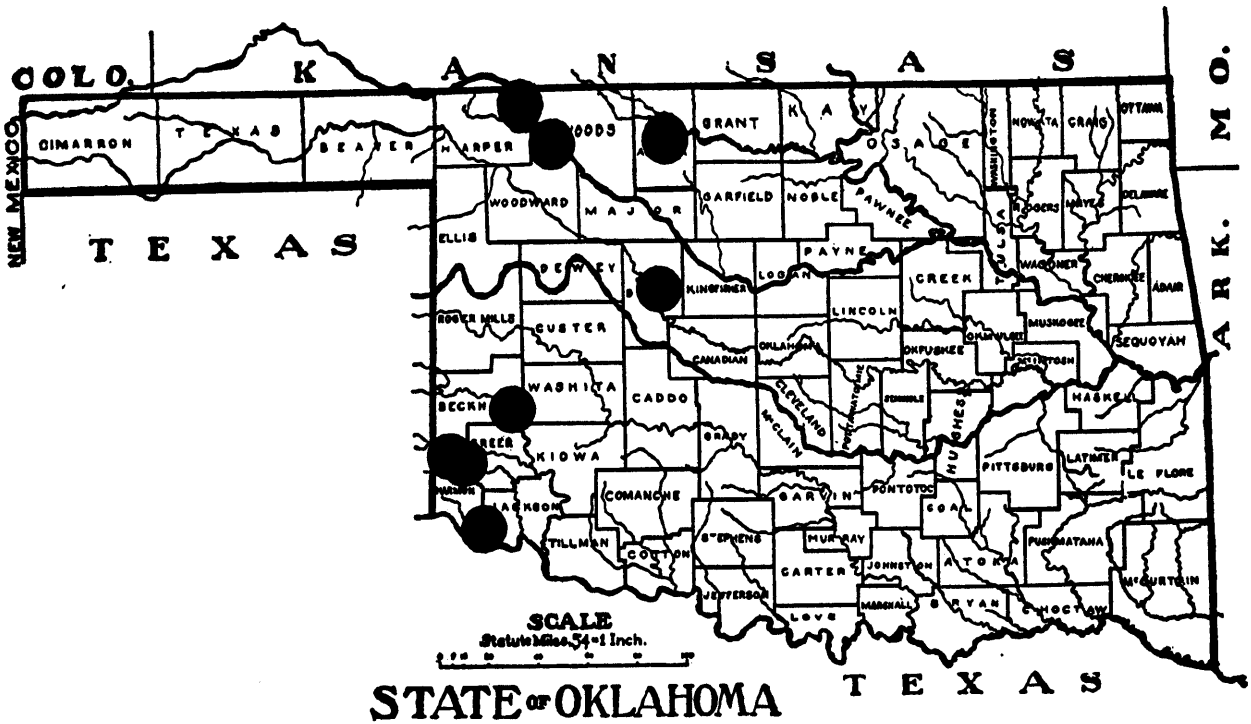

FIGURE 20. LOCATION OF SALT PLAINS IN WESTERN OKLAHOMA

THE ECOLOGY OF THE WESTERN OKLAHOMA SALT PLAINS*

A. I. ORTENBURGER AND R. D. BIRD

I. INTRODUCTION

In the state of Oklahoma west of the 98th meridian there are at least eight salt plains large enough to be of interest. During the months of June and July, 1930, the University of Oklahoma Biological Survey party, making its sixth annual expedition, studied two of these plains, both located in northwestern Oklahoma. The two chosen for our study are the largest in the State; the one at Cherokee covers an area of approximately 43 square miles, while the other plain at Edith is considerably smaller, covering about 12 square miles along the Cimarron River. Two plains were not visited; one along the Cimarron River 5 miles above the north end of the Edith Plain, and the other 2 miles southwest of Hitchcock. The other four salt-plain areas in the State are smaller, probably not over five square miles in area in any instance. Short visits were made to these smaller plains. (Fig. 20.)

The Survey party for the summer of 1930 consisted of the following members in addition to the authors:—Dr. H. H. T. Jackson, Senior Biologist, United States Biological Survey, and H. E. Warfel,† E. B. Webster, Kelly DeBusk, and Marcus M. Ravitch, students.

We gratefully acknowledge our indebtedness to the following authorities for the identification of the groups noted:—C. H. Curran, The American Museum of Natural History, Diptera; Ralph Hopping, Entomologist, Department of Agriculture, Canada, Coleoptera; Harry C. Oberholser, United States Biological Survey, birds; J. B. Wallis, Winnipeg, Manitoba, tiger beetles; E. P. Creaser, University of Michigan, copepods; U. S. National Museum, plants; C. L. Hubbs, University of Michigan Museum of Zoology, fish.

Dr. Charles N. Gould, Director of the Oklahoma Geological Survey, has kindly written the section on geology. Our thanks are due the Cherokee Chamber of Commerce for their generous cooperation and help.

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†Howard A. Kelly Fellow.

II. GEOLOGY*

The salt plains occur as part of the Permian red beds, which outcrop throughout the western part of the State. The red beds as a whole consist largely of great masses of red clay shales containing ledges, lenses, and beds of four other kinds of rock, namely, sandstone, gypsum, dolomite, and rock salt. The three former occur on the surface as prominent ledges which, because the rock is harder than the red shales in which they are contained, weather out, forming scarps, buttes, ridges, and other prominent topographic features.

Salt, being more soluble, is never exposed on the surface in the form of rock salt, but its presence is known by the drill and by salt springs which occur in various areas.

The red beds were deposited in shallow water, chiefly as deltas or offshore deposits. The source materials are thought to have come from land areas to the north, east, and south. The sea in which these deposits were laid down was probably retreating to the southwest. The climate was probably arid.

