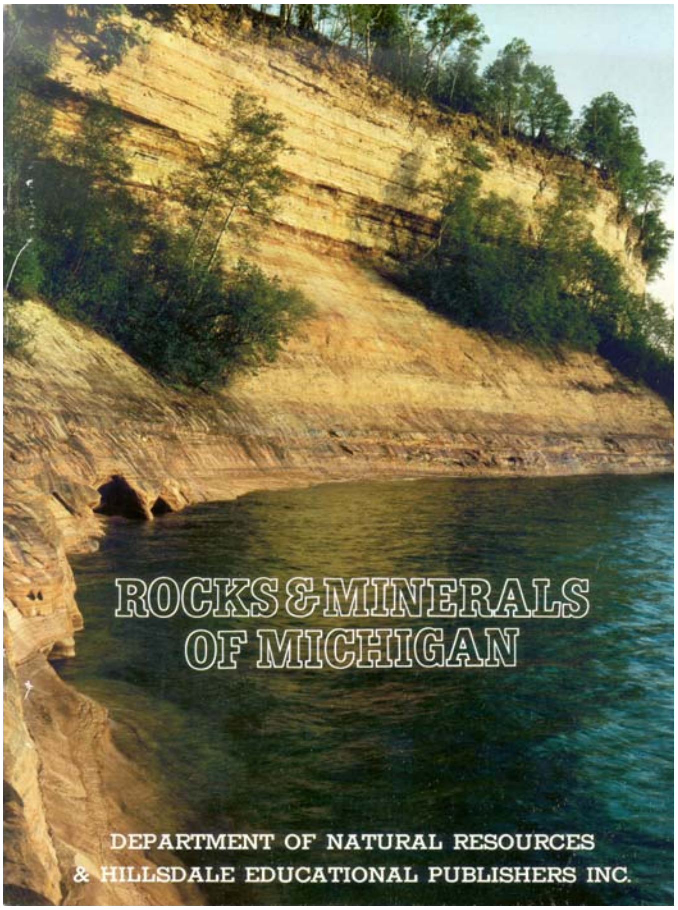

ROCKS AND MINERALS OF MICHIGAN

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OF NATURAL RESOURCES
1971

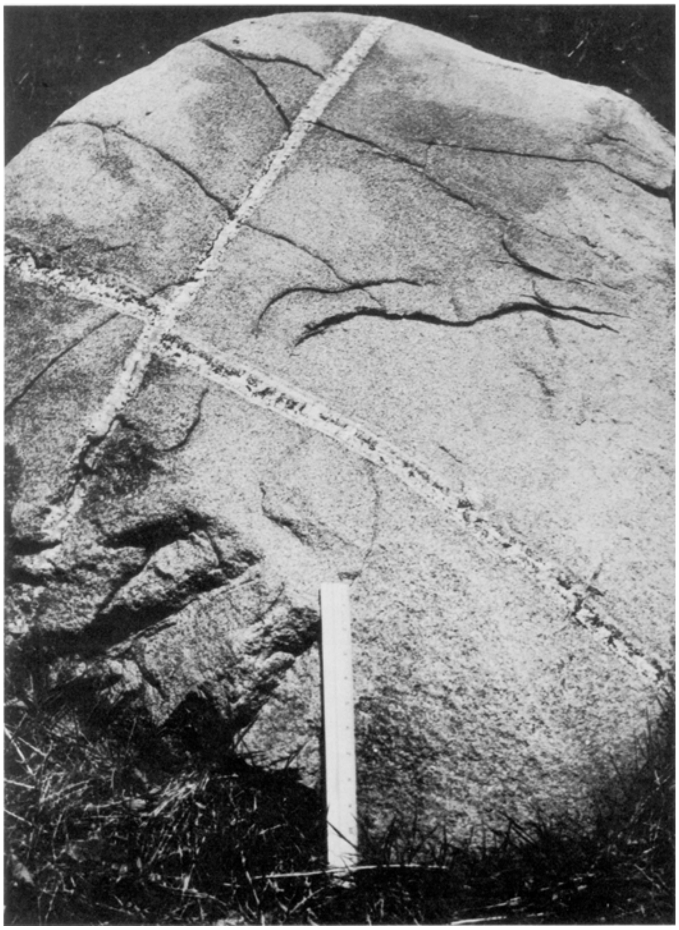
Published by
HILLSDALE EDUCATIONAL PUBLISHERS, INC.
Hillsdale, Michigan

This booklet, prepared especially for non-geologists, is an introduction to the fascinating stories of rocks and minerals. Understanding them adds to the joy and appreciation of the out-of-doors. Information provided in these pages includes the origin, location, and basic uses of rocks and minerals found in Michigan as well as a key to their identification.

CONTENTS

PART I
WHAT IS A ROCK?... A MINERAL?

UNDERNEATH the things we enjoy most out of doors—trees, flowers, brooks, changing scenery, is the earth's firm bedrock which breaks up to make the base of the soil. Fragments of this rock are stones, and for practical purposes the terms "stone" and "rock," as they are used on these pages, are synonymous.



Millions of years ago this boulder lay deep in the earth. Pressures from underneath pushed it to the surface and split it into quadrants. Mineral solutions worked through the cracks and eventually solidified to form the cross-like dykes. Ever so slowly, the boulder was pushed to the surface where a glacier found and carried it to Michigan. During its travels, its corners were rounded into its final shape. The glacier left the boulder to the elements whose extremes in temperatures cracked its surface into the patternless faults evident in its upper half.

The study of rocks and how they attained their present character, form and location is geology; the study of minerals which make the rocks is mineralogy. This chapter is intended to show that these studies are much simpler than you have probably thought and that you already know a great deal about the two subjects. The discussions in Part II go into greater detail and in a somewhat more scientific manner, with odd and interesting facts about each rock and mineral, its location, and use. The chapters repeat but the whole book is intended to explain some of those interesting things which you see about you daily — some of the interesting things that tell the story of how the earth was made.

Pick up a handful of sand and look at it closely (a magnifying glass will help). You will notice that the sand is made of tiny particles. They are of many colors — red, yellow, green, brick, pink, brown, black; some are milky white, others dull or glassy. Some are very hard and firm; others are softer; a few are brittle. Some have sharp edges and sparkle, others are flat and dull, silky and smooth. They are of many shapes and sizes. Obviously our handful of sand is made of a variety of different things, and we call these things minerals.

In order that we may talk about them without confusion each mineral is given a name and in the handful of sand we may find such minerals as garnet, feldspar, magnetite, but the commonest mineral, the bulk of the sand, is quartz. Minerals which are considered precious stones — topaz, aquamarine, sapphire and others — may be found in very tiny particles mixed with the quartz; and it is not impossible that tiny crystals of emerald or diamond might be found. In some places, especially along the shores of Lake Michigan, the sand contains many black particles. Often narrow bands of these black particles are left by waves at their highest level on shore. You can easily separate and collect a handful of the black sand if you have a pocket magnet and a little patience, for the black particles are iron. In some sands, bits of gold, silver, or copper may be found, but in no place in the Lower Peninsula have these metals been located in commercial quantities, nor does it seem likely that deposits larger than interesting scientific curiosities will be found. True, a little pocket of sand may contain flakes of gold, but another such pocket may not be found for many miles in any direction. And all too often the flakes that look like gold are only two other minerals, mica and pyrite, "fool's gold."

Salt is perhaps Michigan's most common mineral. Your magnifying glass will show you that salt grains are six-sided, like cubes. In many crystals one side is missing and the cubes are hollow, and one cube fits inside another like a nest of toy hollow blocks (hopper crystals). In your soft lead pencil you have a mineral, graphite[1], which is dark silver gray or black, feels smooth under your fingertips, and makes a mark or streak of color on paper, but the "lead" had no shape or form. However, a very high-powered microscope will show that graphite also has a crystalline form. The name "lead" is an inheritance from the Middle Ages when it was thought that this mineral that made black marks was a form of, or contained lead.

Perhaps you are familiar with another common mineral, quartz, after it has been melted and manufactured into glass. Colored glass is made by adding other minerals, chemicals, or metals to the melted quartz[2], or melting them with the quartz. Window glass is made from almost pure silica (quartz) sand and the glass of lenses for telescopes, microscopes, and spectacles is made from pure silica. Silica when crystallized is quartz, the rock crystal used for jewelry (copied by the glass beads of costume jewelry).

Iron is a very common metal. You know its many uses in steel, cast iron, machinery, but do you know that iron is Nature's great coloring pigment? Iron coloring in its common form is rust. In Nature rusted iron gives the red to dark brown coloring in rocks and soils. In places (Pictured Rocks, boulders on Lake Michigan shores near Norwood, Charlevoix County) the iron in the rocks has rusted and covered the rocks with a brilliant red so that they look as if they had been painted with a painter's brush. The limestones in the highway roadside park north of Gaylord are stained iron red with "rust" — actually iron ore in the making. Old red barns and the departed little red schoolhouse were painted red because red ocher, and iron rust found in large deposits in the soil, was the chief base of the paint and it was inexpensive and long lasting. Vermilion, a "ghost town" four miles west of Whitefish Point, Chippewa County, was so named from the brilliant color of the iron oxide at that place. The Vermilion deposit is so large that according to reports at one time wagon loads of the ocher were shoveled and carried away and later mixed with water and used for paint on barns near Sault Ste. Marie. And it was red oxide of iron, alone or mixed with yellow clay, which the Indians used for war paint. Just a trace of iron makes quartz sand impure and unfit for the finer glassware.

Copper, another well known metal of our coins, electric wires, and other common things, is also one of Nature's coloring materials, giving the blues and some greens. In fact, metals like iron, copper, and manganese give us the brilliant colorings in the rocks.

Copper, silver, gold are metallic minerals; iron, aluminum, chromium, nickel, tin, zinc, mercury, lead are metals obtained from mineral ores. Salt, gypsum, quartz and many others are nonmetallic minerals. Minerals and rocks from which one or more metals may be profitably extracted are ores.

Let us consider these minerals, quartz, graphite and salt, and find how we distinguish them from each other and from other minerals and metals such as copper, mercury, or water — because water is a mineral in the fluid form, except when it is frozen to ice or heated to a gas. Graphite is gray or black, quartz is pink, red, brown, milky, rose, green, or colorless; water is colorless; mercury is silvery. Graphite leaves a mark on paper, salt does not. Graphite is soft, can easily be scratched with the fingernail, quartz is so hard a knife cannot scratch it. Quartz looks like glass, mercury like liquid silver. Mercury is a fluid that breaks up into little round balls, graphite is shapeless, salt and quartz are crystals. Water, when solidified to snowflakes, forms very beautiful crystals, always with six sides no matter how varied the pattern of each flake. So we have minerals that are very hard or very soft, a few that are fluid. Many minerals can be melted from their ordinary solid form to a fluid and some of them can be heated to a gas. Some of the metals when heated do not readily become a gas but give off light and are used in incandescent electric light bulbs, mercury vapor lamps, blue or red neon signs.

Today we can break up some minerals that are elements and known as radioactive minerals — like thorium, radium, and uranium, and release the energy that holds them together. Energy that was first publicly used in devastating atomic bombs is now being put to peacetime uses, such as motor power and domestic heating plants and, after much more experimentation, may be the energy of the future.

Traces of radioactive minerals have been found in Michigan rocks, but none so far are of commercial importance.

Each mineral is distinguishable from all others by those characteristics which we can readily see, feel, and sometimes taste — color, hardness, luster, the color of the fine powder or of the mark (or streak) it makes, the way it breaks, its type of crystal or its lack of crystal form. Finally a mineral is distinguished by its chemical composition, because by means of chemistry most minerals can be further broken down into simpler substances or elements.

