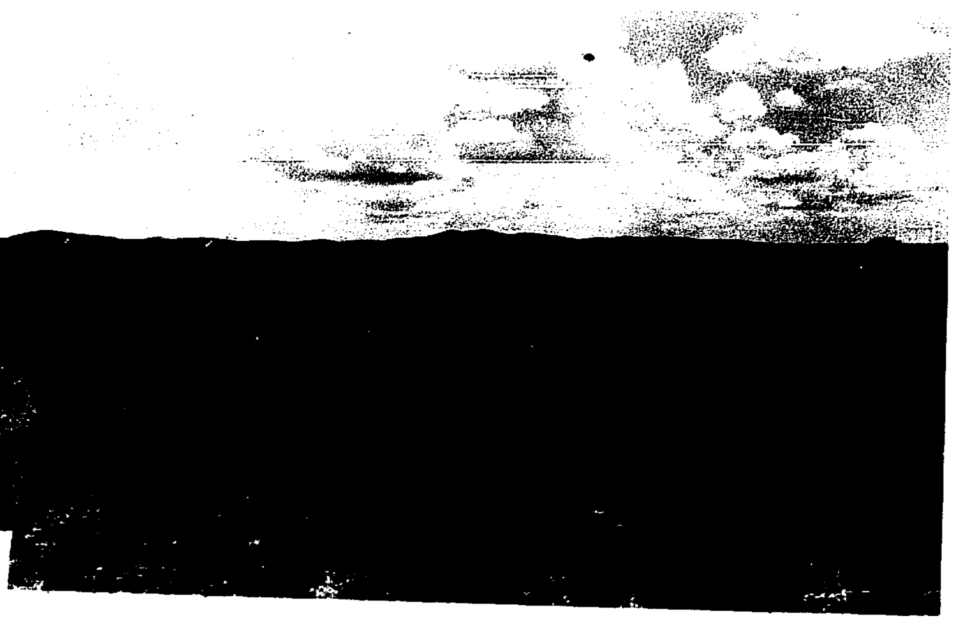
PLATE XLIII

Fig. 1. Surprisingly little known in literature and herbaria, *Opuntia setispina* is a common component of arid grassland associations in the Big Bend. The more or less orbicular joints bear a great many flowers and fruits.

Fig. 2. The above species, with *O. tortispina*, colonizes *Hilaria mutica* flats. Its local abundance does not, in these instances, seem to be correlated with overgrazing, but with very favorable edaphic factors.

PLATE XLIII

1



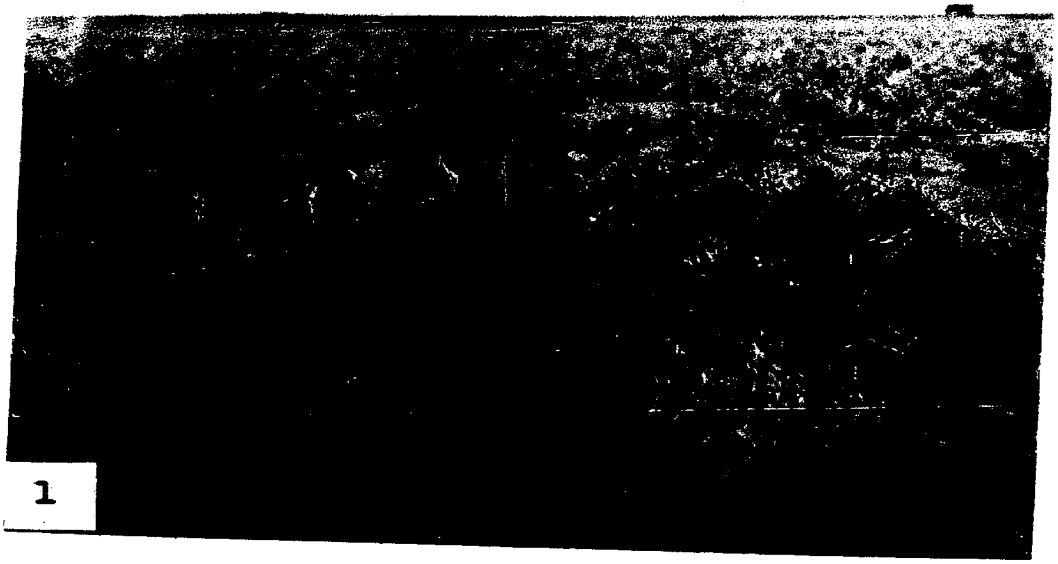
2

PLATE XLIV

Fig. 1. Typical habitat for _Opuntia tortispina_ is a _Hilária mutica_ flat with the bush spreading half-hidden in the tobosa grass. A joint on the far left shows the wrinkled character that is common for stems of this species. (See also Plate XLIII, Fig. 2)

Fig. 2. Joints on this specimen of _O. tortispina_ are less spiny than is typical. The species flowers prolifically and sets many fertile fruits.

