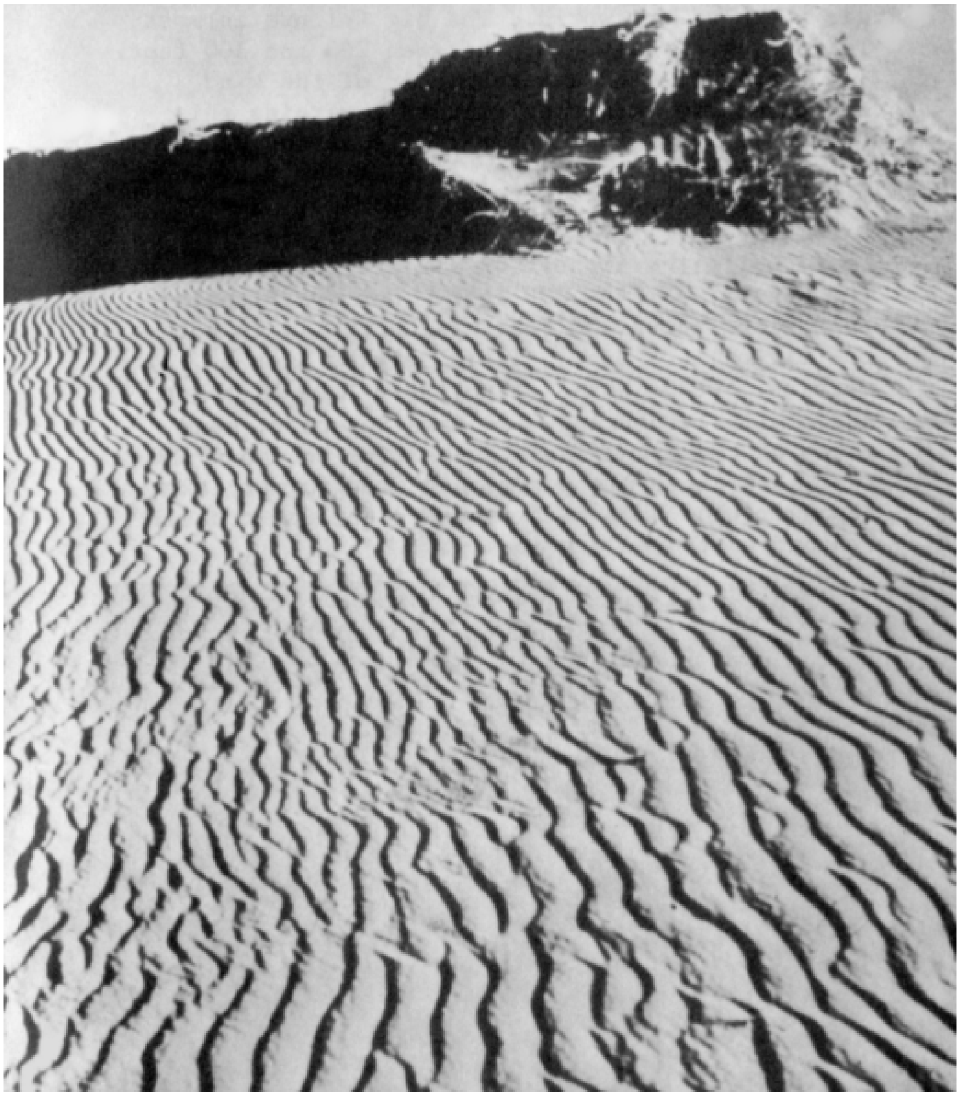
GEOLOGICAL SKETCH of MICHIGAN SAND DUNES



Geological Survey Division
Pamplet 5

By Robert W. Kelly, Lansing, Michigan

The object of a preface to any publication is to reveal its purpose and to give reasons for its appearance.

-- Alvah Bradish (1889)

PREFACE

The increasing number of requests for general information on sand dunes, indicates that more and more people are beginning to discover, or re-discover, that Michigan has some truly unusual, if not remarkable, dunelands. This pamphlet is intended for those who wish to gain an acquaintance with both the occurrence and the geology of these interesting features on our landscape.

The initial version appeared as an article "The Dunes" in the July 1962 issue of Michigan Conservation. Later that year, a more detailed account Michigan's Sand Dunes--a geologic sketch was published as an unserialized pamphlet, and subsequently reprinted many times.

The present version has been re-styled, re-arranged, and serialized, but with only minor revision of text and illustrations.

"This, too, will pass"

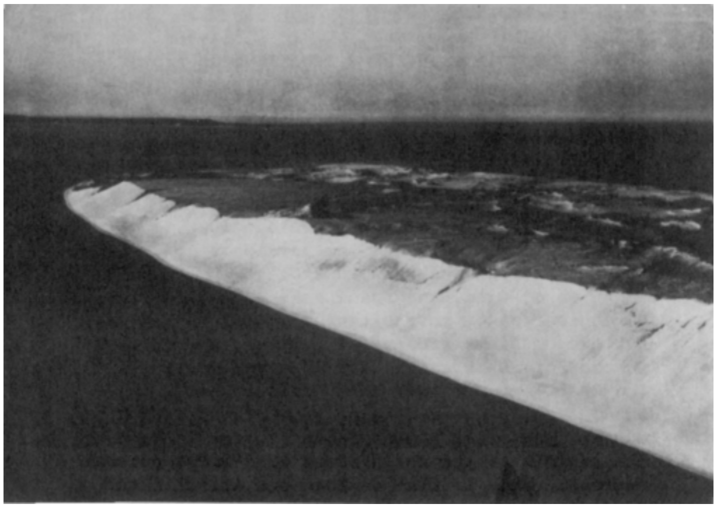
OCCURRENCE

Sand dunes are one of the most striking features on Michigan's landscape. Furthermore, dunes are by far the youngest of our hilly features. Many rocky hills in the Upper Peninsula are millions of years old--a few perhaps more than a billion years. Yet our oldest sand dunes, those found scattered inland in Michigan, are little more than 10,000 years old, while the most prominent of all, the great coastal massifs along our Great Lakes shore (see center-spread map), date back a mere 3000 or 4000 years. Even the man-made Pyramids of Egypt are older than this. Intriguing, isn't it?