Graphite is the element carbon in its formless, that is, its amorphous state. If the carbon has form it is crystalline and as a crystal is the hardest substance we know in Nature, the diamond. It is interesting that the soot of a chimney, the charcoal of a furnace, hard coal, the lead of a pencil, and the diamond are all the one element — carbon. Carbon is the link between the animal-vegetable world and the world of rocks and minerals. If the carbon is pure it may be either the hardest or the softest of minerals, the beautiful crystal diamond or the dull, shapeless graphite. If the carbon is united to oxygen it may then combine with other elements or minerals to form still different minerals; if it unites with oxygen and hydrogen it forms plant and animal tissue.

Quartz can be broken down into two elements, silicon, a solid, and oxygen, a gas. Water can be broken down into two gases, oxygen and hydrogen. Oxygen can be made to unite with other substances, as with black iron to make red rust (ferric oxide). If today we can break down our minerals by means of electricity and chemistry and can also unite various elements, it follows that originally minerals must have been made by the union of these elements, so we may say that a mineral is a chemical compound occurring in Nature.

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[1]The "lead" in hard pencils is black lead or graphite mixed with clay and compressed; the harder the pencil, the more clay is mixed with the carbon or graphite. Sometimes a pencil scratches because a tiny crystal of quartz was left in the clay.

[2]The rare and valuable old glass of museums was colored by the addition of gold, selenium, various copper minerals, and oxides of several metals. These glasses are now copied but cheaper chemicals are usually used as the coloring agent.

ROCKS

Now let us consider a plasterer and a concrete maker at work. The plasterer mixes lime, sand and water for a simple plaster. When the lime takes up, absorbs, some of the water and hardens, it binds or cements the mineral particles of the sand together and makes an artificial rock. To make another type of plaster, the plasterer may use another finely ground mineral — gypsum. The concrete maker pours water over a mixture of coarse sand, gravel and cement in a mixing trough, box or bowl, to make concrete — another artificial stone or rock.

In the making of plaster or concrete, man is only copying what Nature has been doing for millions of years. Nature has cemented minerals together to form rock. Sometimes she didn't bother to use cement, just heated, pressed and locked the minerals together so firmly they have remained as rock ever since. Sometimes the cementing material was the same substance as the crystals; that is, quartz crystals were cemented together by quartz. Sometimes several varieties of crystals were bound together to make one rock. In other places and at other times only one mineral was used to make the rock. Very frequently Nature broke up first-formed rocks, rearranged the crystals and fragments, and made other rocks. So we may define a rock as a mass or aggregate of minerals cemented or held firmly together by Nature. A stone is really a rock fragment broken from the rocks of the earth's crust. A structure may be built *of* stone but *upon* rock.

IGNEOUS ROCKS

What kind of a concrete mixer did Nature use? All the earth was her mixer, all the forces of heat and cold, of moving water and growing things were her tools, and the region now Michigan was one of her great mixing troughs, which is the course of ages has become bowl-shaped.

How did Nature use the materials, tools and bowls to make the rock? It is a long way from rock to candy making, but when you make candy you know that it sometimes "sugars" or crystalizes. Some crystals form on the side of the basin as the candy cooks, or the whole mass may crystallize as it cools; or it gets gummy and won't harden for a long time. Again if you break the crust of the cooling candy the hot thick syrup wells outward over the cooled top having been pushed out by the force of the expanding steam in the syrup. This homely illustration is an example of what Nature has done in somewhat the same way with other materials and in ages past. The cooling earth is believed to have been a thickish mass of molten rock, or a magma (like the syrup of the candy, a mixture of several ingredients), and the minerals crystallized as the magma cooled. As most magmas contained many minerals, so several kinds crystallized together. In some rocks the crystals are interlocked and in others the crystals are arranged in patterns. If they cooled slowly, the minerals had time to grow into large crystals; if rapidly, they assumed no form and became amorphous and glassy.

Have you ever watched frost forming on a window pane? If the moisture condensed and froze slowly on the glass, the ice crystals were very long and in beautiful form, but if freezing was rapid, the window was covered with a coating of many very fine crystals of white ice, or just a coating of clear ice. If you live in a region where ice forms on the ponds in winter you know that clear "glare ice" is formed when the temperature drops quickly to well below freezing and the surface of the water in the pond freezes very rapidly. These are ordinary examples of the cooling and crystallization of a mineral. Molten rocks cool and crystallize in a similar way. Rocks which were formed from these once molten magmas are called *igneous* (fire) rocks.

Intrusive Igneous Rocks

Igneous rocks are not all of one kind, so we put all those which we believe were formed the same way in a group by themselves and classify these once heated rocks according to the manner and place in the earth in which they are formed. Sometimes the magmas forced from the interior of the earth failed to reach the surface, just pushed up and arched (or domed) and in many places cracked the already solidified rocks above them. But they were pushed into a cooling part of the earth's crust and as they very gradually become cold, their minerals formed large crystals. These then are rocks which were pushed *into* others and so are called *intrusive* rocks. Perhaps you have seen a sag in a pavement over a mudhole repaired by forcing "rock material" under the pavement by air pressure — a "mud jack." Holes are drilled in the pavement and through them a mixture of cement and loam is forced under the slabs of concrete to "even up" the pavement. This operation may be used as an example of the way Nature makes intrusive rocks: The cement mixture represents the magma, the paving the crust, the drilled holes the crack through which the magma reaches the surface, and the hardened cement mixture may represent the new intrusive rock. However, the force is man-made and the intrusion and force came from above rather than from below and thus the process is upside down. Some cement-loam mixture may spread sidewise and make a sill or shelf of one kind of concrete projecting into a horizontal crack of another kind of concrete. Nature made horizontal sills in much the same way, forcing the intrusive rocks not only upwards but in some places sideways. You may have watched a plasterer force plaster into spaces between laths, into cracks, or have seen the pavement mender force tar, sand, and asphalt into cracks in the pavement; or maybe you have watched the building of a cement block structure in which the blocks were laid in a bed of cement that later became hard like stone. These examples may serve to illustrate how man, using rock materials and artificial force, copies Nature's work. Incidentally, the fact that the pavement sagged and did not break shows that rocks will bend, as the pavement after all is a hard, tough, artificial rock made of Nature's hard tough rocks.

Extrusive Igneous Rocks

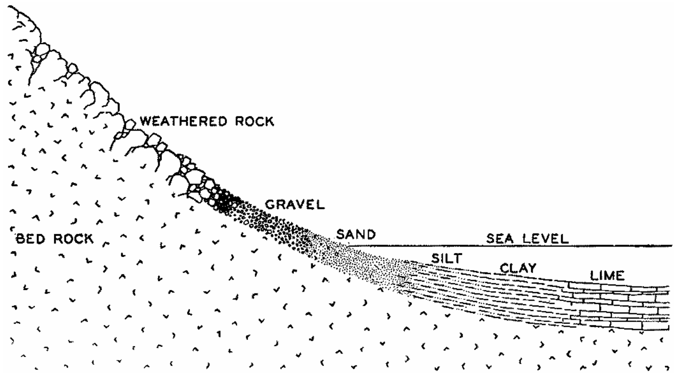
Suppose that the concrete, plaster, or cement mixture, like the sugar solution, broke through and pushed out and over this crust — it then *extruded*. (Somewhat like forcing tooth paste from a tube.) Some of Nature's magmas were likewise forced out, to, or on, the surface and cooled quickly, apparently without crystals or with none that we can see without a microscope. Such igneous rocks are the extrusives. We have such extrusives forming today in the lava flows of Vesuvius, Paricutin in Mexico, the volcanoes of Hawaii, the Philippines, and other places, since extrusive rocks are still forming in the volcanic belts of the earth. Intrusive rocks are probably still forming and their movements and cooling produce some of the great earthquakes. Because we have lava rocks in the Upper Peninsula west of Marquette, we know that at one time lavas were extruded there also, although the volcano-made mountains are now worn away and the mountains made by upheaval are now worn to their roots.

We find then, that some igneous rocks are coarsely crystalline and the crystals are readily distinguishable by color, luster, form. These are the intrusive rocks which we usually, but incorrectly, lump together as "granites." Some are gray of all shades, others are red to pink. In any cemetery you can find several varieties of granites in the tombstones and markers. More detailed classifications of the intrusives are based on the minerals they contain and the color of the rock. Other igneous rocks are fine-grained or glassy. They are the extrusive igneous rocks. Some of the rocks may be found in buildings and in monuments. Igneous rocks are commercially important because in them we find such metals as copper, gold, silver, and certain crystals which are our precious and semi-precious gems—diamond, sapphire, ruby, garnet, agate, amethyst, topaz, and others. Diamond, sapphire, and ruby have not been found in the igneous rocks of Michigan.

SEDIMENTARY ROCKS

From these igneous rocks — these old "granites" — other rocks have been made. Nature never seems satisfied with what she builds nor with the patterns she creates. Build and destroy, create something new out of the old, seems to be her motto. So she set the frost and the sun's heat at work breaking up the igneous rocks almost as soon as they cooled and rose above the ancient seas to form the beginnings of the continents. She caused streams to flow and gave the rock fragments to the streams as tools to scratch and wear down more rock (and of course the tools wore out and more tools replaced them); gave the streams power to carry away the large and small rock particles. In a word, Nature turned the igneous rocks into sediments — mud, silt, sand, boulders — which the streams could carry.

On a grand scale and for millions of years Nature has broken up the rocks and carried and deposited them somewhere else. If you live where rock is exposed you know how its surface changes from year to year, how the rocks break from cliffs, and cracks widen and become filled with fine rock, sand and mud. The waters flowing over and, in places, through the rocks were made acid or alkaline so they could dissolve some minerals and cements and break the rocks that way. The dissolved minerals such as salt, lime, and many others, were carried to the sea. So the sea became salty and bitter with the many dissolved minerals carried to it. Streams lose their force, just as the rainwash does, when they reach a level surface or when they enter a body of quiet water; and then, no longer strong enough to carry sediments, they drop the load of gravel, sand, and mud near their mouths. Sediments are deposited along river banks in quiet water also, but in the course of a river's lifetime such sediments are quite likely to be moved farther and farther downstream, wearing finer and finer on the way, and eventually reach the sea.

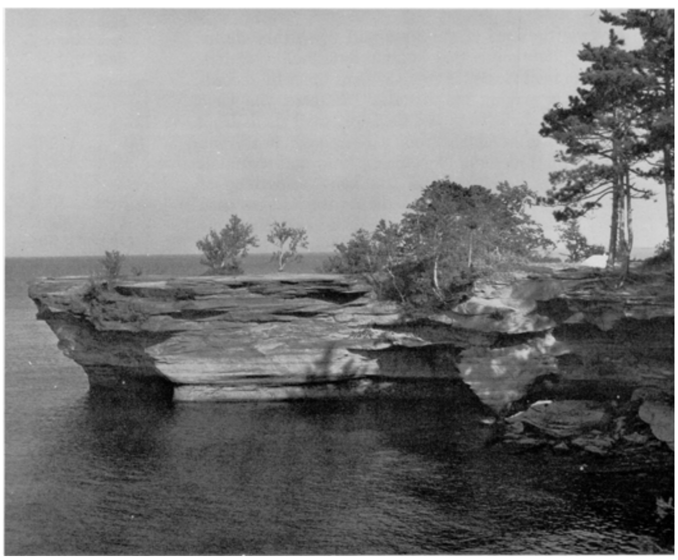


Origin and deposition of sediments.