PLATE XLIV



1

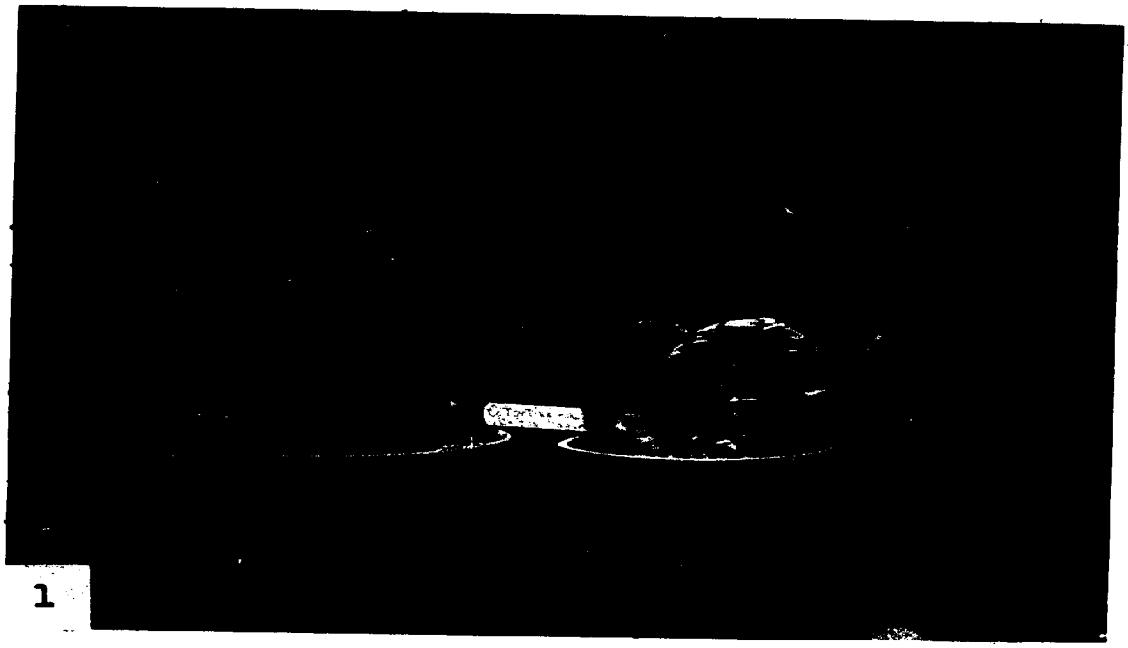
2

PLATE XLV

Fig. 1. Typical joints of _O. tortispina_ (on the left) contrast sharply with joints of that species (on the right) found in the 6500-foot-high Laguna in the Chisos Mountains.

Fig. 2. A possible hybrid between _O. setispina_ (on the right) and _O. tortispina_ (on the left) shows intermediate characteristics of spine form, number, and arrangement.

PLATE XLV



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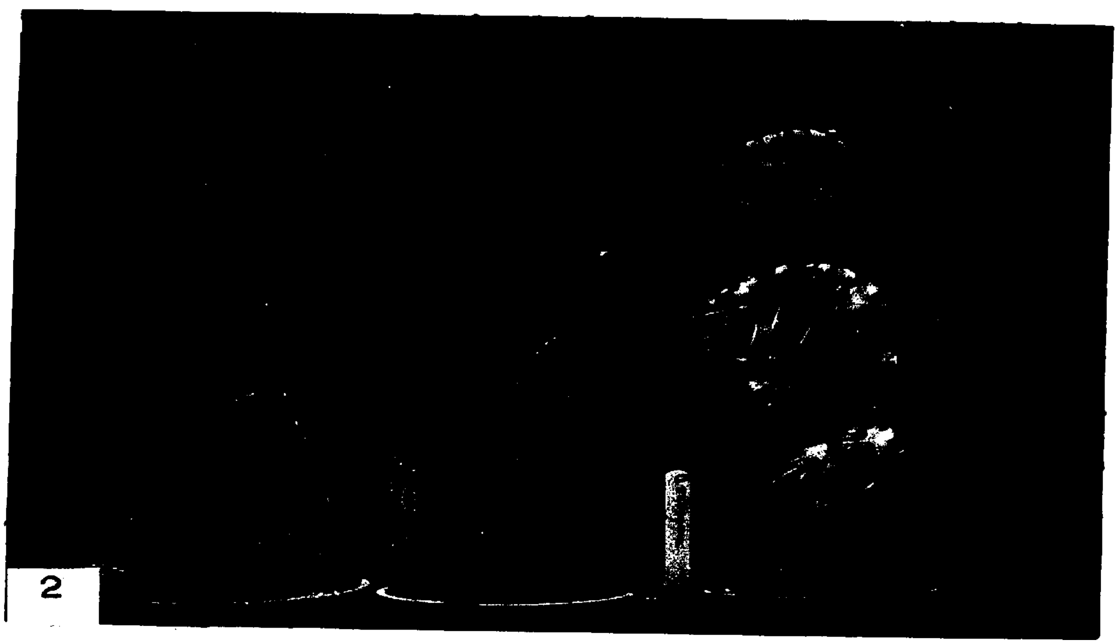