There are many types of dunes. Actually, a dune is any heap of loose, very small mineral fragments that wind has piled up 10 to 20 feet or more. They grow, in many ways, like snow- drifts. Once formed, they tend to keep growing. Most always, dunes are made of quartz sand, but some are not, like the gypsum dunes in New Mexico and the calcite dunes in Bermuda. As a matter of fact, there are even clay dunes along the Gulf coast.

Dunes occur wherever there's enough sand, enough strong wind going one general direction, and a place for the sand to stop and pile up. Thus, sand, wind, and space make for dunes; and dunes are found, most often, in very dry regions. But even deserts are not all dunes. Only a minor portion of the great Sahara is dune-covered; and the most barren of all great arid regions, the Saudi Arabian desert, is only one-third sand dunes. Dunes also occur in the humid and temperate regions of the world along wind-swept coastal regions. This is true on both our Atlantic and Pacific coasts and--not so well known--on the coasts of southern Alaska and western Greenland.

Late afternoon flight over Sleeping Bear dunes. Profile of the Sleeping Bear on the horizon



Sleeping Bear dunes viewed aloft from Lake Michigan. North Manitou Island on horizon at left.

Besides accumulating and being sorted on coasts, sand is also created by winds breaking down all manner of rocks into sand-size particles.

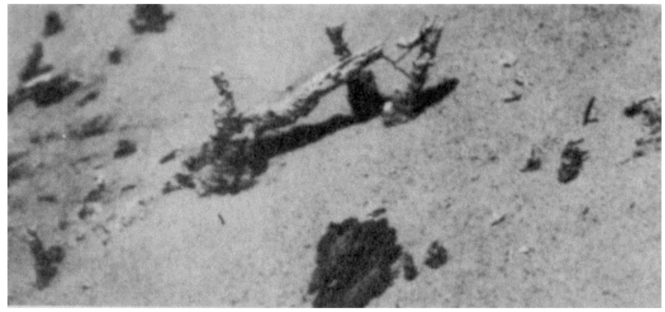
GLACIAL DRIFT

But in Michigan, where did all this sand come from? For the answer, we must turn a moment to one of the most fascinating chapters in all geological history--the great Ice Age.

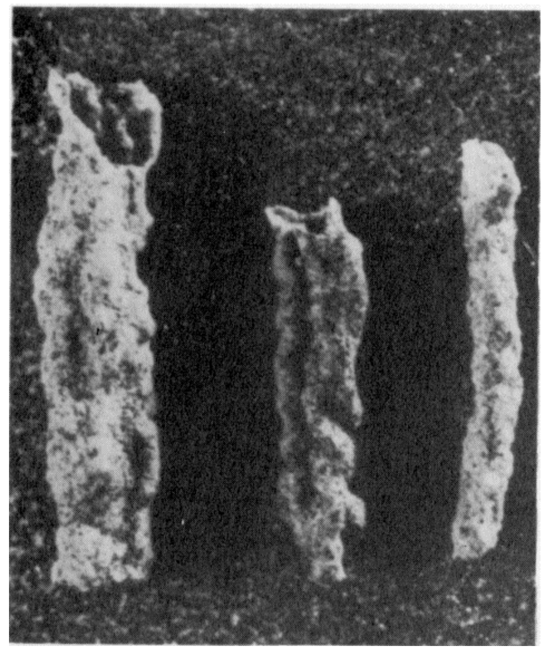
Beginning perhaps 1,000,000 years ago, four great continental glaciers successively scraped across the face of Michigan and a great part of the Midwest. Then each, in its turn, melted back toward the Hudson Bay region. As they advanced southward the glaciers picked up huge quantities of rock debris. The ice was a mile or more thick and locked immense amounts of boulders, sand, clay, and soil in its grip. As it melted, all these materials were deposited on the earth's surface. All materials left by the glacier are called drift and in some places the drift in Michigan is over 1000 feet thick. The average thickness, however, is probably 200 to 300 feet.

Glacial drift is unlike any other geologic deposit because it contains so many different kinds and sizes of rock materials. In some places these materials were washed, sorted, graded, and stratified by melt water. In other places a heterogeneous mixture of materials was deposited directly from the ice without sorting at all, as in the case of moraines--systems of low rounded hills ranged throughout the state.

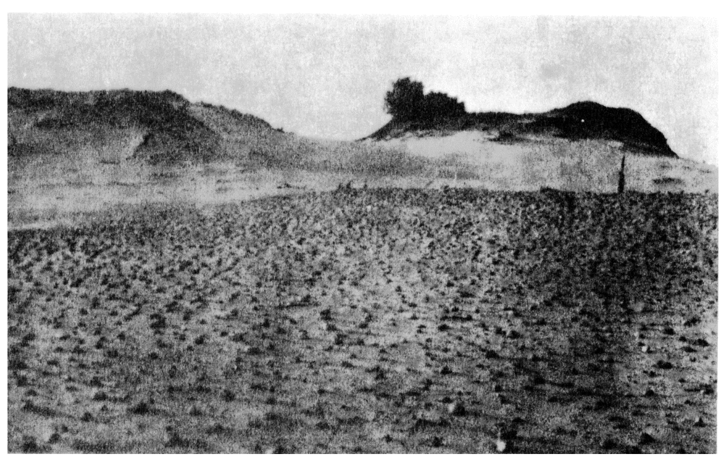
As to the source of sand in most of our dunes, practically all of it comes from drift along shorelines and the near shore beds of the present Great Lakes. Many inland dunes in Michigan are situated on glacial outwash, but many are also associated with earlier lakes.



