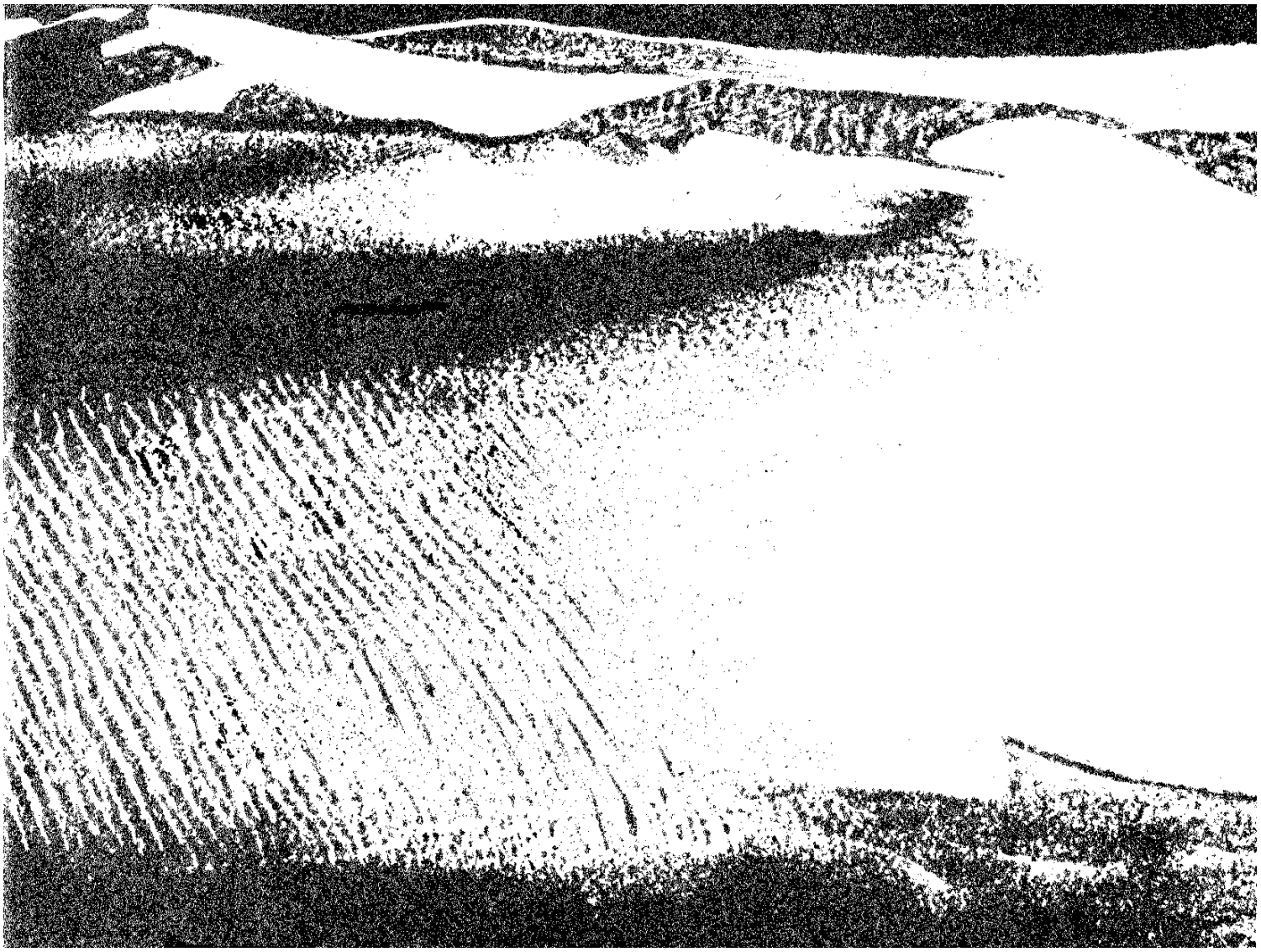
MICHIGAN'S SAND DUNES



Geological Survey Division

Pamplet 7

By Steven E. Wilson Lansing, Michigan

Geological Survey Division

Pamplet 7

AN MICHIGAN'S STUDY OF COASTAL SAND DUNE MINING IN MICHIGAN

By Steven E. Wilson

Lansing, Michigan, 1979, 2000

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INTRODUCTION

More and more, "natural resource" is becoming a household word. Increasingly, we have become aware of the importance of our natural resources and some of the problems relating to wise resource development, management and use. A major point to remember is that some resources are non-renewable. That is, they cannot be replaced, replanted or regrown. In Michigan, one non-renewable resource is commonly overlooked - or even taken for granted. The resource is sand. In particular, sand dune sand. Sand dunes are a natural wonder with beauty and majesty all their own. However, when you know more about the dunes, they take on even greater significance. Once you learn about the complex, dynamic dune ecosystem, you will appreciate dunes even more. Because of the high demand for Michigan dune sand and its unique character it is the subject of many in-depth technical reports. This pamphlet is designed to introduce Michigan's Sand Dunes to you.