2

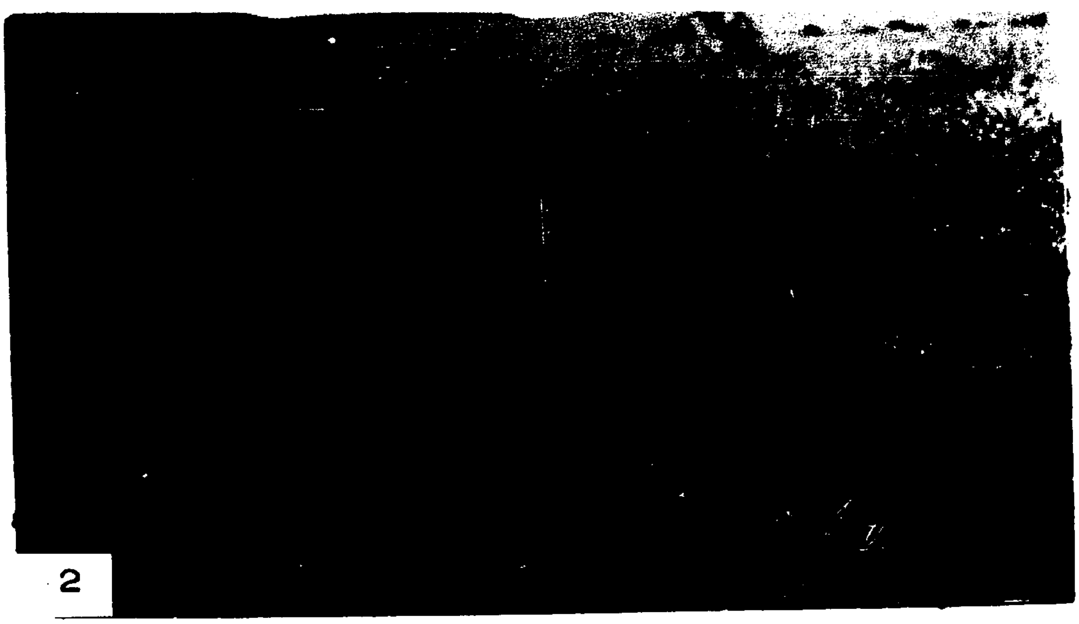
PLATE XLVI

Fig. 1. _Opuntia strigil_ is easily recognized by very closely-set, spiny areoles and great abundance of glochids.

Fig. 2. Plants of _Opuntia Pottsii_ rarely form more than 6-8 joints, although they flower and fruit heavily. Habitat shown with these two plants is on loam soil with Bouteloua-Prosopis vegetation.

PLATE XLVI

1



2

PLATE XLVII

Fig. 1. A Great Plains and northern species, Opuntia polyacantha reaches its most southern known extent of range at altitudes from 6000 to 8382 feet in the Davis Mountains. It is shown here in Quercus-Pinus vegetation.

Fig. 2. Opuntia trichophora is closely allied with O. polyacantha but is readily distinguished by the more attenuate long-obovate joints, and by greater number of spines, many of these long and hair-like.