Notice the fragments left at the end of a gully after a rainstorm. Near the mouth of the gully are the coarse fragments and the finer are washed farther away. So likewise the rock fragments carried to the sea by wind and water eventually settle in order of size and weight. The sediments that rivers carry lose any outward crystalline form they may originally have had and become rounded. In time the sediments, coarse and fine, settle to the bottom of a body of water, become compacted and cemented together, and become another kind of rock which we call **sedimentary.** If for a time no sediment is carried to the sea, the sediments already there will settle and harden somewhat. Then, if more sediments are deposited on top of the first, settling and hardening will take place as before, but between the first and second layers will be a parting. We call that layer a stratum, the parting a bedding plane, and the rock is said to be stratified. At times sediments settle over long periods and thus any partings in the rock are many feet apart and the rock is said to be thick-bedded or massive. In other places and times the settling or deposition of sediment is interrupted and the resulting layers or strata are thin and the rock is said to be thin-bedded. Remember that bedding planes are almost horizontal and that if we find rocks with the bedding planes in any other position we know that Nature has some way tilted, arched and broken the strata.

We have learned that igneous rocks are classified according to the method by, and place in which, they are formed. Sedimentary rocks, because they are made of different minerals, are given descriptive names which tell us what the principal material is in the rock: Thus, a rock made principally of cemented sand grains is a *sandstone*, one made principally of lime is a *limestone*. These have been called "sandrock" and "limerock." Another type was called "clay" or "slaterock" because the material of the rock was so fine that when crushed it became clay and when hard it was like slate. “Clay” or “slaterock” is shale. If the fragments are very large and rounded, the rock is a *conglomerate*—commonly called a “puddingstone” because it looks like an old fashioned pudding filled with nuts and raisins. Perhaps you have walked along a beach and noticed that in some places, the pebbles are sorted from the sand and in other places, pebbles are mixed with the sand. On modern shores, the pebbles may be of several kinds of rock. If the pebbly parts of the beaches should become solidified to rock, a “conglomerate” would be made.

In other places, coarse volcanic pebbles have become cemented to hard rock and are also known as conglomerates. A concrete pavement is really an artificial conglomerate. Most of the sedimentary rocks were made of sediments deposited by streams in water or on flats. But some were made by the deposition of wind-blown rock waste. Thus some of our present sedimentary rocks were once wind-blown sand dunes. A beautiful white sandstone in Monroe County which crumbles like sugar is an example of these ancient wind-blown sediments. Volcanic dusts have accumulated on some parts of the earth’s surface and solidified to very fine-grained sedimentary rocks.



Jutting into Lake Huron from the tip of Michigan’s “Thumb,” at Pointe Aux Barques, is this stratified, weathered Marshall sandstone.

If water evaporates in a teakettle or some other container a hard mineral is left; this is principally “lime”—much like some limestones. Evidently, then, a rock may be formed in other ways than from water-carried sediments. Here was a rock material let down (precipitated) from water. It must have been dissolved in the water. We have beds of limestone which we believe were once lime muds deposited in a similar way. In places and times minerals other than lime have been let down from sea water or left as the sea disappeared. If the water contained a great deal of salt, salt beds were formed which in time hardened to rock salt. If the mineral were gypsum, gypsum beds were deposited which in the course of time solidified to form rock gypsum and alabaster.

Stratification and weathering of massive limestone is shown here. This is Manistique limestone and can be seen near Fayette on the Garden Peninsula in Delta County.

The origin of limestone is not so simple as the origin of sandstones, shales, conglomerates, and beds of rock salt and gypsum. You may have seen some white or light gray substance in a brook, or the fine, gray, oozy mud in a lake where clams like to gather. Perhaps you have seen drainage ditches in black peat or muck lands which have been dug through the black soil on top into a soft, grayish-white mass below. The soft white substance is a lime deposit, marl, often called bog lime; the light gray ooze is also marl. The marl bed in the peat bog or below the muck is probably a mass of “lime” deposited in a former lake bed from which the water is now drained. Michigan is a land of lakes, but once we had many more lakes than now and their sites are marked by marl beds, peat bogs, muck lands, marshes, and swamps. These small deposits of lime were made quite recently, probably within the past 15,000 years and have not yet hardened into firm rock.

However, several times during the long geological (rock-making) history of Michigan, warm seas covered the area of the State and when they disappeared, lime muds that became limestone were left. We can read stories of those ancient times by records Nature is making for us today. Perhaps you have picked up shells from the seacoast, snail shells from a lakeshore, or clams from a river bed; if so, you have collected some of Nature’s tools and materials for making limestone and you know something of the key by which we unlock the records of ages past. Very ancient coral reefs were built in much the same manner as modern reefs are building. The coral reefs are made from the skeletons of little coral animals which live in warm seas and take lime from the water to build their shells and hard parts just as we take it from food to build our bones. When the coral polyps die they leave their shells behind and younger corals build on top; or the waves beat up the coral skeletons into lime mud which settles around the base of the family skeletons and into which shells of other animals are buried; and so through long ages a reef of limestone is built up. Some limestones are masses of the broken shells of ancient animals, others are solidified lime muds made from broken and ground up masses of shells or from lime that was precipitated from sea water like the "lime" in the kettle. In places, thick and thin beds of shells separate layers of more massive limestone and the limestones then become petrified museums of ancient life which is called *fossil* life.

METAMORPHIC ROCKS

Not satisfied with forcing igneous rocks to the surface, breaking them up and redepositing them as sediments, Nature acted upon her rocks in another way. If you take a handful of snow and pack it you compress those snow crystals into a mass of hard ice, which like snow is made of water but has a very different appearance. By the heat and pressure of your hands you have actually changed one type of water crystal into another. You were doing what Nature has done many times in a grand way. She has pressed in bands and/or heated granites so that the crystals become sorted, flattened and arranged something like scales and the new rock we call gneiss (pronounced nice). Sandstones are changed to schists and quartzites, limestones to marbles, and shales to slates such as are used for blackboards in school. We stated earlier that the intrusive rocks pushed up the previously cooled rocks above them but they also supplied pressure and heat to change those overlying rocks. This change is known as metamorphism—a change of form—and the rocks are known as **metamorphic rocks.** Some rocks have been changed into other forms simply by recrystallizing the minerals and pressing them tightly together so that not even the tiniest pore spaces remain, and no gas or water can get through them. In this way sandstones are changed to quartzites, and limestones to beautifully crystalline marble which we see in fine sculptures. Gneiss, quartzite, marble, schist, slate, are known as metamorphic rocks. In the metamorphic rocks west of Marquette we find most of our ores of iron, our building stones, and marble.

In many places in the glacial drift, Nature is making new sandstones and conglomerates. In some gravel pits, you can find pebbles large and small and of all sorts, so cemented together it is difficult for you to break them apart. The cementing material may be iron rust, lime, or material weathered from the pebbles and the drift. Such a rock is known as crag. In some places where the drift is nearly all sand, the sand grains are so closely compacted and cemented that they also are almost hard rock. This process of making rocks by compacting and cementing is known as *induration*. Another example of the way nature reworks old materials to make something new.

Near Union City in Branch County is this Coldwater shale quarry. Note the weathering and stratification.

This metamorphosed iron formation, jaspilite, was photographed at Jasper Hill, near Ishpeming in Marquette County. As the rock was metamorphosed by compression, it was contorted and folded.

In rock gardens and elsewhere you have probably seen rocks of fantastic shape and various colors, perhaps a gray rock with a pink vein through it, or a rock in which small masses of the rock stand out yet are very firmly set in the main rock, a ribbed rock, or a rock of very irregular shape. Many of these rocks are igneous and metamorphic; the pink vein represents an old crack in the gray rock which was filled by melted rock pushed into the crack when both rocks were once far beneath the surface. You will notice a difference in the size of crystals in the vein and the body of the rock. In the igneous rock areas of the Upper Peninsula such mineral-filled veins are so wide we call them dikes and say they "cut across" the main rock mass. Many dikes carry valuable minerals and ores such as pitchblende, an ore of uranium.

The fantastically shaped boulders and cobbles may be igneous, metamorphic, or sedimentary, but they are rocks with hard and soft parts in which weathering has worn away the softer parts and the hard parts remain in relief on the main rock.

COAL, PETROLEUM, PEAT, WATER

Strictly speaking, coal and petroleum are not rocks but are usually discussed with rocks because they are found in them. If vegetation in a swamp dies and falls into the water it is protected from rapid decay and gradually accumulates in the swamp to form peat, which in many countries is cut from the bogs and used for rather smokey, but hot fuel. If the plants decay out of water muck soils are produced.

Rocks which in some way are made by the activity or accumulations of the various organs of plants and animals are termed organic to distinguish them from rocks made without the activity of life forms which are classified as inorganic. Thus peat and coal made from plants and the limestone made from shells and skeletons of animals are organic. Some geologists classify hard (anthracite) coal as metamorphic rock as it was made from soft (bituminous) coal by the action of heat and pressure.

An interesting organic product buried in the rock is rock oil or coal oil—petroleum. We know that petroleum is organic but just how nature made it is an unsettled question, although we now believe that bacteria had a large part in seperating the fats from other organic matter of buried animal life, and these fats later became petroleum. Another interesting organic mineral is the asphalt used for “black top” on highways and for macadam pavements. Petroleum and asphalt are minerals in the liquid and semi-liquid state.

A long story could be written about another liquid in the soils and rocks — water. Very seldom, if ever, do we find pure water in the rocks; that is, water with no mineral matter dissolved in it. Water dissolves out mineral matter in the soils and rocks and produces brines and medicinal waters. Some of the water was probably trapped in the sediments and remained as they became rock, but most of the water in the upper rocks, and probably all the water in the soil and subsoil entered as rainfall or from melted snow and ice of glaciers that once covered Michigan.

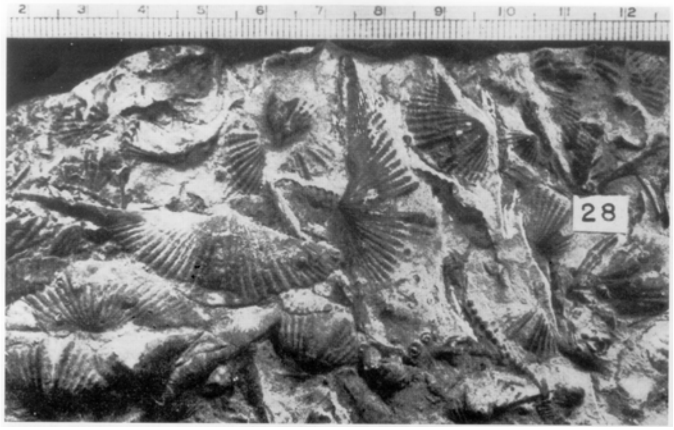
THE SOIL

Nature destroys rocks but she also protects them with a cover of soil and subsoil. To most of us the word soil means the stuff that green plants grow in, that we spade up in the garden, that farmers work in their fields, that agriculture depends on. To some people soil is the weathered, broken, decomposed rock that may be from a few inches to two hundred feet thick. Sometimes it is referred to as “soil in the engineering sense.” It is also known as “parent material.” If the fragments, large and small, resulting from the breaking up (weathering) of the rocks are not washed away to bodies of water, plants start to grow on them and break them up further. If the plant grows on a rock the tiny rootlets which will die from just a touch of your finger, have the power to force their way into the rocks and so break them. Frost can then get into the cracks and complete the breaking of the rock. Also plants take certain minerals for food from some rocks and break down other minerals, thus weakening the rocks and causing them to crumble. The plants die, other plants take their place and continue the work. Acids from the plants change the rock by dissolving out some of the minerals. Creatures like the ant, angleworm, gopher, and chipmunk burrow and expose rock to weathering. They also produce acids which decompose the rock. The process of breaking, rotting, and decomposing, goes on until the mass of finely broken rock, often minus some of its original minerals and plus plant and animal remains, produces soil. Naturally soils made with and on sandstone will be sandy, soils on limestones will be limy and/or clayey, and soils on shale will be clayey. Then ground water, made more powerful by the acids from plants and animals, begins its work on the soil and may carry lime to the sandy soil and clay particles to the limy soil. More vegetation accumulates on the surface, wind-carried dusts of lime, clay, and sand fall on the surface and the soil is deepened and changed and in many places is enriched by the wind-blown material. If the plant material is more abundant than the rocky material the soil is black; shades of color (red, brown, yellow, gray) depend upon the plant and mineral materials in the soils.