Lime tubes. Ground water circulating through dune sand may dissolve lime constituents and precipitate them around plant stems and roots. Silica and iron may also be deposited much the same way.



Fulgurites--Tube-like dendrites of natural glass fused from loose sand when struck by lightning.



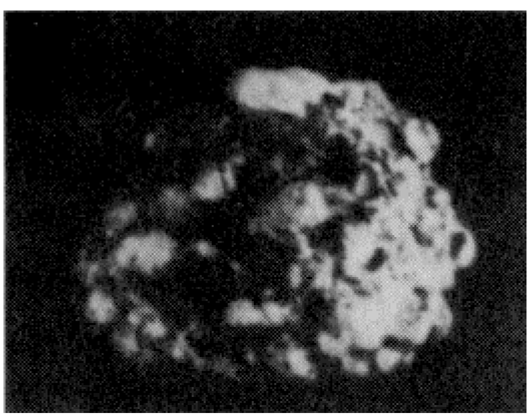
Lag gravel, or pebble armor surface--when fine sands are blown away, stones "lag" behind.

SAND AND SHORE LINES

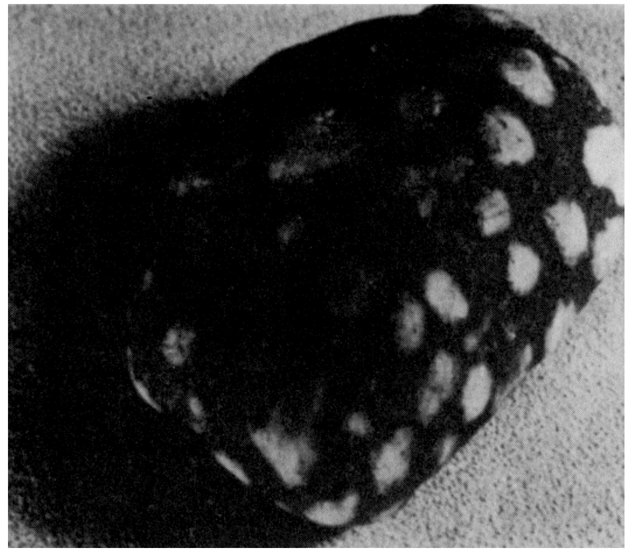
Sand and pebbles gather along shorelines because wave action sifts and sorts granular materials very thoroughly. The fine silts and clays are taken into suspension and carried lakeward and finally settle out in undisturbed deep water. Some of the pebbles and boulders are buried by the sand. Sand particles of a definite size-range are too heavy to be transported lake- ward by water action and, therefore, remain more or less in the shore zone. Meanwhile, shore currents are continually moving sand parallel to the shore, thereby often forming spits across embayments.

Perhaps you have wondered why so much of our sand is quartz. Studies show that it runs about 90 percent quartz, or silicon dioxide, with the rest being a mixture of other minerals, including epidote, garnet, magnetite, hornblende, calcite, ilmenite, orthoclase, tourmaline and zircon. Why? For one thing, silicon and oxygen, that make up quartz, are the two most plentiful elements, by weight, in the earth's crust--silicon comprising 25 percent and oxygen, 50 percent. Occurring together as silica, or free quartz, they are the main elements of common rocks as granite, conglomerate, sandstone, and quartzite-- all commonly found in the drift covering Michigan.

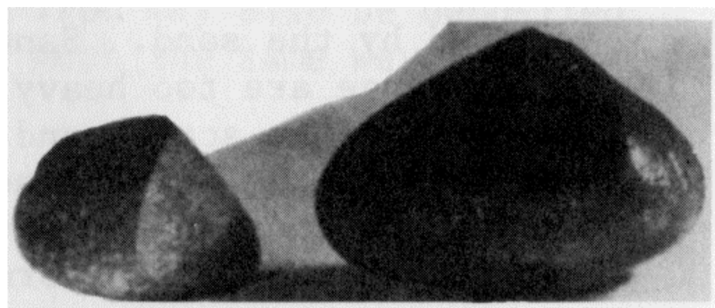
In addition to being abundant, quartz is hard, exceedingly stable, and does not readily combine chemically with other elements and minerals. Some geologists believe a lot of sand grains in existence today have gone through untold cycles of rock formation and breakdown and re-formation into new rocks without much alteration of the sand grains themselves.