WHAT IS SAND?

Before we try to describe a sand dune, we need to know what sand is. This question does not have a simple answer. The designation "sand" does not refer to how the material was formed or what it is made of. Sand can, and does, come from all three major rock types: igneous, metamorphic, and sedimentary. Sand can be primarily one mineral or material, or it can be a mixture. However, in the most general sense sand is considered any loose, granular material having grains which are sand sized. Technically, sand is restricted to particles ranging from 0.0625 to 2.0 millimeters in diameter. That is a vast range of sizes. Many people have tried to define sand more precisely. It should be kept in mind that characteristics of sand may vary greatly within a deposit.

Additional confusion arises because the term sand is used to describe a deposit or area, regardless of particle size. To a geologist the term would be improperly used if 50 percent or more of the grains are not sand size. In summary, it should be pointed out that there are more than 100 terms which apply to sand and sandstone (the major rock formed from sand).

WHAT ARE SAND DUNES?

Sand dunes are mounds of windblown sand which vary greatly in size, from less than one meter to tens of meters high. The size depends upon the supply of sand. There is even greater variation in the area covered by dunes. In Michigan, the smallest dimension is usually the distance from the shore inland. Many of the more recognizable dune forms are ridges or complexes of mounds or crescents. The shape of individual dunes is equally variable. Shape relates to the direction and strength of the wind forming it, as well as to the amount of sand available.

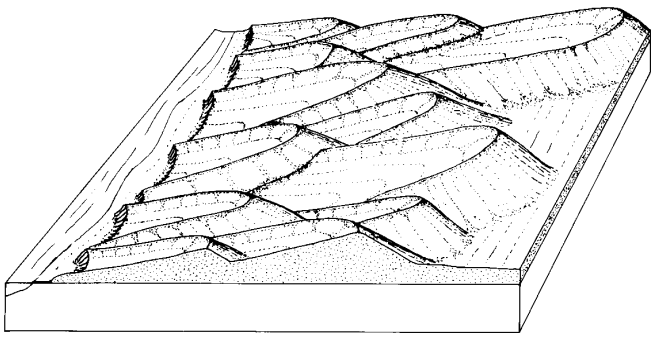
HOW ARE SAND DUNES FORMED?

Sand dunes can and do form in many areas. However, some requirements must be met. Required elements are: I) a source of dry sand, 2) a means to sort and transport the sand, and 3) a land area on which to deposit the sand. Recent studies indicate that a supply of dry sand is the most important factor. The means of transporting and sorting are not rare or out of the ordinary. Running water and normal winds can do this. Strong winds or water action cannot initiate dune formation without a supply of sand. As mentioned, the size and shape of a dune depend on the wind and

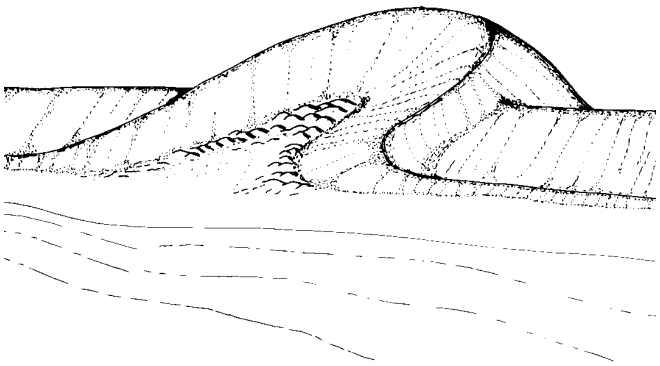
amount of sand available. The amount of sand being equal, wind conditions have a strong influence on the shape of a dune field. Constant winds tend to form more regularly shaped dunes or even long ridges. Irregular or changing wind directions result in irregular-shaped dunes.

The sand making up Michigan's dunes is almost all one mineral - quartz. However, there are dunes elsewhere in the world which are made primarily of other minerals, such as calcite or gypsum. Because sand dunes are wind-laid deposits, they are formed in layers (stratified). Furthermore, the general shape of a dune results in two different sets of beds. There is a gently sloping windward set of beds and a more steeply sloping downwind set. At times, the dunes move or migrate. This movement results in cross-bedding of the sand layers. The cross-bedding found in sand dunes helps geologists to distinguish dune deposits from other landforms.