Thus we have soils that are weathered rock resting on the rock from which it was made. The top of this weathered rock where acted upon by plants and animals (organic agencies) and mixed with decomposing plant and animal remains, furnishes conditions where plants can live — the soil of agriculture. In agriculture soils are classed as “mineral soils,” where minerals are more abundant and “organic soils” where plant and animal remains are more abundant. Between the two are all sorts of soil gradations.

The subsoil is the upper layer of the weathered rock from which the surface soil is made and/or renewed — it is the “parent material” from which plant food is replenished.

Because they are made from granites, sandstones, limestones, shales, plus the remains of many kinds of plants in all stages of decay, we have a great variety of soils. If a soil is not washed or blown away from the rock from which it was made, it is known as a *residual soil* and is made thicker and thicker as the plants and acid waters work deeper into the underlying rock. Such are the soils south of the Ohio and Missouri rivers. But in Michigan, as well as in the area of the United States north of those rivers, most soils are not made from the bedrock but from parent materials given to us by the glacier of the Great Ice Age. The glacier scraped the residual soils and weathered rocks from Canada and carried them southward to be mixed with all sorts of rocks, boulders, sand and clay and the whole mass dumped in Michigan, Ohio, and other states when the ice melted. Thus the greater part of our Michigan soils for one reason or another are *transported soils*. The story of the black muck (*cumulose*) soils is also bound up in the glacial history of the region.



Pictured here is a museum of ancient life; a petrified shell cemetery. The fossils are brachiopods from the Devonian limestone, the "butterfly shell," Mucrospirifer. When the mollusks died their shells accumulated in the limy muds on the floor of an ancient sea. Petrification took place through thousands of years as the muds were slowly, gently, compacted to limestone.

FOSSILS

Clams, oysters, corals take lime from water for their skeletons (shells are outside skeletons). When they die they sink to the bottom and the shells are broken up or dissolved and deposited again, or are filled with lime mud from other broken shells. Animals which take lime from the water and make hard parts as shell or skeletons have existed for millions of years and through the ages have at various times built great masses of limy rock or limestone. Sometimes the skeleton or shell of the animal is preserved, sometimes only its shape is preserved as a cast or mold of the shell and so we have a fossil — a record of former life.

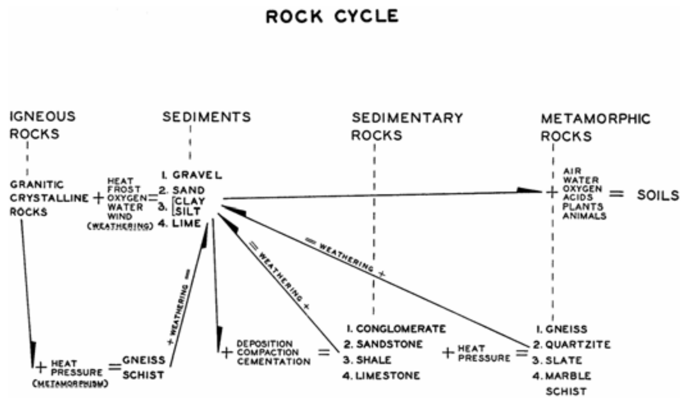
In the rocks of Michigan are found many such records. They are in sandstone, shale, or limestone, but not in the igneous rocks. If fossil records of life were once in the sediments that later became metamorphic rocks, they have been destroyed.

WHAT STONES TELL US

Earlier we told about the deposition of sediments on flat, level, or gently sloping surfaces, and the building up of bedded or layered rock material that we call strata which compacts and hardens in time to stratified sedimentary rock. But Nature isn't satisfied with anything so simple as that, and has made and built up other things of interest and puzzlement in the sedimentary rocks.

In the sedimentary rocks we find forms that resemble petrified turtles, masses of golf or billiard balls, or even "stone washboards."

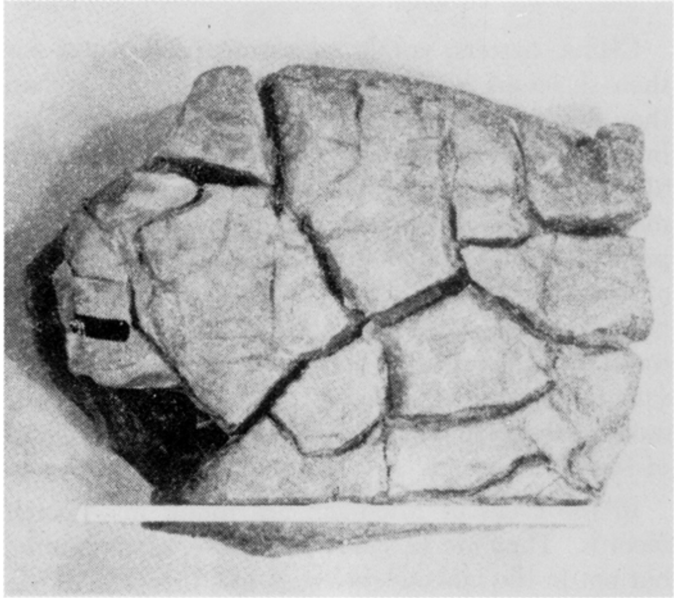
When sediments first settle, the rock grains of which they are made do not stick closely together; therefore the force of moving waters or wind can move and rearrange them. Sand grains are looser, stick together less than clay, lime or silt mud, and so can be piled into ripples, that is into ridges and troughs that resemble small waves, which you can see near shore on any lake or stream where sediments collect, or on a beach or sand dune.



Ripples made by the wind are quite distinctive from water-made ripple marks. Ripples made by the wind are much wider than they are high, the windward slope of each ridge is gentle or gradual, and the other steep; the trough between the two ridges is wide and flat. Fine examples of wind ripples can be seen on the dunes of our lake shores, on the dry sand of beaches above wave level, and on the dry sand or sandy loam of any field where vegetation does not prevent wind action.

Ripples made by moving water currents are higher than wind ripples, the trough between ridges is not flat, and the gentle back slope is not convex as it is in wind ripples. In ripples made by water moving in waves both slopes of the ridges are steep and slightly concave, and the troughs between are concave or flat-bottomed.

Perhaps you have watched ripples forming on a sandy shore as winds blow up waves in the water, or as the swell comes in from a passing motorboat. Then when the wind changes cross ripples are formed on the older sand ridges. Perhaps you have noticed the ripples made about the pilings of a dock or near a board or rock partially buried in the sand. Changes of wind and current direction make all sorts of changes in the patterns of wind, current, and wave ripples on the sediments of today, just as they were made on sediments thousands and millions of years ago. When by undisturbed compaction the ancient sediments became hard rocks they preserved the **ripple marks**; and in the sediments that gently settled on them, molds of the ripples were preserved. Many examples of ripple-marked sandstone ("Petrified washboards") can be found in quarries and small slabs may be found in some gravel pits. You can readily distinguish the mold from the ripple mark — the ridges are wide in the mold and the depressions narrow, but in the true ripple mark the ridges are narrow and the depressions wide.



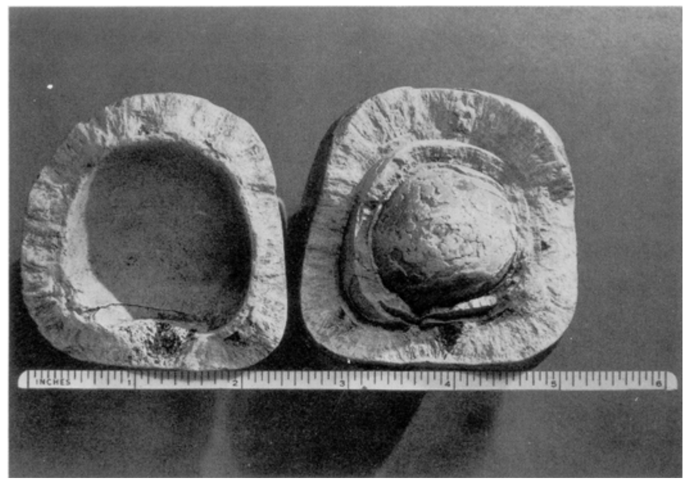
Mud cracks.

Perhaps you have noticed grooves made on shore sands when waves drag clam shells or pebbles into deep water, or grooves made by shore plants as waves or fish moved them, or the trails left by snails and clams in wet mud. Such grooves in the ancient rocks have also been preserved. They were filled with sediments, which compacted and hardened to rock which are often described as petrified twigs.

Wet sediments on shores, edges of streams, in newly made flower beds, or in road puddles left after a rain, shrink as they dry and break into many cracks at sharp angles to each other. The length of the crack is determined by the thickness of the mud — thin muds, short cracks; thick muds, long cracks — some four or five feet in length. These are **mud cracks.** Mud cracks have been preservd in the old sedimentary rocks. They became filled with later silts which in places have a different mineral and color than the cracked sediments. When the mud-cracked sedimentary rocks are split open, casts of the cracks, the crack fillings, are found on the lower side of the upper stratum in a curious pattern of ridges. Records of ancient mud cracks tell us a story of ancient shores and deltas.

We know that rain, hail, and sleet storms occurred millions of years ago as they do today, because the imprints and impressions that raindrops, hailstones, and sleet pellets made as they pelted on wet sediments have been preserved just as ripple marks and mud cracks were. We can even determine the direction and force of the storm by the shape and slope of the pits made by the hailstones.

In some rock exposures and in many gravel pits you can find odd-shaped rounded masses of stone like small balls or nodules cemented together. Perhaps you have found and cracked open a red-brown stone and found that red-brown mineral was a hard shell around a core of lighter colored stone or fine soft sand or clay, or perhaps you found a silvery metallic mineral in the center. These are **concretions.** We don't know much about their formation or why they should be so symmetrical, but believe that water seeping through the cracks dissolved some mineral from one rock and redeposited it in another, and when dissolved the molecules ganged together and so were deposited together. Thus separately iron minerals were dissolved, ganged together, were then redeposited around a bit of sand, clay, or a fossil, making a clay "ironstone" concretion. Clay minerals formed "clay stones." In limestones, chert balls or concretions are formed. They were once masses of stiff jelly-like silica (the quartz mineral) that by chemical changes have become hard chert or flint pebbles. The arrowheads Indians used in the bow and arrow, were carved from flint and chert pebbles. Concretions can be found in gravel pits, in sandstone, shale, in the coal, copper, and iron formations, in limestones, and in some of the glacial clay pits.