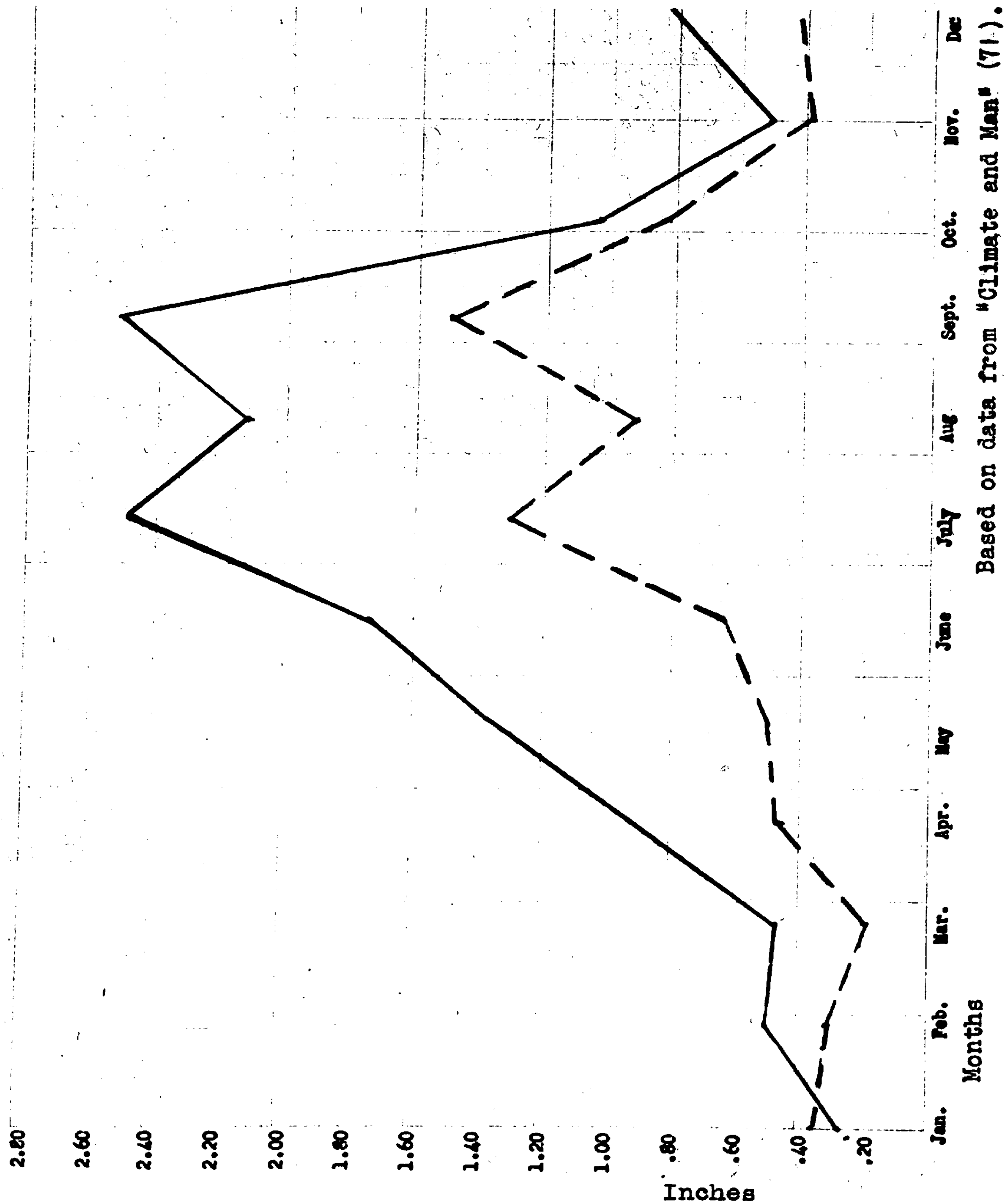
PLATE XLVII

1

2

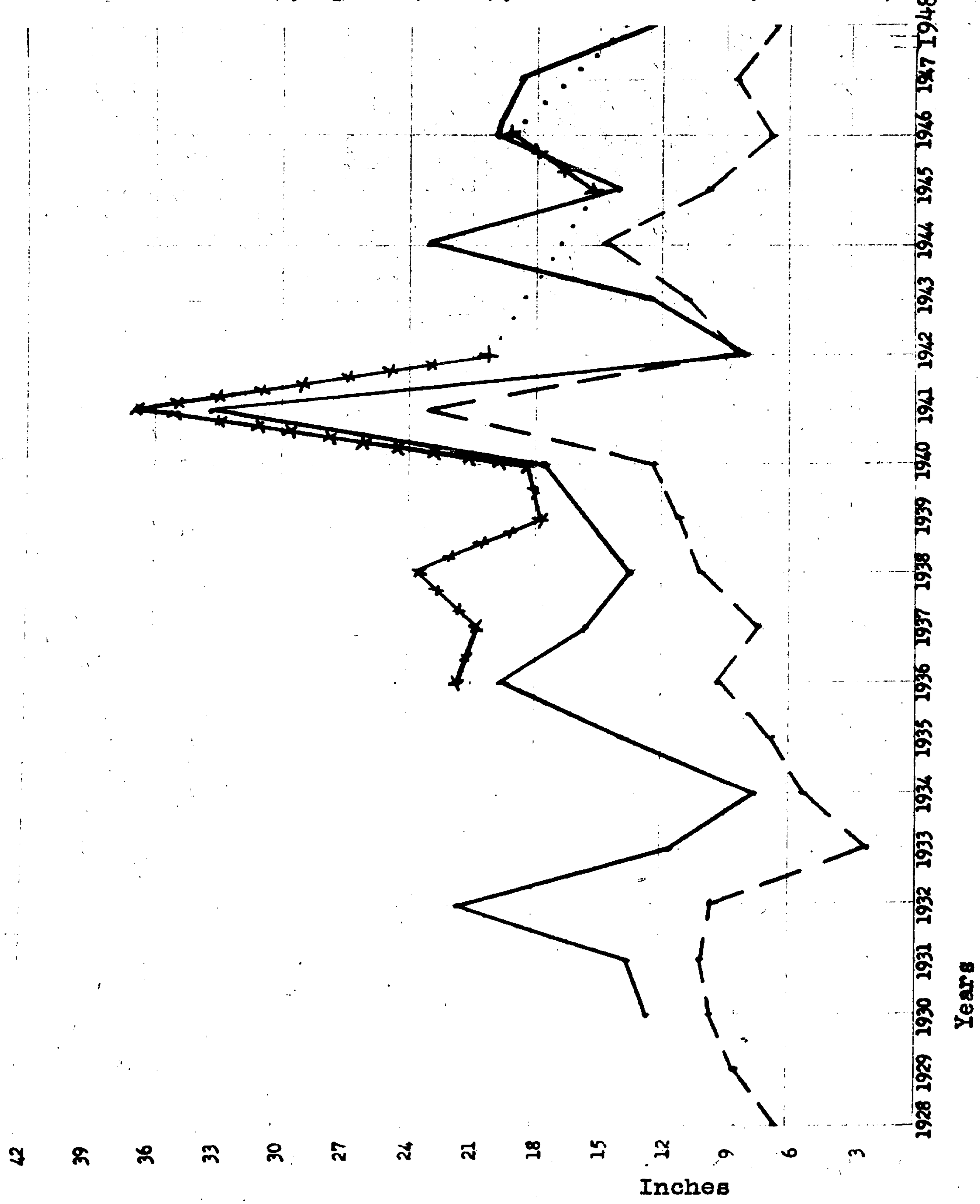
GRAPH I

PRECIPITATION — Total per month at Presidio (— — —) and Alpine (——), based on average over 11 years' record.