Practically all of the red beds contain large amounts of various mineral salts, of which sodium chloride, or common salt, is the most abundant. The salts of calcium, sodium, magnesium, and boron occur in greater or less amounts throughout the red beds.

The various formations making up the red beds occur on the surface in central and western Oklahoma and outcrop as bands or zones extending north and south, or northwest-southeast across the State. In ascending order, these formations are (beginning with the lowest which are exposed farthest east) the Stillwater, Wellington, Garber, Hennessey, Duncan, Flowerpot, Blaine, Dog Creek, Whitehorse, Day Creek, Cloud Chief, and Quartermaster. The beds of rock salt occur chiefly in the Hennessey ond Flowerpot formations.

The Cherokee Salt Plain is located on the outcrop of the Hennessey. Geologists have long puzzled over the source of this salt. There seem to be no extensive beds of rock salt beneath the surface, at least the drill has not revealed them, but the belief is that the Hennessey at this particular place beneath the surface contains unusual amounts of saline matter and that this material is dissolved out, forming the salty incrustations. As the people of the region express it, the salt "sweats up" from the bottom of the plain. There are, however, no strong springs of salt brine on this plain so far as I know. A core drill hole recently drilled off the north end of the plain is said to be flowing a stream of fairly strong brine. A well drilled about thirty years ago in the vicinity of Jet, just south of the plain, also showed a strong flow of brine.

The other salt plains in western Oklahoma occur in the Flowerpot shales, usually 50 to 150 feet below the Blaine gypsum, which forms bluffs and cliffs near the various plains. These plains are seven in number: Big Salt Plain of the Cimarron at the mouth of Buffalo Creek in extreme northern Woodward County (Edith Salt Plain), Little Salt Plain of the Cimarron near the Kansas line between Woods and Harper counties, Blaine County Salt Plain on Salt Creek west of Hitchcock,

*By Charles N. Gould.

Carter Salt Plain in southeastern Beckham County near the town of Carter, two salt plains along Elm Fork of Red River in northern Harmon County, and a small plain along Sand Creek (Lebos Creek) in southwestern Jackson County. All of these plains are fed by springs which issue from the surface of the salt plains and from which the water flows into streams. Geologists believe that these salt springs are fed from beds of rock salt at no great distance beneath the surface.

III. METEOROLOGY

Over the larger part of the western portion of the State where all of the salt plains are located there is sufficient annual rainfall to produce safe agricultural conditions. Approximately three-fourths of the yearly precipitation occurs in the growing season, that is, between March 1 and October 31 (data from the United States Weather Bureau). Rains ordinarily are general in the spring and early summer. Late summer and early autumn rains are largely local thundershowers, not infrequently cloudbursts.

The average mean temperature is between 60° and 62° along the Red River in the southwestern part of the State and decreases to 50° along the Kansas border. The summers are long and usually hot and dry. The winters are mild and of relatively short duration. In western Oklahoma temperatures of 100° may be expected at least during June, July, and August. Such temperatures have been recorded as early as March and as late as October. When temperatures are unusually high they are accompanied by very clear skies and usually by excessively dry, hot winds from the south or southwest. Nights are usually cool, owing to the dry atmosphere and the nature of the surface of the region which allows rapid radiation.

The prevailing winds are southerly over the entire western part of Oklahoma during the warm months of the year. In the winter, late fall and early spring there are commonly developed within a very short time sudden changes in the direction of the wind from the southwest or south to the north, producing the well-known "northers" and the very rapid decrease of temperature for which this part of the country, as well as the Texas Panhandle, is so well known. There is a high average wind velocity over the entire western half of Oklahoma. The average date of the last killing frost in the spring is about April 1 in the southern part. Killing frost may occur as late as May 1 in the entire western half of the State.

Rainfall records were obtained from the United States Weather Bureau at Cherokee. During a five-year period the average annual mean precipitation was 24.47 inches for the region surrounding the Cherokee Salt Plains. The figure as taken from the station at Buffalo is somewhat lower for the territory near the Edith Plain, where the mean is given at 23.57. The average annual mean temperature calculated over a period of 20 years (Alva) is 58.3°, with the following monthly averages: January 34.8; February 36.6; March 48.2; April 58.0; May 66.9; June 76.4; July 81.0; August 80.1; September 72.6; October 59.6; November 48.2; December 36.8. The highest temperature recorded is approximately 114°

for both regions. The lowest temperature recorded is −14°. The mean maximum temperature is approximately 72°; the mean mimimum temperature, 46°. The annual average number of days with more than 0.01 inches of precipitation is 60. The average annual snowfall is approximately 14.8 inches. The average wind velocity is approximately 11 miles per hour. The mean relative humidity is 78.0 early in the morning, dropping to 52.0 at 7 P. M.

The above data give the approximate figures for this general region. During the month of June, our records at the Cherokee Salt Plain, show that the temperature varied from a maximum of approximately 105° during the middle of the afternoon to as low as 80° between three and four in the morning. The relative humidity varied from 80 or 90 early in the morning to 20 or 30 during the heat of the day. While no measurements were actually made, there is little doubt that the wind velocity averaged considerably higher than is indicated above for the general region. This is probably due to the nature of the locality itself, particularly on the flat Salt Plain. The dehydrating effect of this wind blowing almost constantly from the south was very noticeable. The wind was commonly so strong that it made seining in the shallow streams of the Plain very difficult, for the seine was repeatedly blown out of the water. The sky during the month of June was almost always clear; even a few small clouds were so rare as to cause comment.

Rainfall during the month of June averaged over a period of six years (1915-1920) is only 4.74 inches. Due to cloudless skies and the very high reflecting power of the white salt, the light on the plains is of extreme intensity and very likely to produce conjunctivitis. Photographic work very clearly demonstrated the intensity of the light, which varied somewhere between eight and sixteen times normal for this part of Oklahoma.