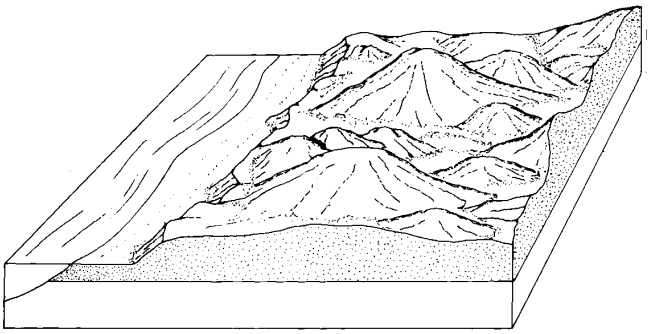
Because quartz grains can form from a number of different rocks, the original source of the quartz dune sand cannot be singled out. It should be noted that relatively few bedrock outcrops occur in Michigan. Instead, glacial drift almost completely covers the State. Therefore, one can safely assume that sand for the dunes comes from the drift. Yet, much of the sand found in drift is mixed with a variety of other particles,



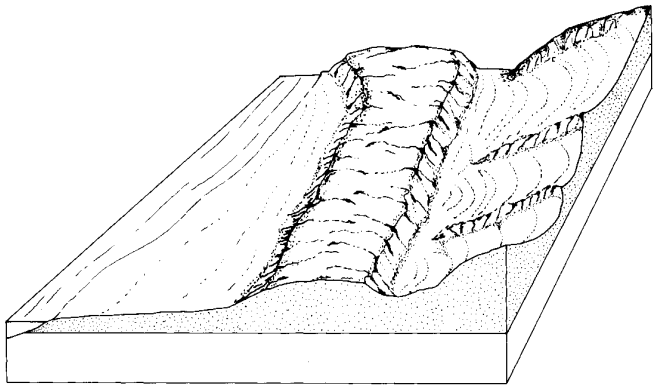
En echelon and overlapping dunes



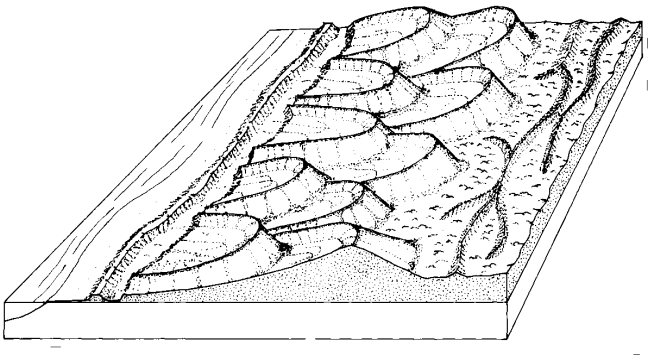
Idealized parabolic dune



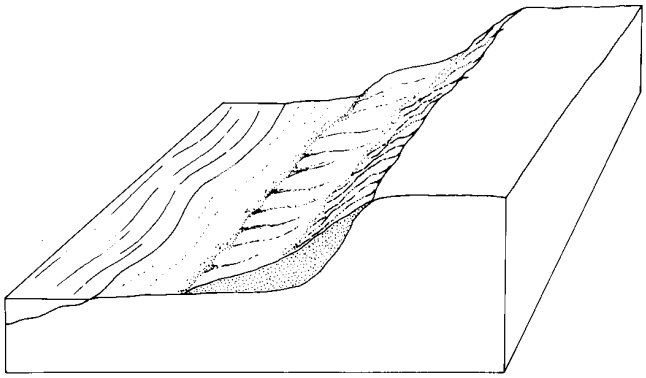
Domal dunes



Dune platform



Association of various dune forms



Overriding dunes

from clay to cobble size. The drift is eroded, transported, sorted and redeposited by water - the running water of a river or the pounding surf of a beach. Water tends to concentrate sand-sized particles in particular areas.

Continued erosion and transportation of sand replenishes the sand blown into the dune. As long as more sand is supplied, the dunes will continue to grow. When the supply diminishes, the dunes are likely to stabilize, or at least stop growing. Places where sand accumulates are numerous in near-shore environments. You may have noticed this along many of the lovely beaches. Sand, if available, accumulates on the beach as well as out into the lake to a varying degree.

The size range of sand grains that make up dunes is remarkably close. This is because grains that are smaller-than-sand-size (silt or clays) are carried farther away by the action of wind and water. Grains or stones that are larger-than-sand-size (pebbles, cobbles, boulders, and the like) are left behind. When enough of the larger materials (usually small to confused with tubes formed around the roots of plants growing on the dunes. An easy test will distinguish a fulgerite from a root cast. Place the specimen in a container of vinegar. If it fizzes and falls apart, it was a root cast. The cementing material was dissolved by the slightly acid vinegar. However, if the specimen is a fulgerite, it will not be affected to any great extent by the vinegar bath.

medium size stones, 10 mm or more) are left behind, a rock pavement or lag gravel is formed. This can effectively stop further erosion of sand. The larger, immobile stones cover the sand, preventing further movement.The dunes leave their inprint on the things around them. One common artifact of the sand dunes is a windkanter or ventifact. Much of the sand moved by wind bounces along very close to the surface. This bouncing movement is called saltation or traction. Sand moving in this manner is very abrasive. The wind carrying its load sandblasts the stones. This results in the development of flattened to slightly rounded, highly polished faces on the stones. One or more faces can develop on a single ventifact. Studies of the orientation of ventif act surfaces help to indicate the prevailing wind directions in a dune field.