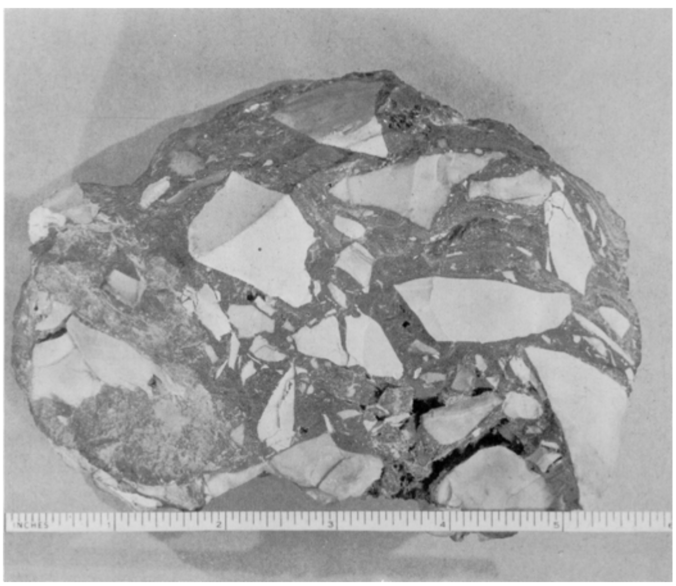
A concretion.

"Petrified mud turtles" are occasionally reported, but they are "claystone" concretions that have cracked, and the cracks have been filled with some mineral, generally calcite. In some cracks the filling mineral is formless, in others it has developed into crystals. The scientific name of these petrified turtles is **septaria.**

If you have cracked open a stone that you found was hollow you broke a **geode.** The cavity in the stone was probably lined with a layer of mineral differing from the outside of the stone or it was lined with crystals. Water is the agent that carries dissolved mineral matter into cavities and as it evaporates, fills the openings with minerals. If evaporation is rapid the minerals are deposited in layers, lining the cavity, or in horizontal bands on its floor. If evaporation is slow the deposited minerals assume their characteristic crystal form. In many sedimentary rocks the crystals were formed inside the cavities of fossils; in lavas they were formed in gas-bubble cavities; and in other rocks geodes form in water- or gas-made cavities. Many geodes have become nodules of minerals, like our banded agates, by complete filling of the cavity. Calcite, selenite, dolomite, pyrite, and quartz of many colors are the common crystals found in geodes.

Water dripping through cracks in the roofs of caves slowly evaporates and builds rings of finely crystallized calcite — the limestone mineral — about the opening. Ring after ring is deposited and hollow pencil-like formations slowly "grow" downward from the roof. These are **stalactites.** Some of the water drops and spatters on the floor of the cave, evaporates, and leaves a heap of calcite with imperfect or no crystals which grows upward, building a **stalagmite.** Eventually the slender hollow stalactite meets the broad stalagmite and a pillar is formed. We have found no caves with stalactites and stalagmites in Michigan, but lime-filled waters seeping into an old quarry near Marshall and in the gypsum quarries at Grand Rapids have made stalactites one or two inches long in a relatively few years. Some old rusted water pipes cut from old plumbing in areas where the community water supply is "hard" have been found, filled with banded lime deposits like a long conical geode or agate.

Nature built other records — cone-in-cone, moss agates, and others, using water as her tool and minerals as her building material, and from all these "petrified records," we can read what happened in the past, what the climate, and even the weather was like.



This is breccia—broken, angular, unweathered fragments of rocks cemented together.

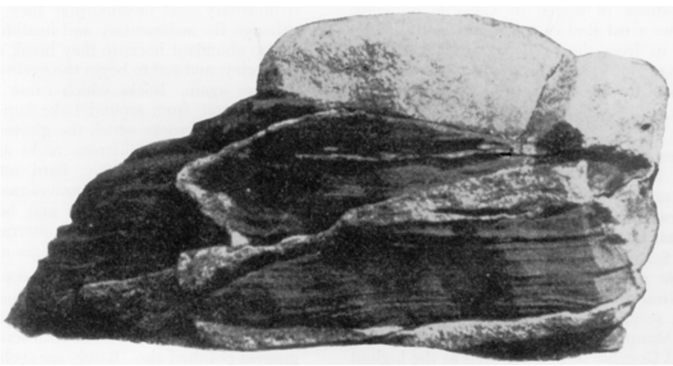
Where Found

Where can we find these minerals, rocks, fossils, and soils in Michigan? In a stony river bed, or in a gravel or a sand pit you can find many varieties of rocks broken into large and small fragments and made smooth and rounded. Along lake shores you can find not only sand, but cobbles and boulders of many varieties, and in places along the Great Lakes you will find the bedrock at the lake shore. Some hillsides have been gullied by rain. From other hills the topsoil has been blown away by the winds. In such places you can find a great collection of rocks. Compare the stones of the streams and gullies with the stones in the wind-swept areas. You may find some smooth, angular, three- to five-sided pebbles in the wind-worn areas. Some of them look as if covered by a coating of varnish.

Stones moved by the waters of streams are rolled over and over and become round and smooth, but not polished. Stones moved by waves and currents along the shore become flattened but with rounded edges; hence the name "shingle" for the flat stones of beaches. The glacial drift contains all types of wind and water-worn pebbles, cobbles, and boulders. Some are little changed, but many are scratched and polished, and their sharp edges rounded showing ice action. If we understand how wind, waves, water, and ice act on rocks and know the form of pebbles produced by each activity, we can often read the story of a pebble's travels by the minerals it contains which determine its rock ancestors and place of origin, and by its shape which reveals the transporting agent. Thus we know that some of our gravel pits are in old beaches, others are in dry river channels and others are concentrations of gravel in the glacial drift.

Stone fences, stone piles, and boulders in fields and along the roadside contain all sorts of rock. Gravel pits, stone piles, stream beds, even rock gardens are available for examination almost any place in Michigan. And the cut stone of houses and foundations is well worth noticing as such stone is mainly igneous or metamorphic rock and the fresh cut surfaces show the character and beauty of the rock. But the bedrocks of the State are nearly everywhere buried under a cover of glacial drift, a great mass of all sorts of rock and soils, sands, gravel, and clays, brought, as stated before, by the glacier from Canada and northern Michigan and left plastered over the old bedrock when the ice melted. This mass of all sorts of rock is called *drift* because it was once thought that it was drifted by currents and icebergs in an ancient sea. We now know it was left by a continental glacier similar to the one now covering Greenland and the ice cap of Antarctica and the great ice field which feeds the Malaspina and other Alaskan glaciers.

In a few areas, however, only thin soil is above the rocks and in a few other areas the rock is so exposed that it has made interesting scenery, as at Grand Ledge, Eaton County; at Point aux Barques, Huron County; the Pictured Rocks, Lake Superior shore; the falls of the Tahquamenon, Chippewa and Luce counties; the falls of the Ocqueoc in Presque Isle County; the Porcupine and Huron mountains, the shores of the Keweenaw Peninsula, Rock Ravine near Laurium, and elsewhere. Man has opened quarries in the rocks at Marquette, Petoskey, Grand Rapids, Napoleon, Alabaster, Alpena, Rogers City, Sibley, and other places. Mines have been opened and show us what the bedrock is like in the copper and iron districts, in the coal fields of Bay, Eaton, Ingham and Saginaw counties, in the gypsum beds of Grand Rapids, and in the salt mine in Wayne County. When we map all these rocks we find that Nature made and left many "mixes" of rock one on top of the other in her old granite mixing bowl, and that as the ages went by the trough became filled with irregular bowl-shaped layers of sedimentary rock. We can study at the surface only the rocks on the rims of the bowls. The map and cross section show that the irregular rock bowls fit one into another and that all are mostly buried under a cover of glacial drift. Each bowl or set of rock bowls east of the meridian of Marquette is given a name for convenience in talking about them. (Cambrian, Ordovician, Silurian, Devonian, Mississippian and Pennsylvanian). The rocks west of Marquette are the ancient granites, the iron formations and the copper-bearing rocks. (Archean, Huronian, Keweenawan) They are referred to collectively as Precambrian. In places, rivers have cut through the drift to uncover the bedrock, waves of the lakes have exposed rock on some of the lake shores, and man has cut quarries and pits through the soil and drift into the bedrock in search of valuable minerals. Elsewhere we must find rock samples conveniently brought to us from the north by a glacier which robbed one region to give to another — before Nature destroyed the ice.



A Story in Stone

This two-ton boulder's story covers more than a billion years. Now resting on a windswept moraine in southern Wexford County, the boulder had its beginning in the silty mud on the floor of a sea. In time the mud hardened to rock— shale with horizontal and vertical cracks resulting from compaction of the muds, the black part of the boulder. Then earth changes and movements forced molten rock (magma) into cracks in the shale. Some of the magma spread horizontally (base of the boulder) and some pushed its way upward. Hot magma and great pressure baked the shale to slate. The magma cooled slowly, so large crystals resulted as the intrusive magma became dikes of granite — the narrow lighter streaks at the base and through the boulder.

Weathering removed the top of the intruded slate and exposed the ends of the granite dikes. A sea came in and covered the weathered surface. Sand sediments accumulated on the sea floor and settled on the weathered slate. In time the sand became sandstone.

All this happened some place in the area of iron formations; perhaps in Marquette County. Then the glacier came, picked up the sandstone-covered slate with its tell-tale dikes of granite, and carried the boulder some 300 miles to the glacial drift hills near the Wexford-Osceola county line.

In the Upper Peninsula rock exposures may be found in every county — sandstones in northern Chippewa and limestones in the southern part of the county; limestones, some gypsum, and shale in Mackinac; sandstones in Luce, Alger, Marquette, Baraga, Keweenaw, Ontonagon, Gogebic, Dickinson and Iron; limestones in Menominee, Dickinson, Delta and Schoolcraft counties. The igneous and metamorphic rocks, with their wealth of copper, silver, and iron ore, crop out to make the wild and picturesque scenery and the gorges of Keweenaw, Houghton, Marquette, Dickinson, Baraga, Iron, Ontonagon and Gogebic counties as well as the highest peaks in the State — the Huron and Porcupine mountains. In the dumps and rock piles of the mines, minerals and rocks from far underground may be found.

In the Lower Peninsula bedrock is exposed in twenty-three of the sixty-eight counties: sandstones in Hillsdale, Monroe, Jackson, Calhoun, Eaton, Ottawa, Ionia, Clinton, Ingham, Shiawassee, Genesee, Huron, Tuscola and Arenac counties; limestone in Monroe, Wayne, Jackson, Eaton, Kent, Huron, Arenac, Iosco, Alpena, Presque Isle, Cheboygan, Emmet, Charlevoix; shale in Branch, Hillsdale, Jackson, Eaton, Genesee, Huron, Ingham, Shiawassee, Alpena, Cheboygan, Antrim; gypsum in mines and quarries of Arenac, Iosco and Kent counties; coal in abandoned surface and shaft mines in Eaton, Ingham, Shiawassee, Saginaw, Bay, Tuscola, and Jackson counties. Other counties have other rocks and minerals, but they are obtained from far below the surface. Rock salt is mined under Detroit; the rock minerals — petroleum, natural gas, salt brines — are obtained by deep wells in many counties. No rock salt is at the surface but in some parts of the State the water used for drinking taken from shallow wells is quite salty and in some of the limestone, and shale exposures as well as in bits of shale occasionally found in gravel pits, dried crude oil may be found. Water is found in nearly all the rock bowls. In many of the rocks the water is fresh near the rims of the bowl but becomes salty with depth toward the central part of the State. In a few of the rock formations the water at the rims contains hydrogen sulphide and is unfit to drink. Great quantities of water are stored in the sand and gravel beds of the glacial drift and glacial lake deposits. But to all the counties the glacier brought gifts from Canada and northern Michigan and left them piled in rolling hills into which man has cut, dug, and shoveled with huge "tons-at-a-time" shovels to obtain construction materials. In these gravel pits sample of igneous, sedimentary, and metamorphic rock may be found although the sedimentary and fossiliferous rocks are not so abundant because they break up readily into sand, clay, and soil to begin the cycle of rock making all over again. Rocks which came from north of Lake Huron, from around Lake Superior, are jumbled with the rocks which the glacier picked up on its way south. Fossiliferous rocks are mixed with igneous and metamorphic; hard rocks jostle and break soft rocks; sand and gravel may be in layers, or sand, gravel and boulders may be in confusion. A gravel pit is a natural, but unarranged, museum of rocks and minerals of many ages and types.