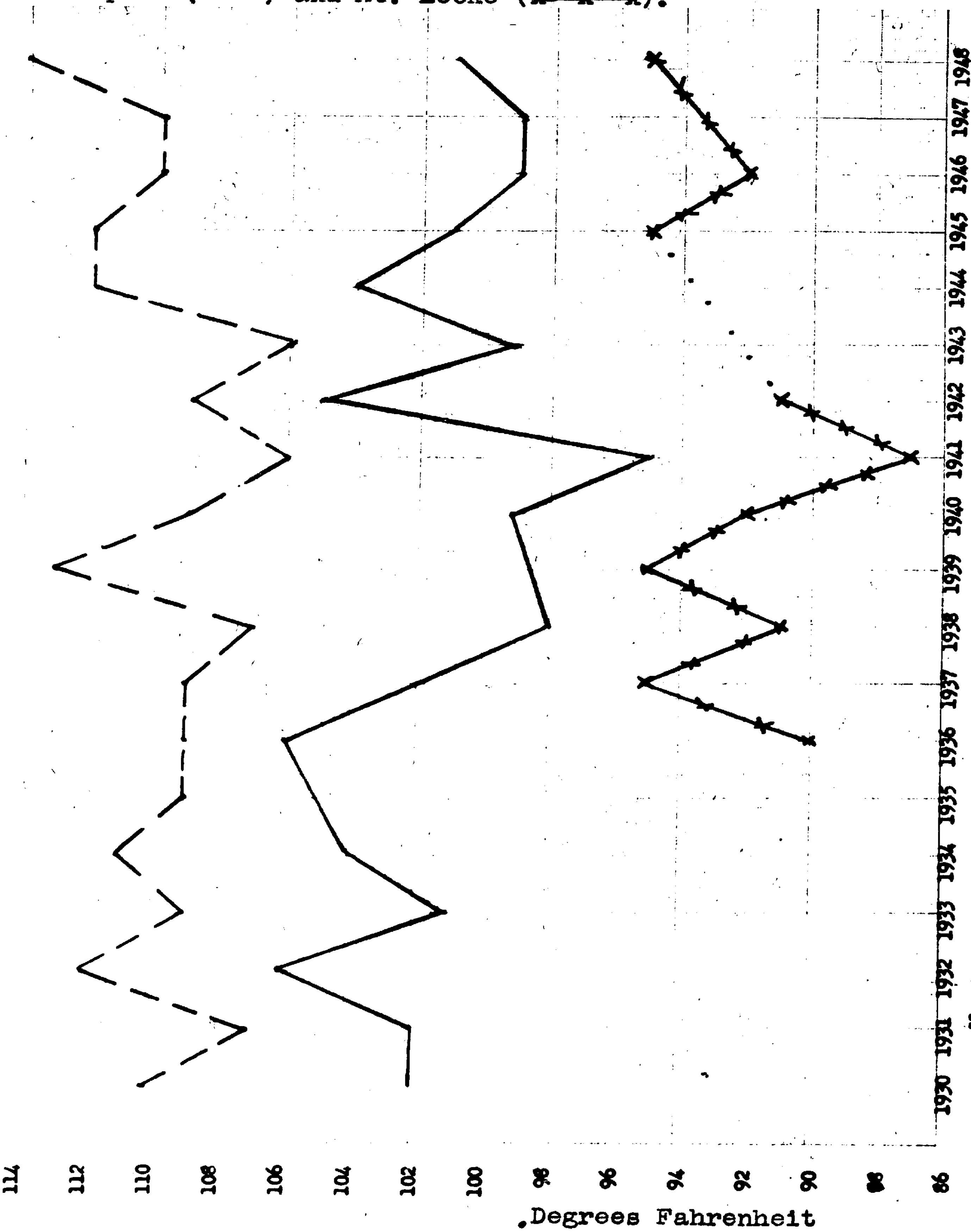
GRAPH II

PRECIPITATION — Variation in annual totals for Presidio (— — —), Alpine (——), and Mt. Locke (x—x—x).