Also found in sand dunes are fulgerites. These are tubes of fused sand, formed when lightning hits the sand. The tremendous heat and energy released when lightning strikes the sand welds the grains together. (Temperature exceeds l,700^{0}C.) Fulgerites are rather fragile and hard to find. They are easily confused with tubes formed around the roots of plants growing on the dunes. An easy test will distinguish a fulgerite from a root cast. Place the specimen in a container of vinegar. If it fizzes and falls apart, it was a root cast. The cementing material was dissolved by the slightly acid vinegar.

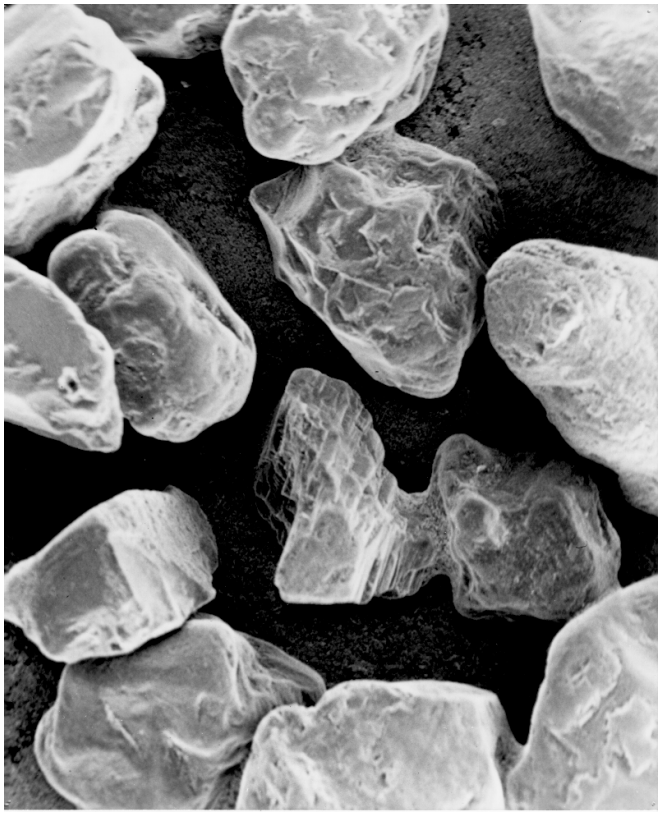
WHERE DO WE FIND SAND DUNES?

In Michigan, sand dunes are found along much of the shoreline of the Great Lakes. The best known and most studied Michigan sand dune areas are along Lake Michigan. Here, the supply of dry sorted sand and a prevailing wind direction toward land lead to dune development. However, close inspection shows that some of the dunes or dune-like structures are not close to today's lake shoreline. These inland dunes reflect previous dune-forming conditions. These dunes are a result of massive ice sheets which covered Michigan, and much of North America, during what geologists call the Pleistocene Epoch, some 1,800,000 years ago. Glaciers transported sand and other materials and deposited them as glacial drift. Large masses of glacial ice gouged out the basins that now confine the Great Lakes.

However, the glaciers did not simply advance and retreat. Instead, a complex sequence of advances and retreats occurred. These fluctuations had great impact on the landforms. At times drift was deposited, forming barriers which ponded meltwaters in large lakes. When the barriers were eroded or otherwise breached, lake levels changed. When the water level dropped, sand deposits could dry out and then be blown into dunes. Therefore, one can find dunes along the ancient lake shores where sand accumulated. Yet, the supply of sand, water and wind varied greatly from area to area. The distribution of dune landforms usually implies the existence of an old beach. However, the absence of dunes does not necessarily mean a beach did not exist.

In some places in Michigan, dunes formed on top of the glacial drift. These dunes are called perched dunes. As the water level changed and migrated, so did the dunes. If the shoreline retreated, the dunes were more likely to stabilize. And, if conditions were proper, new dunes formed along the new shoreline. The older dunes, formed at a higher lake level, remained on the glacial drift. If the shoreline later advanced with a rising lake level, the older stable beach lines and bluffs were eroded. Through time, erosion might cut through a dune and the underlying drift. If you were there, you might see the cross-bedding which records migration of the dune, as well as see the glacial drift which had not been sorted to provide sand for even more or larger dunes. Ventifacts are common in eroded perched dune areas.

Unsorted sand and gravel as it was left by the glaciers almost I million years ago.



Grains of sand from a dune as seen by scanning electron microscope.

A ventifact showing sandblasted faces.

Fulgerites form when lightning hits sand and fuses the grains together.

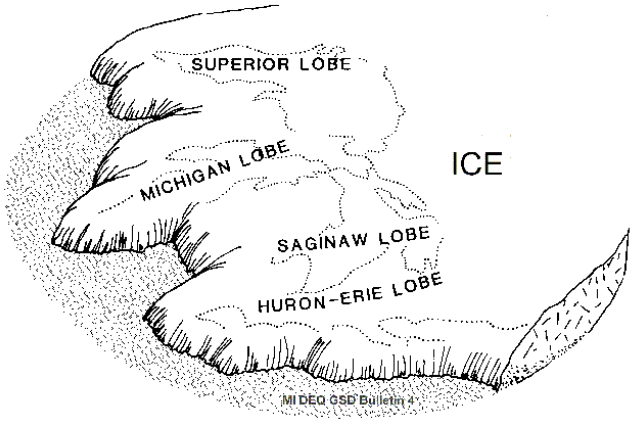
WHY ARE SAND DUNES FOUND IN MICHIGAN?