In summary it may be said that this region in the summer is characterized by high temperatures, low relative humidity, and dry, hot southerly winds of high average velocity.

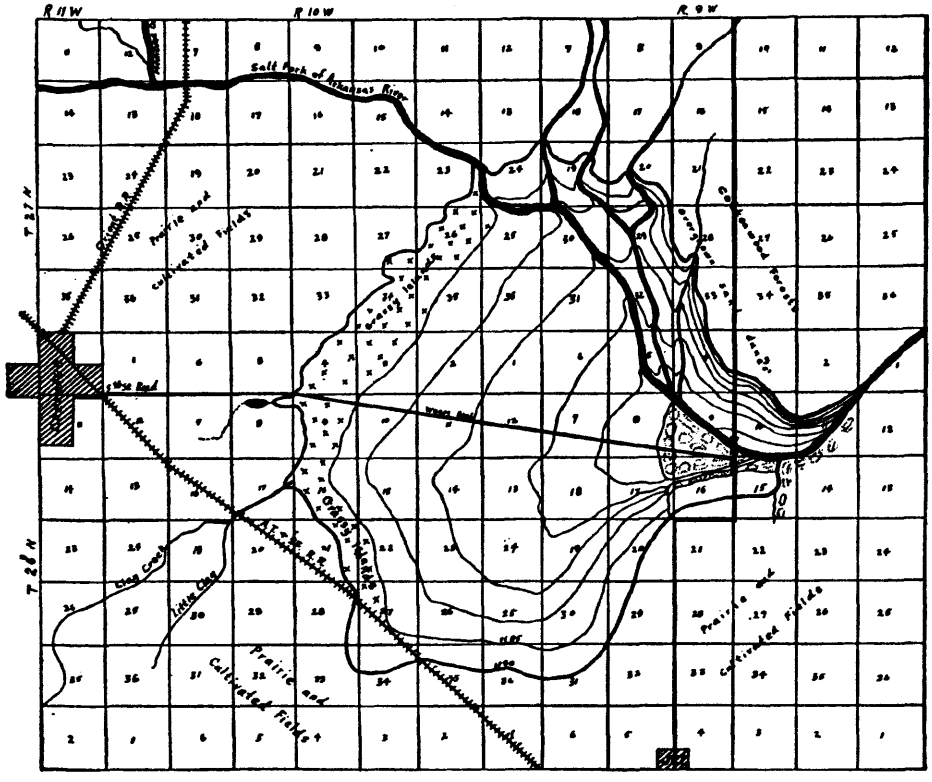
IV. DESCRIPTION OF THE SALT PLAINS

1. The Cherokee Plain

The Cherokee Salt Plain is located three miles east of the town of Cherokee in Alfalfa County. Upon first sight it resembles a lake glittering in the sun. The entire area, roughly circular, is covered with a thin coat of crystallized salt giving the plain a dazzling white surface. After a rain the salt is washed into the ground, leaving the sand and clay exposed. The area is approximately eight miles long north and south, and six miles wide east and west. The surface is remarkably level, but topographical surveys show that there is a slight slope from the west to the east, the Plain being lowest at the point where the Salt Fork of the Arkansas River leaves it. The elevation is approximately 1190 feet at the west side and drops off very gradually to 1162 feet at the southeast portion, a drop of 28 feet in a distance of six miles. (Fig. 21.)

While the surface is unusually flat, allowing cars to travel over it at a high rate of speed, there are scattered over this area numerous shallow depressions left by temporary streams resulting from occasional heavy rains. In general the surface is surprisingly hard and firm, much more so than ordinary soil; in the greater part of the area it is quite difficult to produce even a heel print. There is a considerable difference in the firmness of the sand making up this plain; this varies greatly from day to day, and also from place to place. An area which is apparently as hard as the best dirt road may on the next day, with no rain or other obvious change in the meantime, allow a light Ford car to sink rapidly in what appears to be quick-sand. Ordinarily it is quite impossible to tell from the appearance of the surface whether the soil is actually hard or very "quicky."

The general surface of the Plain is covered with a thin layer of salt, usually from 1 to 3 mm. in thickness. When one walks over the Plain, the salt breaks in flakes which are blown off by the ever-present wind. Small thin masses of salt crystals are found commonly on the bottom of the small stream flowing over the Plain. The exceptions to this salt covering



CHEROKEE SALT PLAINS

FIGURE 21.

are the areas immediately along the Salt Fork of the Arkansas River, the sand islands to be mentioned later, the shallow depressions mentioned above, and areas of clay. (Fig. 39.)

The Salt Fork of the Arkansas runs along the northeast side of the Plain. (Fig. 21.) The Plain slopes very gradually into the river on the southwest. On the northeast there are a few low, overgrown sand dunes. (Fig. 39.) A mile or so back from the river are many cottonwoods of fair size. The salt is not confined to the Plain proper, but is obviously present in the subsoil for a few miles away from the Plain. It may be seen as little white patches in depressions. Flowing into the Plain from the west side is Clay Creek, which supports a rather abundant fauna. To the northeast, three branches of the Salt Fork of the Arkansas enter the Plain and flow for a mile or more through the northeast part of the Plain before entering the river.

The salt of the Cherokee Plain is not particularly pure, but it seems well established that no iodides nor bromides are present. To date we have been unable to obtain analyses of the salt taken as samples, but we know that the ground water varies in density from 1.061 to 1.208, being saltier on the west side than on the east; and that the percentage of chlorine varies of course with this density from 5.18% to 15.79%. In addition in some parts large penetration twin crystals of gypsum were found; this is a rare form interesting from the standpoint of the crystallographer.

Surprising as it may seem, the Salt Fork of the Arkansas under ordinary conditions contains insufficient salt to be detected by tasting. This is not the only river in Oklahoma named Salt Fork which is not salty. The Salt Fork of the Red River in southwestern Oklahoma has been found to contain not enough salt to taste, while other near-by rivers such as the North Fork and Elm Fork of the Red River contained much more salt.