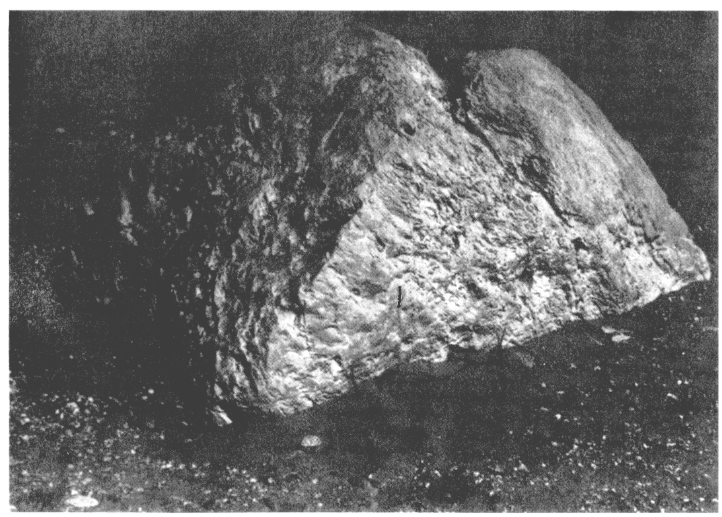
***VENTIFACTS** -- stones shaped by wind. Granite pebble with quartz crystals etched in relief.*



Basalt cobble with feldspar crystals etched in relief.



Winkanter -- wind-facetted stones on which two or more intersecting faces form sharp ridges.



Huge limestone boulder on the wind-swept

DRY BEACHES

Wave and current action concentrate sand along shorelines. From these source areas, dunes can begin to form in a particular way. If a beach remains damp, the wind can't move the sand. Only when sand is dry is it loose enough to blow about. To make a wet beach dry, the water level must drop, and this has been happening in a general way over the centuries to all the post-glacial lakes. Thus, formation of dunes is tied to the long range lowering of water levels.

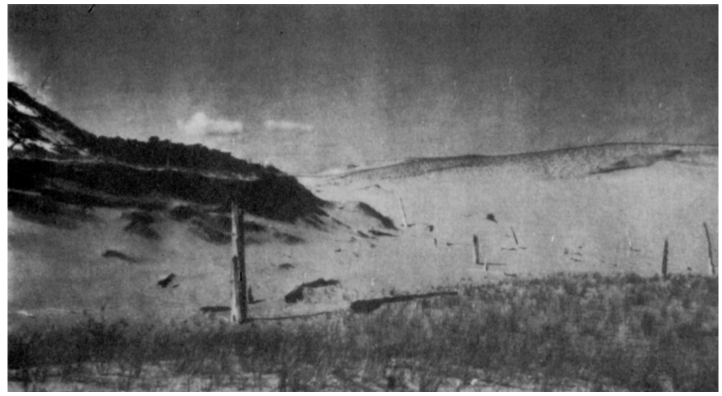
Another way in which beaches become dry is through year-to-year changes in water levels. Some years the Great Lakes are five to six feet higher than in other years, even though the average lowering over a full century may be very slight. Still, these year-to-year changes do expose much sand to the wind. Although the causes of annual variations are not completely understood, rainfall is surely an important factors. These fluctuating levels, therefore, insure ever-changing shore lines. Wet beaches and offshore bars emerge during low water and are exposed in the wind. During high water all shore materials are reworked by water action.

Another reason shorelines are rising--and thus offering sand to wind action--is because of a process called crustal rebound. The tremendous bulk of the glaciers actually depressed the earth's crust in the Great Lakes region. As the ice melted away, the earth's crust began an upward recovery that is still going on. This is true in a moderate way in the northern half of Michigan, but in northern Ontario, the rebound amounts to hundreds of feet.

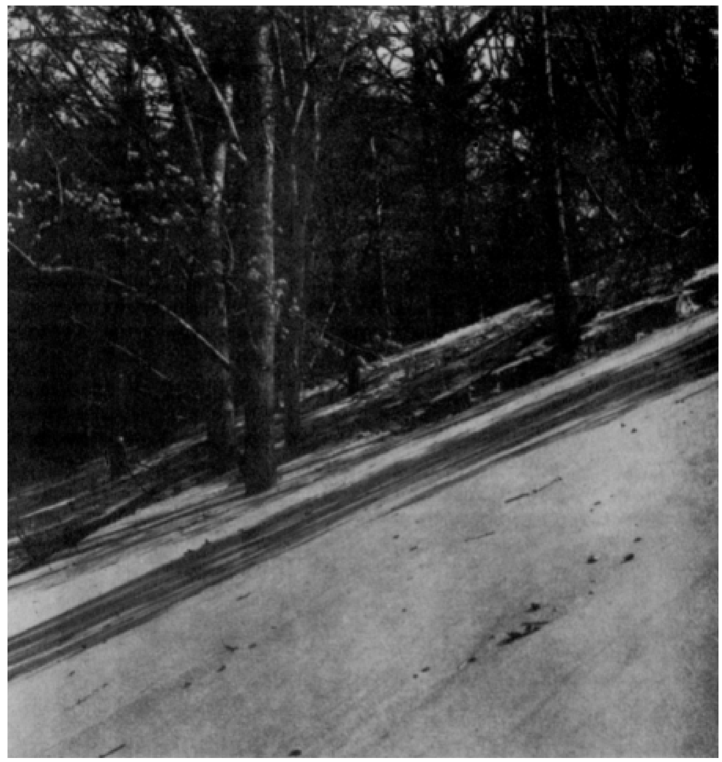
THE WIND

Thus, for whatever causes, sand comprising our coastal dunes was blown inland from the beaches. Strong winds frequently blow toward shore along most all exposed coasts regardless of prevailing regional winds. As landmasses heat up they draw cooler air from adjacent water bodies. Coastal dunes, therefore, are not necessarily the product of prevailing winds, but the result of effective local winds blowing roughly at right angles to the shore. However, the greatest dunes of the entire region occur along the east coast of Lake Michigan because the prevailing Westerlies gather added energy as they fetch across this unbroken expanse of lake.