When you think of sand dunes, you commonly associate them with the desert. If Michigan is not a desert, then why do we find dunes here? The answer lies in the Great Lakes, primarily Lakes Michigan, Superior and Huron. All along the shores of these beautiful lakes, wave action sorts the sediments in the near-shore area. As the waves pound the beach, much of the finer-than-sand-sized materials are carried out into deeper water while the sand-sized grains and larger particles and pebbles are moved nearer to the beach. During storms, large quantities of sand are moved past the beach. Eventually these piles dry out. Until the sand dries, water between the grains holds the sand together. The adhesive quality of the water makes the sand temporarily immobile. The adhesion does not remain after the sand dries. The dry sand can then be transported and winnowed by the wind. The wind carries the sand inland, where it is deposited as a dune.

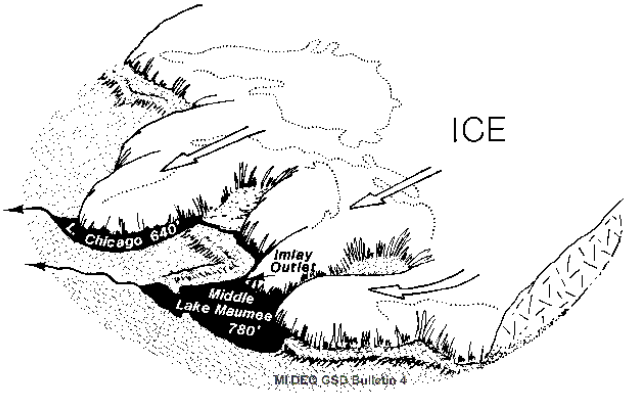
A plant or some other object may deflect the wind. The deflection causes the wind velocity to decrease, and the sand is dropped or deposited. This leads to the formation of a larger and larger mound that will eventually become a dune. In time the mound may become big enough to cover the object that started its formation.

In Michigan the supply of sand is not constant. So, in time, the dunes become covered with grasses and other forms of vegetation - even trees. In fact, some of Michigan's sand dunes look more like "tree dunes". The climate encourages this vegetative cover. The presence of ground water near the surface further promotes vegetation. When vegetative cover prevents the wind from moving the sand, the dunes are stabilized.

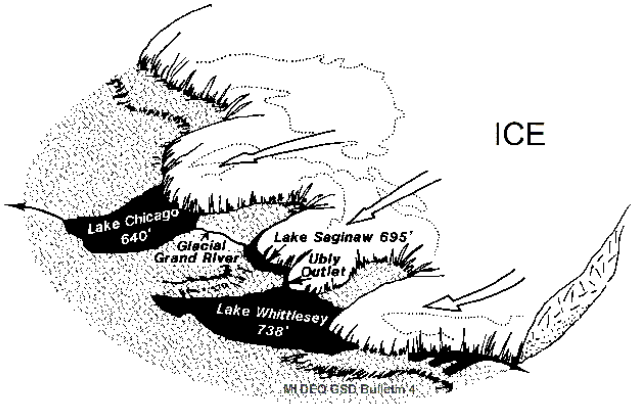
However, if the protective vegetation is removed, or if there are exceptionally high winds or the groundwater level drops, the sand is exposed to wind erosion, and movement or migration begins again. The area where migration begins is called a blowout. Renewed dune movement can bury anything in its path, even the forests which once may have stabilized the dune. An example of a buried forest can be seen at Sleeping Bear Dunes National Park.