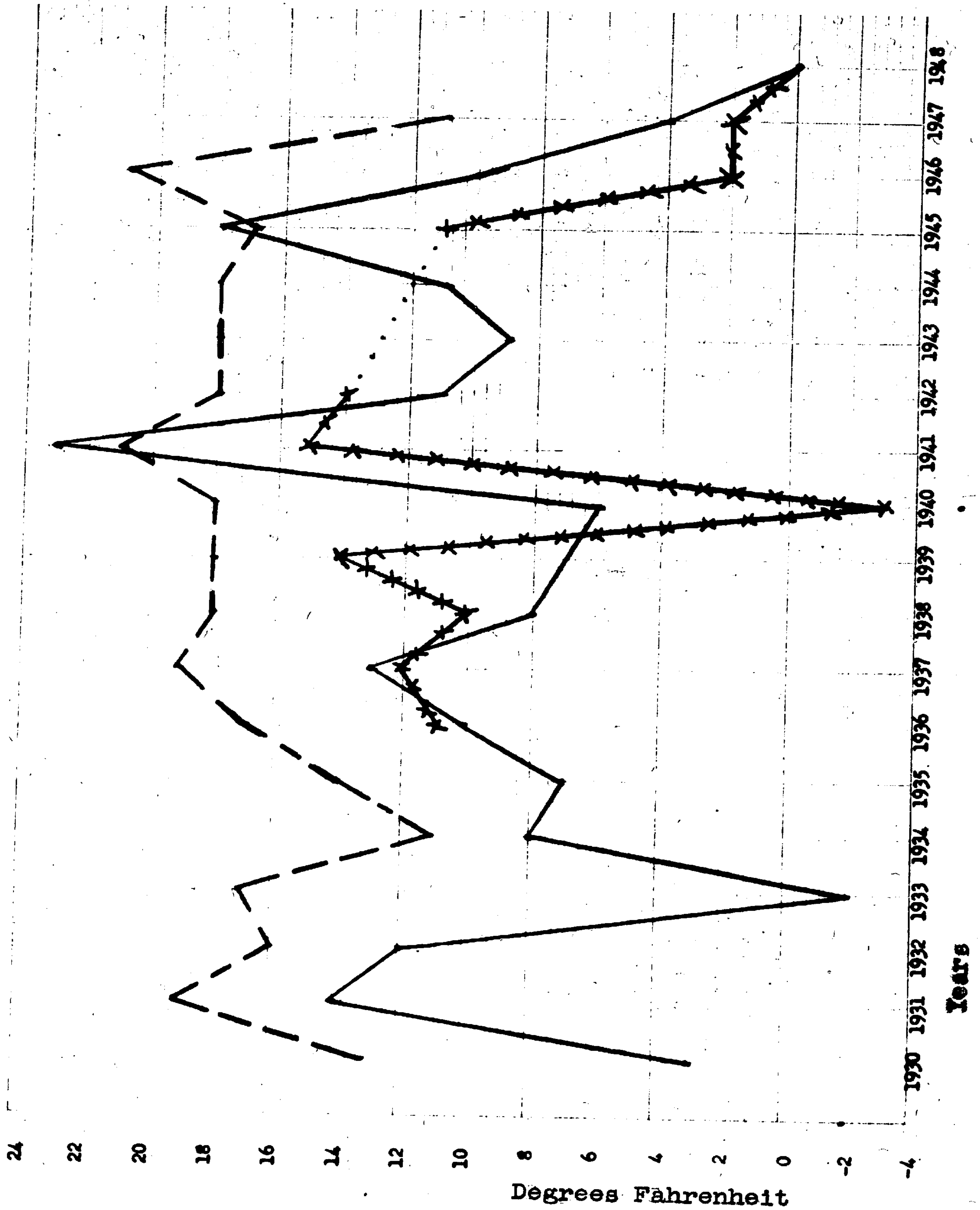
GRAPH III

TEMPERATURE — Maximum temperatures for Presidio, (———), Alpine (— —) and Mt. Locke (x—x—x).