How much wind is required to move sand? The threshold at which sand begins a slight movement is 7-8 miles per hour. A gentle breeze of 8-12 mph can roll fine sand but no real movement of medium size grains begins until about 20 mph. Strong breezes of 25-31 mph can move coarse grains of about 1 millimeter (1/25 inch), and a gale of 39-46 mph can temporarily lift sand well over 100 feet into the air. Hurricane force winds exceeding 75 mph can roll 2- to 3-inch pebbles and cobbles.

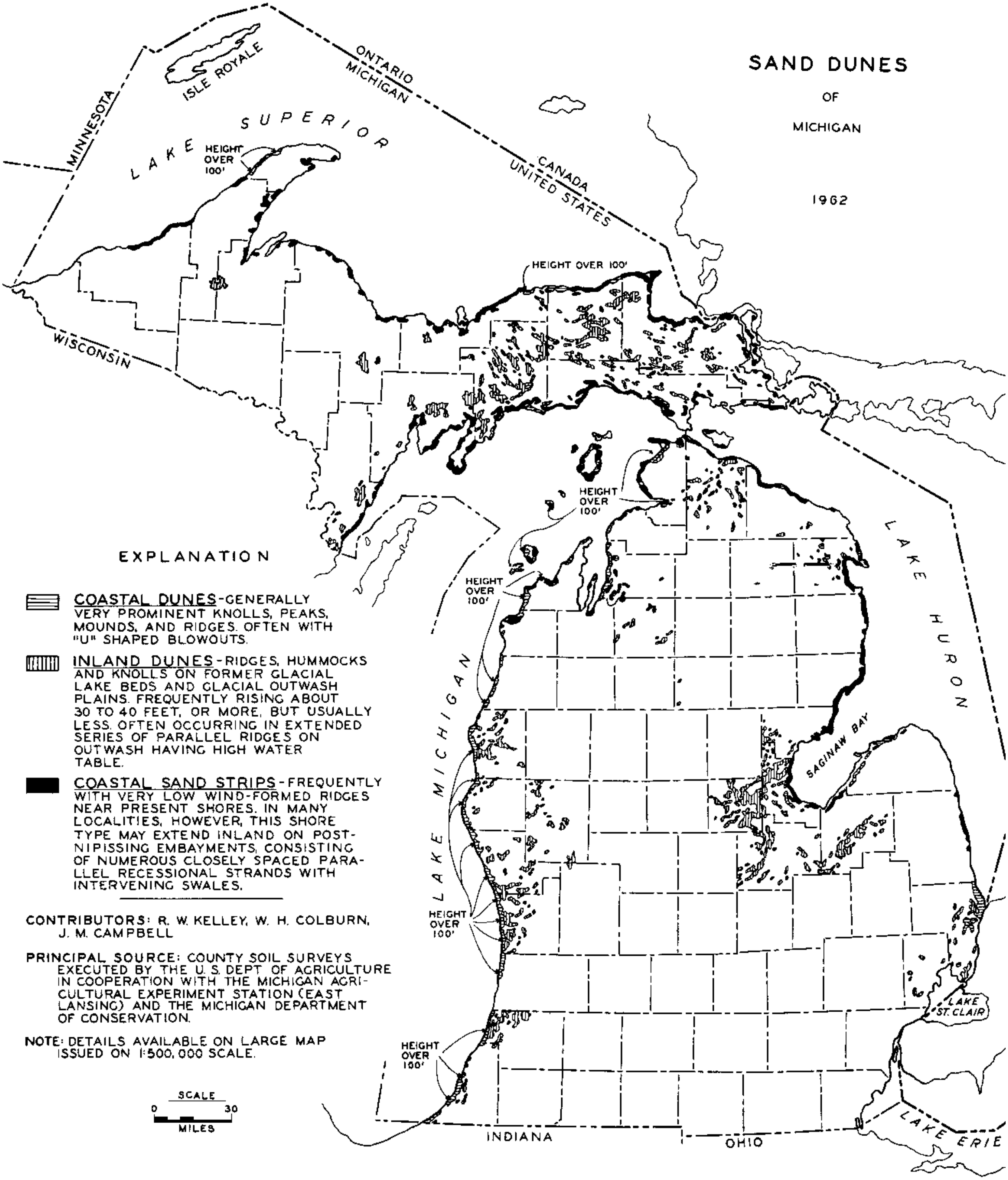


Relics of an ancient forest stand being exhumed in a blowout. Pyramid Point area, Leelanau County.



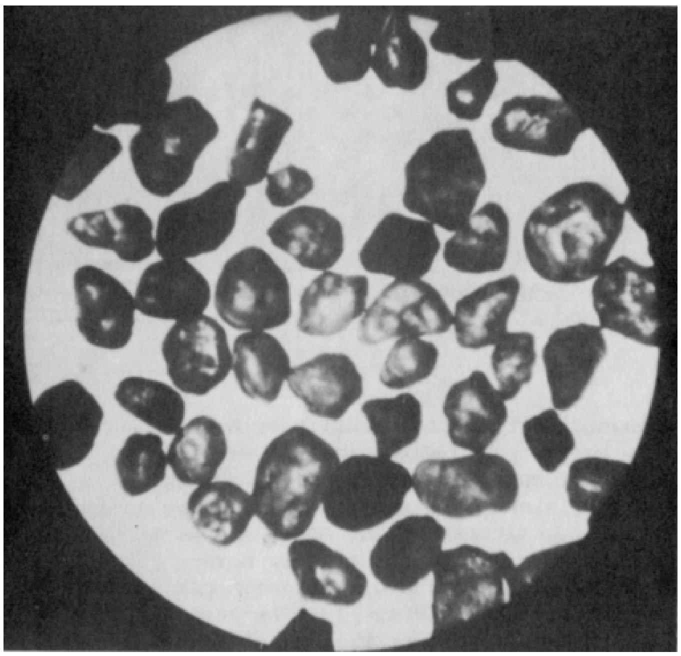
Not a giant snowdrift, but sand overwhelming a hardwood stand in the Holland area, Ottawa County.