Michigan area 16,000 years ago

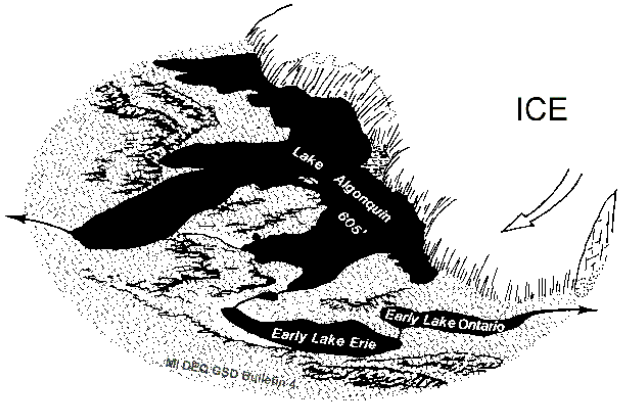


Michigan area 14,000 years ago

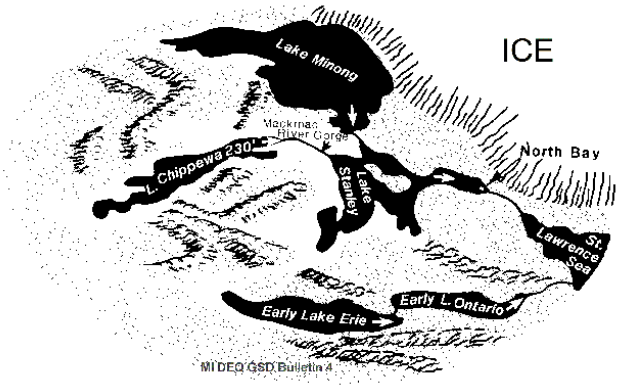


Michigan area 12,500 years ago

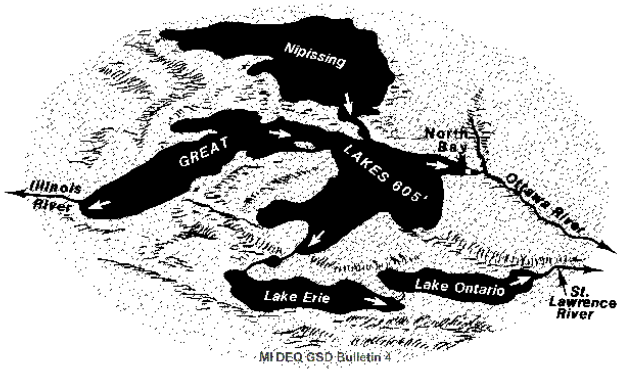
DUNE CYCLES



Michigan area 11,000 years ago



Michigan area 9,500 years ago



Michigan area 4,500 to 3,500 years ago

Aside from human impact, many natural occurrences alter dune environmental balances. The peaks and lows of the phenomena are cyclic. These cycles are seasonal, annual and multiple-year in duration. The changes are seen directly as fluctuations in the level of the Great Lakes and indirectly in the level of the water table (the depth to which the underground is saturated with water). Both of these changes affect the vegetation that stabilizes the dunes.

Yearly fluctuations in the Great Lakes average about one-half meter. Maximum lake level occurs in July, and minimum in f December. The annual fluctuation of lake level has little impact on the near-shore sand supply. This is because the extremes usually occur in mid season. As a result the influence of storms is minimal. Storms which occur at these times are usually not too severe nor do they last long. The principal activity during annual lake level fluctuation is sorting and accumulation of sand. Only limited erosion occurs.

Fluctuations in lake level of more than one-half meter occur over a longer period. This period is roughly 10 years and reflects differences of as much as 2 meters. High levels result in increased wave activity over a wider area. Increased wave action has significant impact on the dunes. The overall effect is an. alternation of erosion and deposition along the beaches. During high water levels the average beach line is eroded. During low water periods deposition occurs, possibly even creating an extension of the beach into the lake. In some areas this difference in beach levels is as much as 50 meters or more. When the water level is high, at times even previously unexposed glacial deposits or older sand dunes may be eroded.

When the water level drops, the shoreline retreats and the water table drops, too. This exposes a new supply of dry sand to the wind. New dunes may result, and in some cases older stabilized dunes may become active once again. When the water table rises, much of the sand supply is covered, and a blowout in an older dune may become partially stabilized. At this time vegetation may re-establish relative stability to the blowout area. Fluctuations in the water table mirror the cycles seen in water levels of the Great Lakes.

Dunes like these near Houghton Lake can be found far from current Great Lake beaches.

The changing of the seasons only add to the beauty of the sand dunes.

USES OF DUNE SAND

Dune sand has a number of uses. The size, uniformity, chemical purity and nature of dune sand make it a singular resource. The demand for this resource is increasing, because of an increase in the number of products using dune sand and because other new uses have been developed.

The major use of dune sand is in foundries. The sand is used to make molds and cores. The molds are used to form metal into a variety of shapes. Core sand fills the spaces where metal is not needed or wanted. The requirements are very demanding. Dune sand is particularly suited to foundry use because I) it can withstand the high temperatures (from 1,300^{0}C to l,700^{0}C) of the molten metal, 2) it can withstand associated pressure, 3) gasses can escape through the sand, and 4) the sand has the proper texture and composition to make a smooth casting and does not react with the metal. Sand properties are checked regularly in most foundries. At best, the sand can be recycled only about twice before it can no longer be used and becomes a waste product. With treatment, these sands can be used as landfill in some cases.

Silica (quartz) sand is also used in glass manufacture. Quartz comprises 50 to 65 percent of the mix used to make glass. The high purity of dune sand makes it especially useful in some glass manufacturing.

Railroads use large amounts of sand to improve traction on wet or slippery rails. Sand is used in sandblasting. The floors of some large open hearth furnaces are lined with silica sand. Sand is an excellent filter for removing sediment and bacteria from water.