After a rain the appearance of the Plain is markedly different. The color changes from the dazzling white produced by the surface covering of salt crystals to a muddy brown which may last for several days. It may assume a greenish tinge due to the rapid growth of *Oscillatoria*. During the months of June and July very little rain falls in western Oklahoma.

REPORT ON BRINES FROM THE CHEROKEE SALT PLAINS*

1. Neutral to litmus 2. No iodides, no bromides 3. No.	*Density*	*Total solids*	*Chlorine*	*Ratio Chlorine / total solids*
1. East side	1.061	9.18%	5.18%	0.564
10. East side	1.206	27.99%	15.79%	0.564
12. West side	1.151	20.66%	11.90%	0.576
13. West side	1.208	27.53%	15.61%	0.567
14. Center	1.196	26.36%	15.16%	0.575
15. Center	1.196	26.11%	15.07%	0.577

*These figures are used by kind permission of Dr. O. M. Smith, Head of the Chemistry Department, Oklahoma A. & M. College; the analyses were made by Dr. H. McC. Trimble, Professor of Chemistry.

The western side of the Cherokee Plain is quite different in certain respects from the eastern, the most noticeable feature being the presence of what we have called "islands" along the western edge. These islands are isolated mounds of sand usually not over 5 or 6 feet above the flat surrounding surface of the Plain. They vary in size from those only a few feet in diameter to some covering 3 or 4 acres. They are covered with *Andropogon furcatus* Muhl., the dominant plant, which furnishes good food and cover for the kangaroo rats and the grasshoppers. The soil of these islands is apparently nearly pure sand, but, as pointed out later, there is a very sharp line of demarcation between these sand islands and the salt-covered Plain. (Figs. 38, 42, 44.)

The vegetation on the Plain is very scanty. Patches of *Sesuvium sessile* Pers. and *Dondia depressa* (Pursh) Britton are found. These plants and the abundant *Oscillatoria* (the latter seen only after rains) are the only plants growing out on the Plain. (Figs. 35, 44.)

2. Description of Edith Plain

This salt plain is named after Edith, a station on the Waynoka-Buffalo branch of the Santa Fe Railroad. The town is situated near the eastern end of the Plain, which extends along the valley of the Cimarron River for a distance of about six miles and is three miles wide at its center, the widest portion. The River runs in a direction slightly south of east close to the southern side of the Plain. Here it is bounded by gypsum-capped clay bluffs about 100 feet high. In most cases the salt extends to the very foot of these cliffs. The north side of the Plain is bounded by low-lying land which rises gradually to the northward to a distance of more than one mile and then breaks into a series of hills about 75 feet in height. These are cut by deep water courses and mark the northern bank of the river valley. On the south the River is joined by two semi-permanent streams, Buffalo Creek and Wild Cat Creek. The surface of the Plain is almost flat, but slopes gently toward the River. The soil is a sandy clay.

The Edith Plain is much saltier than that of Cherokee. The salt is of exceptional purity (99.8% sodium chloride) and has been commercialized. In 1902 the Santa Fe Salt Company of Pomeroy, Ohio, was organized and built a plant on the north bank of the River close to the Santa Fe tracks about two and one-half miles west of Edith. On May 22, 1923, the plant was destroyed by tornado and abandoned. The salt is still being worked by a local farmer.

The source of the salt is principally two brine streams arising near the center of the Plain and flowing into the River. They have been estimated by the Santa Fe Salt Company to flow 150,000 and 200,000 gallons of brine daily. In addition the two creeks, Buffalo and Wild Cat, respectively contribute daily 60,000 and 754,000 gallons of brine. The brine streams are mostly within sections 27 and 28, T. 27 N., R. 19 W. The Cimarron River carries relatively little salt; it may dry up completely as it did in July, 1930.

Although at high water and after rains no salt is visible, it crystallizes out during fair weather under the heat of the summer sun and

with the desiccating winds as at Cherokee, but in much greater quantities. This occurs principally along the brine streams, where it may reach a thickness of 4 to 6 inches. The salt crystallizes in the form of twinned cubes. These begin to form on a point on the shore or some object projecting above the surface from which they extend in finger-like processes, like ice, out over the surface of the water. The crystals soon reach a size which is too great for the water to support, break off, and sink to the bottom. A solid mass of crystals is built up in this way.

On account of the greater salt content there is less life, both plant and animal, than on the Cherokee Plain. There are fewer patches of *Sesuvium*; islands are present only above the brine streams; tiger-beetle larvae are common only near the shore line and the burrowing staphylinids (*Bledius*) are nowhere as abundant as at Cherokee.

3. Other Salt Plains

In Beckham County, three miles south of Carter there is a salt plain divided by a small creek into a western and an eastern portion. These were visited on May 16, 1931. They are described as follows:

West Carter Salt Plain. This is a rather small area about one-quarter to three-eighths mile long in a northeast-southwest direction and about one-eighth mile wide. Two brine streams flow from gypsum rock and are extremely bitter to the taste. The large spring on the south side forms a stream 2 inches deep and 5 inches wide. There was gas, probably carbon dioxide, continually escaping from this spring. The stream from the smaller spring is one-half to 1 inch deep, and about 2 inches wide. Salt water collects in shallow pools near the middle and north end of the Plain. (Fig. 47.)

The Plain is surrounded by gypsum bluffs about 25 feet high; several arroyos lead into it. These bluffs have a few bushes of *Rhus trilobata* (Nutt.) Small and mesquite, *Prosopis glandulosa* Torr., growing on them; in addition there are *Yucca* and a large-flowered *Oenothera*.

