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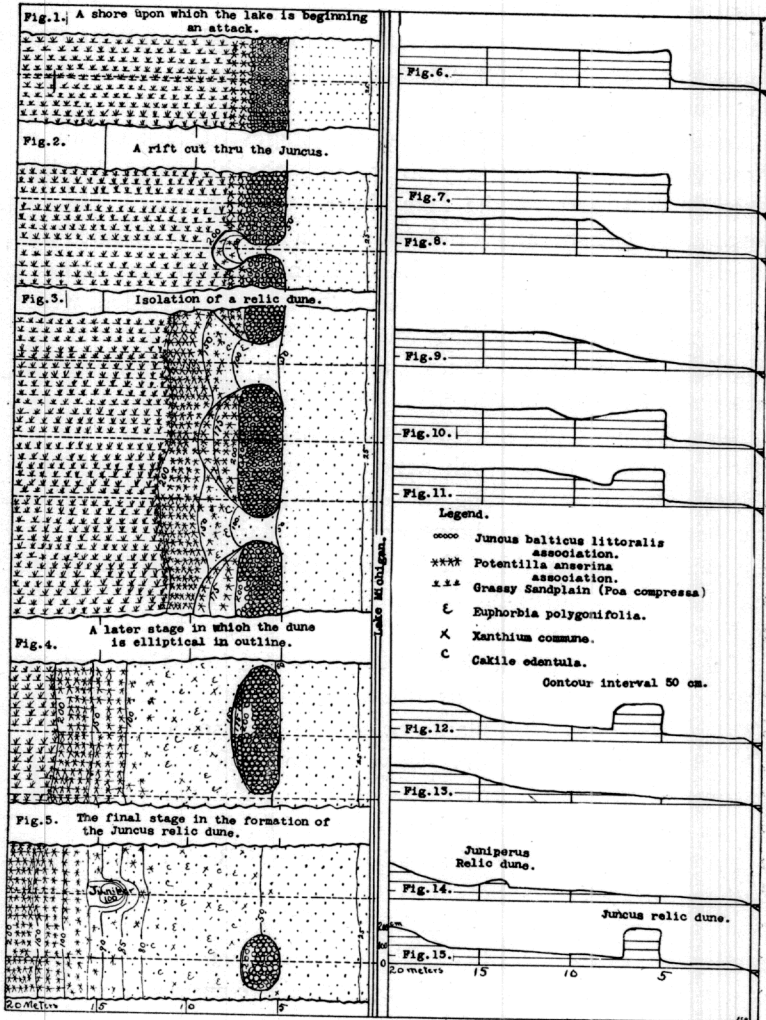
RELIC DUNES, A LIFE HISTORY.

A relic dune is a mound of sand left for a time during the washing away of a beach. It is but a temporary stage even when well protected by an efficient plant covering. The relic dunes with which this article deals are to be found along the

western shore of Lake Michigan from Kenosha, Wisconsin, down to the Illinois-Wisconsin state line. In that locality the shore is being gradually washed away by the action of Lake Michigan. The dunes were studied during 1908 and 1909, during which time the complete stages of destruction of some of the dunes were observed.

To explain the formation and the stages of destruction of these dunes, it is necessary to go into the historical development of this part of the lake shore. This beach is the exposed lake bottom and sand bars of a glacial Nipissing lake which preceded the present Lake Michigan and was from 3 to 17 meters above it in level. Since the low-water period, which ended about 1896, the rising waters of the lake have been cutting into the beach in places and carrying the sand along the beach toward the southwards. From Winthrop Harbor north to Kenosha is a place where the shore is being washed away fairly rapidly. When such action commences, there is usually a bluff formed at the line of contact of the storm waves and the beach. The bluff, however, is maintained by plants, for the sand of which the soil is composed will not of itself remain in such a position. The profile of such a beach is shown in Fig. 6 of the diagram.

The plant association that is all important in maintaining the bluff is the *Juncus balticus littoralis* association. From 97 to 99% of the individual plants belong to that species of *Juncus*. The rhizomes form a very dense tangle, which not only helps to protect the beach from the attack of the waves, but also serves to protect the sand from desiccation, for dry sand forms a gradual slope instead of an abrupt bluff. Back of the *Juncus balticus littoralis* association is the *Potentilla anserina* association, a narrow zone, separating the *Juncus* from the grassy sand plain which stretches back for many meters. As was the case with the *Juncus* association, the facies comprises more than 80% of the *Potentilla anserina* association. The secondary species which make any showing whatsoever are *Monarda punctata*, *Sporobolus cryptandrus*, and *Cenchrus carolinianus*. Both of these grasses usually occur in the tension zone between



Diagrams showing the development of a relic dune.

this association and the grassy sand plain. This later association is composed of over 90% of *Poa compressa*, which, however, does not grow sufficiently thick to prevent the sand from giving the color tone to the area. Secondary species appear scattered throughout, but they are never of much importance, as they occur only as individuals here and there in the grass. Some of the most frequently occurring secondary species are:

<i>Euphorbia corollata</i> ,	<i>Poa pratensis</i> ,
<i>Verbena hastata</i> ,	<i>Rumex acetosella</i> ,
<i>Erigeron canadensis</i> ,	<i>Achillea millefolium</i> ,
<i>Verbascum thapsus</i> ,	<i>Anaphalis margaritacea</i> .
<i>Cacalia tuberosa</i>	<i>Oxalis stricta</i> ,
<i>Monarda punctata</i> ,	<i>Lobelia spicata</i> ,
<i>Pycnanthemum virginicum</i> ,	<i>Scutellaria parvula</i> ,
<i>Panicum (?pseudopubescens)</i> ,	<i>Hypericum kalmianum</i> ,
<i>Isanthus brachiatus</i> ,	<i>Potentilla arguta</i> .
<i>Erigeron divaricatus</i> ,	

The most important secondary species of this association from the view-point of this article are *Juniperus horizontalis* and *Juniperus communis depressa*, because they are the only secondary species that can form relic dunes. There are a few mats of each of these junipers at intervals in the sod. These together with the *Juncus balticus littoralis* are the only species which, in this region, are instrumental in the formation of relic dunes.