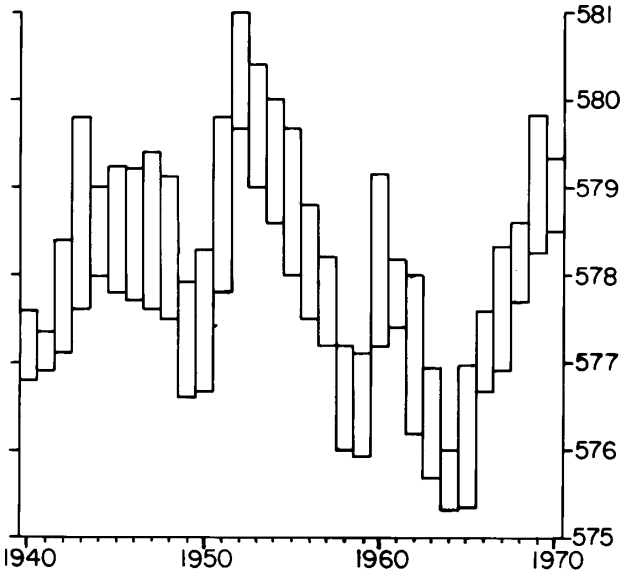
One area of increased use of sand is in fiberglass manufacturing. Fiberglass is used to reinforce many plastic products. These products are enjoying increased use in processes where lightweight corrosion-resistant materials are desirable. Boats, cars and airplanes are some of the products finding increased uses for fiberglass.

The petroleum industry also uses sand. Under pressure, sand is injected into an oil well. The sand goes into the cracks and crevices where the oil is trapped. When the pressure is released, the sand helps hold the cracks open. When this process works, oil production can be increased greatly. The process is called sand-fracturing.

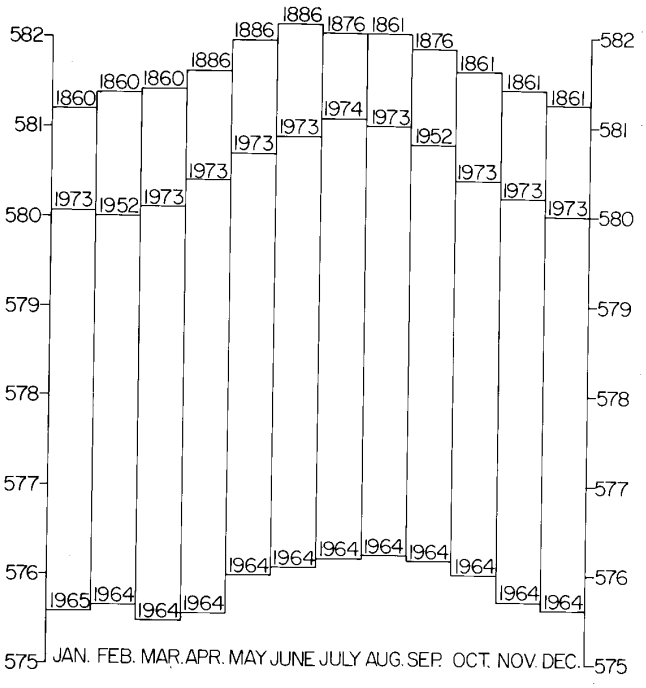
The chemical purity of sand also makes it useful as a material to alloy with various metals. These hybrid metals are in wide use today with possibilities for even more uses in the future. All of the uses relate to the unique properties of the quartz-pure dune sand.

These numerous demands for sand require mining of our dunes and other sand resources. Michigan is one

of the largest producers of dune sand in the United States. Demand appears to be increasing. Yet, the supply is nonrenewable and decreasing. What is the answer? There is no simple, easy answer. However, the solution will involve 1) wise management and use of existing supply, 2) development of techniques which can use other materials, and 3) recycling materials made from dune sand. By application of these ideas the resource will serve more people longer.



Water level fluctuations recorded for Lake Michigan from 1940 to 1970



Record high and low water levels month by month for Lake Michigan through 1970.

DUNE ENVIRONMENT

Many people think of dunes as a kind of desert, and dunes do form in desert areas. However, Michigan's Great Lakes shoreline is not even remotely related to a desert environment. 'In fact, the shoreline receives large amounts of rainfall. The rainfall and relatively high water table help to stabilize the dunes. Some plants common in dunes may be rare or absent elsewhere, particularly in dryer upland areas. Furthermore, there is a great diversity of animal life in the dune ecology. Every major type of land-dwelling animal in Michigan can be found in the dune areas. The dunes are special and one of a kind in many respects. One unique feature is that they are commonly part of the migratory flyway for many birds. When you can take the time to look and be patient, you will be astonished by the diversity of the dune ecology.

Sand dunes are unique. They are a limited, non-renewable resource. The dune ecosystem is not static; it is dynamic, and many factors can readily change existing balances. The impacts of human activities should be such that they do not eliminate the dunes. Dune sand is a unique resource base for many industries. The dunes are lovely to visit or a nice place to live in. Our recreation and lifestyle have to adapt to the dunes. The dunes cannot adapt to us, particularly to any misuse by us. If we treat them with respect, there is hope for the dunes.