Wind-blown sand travels primarily by a process known as saltation in which individual grains move in a jumping, skipping, bouncing fashion through violent collisions. Bagnold, a British physicist, calculated that saltation accounts for about 75 percent of the grain movement of dunes. The other kind of motion is called, surface creep--traction, sliding, pushing and rolling. In any event, sand particles seldom get more than a foot or two off the ground. But they can be very abrasive, easily cutting wood and metal poles, softening the sharp edges of broken glass, and faceting hard pebbles and boulders (see ventifacts illustrated on page 6).


SAND DUNES
OF
MICHIGAN
1962
LAKE SUPERIOR
ISLE ROYALE
MINNESOTA
ONTARIO
MICHIGAN
CANADA
UNITED STATES
WISCONSIN
HEIGHT OVER 100'
HEIGHT OVER 100'
HEIGHT OVER 100'
HEIGHT OVER 100'
HEIGHT OVER 100'
HEIGHT OVER 100'
LAKE MICHIGAN
LAKE HURON
SAGINAW BAY
LAKE ST. CLAIR
LAKE ERIE
INDIANA
OHIO
EXPLANATION
COASTAL DUNES - GENERALLY VERY PROMINENT KNOLLS, PEAKS, MOUNDS, AND RIDGES. OFTEN WITH "U" SHAPED BLOWOUTS.
INLAND DUNES - RIDGES, HUMMOCKS AND KNOLLS ON FORMER GLACIAL LAKE BEDS AND GLACIAL OUTWASH PLAINS. FREQUENTLY RISING ABOUT 30 TO 40 FEET, OR MORE, BUT USUALLY LESS. OFTEN OCCURRING IN EXTENDED SERIES OF PARALLEL RIDGES ON OUTWASH HAVING HIGH WATER TABLE.
COASTAL SAND STRIPS - FREQUENTLY WITH VERY LOW WIND-FORMED RIDGES NEAR PRESENT SHORES. IN MANY LOCALITIES, HOWEVER, THIS SHORE TYPE MAY EXTEND INLAND ON POST-NIPISSING EMBAYMENTS, CONSISTING OF NUMEROUS CLOSELY SPACED PARALLEL RECESSIONAL STRANDS WITH INTERVENING SWALES.
CONTRIBUTORS: R. W. KELLEY, W. H. COLBURN, J. M. CAMPBELL
PRINCIPAL SOURCE: COUNTY SOIL SURVEYS EXECUTED BY THE U. S. DEPT. OF AGRICULTURE IN COOPERATION WITH THE MICHIGAN AGRICULTURAL EXPERIMENT STATION (EAST LANSING) AND THE MICHIGAN DEPARTMENT OF CONSERVATION.
NOTE: DETAILS AVAILABLE ON LARGE MAP ISSUED ON 1:500,000 SCALE.
SCALE
0 30
MILES

THE GRAINS

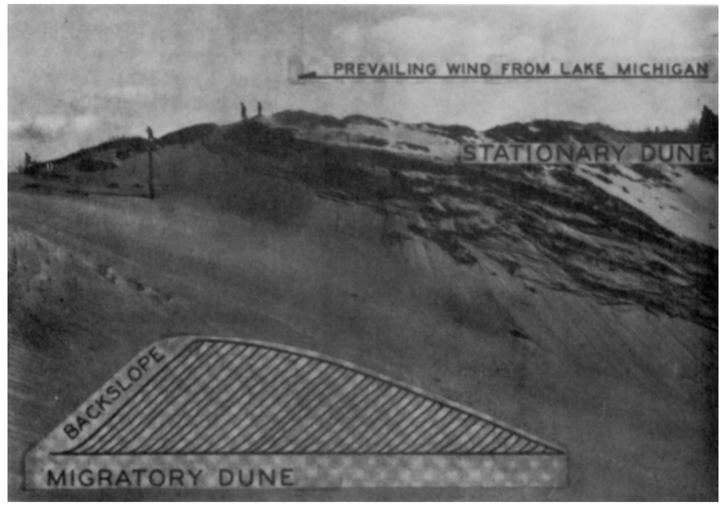
How about the shape and size of sand grains in Michigan coastal dunes? The sand has already been selectively sorted by water processes along the shoreline. Wind, too, does an additional classifying job, so that, in the end, about 80 percent of the grains range from 1/100 to 1/50 of an inch in diameter, with only a small percentage exceeding 1/25 inch. Less than 15 percent is finer than 1/100 inch. The finest materials, silts and dust, are taken into suspension and deposited elsewhere. Dune sands are generally clean and well sorted, with very little clay or coarse material. The grains are characteristically more rounded and frosted than water-sorted grains, but these qualities are not always apparent even under magnification.



X25 magnification shows the predominance of rounded and frosted grains in dune sand. (Sample from Muskegon area, courtesy Standard Sand Co., 1962)

DUNE ORIGIN AND STRUCTURE

Exactly why and how the first grains of sand begin to pile up to make a dune is still unanswered, but most likely some slight obstruction, as vegetation, can start the process. At any rate, once a hummock is formed, the wind drives the sand grains up the windward slope to the crest. At the crest the grains are freed by the wind to tumble down the steeper backslope. On active dunes free of vegetation, the windward slope is gently inclined upward at 10-20 degrees although where cut by waves, the angle is much steeper. The lee slope, out of the wind, generally varies from 15-25 degrees and is rarely more than 30-35 degrees--the normal angle of repose of dry sand. Differences depend on the quantity of sand, its coarseness, rate of deposition, and moisture content.