In the gravel pits and clay banks we often find smooth, highly polished stones, some are flat and angular, but with sharp edges polished off, many are scratched or grooved but with scratch marks and grooves polished also. Rarely are such stones ancient Indian relics, as often thought, but are more ancient glacier tools used by the ice to cut, scratch and gouge the rocks over which the ice passed and in the process were themselves scratched, smoothed, and polished.

Do Stones Grow?

We know farmers complain that land cleared of stones when first put under the plow becomes stonier each year and plow points hit rocks where none were the year before. The answer is that Nature just can't leave things alone. When the plow loosens the topsoil it is easier for the frost action to "heave" the stones in the subsoil nearer the surface to be uncovered by later plowing and by wind activity.

Although stones do not grow, they do become cemented together and make rock. In many places in the glacial drift, the drift has been cemented by lime to form a rock so hard it has been used for building stone, for rock gardens and for pools. It is known as crag. In other places iron is the cementing material, pebbles are cemented together forming conglomerates, and sand cemented to a fairly hard sandstone. In other places the weight of the drift pebbles and/or sand has caused compaction by squeezing out water. The process is known as *induration*.

PART II
ROCKS AND MINERALS

At the beginning of this book you were told about the minerals that may be found in a handful of sand. Where do these minerals come from? Pick up a pink or reddish pebble or cobblestone from the ground or from a cellar or from any excavation. If you examine closely the pebble or cobblestone you will see that it is made of the same minerals found in the handful of sand. The red, pink or white portions of the pebble are crystals of the mineral orthoclase, or of some very similar member of the mineral family known as the feldspar group. Minerals that are very like one another are placed in a group and may be likened to brothers and sisters of the animal world or to the family groups of plants and flowers. Thus we have the families of quartz, feldspars, micas, and many others.

Among the pink grains of feldspar you will see grains that look like drops of melted glass. These are quartz crystals. Notice a black mineral also. It is mica if shiny and flaky but is either hornblende or augite if it is dull and black and in long prisms. Bright red crystals of garnet can be seen in certain kinds of pebbles.

Pebbles, stones, rocks, mean about the same thing to the average person, but to the geologist or mineralogist these words have different meanings. The term "rock" is used for the hard substance which everywhere underlies the subsoil. If the rock crops out above the soil, "rock quarries" or "stone quarries" are often opened for road or building material. The geologist uses the word "stone" when speaking of building material. A pebble, cobble or boulder is a rock or stone usually rounded at the corners by water, wind and ice. It is a fragment of the bedrock. A mass or conglomeration of pebbles in sand make up our familiar gravel pits.

Rocks are made up of minerals. The pebbles in gravel pits, along beaches, stream beds, in the soil, or along the roadside are of rock. The pebbles, or rocks, in which we find quartz, feldspar and mica are called by the geologist "granite." Granite is the name of a *rock*, whereas quartz, feldspar and mica are the names of *minerals*. Minerals are parts of rocks in the same way that threads of different colors are parts of a pattern of cloth.

In almost any gravel pit or stone pile you will notice pebbles or cobbles that have rotted and fallen to pieces. Some pebbles are so rotten that you can crush them in your fingers. In doing so you break the rock down into the different minerals of which it is formed and actually make sand. The sand of our lake shores, stream beds, and elsewhere, was made simply by the rotting or weathering of large masses of rock. The sand thus formed is washed into the streams and finally to lakes or to the ocean. Most of our sand in Michigan is rock gathered in Canada by the glacier of the glacial period ground to sand by the ice as it moved southward and then washed out by streams of water running from the melting glacier.

You have been told that the commonest mineral in sand is **quartz.** Quartz makes up the bulk of sand, not because it is the most abundant of all minerals, but because it is the *hardest*, most resistant, and so least destroyed of the common minerals. **Feldspar** is the most abundant mineral in rocks, but although it is very hard, acids dissolve it and change it to *clay* which is easily washed out of sand deposits. **Mica** is very light and is also washed away by the water. Some feldspar and mica, however, are nearly always found in sand.

Garnet, magnetic, tourmaline, zircon and topaz are other hard resistant minerals found in sands.

Pebbles of almost pure **quartz** may be found in any Michigan gravel pit. Sometimes you may find pebbles which when broken with a hammer will be found to have a hollow inside lined with six-sided, pointed crystals of quartz. Clear crystallized quartz is the familiar "rock crystal" used for crystal beads and other jewelry. Pure rock crystal is as transparent as glass and sometimes so lustrous that it may be mistaken for diamond. "Mexican diamonds" are a very lustrous kind of crystalline quartz. Perfect quartz crystals are essential in modern radio communication for frequency modulation, radar and television.

Quartz crystals are most easily found on the waste rock piles of the iron- and copper-mining districts of the Upper Peninsula. The crystals fill openings (geodes) in the igneous and metamorphic rocks and ore deposits and the crystal-lined cavities are exposed when the rocks are broken by mining. In the iron-mining regions, bright blood-red crystals of quartz colored by iron oxide are found in hollows or geodes. Purple quartz, or **amethyst,** is sometimes found in the copper-bearing rocks. **Chalcedony, carnelian, agate, jasper, onyx, chert** and **flint** are finely crystalline varieties of quartz found in Michigan. Chert and flint are common in any gravel pit and agates are occasionally found. Chert and flint nodules are abundant in the limestone quarries of Huron and Arenac counties, and in the Niagaran dolomites of the Upper Peninsula. Small geodes containing quartz crystals may also be found in these limestones and dolomites. An attractive variety of reddish mottled and banded chert is found in the Traverse Limestone north of Norwood in Charlevoix County. Pebbles of red and yellow jasper can be found in most any gravel pit. Red and black pebbles of jasper and pebbles of white quartz are cemented together in a very beautiful field stone known as jasper conglomerate, which is called "puddingstone" because the pebbles of jasper look like plums in a pudding. Jasper, beautifully banded with hematite, is a typical rock in the iron-mining districts of Michigan.

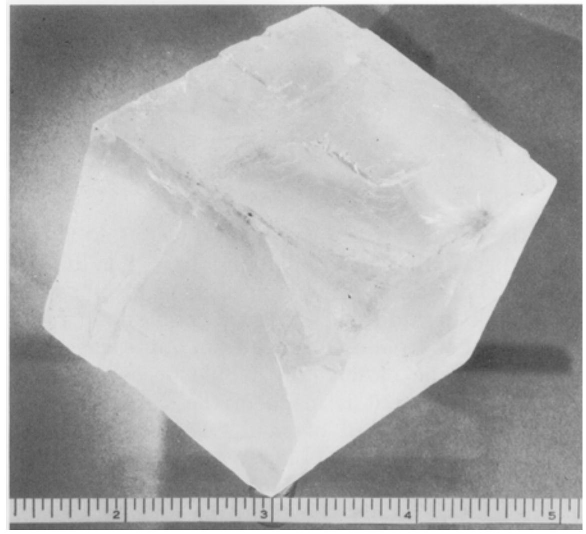
Nearly everyone has seen the flint arrowheads made by prehistoric man and those used by Indians. Chert is very similar to flint except that it is light-colored, whereas flint has a dark, smoky gray to black color.

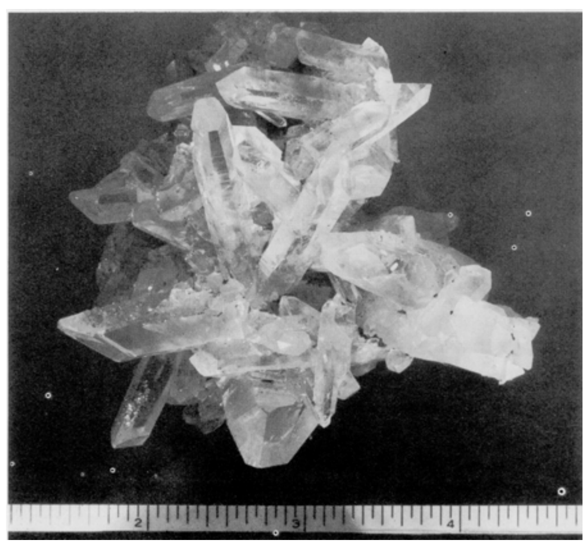
Cameos are made from agates having layers of differently colored finely crystalline quartz.

Veins of massive, uncrystallized quartz, in some places several feet thick, are found in the igneous rocks of the western half of the Upper Peninsula. **Gold, molybdenite, tourmaline,** and other rare minerals are sometimes found in these veins.

Sandstone and quartzite are common types of rock composed almost entirely of quartz grains.

All varieties of quartz scratch glass easily. This superior hardness, the crystal habit, and glassy luster are the important means of identifying this mineral.





Top: Halite (salt) cube.

Center: Tabular calcite. Note double refraction.

Bottom: Prismatic, six-sided quartz.

You have already been told that the pink mineral found in sand is a variety of **feldspar, orthoclase,** and that this mineral gives the pink or reddish color to the granites of buildings, monuments, and tombstones. But feldspar is white or light gray as well as pink or reddish. Some varieties are dark gray and others are green. All varieties scratch glass but are not as hard as quartz. Feldspar takes an excellent polish. In addition to the color and hardness, the most important property of feldspar is the manner of cleavage, or splitting, by which two smooth, lustrous faces almost at right angles can be produced on large crystals. Even where the crystal grains are small, as in granite, one cleavage face or plane is always visible. These cleavage faces give the shiny light reflections from a freshly broken piece of granite.

Feldspar is found everywhere in Michigan in the granite pebbles, cobbles and boulders in the soil and in gravel pits. Sometimes crystals one-half inch or longer can be found in certain kinds of granite.

Large areas of granite form the bedrock in the western part of the Upper Peninsula. In some places **pegmatite dikes** which contain unusually large crystals of feldspar cut across other kinds of rock. Some of these dikes are located near Felch and Foster City in Dickinson County, near Republic in Marquette County, and near Gogebic Lake in Gogebic County. Red **microcline** is found in cavities in the lava flows of the copper district, and large crystals of **labradorite** in a porphyritic rock in the same region.

Much of our soil is formed from the decomposition of feldspar which breaks down to clay and sand (quartz). Feldspar is of commercial importance in the manufacture of porcelain ware and glass. The deposits near Republic have been used in porcelain manufacture.

Another commercially common mineral is mica. This was the isinglass window in the door of the old pot-bellied stove. You look through mica when you look into a fuse plug.

The important thing about mica is its scaly or platy structure. It can be split into very thin leaves. The colorless variety of mica, **muscovite,** is in demand for commercial purposes. The black or **biotite** variety contains iron and does not have the heat and electrical resistant properties of the uncolored muscovite.

Biotite mica bleaches to bronze and golden yellow shades when long exposed to air and water. It is often mistaken for gold. Gold is, however, much heavier, and does not split into thin scales as mica does. You can pound mica to a powder but gold, being malleable, simply flattens when pounded.