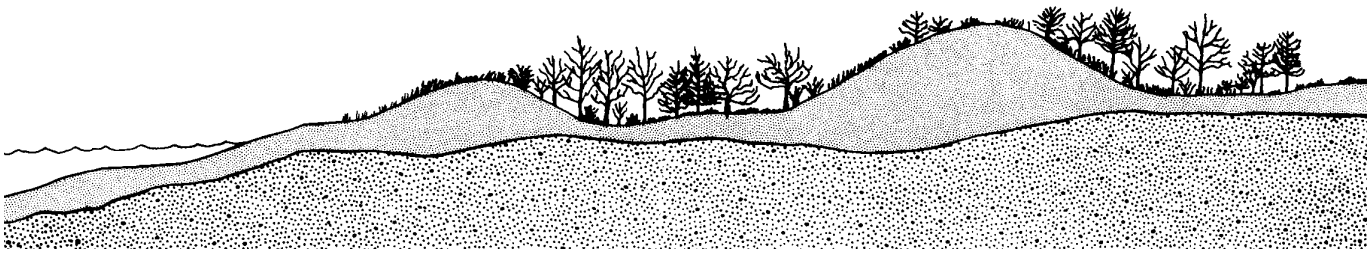
Metal parts (engine crankshafts) made from dune sand molds

Who is responsible for sand dunes? We all are. We all have to protect this dynamic environment. It must be managed and developed responsibly. Man can live in harmony with the environment. Balance must be struck among industry, recreation, urbanization and wilderness.

On July 30, 1976, Governor William G. Milliken signed into law the Sand Dune Protection and Management Act (Act Number I 222, Public Acts of 1976; Michigan Compiled Laws 281.651-281.664). This legislation is directed toward management of the mining of sand from dune areas. The statute gives the DNR authority to assure the wise management of this non-renewable resource. All new mining in sand dune areas will be reviewed and the potential impacts on the environment will be evaluated. Miners are required to reclaim the site when mining is completed. Several comprehensive studies are required by this law to help ensure that proper decisions are made. The DNR is responsible for making the rules necessary to carry out the law. Central to the process is designating a sand dune area. The law defines a sand dune area as “an area which includes those geomorphic features composed primarily of sand, whether windblown or of other origin and which lie within two miles of the ordinary high water mark of a Great Lake." Such a broad definition is open to many interpretations. The Geological Survey has guidelines as well as a publication (Buckler, 1979) that help give more definition to these terms.

If you have any questions about the sand dune management program or other resource management programs, contact your local Department of Natural Resources office. There are a number of publications about DNR programs. Publications of the DNR are available from Information Services Center, Michigan Department of Natural Resources, -Box 30028, Lansing, Michigan 48909.

This pamphlet has only touched on some of the basic geologic principles relating to sand dunes. Several more specific reports have been written, and more research needs to be done. This report has not dealt with the plant and animal communities that thrive in the dune ecosystem; it is only a simple introduction to the tip of a complex, beautiful, unique iceberg. Don't stop here. Visit a dune, experience it first-hand, become involved with your environment.



Cross section of a typical Michigan dune field

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The following titles are suggested for further reference. It should be kept in mind that publications cited here may be out-of-print. Please refer to the current List of Available Geological Survey Publications before ordering. For those not found in the publication list, may we suggest you secure loan of the reference through your library or purchase references cited through a local bookstore.

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OTHER THINGS TO LOOK FOR AT THE DUNES

Geology is only one grain in a dune field. There are many other things to see and appreciate when you visit the dunes. To help introduce some of these to you we have included a generalized checklist of animals you might find in the dune environment. For more detailed information about this and other aspects of the dune environment see the reference list, particularly Hartz and Kane, 1976, Michigan DNR, 1979, and Thompson, 1967.

AMPHIBIANS: (4)

- Frog
- Newt
- Salamander
- Toad

REPTILES: (2)

- Snake
- Turtle

FISH: (17)

- Alewife
- Bass
- Bluegill
- Carp
- Catfish
- Gar
- Goldfish
- Lamprey
- Minnow
- Perch
- Pike
- Salmon
- Shiner
- Smelt
- Sucker
- Sunfish
- Trout

BIRDS: (48)

- Bittern
- Blue Jay
- Bobolink
- Bunting
- Cardinal
- Cedar Waxwing
- Chickadee
- Crane
- Crow
- Dove
- Duck
- Eagle
- Egret
- Finch
- Goose
- Grackle
- Grosbeak
- Gull
- Hawk
- Heron
- Hummingbird
- Junco
- Killdeer
- Kingfisher
- Lark
- Loon
- Meadowlark
- Nuthatch
- Oriole
- Osprey
- Owl
- Pheasant
- Raven
- Red-winged Blackbird
- Robin
- Sandpiper
- Sparrow
- Starling
- Swallow
- Swan
- Tern
- Thrush
- Turkey
- Vulture
- Whip-poor-will
- Woodcock
- Woodpecker
- Wren

MAMMALS: (19)

- Bat
- Chipmunk
- Deer
- Fox
- Lemming
- Mink
- Mole
- Mouse
- Muskrat
- Opossum
- Rabbit
- Raccoon
- Rat
- Shrew
- Skunk
- Squirrel
- Vole
- Weasel
- Woodchuck