A large species of *Bledius gularis* (?) Le C. and several tiger beetles, *Cicindela echo* Csy., *C. fulgida* Say, *C. circumpicta* Laf. and *C. cuprescens* Le C. were common. Two species of brine fly, probably *Ephydra salina* Curran, and *Lipochaeta slossonae* Coq. were observed along the main stream. Dragonflies of the following species were taken along the stream that flows through the Plain: *Tetragoneura cynosura* Say, *Sympetrum corruptum* Hagen, *Enallagma civile* Hagen, *Ischnura denticolis* Burmeister, *I. kellicotti* Williamson, *I. verticallis* Say, and *Argia apicalis* (Say).

Five species of fish were found in the streams flowing over the Carter plains. Of these *Cyprinodon bovinus rubrofluviatilis* (Fowler) was the most common. The other species taken were—*Notropis lutrensis lutrensis* (B. and G.), *Ceratichthys vigilax* B. and G., *Pimephales promelas confertus* (Girard), *Plancterus kansae* (Garman).

Both killdeer and nighthawks were observed in both parts of the Carter Salt Plain.

East Carter Salt Plain, Beckham County, three miles south of Carter. This is another salt basin within a few hundred yards to the east of

the West Carter Plain. The area is about one-half mile across from north to south and one-eighth from east to west. About half or three-fourths of a mile south of the two plains there is a narrow salt area connecting them. (Fig. 47.)

This East Plain is fed apparently by a single spring from the gypsum bank on the north side. This spring has a good flow, making a stream of brine from two to three inches deep and six to ten inches wide. The water, as in the West Plain, is extremely bitter and very clear; the bottom of the stream is of sand. Fish were found here within 20 feet of the spring, although apparently they were most numerous at a distance of about 150 feet, and sedge was in the water within 100 feet of the spring. Tamarisk was growing in the salt stream to within 10 feet of the spring. In addition, *Sporobolus airoides* Torr. was found growing in and at the edge of the stream about 150 feet from the source. This is the same grass which was growing on the Cherokee Salt Plain.

The East Carter Plain is surrounded by gypsum bluffs from 25 to 50 feet high, covered with the same vegetation as those at the West Carter Plain.

The Eldorado Salt Plains along Sand Creek (Lebos Creek) about three miles south of Eldorado, Jackson County, were visited on May 16, 1931. There are three small plains along Sand Creek. These salt regions are small, averaging possibly 100 by 300 or 400 yards. The surface, composed of sand and small pebbles, is weathered conglomerate sandstone. The general shape of the plains is oval with the long axis north and south. Fish in the streams were numerous; this was also found to be true in the summer of 1926 when collections were made in Sand Creek nearer Hollis. Apparently a large amount of sewage is present in this water, judging from the smell and blackish color. The main stream here (Sand Creek) is 10 feet to 15 feet wide and 1 to 3 feet deep, flowing rapidly over a bottom which is either black mud, or sand, in some places where the stream is shallower. The smaller branches flowing from the salt areas are from 2 to 6 feet wide and 6 inches deep, the water quite clear, the bottom composed of sand and pebbles. Some algae were present. Tamarisk was found on the middle one of the three plains only. Yucca and mesquite were the common plants around the edges of the plains. *Artemisia* sp. was present around all of them, as well as *Opuntia* sp. *Sporobolus airoides* Torr. sends out runners onto the salt-encrusted sand just as at Cherokee. Salt is present in a very thin layer on the surface of the soil. (Fig. 49.)

No small *Bledius* were found, but brine flies, probably *Lipochaeta slossonae* Coq., were common. Saldids, *Pentacora signoreti* (Guerin) were taken. Several species of tiger beetles were taken also (*Cicindela fulgida* Say, *C. circumpicta* Laf., *C. cuprescens* Le C., *C. globicollis* Coq.). Odonata were common along the stream: *Gomphus externus* Hagen, *G. militaris* Hagen, *Progomphus obscurus* Rambur, *Hetaerina americana* Fabricius, *Argia moesta* (Hagen), *Argia sedula* (Hagen), *Enallagma civile* Hagen, *Ischnura barberi* Currie, *I. kellicotti* Williamson. Both Killdeer, *Oxyechus vociferus L.*, and Least Tern, *Sterna antillarum* (Lesson), were seen.

THE WEST SALT PLAIN OF ELM FORK is a small plain in an arroyo emptying into the South Fork of Elm Fork of the Red River in Section 5, north, Harmon County, about 6 miles west and 2 miles north of Vinson. This plain was studied May 16, 1931.

The Plain extends for a distance of about three-eighths of a mile in the arroyo in a north-south direction, and is about one-eighth of a mile wide. It is located between gypsum bluffs about 25 to 50 feet high with a considerable growth of mesquite along the small brine stream. There are three springs on the east side, one on the west.

THE EAST SALT PLAIN OF ELM FORK is about one mile east of Elm Fork West Salt Plain. This is located in a small arroyo entering the south side of Elm Fork of the Red River. The arroyo varies from about 25 to 200 feet in width and like the other Elm Fork plain is bordered by gypsum hills about 50 feet high. The salt area is about three-eighths of a mile long and about 50 feet wide. The salt here forms thicker masses of crystals than on any other salt plains in the State except at Edith. The salt is apparently nearly pure sodium chloride. Five large evaporating tanks have been installed, and the salt is sold commercially. (Fig. 48.)

No species of *Bledius* or tiger beetles were seen. Both saldids and *Ephydra* were common. Killdeers were observed on the Plain. These remarks concerning the animal life apply to both the Salt Plains of Elm Fork.

It is interesting that the same five species of fish taken at the Carter Plains were taken here also. An additional species found in the streams of no other salt plains thus far was also taken, namely—*Dionda nubila* (Forbes).