The gently-inclined bedding on the windward slope of this large dune near Grand Haven is a clue to its stationary character. Such bedding cannot develop on the windward slope of a migratory dune because sand grains are in transit on that surface, to be deposited in more steeply-inclined layers on the backslope.

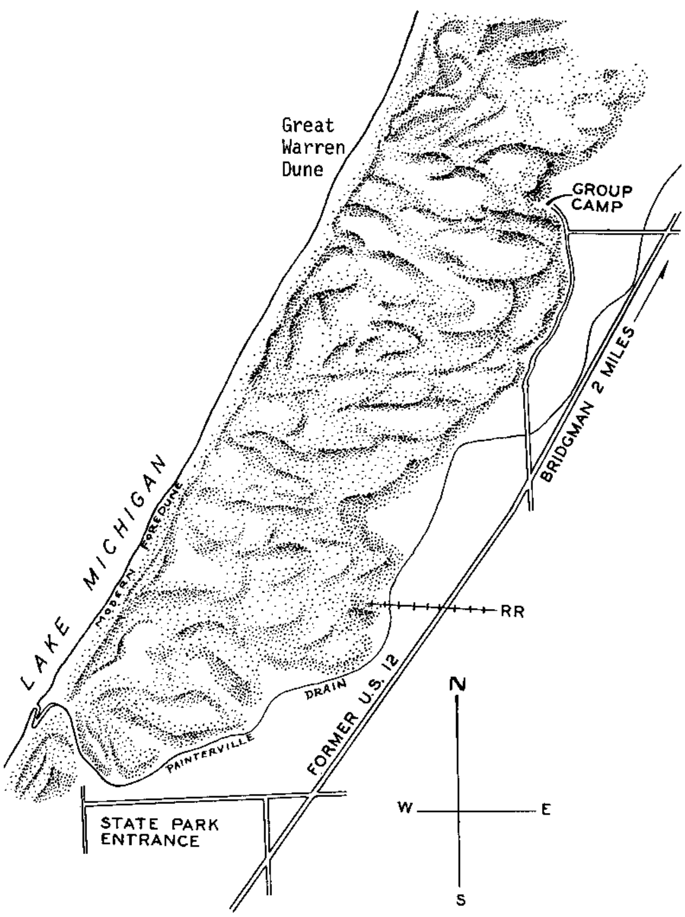
DUNE TYPES

Several kinds of dunes occur in Michigan, and they differ sharply from those of arid regions. Probably the most significant differences are caused by plants, especially grasses, which keep pace with the sand continually accumulating about them. In other words, the sand cannot overwhelm the grass.

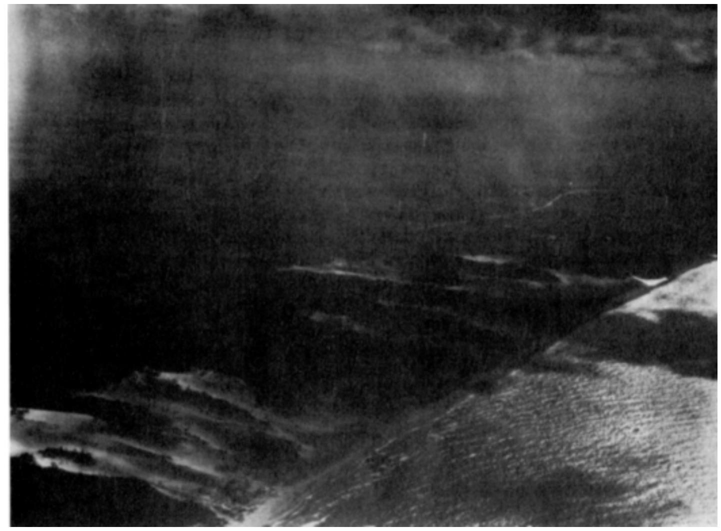
The most common type of dune found along our sandy coasts is the foredune, situated immediately adjacent to the beach and parallel to it. Seldom higher than 30-50 feet, the foredune is usually much less. It is the first ridge to form when the sand escapes from the beach or source area.

Whenever plants on the foredune are injured or destroyed, the wind has access to the raw sand and creates a blowout, a saddle-shaped breach in the ridge, through which the sand commences a march inland. Many blowouts change the foredune into a very irregular feature called a dune ridge. Further extension of blowouts develops a very pronounced U-shaped dune topography typical of humid coastal areas--unlike anything seen in arid deserts. Some of these dunes along southern Lake Michigan attain heights exceeding 250 feet and may stretch inland from the beach for one-half mile or more.

Typical coastal foredune with windward slope notched by recent storm waves, but stabilized by roots. (top left) Huge blowout in Great Warren Dune. Looking inland from foredune.(bottom right)



"U"-shaped dune topography at Warren Dunes in Berrian County.