With this brief consideration of the physiographic appearance of the region and the plant associations which occupy it, the steps in the formation of the relic dunes are now in order. In places where in every storm, not merely the more violent ones, the waves attack the bluff, sooner or later passageways or rifts will be cut thru the *Juncus* association. This allows undermining of the sand plain, whose surface is sparsely covered with vegetation, the roots of which have but a very limited sand-binding capacity. Consequently the plain is washed away as far as the waves have power. A few of the stages that follow are shown in the accompanying plate, in which the structure of the surface is shown on the left, and on the right selected profiles have been constructed.

The sand from immediately to the landward of the *Juncus*

is carried into the lake in the backwash of the waves, thus leaving a mound of sand, thoroughly permeated with *Juncus* rhizomes and usually having a coat of exposed rhizomes, which become dry under the desiccating action of the wind and sun.

At first the relic dunes are elliptical in shape, with their major axis parallel with the shore line. By washing away the ends, however, succeeding storms reduce them to an approximately circular outline. In this form they may endure for a couple or more years, depending upon the violence of the storms.

The relic dune itself is a mound of sand about 2 meters high and about 2.5 meters broad. At the top is a very dense growth of *Juncus balticus littoralis*, whose rhizomes thoroughly permeate the dune. At the outside the exposed rhizomes, which usually form a rather dense matwork, protect the dune from both the desiccating and mechanical effects of the wind. From the attack of the waves the rhizomes are of relatively smaller value. The sides of the dunes are cut out in grooves, especially near the bottom where the wind and wave action is more pronounced. A few secondary species occur on the cap, such as *Sporobolus cryptandrus*, *Cornus stolonifera*, *Calamovilfa longifolia*, and *Salsola kali tenuifolia*, but the number of individuals is so small that they are of relatively no importance.

The *Juniperus communis depressa* relic dune, of which at the present writing there is only one in the area, is a poorly developed dune near the limit of wave action. The roots of this plant have not the sand binding power that those of the *Juncus* have. Consequently any exposed sand would be blown away. As the sand is removed by blowing or otherwise, the outermost branches of the juniper sink down and cover the sides of the mound with vegetation which protects it in quite a fair measure from much further action by the wind. Toward the west or landward side the prevailing westerly winds keep piling up sand faster than the juniper can cover it up. Within the next few years, if the present rate of erosion continues, there will be seven or eight more relic dunes of both species of juniper, at which time a better understanding of this class of relic dunes will be possible.

The destruction of the relic dunes takes place thru the same agencies that were instrumental in their formation. The wave action during violent storms is one of the most potent agencies of destruction, both because of its mechanical force and the ready movement of sand grains when submerged. The wind in general acts as a desiccating agent, but obtains direct action where the sides of the dunes are unprotected. As the surface dries, the outside grains no longer stick to the moister ones within, but either fall to the base of the dune because of gravity, or are blown away by the wind. This method of destruction is very slow because the dunes are abundantly supplied with water by capillary attraction from the water table, by spray blown in from the lake, by the quite frequent rains of this region, and by dew which is often deposited upon them during the nights when the sand cools down much faster than the surrounding air.

A more violent, though rather infrequent agency, is the disruptive power of freezing water. In instances of the action of this agency in 1909, the dunes were thoroughly soaked by a heavy rain, which was followed immediately by a drop in temperature from 0.5° to 12°C, the result of which was the cracking of the dunes. The broken pieces were like rocks on account of the ice, but as soon as the ice at the surface evaporated, the wind scattered the loosened sand grains over the surface of the beach. Several of the smaller relic dunes were thus disintegrated during November 1909. The larger dunes merely suffered the removal of 10-20 cm. of sand from around the edge of the crown. The vegetation of the rim slipped down and now serves to protect the dune during the winter.

In the part of the area which has been under consideration, the lake is advancing upon the shore rather rapidly, so rapidly that the *Juncus*, even with its relatively rapid means of vegetative propagation, has been unable to retreat. It merely holds the ground upon which it had formed a zone parallel to the shore line. Consequently, as soon as the *Juncus* relic dunes are destroyed, the *Juncus* association will become non-existent in this particular area. The *Potentilla anserina* association, on the

other hand, spready by seeds as well as vegetatively. It has widened out from a strip 0.5-1.0 meters wide back of the *Juncus*, to large mats 5 to 7 or more meters in diameter, which occupy the sand area between the relic dunes and the grassy sand plain. The maximum development occurs just below the grass. Where it overlaps into the grass the vegetation is noticeably heavier than in either of the two associations. This is aided by a few secondary species, especially *Sporobolus cryptandrus* and *Monarda punctata*. The grass (*Poa compressa*) forms a permanent vegetative covering, but the *Potentilla* dries up during the winter. During the growing season much blowing is prevented by the covering of *Potentilla*, but with the removal of this in the fall the blowing of sand commences, and during the winter the amount that is blown away is noticeable. Much of it tends to accumulate southward of this area.

From the state line south to Winthrop Harbor the shore dips away from so direct an attack from the waves. Here the *Juncus* is able to retreat from the shore line, and although relic dunes still are being formed, there is still a relatively wide zone of *Juncus* behind them which protects the grassy plain from being washed away.

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