The best places to find flakes of mica are in the pegmatite dikes and mica schists of Dickinson, Marquette, and Gogebic counties. The black scaly mineral of granite pebbles is biotite mica.

Mica, however, is not the only black mineral found in granite pebbles or boulders. A coal-black mineral in long slender prisms instead of scales, and which does not have the shiny luster of mica, is **hornblende.** It is not as common in granite as in the somewhat similar rock known as *syenite*. Another black mineral is **augite.** Augite looks very much like hornblende but the prisms are short and blunt instead of long and slender. Augite is not found in granites but in darker-colored rocks such as *gabbro* and *peridotite*. Hornblende and augite may be distinguished by the way the crystals split or cleave. The cleavages of hornblende come together in an angle of about 120° but in augite the cleavages form an angle of about 90°. Sometimes with the aid of a magnifying glass these cleavages can be seen in a pebble.

You have been informed about the black magnetic particles sometimes found in streaks or bands along the shores of the Great Lakes. They are grains of the mineral **magnetite** and you can see them in any handful of sand. It is generally the most common of the black minerals found in sand. If you examine the black grains with a magnifying glass or microscope you will see that some of the grains have triangular-shaped faces, and you may perhaps see some almost perfect eight-sided or octahedral crystals formed by the joining of eight of the small triangular faces. This *octahedral habit* of magnetite, and the fact that it is quite heavy and is attracted by a magnet, makes it easily recognized. Magnetite contains iron which causes its magnetism; in fact, the mineral looks quite a bit like a chunk of iron.

Samples of magnetite can be picked up in large quantities on the old mine dumps at Champion, Republic and Michigamme, in Marquette County.

At Michigamme numerous tiny, almost perfect, eight-sided crystals (octahedrons) are imbedded in a soft, grass-green mineral known as **chlorite.** These crystals were magnetite at one time but they have been changed into a mineral known as **martite** which keeps the same form as magnetite. Although martite has the same shape and appearance of magnetite, it can be distinguished from magnetite by crushing a small amount to a fine powder. The fine powder of martite is dark red, but powdered magnetite is black. Most of the greenish pebbles found in gravel pits owe their color to chlorite which is mixed with other minerals. Pebbles and boulders of granite, however, often contain streaks or veins of a yellowish-green mineral known as **epidote.** In the copper-mining district epidote and chlorite are common minerals. Epidote forms bright green crystals in "bubble holes" in lava. Chlorite is darker green and forms small round shot-like balls filling these "bubble holes."

Garnet is the last of the minerals easily seen in a handful of sand. The grains are bright red. Few minerals form more perfect or more beautiful crystals than garnet, which usually has twelve diamond-shaped faces. Garnet of the gem variety is not known in Michigan but good dark red crystals—some more than an inch in diameter—partially imbedded in magnetite, can be found on the old waste rock piles at Champion, Marquette County. Garnet crystals two inches or more in diameter are not uncommon in the chlorite schist at Michigamme, but the garnets, although red inside, are almost completely altered on the surface of the crystal to the green chlorite in which they are imbedded. Garnets enclosed by plates of biotite mica, and often changed to mica, are found at Republic. Garnet is very hard and will scratch glass.

Garnet

Hematite and **limonite** are nothing more than forms of iron rust. Large deposits of these minerals are found in Michigan. The great deposits of iron ore in northern Michigan are mostly hematite, and limonite forms the deposits of "bog iron ore" throughout the State. Limonite is yellow or brown and hematite is red or black. The fine powder of hematite is, however, always red and this characteristic is the best means of identifying it. Ordinarily hematite is soft, bright red, and soils the fingers easily, but some varieties, **specular hematite, micaceous hematite,** are black, hard and scaly, with a very brilliant luster.

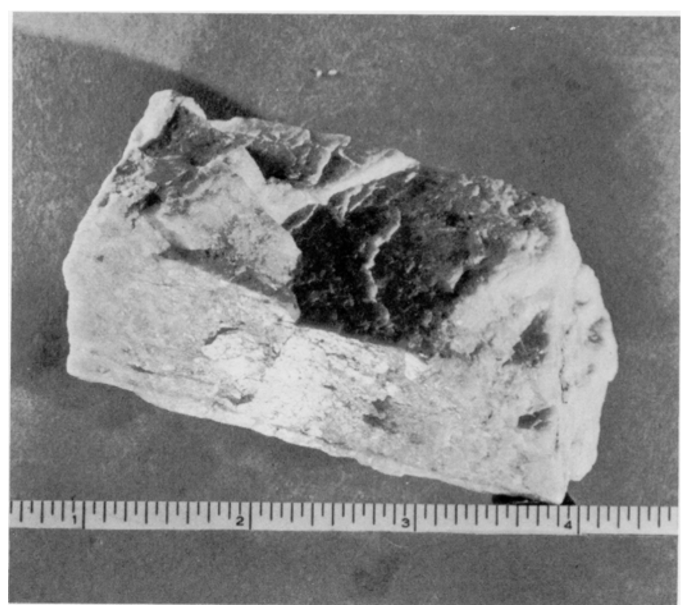
Hematite and limonite are the minerals which color soils red or yellow and make red, brown or yellow streaks and stains on rocks or minerals.

Pebbles, cobbles and boulders made mainly of quartz and feldspar, mixed with mica or hornblende are generally pink or light gray ("salt and pepper"). Black or greenish stones contain hornblende, augite or chlorite. Pebbles containing quartz, feldspar, hornblende, augite, are very difficult to break or scratch because of the hardness. Many pebbles, however, can be cracked quite easily with a hammer, and scratched with the point of a knife. These pebbles are generally buff, brown, light gray, or bluish, and appear to be made of but one kind of mineral. They are probably *limestone* or *dolomite* pebbles. Limestone is composed entirely of the mineral **calcite. Dolomite** is the name of a mineral and also of a rock (which is composed of the mineral dolomite).

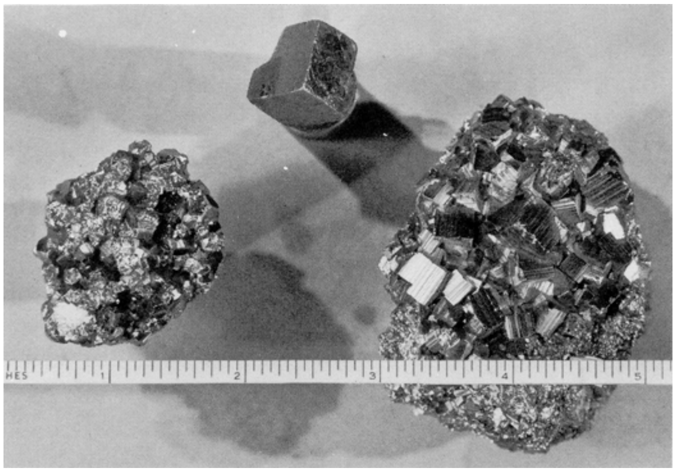
Sometimes in a pit or field you can find a slab of limestone which has a small hollow filled with clear crystals of **calcite.** Such a cavity is known as a *geode*. Because of their clearness, calcite crystals are often mistaken for quartz, but calcite is much softer than quartz, can be scratched with a knife, and breaks or cleaves to form smooth pearly surfaces. If the break follows several directions you can sometimes see a rhombic face. Calcite is said to have *rhombohedral cleavage*. The crystals of calcite are different from those of quartz. Some are sharp and pointed and are called "dog tooth" crystals. An easy way to tell calcite from quartz and other minerals which it looks like is to put a drop of dilute muriatic (hydrochloric) acid on the mineral. Calcite fizzes and gives off carbon dioxide, the gas used in soda water, carbonated water, and from which "dry ice" is made. Muriatic acid will not affect quartz, feldspar and other minerals.

Dolomite looks very much like limestone but will not fizz in acid unless you make a little fine powder by scratching the stone. The dilute acid will then cause the fine powder to fizz. Dolomite crystals found in geodes are also of a different shape than the calcite crystals.

In many dark-colored pebbles you may notice a tiny yellow grain which will excite your curiosity. The chances are, however, that this glistening mineral is not gold but is the very common mineral known as **pyrite** or **iron pyrites.** Like golden-yellow mica, pyrite is frequently mistaken for gold, in fact, it has been called "fool's gold." If you had a gold nugget to compare with the yellow pyrite so commonly found in pebbles and field stones you would see that pyrite is not really the color of gold but rather the color of brass. If you examine the brassy grain with a magnifying glass you may see that it has a certain shape or crystal form. Most grains of pyrite are almost perfect cubes but some have twelve five-sided (pentagonal) faces. You can often see fine parallel lines on the square, or cube, faces of the mineral. Gold is practically never a crystal and is very soft whereas pyrite is quite hard.



Feldspar



Pyrite

Pyrite is not often found in granite pebbles and boulders, but in the darker colored iron-bearing rocks. Pyrite also is common in shales, limestones, and sandstones. It is a compound or iron and sulphur.

Pyrite is found most abundantly in Michigan in the dark shales of the “coal measures” and in the coal itself. In some places it is in very thin veins which can be followed for hundreds of feet. Very fine coatings of pyrite can be seen on lumps of Michigan coal.

Marcasite is a mineral of exactly the same composition (iron and sulphur) as pyrite, but it has a silvery color and a different crystal form. Marcasite generally forms balls or concretions in shales or sandstones. It is also common in the coal-bearing rocks. Very interesting concretions of marcasite can be found in the black Antrim Shale which crops out in Alpena, Cheboygan, and Charlevoix counties.

Quartz, feldspar, mica, hornblende, augite, magnetite, garnet, chlorite, hematite, limonite, pyrite, calcite and dolomite are the minerals which the average student or resident of the State finds most frequently. These minerals are found in pebbles, cobbles, and boulders scattered over the State, and in the sand of its lakes, streams, gravel pits, and northern plains. They are the principal rock-forming minerals.

Residents of the western part of the Upper Peninsula, particularly those who live in the vicinity of the iron and copper mines, are fortunate because the great heaps of waste rock from the mines are the best hunting grounds for minerals in the State. The “rock piles” of the “Copper Country,” Houghton and Keweenaw counties, abound with minerals. In the region from Ishpeming west to Michigamme and south to Republic many minerals of the iron-mining districts can be found.

Residents of the Lower Peninsula are not so fortunate in having nearby highly mineralized districts which yield a variety of minerals. Some fine specimens of minerals not found in the Upper Peninsula can be obtained, but mineral localities are few and only one or two minerals can be found at a place. The reason for this difference lies in the geological history of the rocks. In the western half of the Upper Peninsula the rocks are *igneous* and *metamorphic*, but the rocks of the eastern half of the Upper Peninsula and all of the Lower Peninsula are *sedimentary*.

A MINERAL TOUR

Let us suppose that you live in southern Michigan and that you plan a vacation tour of the Upper Peninsula. If at all possible, spend an evening or two studying mineral collections. Many of our colleges and museums have excellent displays. A few hours spent looking at one of these mineral collections will greatly increase the pleasure and value of your mineral hunt and acquaint you with the appearance of the minerals here described.

If your route takes you northward along the east side of the State your first stop for minerals is at Alabaster, or National City, in Iosco County, where you may ask permission to select a small sample of **gypsum** from the large quarries. Gypsum is a very beautiful pink or white, very soft, mineral. It can be scratched with the fingernail. It is the **alabaster** of the ancients, used for making statues and ornaments. In Michigan, however, gypsum is ground and burned for making wall board, plaster of pans, and other building materials. If your trip begins on the west side of the State, you can find the same mineral in the old quarries at Grandville, near Grand Rapids. Transparent flakes of crystals of **selenite** (crystallized gypsum) can also be found.