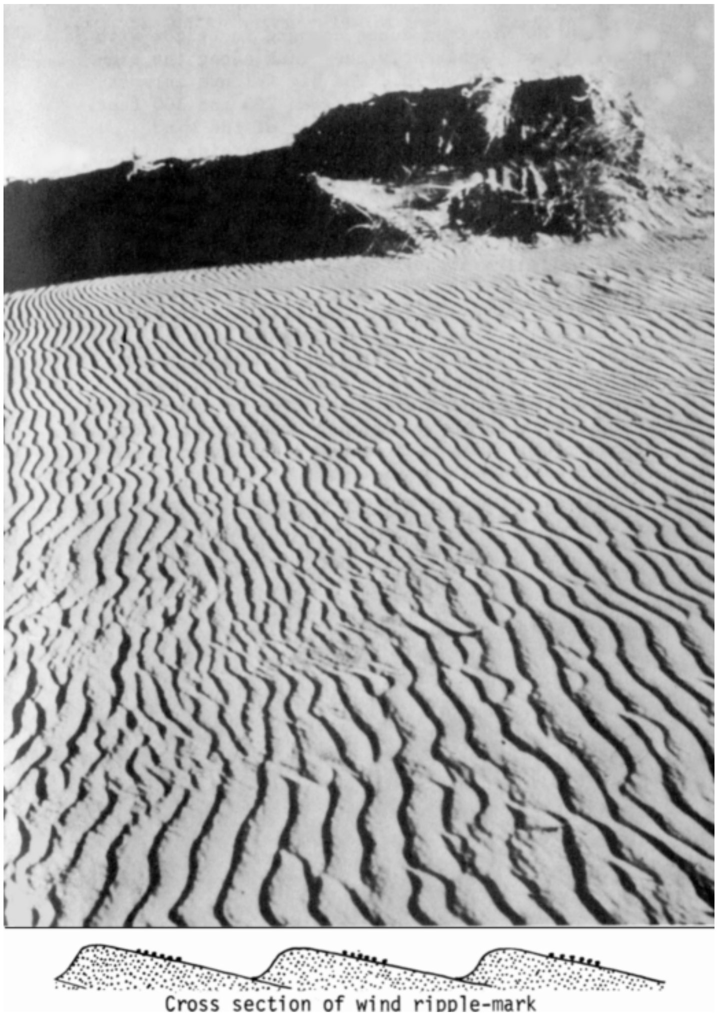


"U"-shaped dune topography along Lake Michigan at Warren Dunes State Park. The Great Warren Dune is in lower left corner.

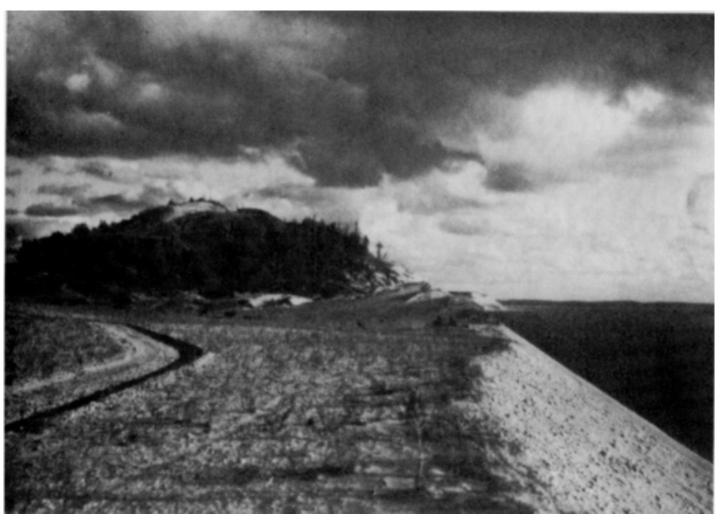
Very few dunes in Michigan can be classed as truly migratory. Some are growing, thus appearing to be migratory, but their actual movement is hardly comparable to the migrating barchan dunes of the desert. Several coastal towns have been buried along Lake Michigan, but facts in this connection have grown dim with the passing of time. Also, rates of sand movement vary a great deal from place to place. Some measurements have indicated backslope growth ranging from one to five feet per year. Compare this with a dune in Asia reported to have moved some 60 feet in a single day! Movement varies so greatly that trying to figure a normal rate of dune movement would only be misleading.

HEIGHT

How do Michigan dunes compare in height with other areas? Apparently they rank among the bigger dunes of the world. The big fellows in most regions, they generally range between 200 and 300 feet. The supply of sand and character of the wind doubtless are important factors governing this curious situation--another riddle of the dunes. There are exceptions, too, such as the sand dunes topping 600 feet in southern Colorado. Some in Libya are over 500 feet; in Saudi Arabia, 700 feet; while the highest of all are reported in the Sahara, perhaps 900 feet. Our own Sleeping Bear rises above 450 feet, yet actually is not one big pile of sand. It is perched atop a moraine. Other dunes of northern Lake Michigan are similarly perched. On Lake Superior, sand peaks of the Grand Sable Dunes rise to about 380 feet, but these are positioned atop former lake deposits that have been elevated through crustal rebound mentioned previously.



Ripple-mark--transverse dunes in miniature. Cross section of wind ripple-mark (In water ripple-mark, height is increased relative to length, and, coarse grains congregate in troughs)



Sleeping Bear, perched high on the wind-swept moraine plateau overlooking Lake Michigan.

USES

What is the value of dunes? Certainly, because of their relatively high purity and uniform fineness, many dunes are natural stockpiles of a valuable raw material needed in industry. Their most significant use today is in the foundry business--the making of cores and molds. Most of the sand operations of this type are situated a- long the coast of Lake Michigan, although several inland dune areas in Tuscola County are being ~ for the same purpose. Other commercial uses of our dune sand include: fill material, mortar and plaster, asphalt dressing, locomotive rail traction, furnace lining, abrasives, filters, and fiberglass. But perhaps foremost in the future will be the fun to be discovered in the surf and sand along our dune-fitted shores.

Backslope fun