V. PLANT LIFE

Immediately surrounding both the Cherokee and Edith plains is a sandy prairie in which *Andropogon furcatus* Muhl. is dominant. Other common plants are: *Poa arida* Vasey, *Distichlis spicata* (L.) Greene, *Callirhöe involucrata* (T. & G.) A. Gray, *Cyperus Schweinitzii* Torr., *Yucca glauca* Nutt., *Meriolix serrulata* (Nutt.) Walp., *Indigofera leptosepala* Nutt., *Parosela lanata* (Spreng.) Britton, *Petalostemum multiflorum* Nutt., *Elymus canadense* L. Most of them extend up to within a few feet of the salt. *Sporobolus airoides* Muhl. is found abundantly at the very edge of the salt both about the mainland and islands, but in a few places *Chenopodium (fremonti?)* S. Wats., occurs between it and the Plain. *Distichlis spicata* (L.) Greene, although not as abundant as *Sporobolus,* is found in a few places on the edge of the plains. Along Clay Creek, in particular, it occurs in dense mats a yard or more across and a quarter of a mile from the mainland. The linear-leaved *Baccharis, B. neglecta* Britton, is found abundantly in the alkaline flats along the Salt Fork and Cimarron rivers. On the northeast side of the Cherokee Plain it is in many places the dominant plant on the islands. Along the banks of streams which flow out on the plain, *Scirpus americanus* Pers. is the dominant sedge. About the Edith Plain a bushy sage-brush, *Artemisia* sp., is very common. A limited amount of *Mimosa borealis* Gray and the mesquite, *Prosopis glandulosa* Torr., is found.

Three plants are confined to the Plain proper: *Sesuvium sessile* Pers., *Dondia depressa* (Pursh) Britton, and *Oscillatoria*, a blue-green alga of one or more species. Under normal dry conditions *Oscillatoria* is not in evidence, but after a heavy rain it becomes sufficiently abundant to give a greenish tinge to the surface. It forms the food supply of the enormous numbers of staphylinid beetles which inhabit the Plain. (Fig. 35.)

VI. SUCCESSION (in both Cherokee and Edith Plains)

There is a cycle of succession on the Salt Plains which seldom forms a sub-climax. We believe that there is no definite advance of vegetation, but rather alternate advances and retreats associated with periods of rain and drought. Patches of the Western Sea Purslane (*Sesuvium sessile* Pers.) are found well out on the Plain, usually in places where the soil contains more clay and hence gives up less water, with a correspondingly smaller deposition of salt. This prostrate *Sesuvium* is high enough to cause drifting sand to accumulate about it and grass seeds (*Sporobolus airoides* Muhl.) to lodge and germinate. With the increase in vegetation more sand lodges and an island is formed (Fig. 34). This is the first grass to come in on a developing island, but it is quickly followed by *Andropogon furcatus* Muhl., which becomes the dominant plant (Fig. 42). Herbs such as sand burs, *Cenchrus carolinianus* Walt., *Cyperus Schweinitzii* Torr., etc., appear later. If a period of abundant rainfall follows, the islands may increase to sufficient size to be permanent and withstand periods of drought. What most frequently happens is that following the spring rains a severe July and August drought sets in; this, accompanied by the persistent strong winds and high evaporating power of the air, so desiccates the plants that most of them are killed. The *Sesuvium* by means of its succulent leaves and roots is most resistant, and although killed back to the ground will again spring up if the drought is not too prolonged. The prevailing winds are from the south, with the result that the islands are blown out on this side (Fig. 44), but may still advance, or at least hold their own on the north (Fig. 42). Weather tends to go in cycles of wet and dry years. In the former there may be a general encroachment of vegetation on the Plain with the formation of new islands and the enlargement of the old. In dry years the small islands may be completely blown out and destroyed and the larger ones considerably reduced on their southern exposures.

The blow-outs have more or less vertical banks of sand 2 to 5 feet high. On the tops are embedded clumps of grass, the roots of which extend down several feet. It frequently happens that the more persistent grass is isolated in hummocks 1 to 3 feet in height. This is particularly noticeable on the east side of the Cherokee Plain near the Salt Fork River (Fig. 44).

Animal life was closely correlated with these early associes. The turret-building tiger-beetle larvae (Fig. 41) made their homes among the patches of *Sesuvium*. The dominant animals of these grassy islands were the kangaroo rats, *Dipodomys ordii richardsoni* (Allen), many species of short-horned grasshoppers and the box turtles, *Terrapene ornata* Agassiz. The burrowing of the kangaroo rats and digging of the

box turtles loosened the soil and killed the grass so that erosion was aided. The rats, the turtles and the insects fed upon the grass. The ant, *Lasius niger neoniger,* is very abundant on the islands (Fig. 45).

About the edges of the established islands and along the shore of the mainland, succession results mainly from the encroachments of the rhizomes of the grass, *Sporobolus airoides* Muhl. (Fig. 43.) Western Sea Purslane (*Sesuvium sessile* Pers.), and associated with it *Dondia depressa* (Pursh) Britton, play a lesser part. The workings of the mole, *Scalopus aquaticus intermedius* Elliott, extended some distance out on the Plain. This secondarily aided succession, for the burrows loosened the clay soil of the Plain, thus making it hold more moisture and enabling the grass rhizomes to extend a greater distance.

VII. ANIMALS CHARACTERISTIC OF THE CHEROKEE SALT PLAIN

The animal life of the Plain proper is made up of a large number of individuals but a small number of species, most of which are peculiar to the Plain.