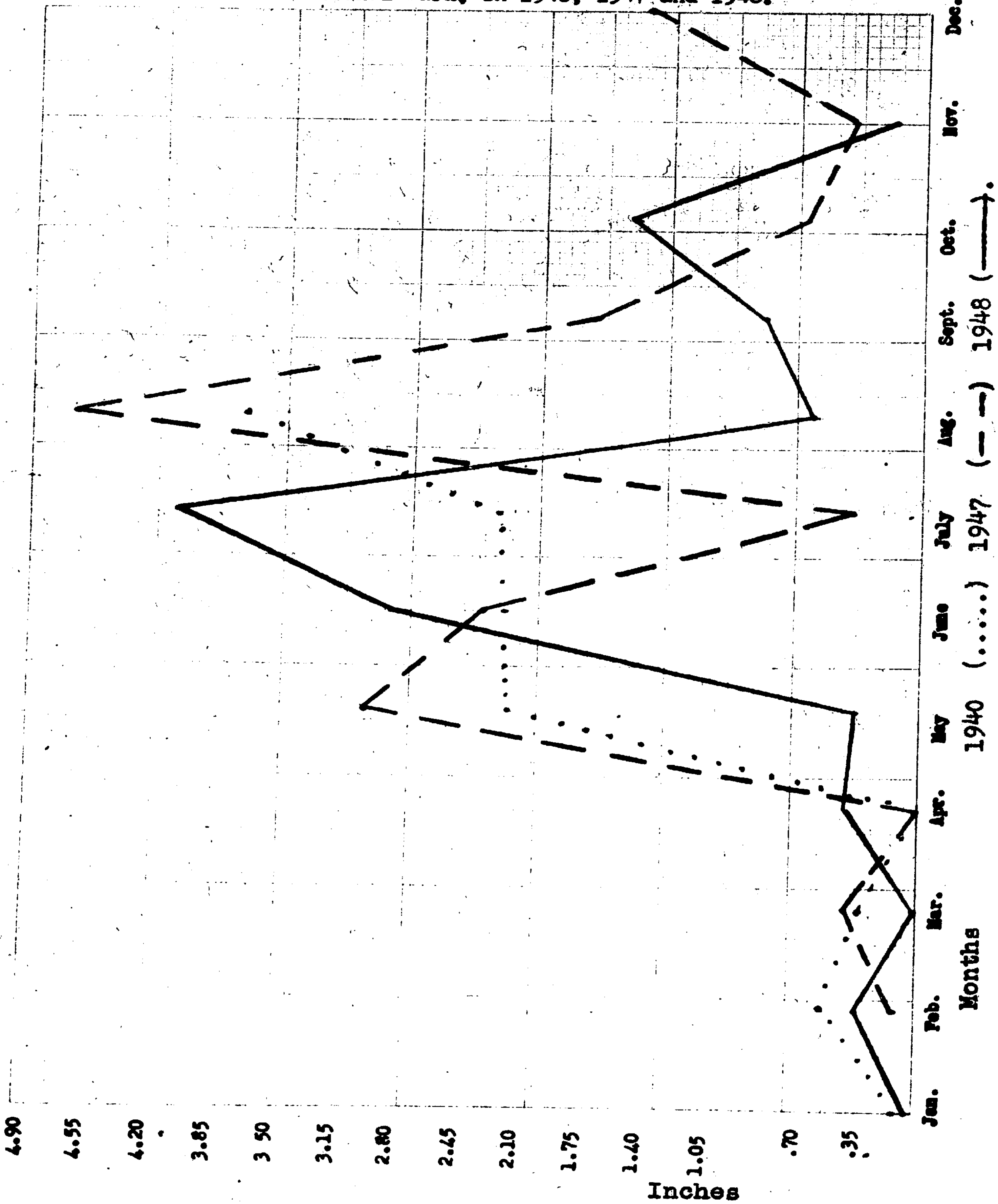
## GRAPH IV

TEMPERATURE — Minimum temperatures for Presidio (— — —), Alpine (——), and Mt. Locke (x—x—x—).