The terrestrial vertebrate life included two birds, the Least Tern and the Snowy Plover. Both birds build scarcely any nest, laying their eggs on the bare salt. The Least Tern is found also along other rivers of the State, but the Snowy Plover appears to be peculiar to the Salt Plains. This plover breeds along the Pacific Coast from California to British Columbia, and has been found about local inland salt areas.*

The amphibian-reptile population of the Plain is very scanty both as to number of species and as to number of individuals. It is very doubtful if any reptiles or amphibians can live out on the Salt Plain proper, as there is no protection whatsoever, and the temperatures—at least in mid-day—are much too high for any cold-blooded terrestial animal to survive. The following forms, then, are cited as accidentally occurring on the Cherokee Plain: *Sceloporus undulatus thayerii* (B. & G.) (=*consobrinus*), one west of the River and one 150 yards from an island near the western edge of the Plain; one *Bufo woodhousii* Girard, near the middle of the Plain, dead and dried up; one *Terrapene ornata* Agassiz, crawling near the middle of the Plain; one *Pituophis s. sayi* (Schlegel), about one mile from the western side; and one *Chelydra serpentina* (L.), in the small salt creek on the Plain.

This short list indicates that very few species and individuals actually get out on the Plain. The grass-covered islands and hummocks, on the other hand, sustain a more numerous and more varied population. The commonest form of all is *Terrapene ornata* Agassiz; 91 specimens were taken from the islands alone, and many more could have been collected. *Holbrookia m. maculata* (Girard), is the next commonest reptile; it is found quite frequently on the islands and the Plain immediately surrounding them. *Holbrookia* was also common at the eastern edge of the Plain in the hummock region, as was also *Cnemidophorus sexlineatus* (L.). The only other lizards taken on any of the islands (and these only in

*See pages 69, 70 for discussion of mammals.

small numbers) were *Sceloporus u. thayerii* (B. & G.) and *Eumeces obsoletus* (B. & G.). Four species of snakes were collected on the islands, *Sistrurus catenatus edwardsii* (B. & G.), *Arizona e. elegans* (Kennicott), *Heterodon nasicus* B. & G., and *Pituophis s. sayi* (Schegel). At the edge of the Plain two other species of snakes were taken—*Rhinocheilus lecontei* B. & G., and *Heterodon contortrix* (L.).

The invertebrate population was characterized by enormous numbers of a very small burrowing staphylinid beetle, *Bledius,* apparently a new species. (Fig. 40.) On a favorable locality on the Cherokee Plain, we counted 285 burrows to the square foot. (Figs. 36, 37.) There are three larger species of this subfamily (*Bledius brevidens* Le C., *B. ineptus* Csy., *B. gularis* Le C.) which were found in the more moist portions of the plains, but which did not occur in such large numbers. Tiger beetles of the following species were also a characteristic part of the fauna: *Cicindela echo* Csy., *C. fulgida,* Say, *C. circumpicta* Laf., *C. knausi* Leng, *C. cuprescens* Le C., and *C. globicollis* Csy. (Fig. 22.) *Cicindela scutellaris* Say, and *C. punctulata* Oliv. were common on the islands. (Fig. 46.) A small yellowish ground beetle, *Pogonus planatus* Horne, was common under sticks and other objects on the Plain.

About the brine streams there was no life, but along freshwater

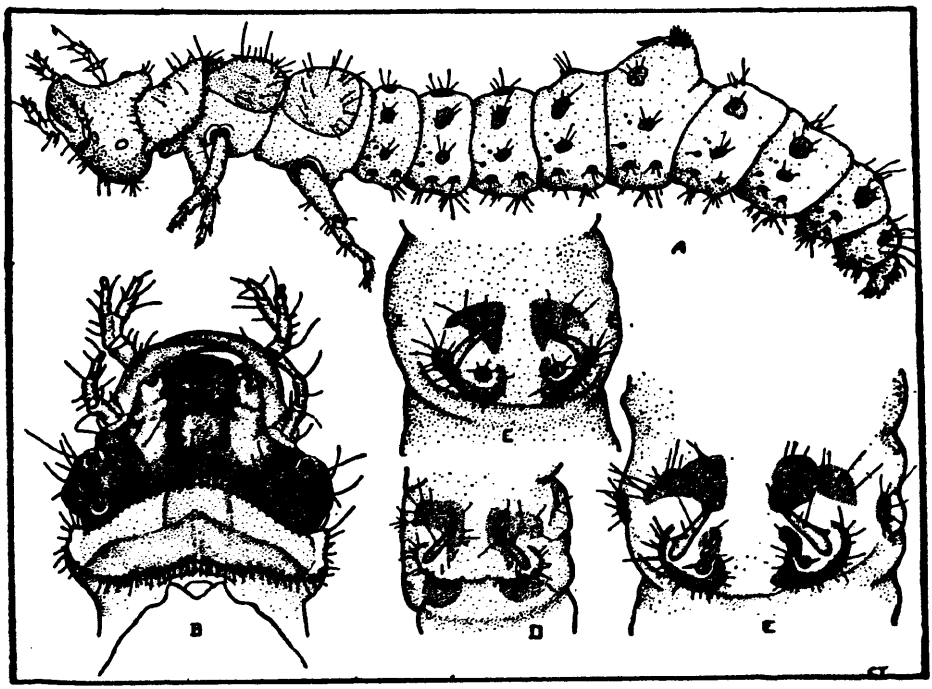


FIGURE 22. TIGER BEETLE LARVAE FOUND ON CHEROKEE SALT PLAIN. A. Lateral view, B. Head, C. Fifth abdominal segment of the turret-building larva *Cicindela* sp., D. Fifth abdominal segment of *Cicindela globicollis,* E. Fifth abdominal segment of *Cicindela cuprescens.*

streams (*e. g.,* Clay Creek on the Cherokee Plain) which flow on the Plain and pick up a high concentration of salt, there is considerable life. Two species of flies (*Ephydra salina* Curran and *Lipochaeta slossonae* Coq.) occur in great numbers along the water edge, and a corixid, *Trichocorixa verticalis* Fieber, is found in the water, together with numerous copepods (*Marshia albuquerquensis* Herrick).

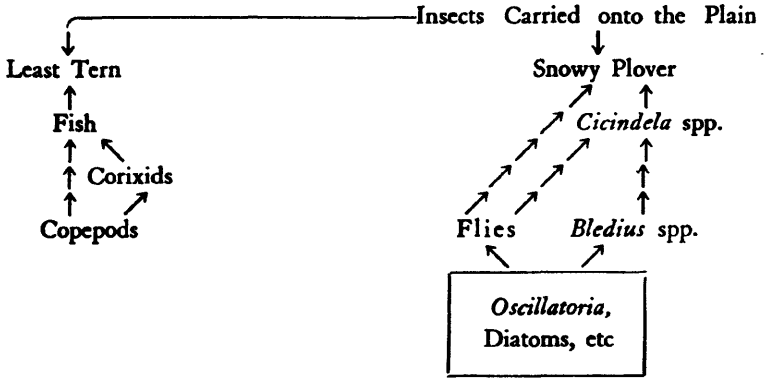
In the hot, dry season (July and August) most of the invertebrates aestivate. The small species of *Bledius* in particular is active after a rain. *Pogonus planatus* Horne disappears in the middle of June.

The only fish found in the water on the Cherokee Plain proper was *Plancterus kansae* (Garman).

VIII. BIOTIC COMMUNITIES OF SALT PLAINS

The Salt Plains proper may be termed a *Bledius-Cicindela-Oscillatoria* association, for these appear to constitute a subclimax community with these forms predominating. To this permanent assemblage are added two vernal and aestival societies: (1) of Snowy Plover which nest on the Plain and feed on its insect life and (2) of Least Terns which also nest on the Plain but feed principally on the fish that are found in the river and which ascend the temporary streams. Many insects are blown or washed out on the Plain and add to the food supply of the predominant animals.

The food-chain relationships of the Salt Plain community are illustrated by the following diagrams:



On the islands and adjoining mainland an *Orthoptera-Dipodomys-Andropogon* community is found. *Andropogon furcatus* Muhl., is the dominant grass; it forms a basis of the food supply of *Dipodomys ordii richardsoni* (Allen). In the fall considerable quantities of seeds and grass are stored by this rodent. The Orthoptera comprise several species of short-horned grasshoppers, which, as yet, are undertermined.

The boundary between these communities is generally very sharp and definite, but along the small ecotone of only a few feet between them, we find an interesting zonation of tiger beetle larvae. (Fig. 42.)

Cicindela globicollis Csy. is the species found generally over the Plain and its burrows extend to the edge of the salt. These burrows are characterized by a straight hole about 8 inches deep. The top is flush with the surface and there is no dirt pile.

Cicindela sp. is a species we have not been able to raise to the adult stage. It is found only in the vicinity of islands and patches of *Sesuvium* in soil which contains considerable clay. It is found most commonly within five yards of the edge of the salt, but may occur in scattered formation to a distance of 50 yards out on the Plain and right up to the very edge of the grass. This species makes a turret one and one-half to two inches high composed of pellets of clay. The top is saddle-shaped and there is a small dirt pile. (Fig. 41.)

Cicindela cuprescens Le C. larvae make two types of burrows. (1) In a narrow zone close under the overhanging grass of the outlying clumps where the soil is composed principally of sand, the burrows have a crater-like top and no dirt pile. (2) On the islands or mainland close to the edge the larva burrows deep into the soft sand and there is usually a pile of dirt near the hole.

IX. SUMMARY

1. The areas studied were two of the eight salt plains in western Oklahoma,—the Cherokee Plain just east of Cherokee in Alfalfa County, and the Edith Plain along the Cimarron River in Woods County. Five of the smaller plains were visited for comparative studies.

2. The Salt Plains occur as part of the Permian red beds in western Oklahoma. The Cherokee Salt Plain is located on the outcrop of the Hennessey formation, whereas the Edith Salt Plain occurs in the Flowerpot shales. Both plains are fed by springs issuing from the surface. It is believed that these springs at least at the Edith Plain are fed from beds of rock salt at no great depth.

3. The Cherokee Salt Plain is the largest one in the State, having a roughly circular shape and covering an area of approximately 43 square miles. This plain is very flat, and is covered with a thin layer of salt. The Edith Plain is smaller, covering an area of about 12 square miles. It is covered by a much thicker deposit of salt which is very nearly pure sodium chloride.

4. The plant life on both plains is very poor, both in number of species and actual number of plants. The only plants found on the plains proper are Western Sea Purslane (*Sesuvium sessile* Pers., *Dondia depressa* (Pursh) Britton and a species of *Oscillatoria*.

5. On these Plains there is a cycle of succession which alternately advances and retreats with periods of rain and drought.

6. The animal life, like the plant life, is made up of a small number of peculiar species, but unlike the plant life there are large numbers of individuals present. The terrestrial vertebrate life out on the Plain proper consists of two birds, the Least Tern and Snowy Plover. A fish

Plancterus kansae (Garman) and at least one copepod, *Marshia albuquerquensis* Herrick are typical aquatic forms. The terrestrial invertebrate population is characterized by an enormous number of very small burrowing staphylinid beetles, *Bledius* sp. Tiger beetles of a number of species also characteristic.

7. The Salt Plains proper may be termed a *Bledius-Cicindela-Oscillatoria* association. On the islands and on the adjoining mainlands we find an *Orthoptera-Dipodomys-Andropogon* community.

8. A comparison of the Cherokee and Edith Salt Plains may be given as follows: (Cherokee data are listed first in each case).

a. Area 43 square miles; 12 square miles.

b. Salt content low, not of commercial value; high, used commercially.

c. Invertebrate population high; considerably smaller.

d. No brine streams; two large brine streams and two creeks.

e. Many large islands; few small islands.

f. Many patches of *Sesuvium;* very few patches of *Sesuvium.*