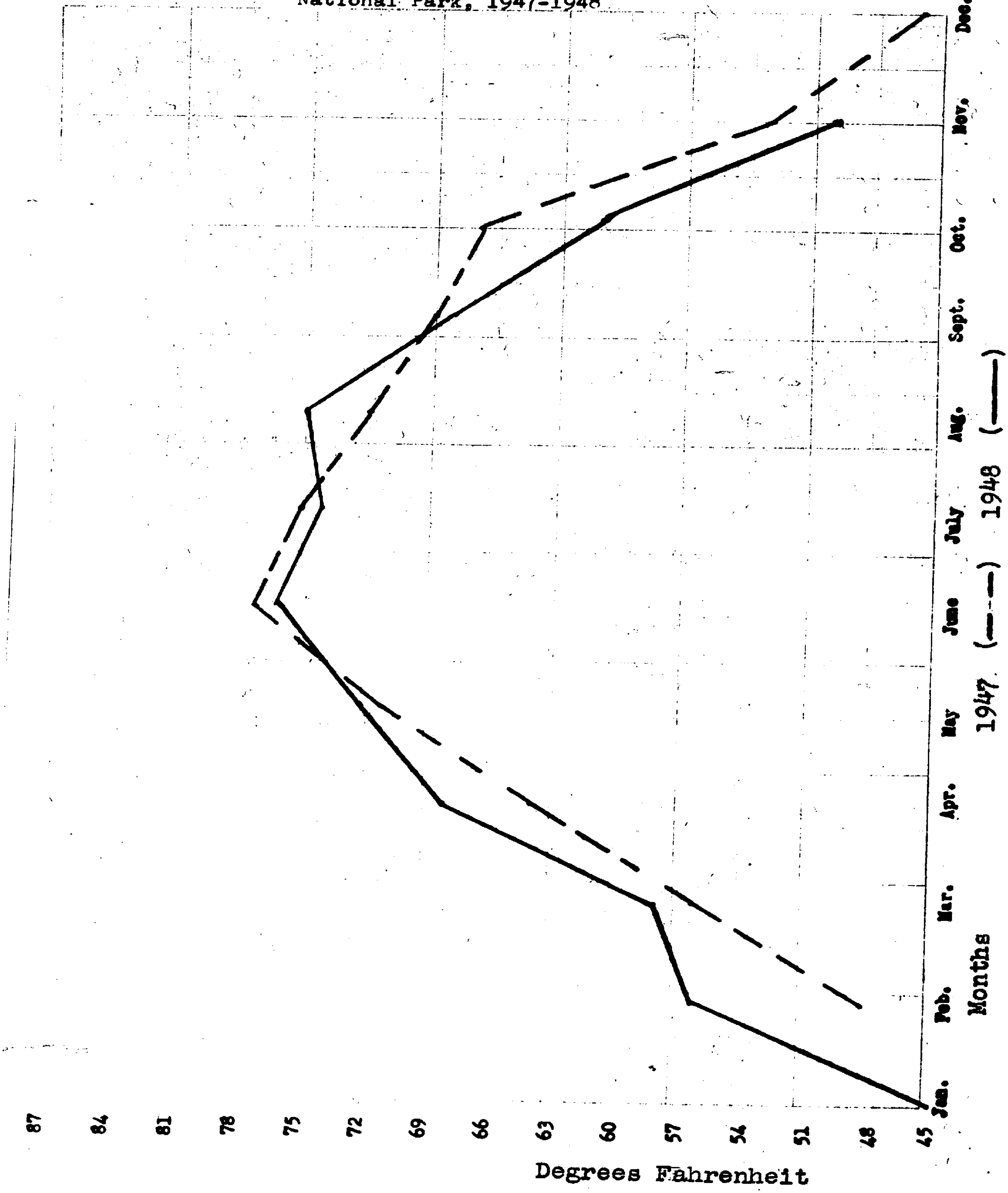
GRAPH V

PRECIPITATION - Monthly totals in Chisos Basin, Big Bend National Park, in 1940, 1947 and 1948.



GRAPH VI

TEMPERATURE - Monthly averages in Chisos Basin, Big Bend National Park, 1947-1948



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