Leaving Alabaster, your next mineral locality is at the black shale outcrops near Squaw Bay, a few miles south of Alpena, where samples of a variety of **calcite,** known as **anthraconite,** may be broken from the large boulders or concretions imbedded in the shale. If you search diligently you may find pieces of shale which contain small crystals of **pyrite** and you may also find small peculiarly shaped nodules or concretions of **marcasite.**

If your trip is northward along the west side of the State, you should make a short side trip to Norwood, in Charlevoix County, and look for these minerals about a half mile south of Norwood along the shore of Lake Michigan.

Anthraconite is a brown mineral made of long, needle-like crystals, packed closely together and which break to reveal shining *cleavage faces*. Strike the mineral a sharp blow with the small hammer every mineral collector should carry, and you will get the pungent odor of crude oil. Because of this odor, anthraconite is sometimes called “stinkstone.” The numerous large concretions of anthraconite are an interesting feature of the Antrim Shale. If you have time to go about one mile north of Norwood you can find attractive colored and banded **chert** along the lake shore. From Alpena or Norwood to the Straits of Mackinac there are no recommended stops for minerals, but if you wish to collect rock specimens, a number of localities may be visited along the way. See discussion of “Rocks,” in order to find where to collect.

Upon crossing the Straits of Mackinac your route turns westward. Stop at Pointe Aux Chenes about ten miles west of St. Ignace. Look in piles of stone along the highway. You may find some mottled brown and white **gypsum** or some beautiful specimens of very fine needle-like crystals with a satiny luster. This variety of gypsum is called **satin spar.**

If you have time it would be worth while to make a side trip to a quarry about nine miles east of Trout Lake where excellent and abundant samples of **chert** and **flint** can be obtained. Chert and flint can also be obtained in the old quarries at Manistique if your route is along the northern shore of Lake Michigan. Tours of the Upper Peninsula often take the vacationist by one route and return him by another. If you go first by the route along Lake Superior, excellent specimens of **"bog iron"** ore, **limonite,** can be found about three-quarters of a mile south of Seney and also along the highway west of Seney.

At Marquette you enter the iron-mining district and the region of *igneous* and *metamorphic*, or the *crystalline* rocks which make up the western half of the Upper Peninsula. Veins of **green epidote,** an inch or more in width, show in the granite cuts of Sugar Loaf Mountain a few miles northwest of Marquette and in the granite outcrop near the Dead River Bridge not far from the ore docks in Marquette.

At Ishpeming you really get into the "mineral country." Beautiful light green **talc,** a very soft, greasy-feeling mineral, can be obtained near the Ropes Gold Mine, a few miles north of Ishpeming. At the same locality, **serpentine,** a much harder dark green mineral, that may be streaked with white **dolomite,** can be found. Mixtures of serpentine and dolomite, calcite or talc are known as *verde antique marble*. You may also find at the marble quarry short thread-like fibers of the mineral **asbestos.** From it the asbestos paper and other fireproof materials are made. Vein quartz is abundant at the Michigan Gold Mine a few miles west and north of Ishpeming. Some fragments of quartz contain **tourmaline,** a black shiny mineral in long needle-like crystals. Other minerals such as barite, a white platy heavy mineral, and manganese-bearing minerals such as **pyrolusite, manganite,** and **psilomelane,** can be collected near Ishpeming. Specimens of **iron ore, hematite,** can be obtained at any mine. "Jasper Hill," in Ishpeming, is a convenient place from which to obtain specimens of beautifully banded **jasper** and **specular hematite,** known as jaspilite.

In Negaunee a monument has been erected marking the place where the Jackson Mining Company discovered iron ore in 1845, the year following the first discovery of iron ore in the Upper Peninsula (September 19, 1844). The monument is made of every kind of rock, ore, and mineral found in the Iron Country.

Your next stop should be at Champion. On the old rock piles on Beacon Hill a number of minerals can be obtained. **Specular hematite,** a variety composed of thin, very lustrous, scales of hematite closely pressed together, is the type of iron ore found at this locality. **Magnetite** is abundant and dark red **garnet** crystals are partially imbedded in lumps of magnetite. Long, slender interlaced prisms of black tourmaline have also formed on the magnetite. **Tourmaline** crystals, when broken, show a spherical triangular cross section, that is, the prisms have three sides but the sides are curved. Fine parallel lines are on the long prism faces. Be sure to pick up fragments of **quartz** from the Champion rock piles. In many of these quartz crystals you will see slender prisms of tourmaline. A brown mineral with cleavage like that of calcite is occasionally found at Champion. This is **siderite,** a carbonate of iron.

Let us go to the Athens mine. There the red and dark brown of the heaps of iron ore minerals are in striking contrast to the yellow and buff surface clays, once the deposits on the bed of an old glacial lake. The red mineral is **hematite.** Some hematite is dense, hard, and crystallized in long fibers. Masses of large fibers are known as "pencil ore." Some crystals arrange themselves in oddly shaped masses of concretions know as kidney ore. Some hematite is soft, as you will find when your clothing is soiled if you are not careful how you handle the powdery, non-lustrous ore. **Goethite,** a brown iron mineral that is really hematite plus water, may be found in beautiful orthorhombic crystals in cavities. Nearby is another dark brown mineral, never found in crystals. It is known as **limonite.** It may not be a separate distinct mineral but a fine-grained goethite.

A side trip to Republic, eight miles south of Champion, may add several minerals to the collection. Specular hematite and magnetite are abundant on the old mine dumps. You may find crystallized quartz in openings in the specularite, and occasional crystals of **staurolite** in a light-colored mica schist. Good specimens of **feldspar** can be found at several places. A lead-colored, soft, foliated (in scales or leaves) mineral, **molybdenite,** has been found in quartz veins near Republic, and also in the quartz veins at the Michigan Gold Mine near Ishpeming, but it is in too small amounts to make a search for it worth while.

Return to the junction east of Champion and go west to Michigamme. Five minerals are found in the rock piles of the old mines on the north side of the main road opposite the village. Much of the rock on these dumps is a dark green, soft **chlorite** which is peppered with small octahedral crystals of **martite** and often filled with large crystals of dark red **garnet.** The garnet crystals can be broken out of the chlorite rock by careful chipping with a hammer. The garnets range in size from crystals about one-half inch to crystals two inches in diameter. They are not "fresh" like the garnets found at Champion as they have been changed to the green chlorite which encloses the crystals, but the Michigamme garnet shows excellently the twelve-sided crystal habit of the mineral.

The Lake Superior area's great iron mining industry was born here. Shown is the Jackson pit, near Negaunee, where in 1847 the Jackson Mining Company began mining iron ore. It was near this pit that William A. Burt, a deputy government surveyor, in 1844 discovered the iron ore deposits. He had noted fluctuations in his magnetic compass which led him to ask his men to seek the cause. They returned soon with pieces of iron ore from outcroppings in the area. Subsequently, prospectors from Jackson, Michigan, visited the location, obtained a mining permit, and began operations.

Magnetite is abundant at this location. On one side of an old pit you may notice an outcropping ledge of rock which contains magnetite mixed with a silky looking, asbestos-like mineral known as **grunerite.**

Now take a short side trip through the village of Michigamme, cross the bridge at Michigamme Beach and follow the road on the south side of Lake Michigamme for about one and one-half miles. You will see a rock-cut on the north side of the road in which the dark-colored schist rock has a pimply appearance due to small crystals of **staurolite** which are harder than the body of the rock and stand out in relief as the rock is worn by wind and weather. The staurolite can be easily recognized because so many specimens have two crystals crossed (twinned) to form an X.

You are now ready to head for Michigan's world-famous "Copper Country". Before reaching Houghton, the center of the Copper District, we ask you to stop at a point about seven miles south of L'Anse and examine the rock-cuts for an exposure of **graphite,** a soft, black mineral. The material you will find will probably be rather impure as the graphite is mixed with slate. You have been told about graphite and its use in making "lead" pencils. Graphite was mined from a pit near your sample locality and shipped to Detroit for use in the manufacture of paint.

In this part of Michigan, you are in the heart of the best collecting ground in the North Central States.

Before starting out to make your Copper Country collection you should visit the mineralogical museum at the Michigan College of Mining and Technology in Houghton. There you can see samples of the minerals you are going to look for and your search of the rock piles will be much more interesting.

Starting from Houghton, we suggest that your first expedition be to the Baltic No. 2 mine near the village of South Range, about seven miles from Houghton. First you should look for specimens of native, or free **copper.** Lumps, or masses, of nearly pure copper are rather easy to find on all of the old rock piles. You can easily recognize it by its weight and reddish color when scraped with a knife or file. Usually the metal is coated with a black tarnish due to exposure to the air. At the Baltic mine also look for **chalcocite,** a sort of bluish-black mineral, about the color of a gun barrel. It is in narrow veins in rock. If you find a mineral coated with "peacock colors" it is probably **bornite.** Bornite is the color of bronze when fresh but on exposure to the air tarnishes to shades of purple and red. If you find a mineral which looks much like brass, it is **chalcopyrite.** These three minerals all contain copper and are the types of ore mined in some western copper-mining districts which do not have the free copper of which we are so proud in Michigan. In fact, in few places in the world is copper mined in the free or native state.

On the return to Houghton you can inquire at the village of Atlantic for the Isle Royale series of shafts and the old Huron mine. On the old rock piles of these mines several minerals can be found. You should have no trouble in picking up attractive specimens of **rock crystal quartz,** the crystals being one-half inch or more in length and projecting into the central part of the geode—a crystal-lined cavity. At the Huron mine, in addition to quartz, a soft pink mineral known as **laumontite** may be found.

Chlorite, a dark green mineral forming small shotlike pebbles imbedded in lava, is one of the easiest minerals to recognize on the Isle Royale rock piles. You should look for **calcite,** a white mineral which breaks or cleaves into rhombs, and you may find some geodes with calcite crystals.

If you find a chunk of rock cut through by a vein of light greenish mineral which has the glassy or vitreous look of quartz, the mineral is **prehnite.** Where prehnite was formed in openings in the rock, much of the surface is a mass of small, rounded knobs with slender crystals radiating into the knobs.

From the Isle Royale mine you can start a tour northward in the Keweenaw Peninsula. The next stop is about twenty miles from Houghton at the Wolverine mine. Here you can find attractive specimens of red **microcline feldspar** filling cavities in the lava rock. Within the microcline is a filling of white calcite, so you should have no trouble spotting this mineral. In the waste rock of the Wolverine mine you can find geodes or cavities lined with green crystals of **epidote.** If you should find a bluish-green mineral which looks like turquoise, it is **chrysocolla,** another copper-bearing mineral. Other copper minerals are **cuprite,** which is a sort of brick red color, and **tenorite,** which is black.

From the Wolverine mine it is not far to the Mohawk, Seneca, and Ahmeek No. 2 mines where you should search for a mineral that looks much like silver. Your find may be either **domeykite** or **algodonite,** two very similar minerals containing copper and arsenic.

The final stop for mineral collections is at the Copper Falls mine where **datolite** has sometimes been found. It forms rather complex crystals of various colors, white, pink, yellow, brown, and greenish. You should also look for cavities in the lava which are lined with small reddish crystals of **analcite.** Long slender needle-like crystals of **natrolite** are sometimes found with the analcite.

The visit to the Copper Falls mine completes the itinerary in the Copper Country. A few additional minerals are common enough to be of interest to the collector. These are **ankerite, anhydrite, gypsum, barite, augite, iddingsite, thomsonite, malachite, whitneyite, apophyllite,** and **adularia.**

Other minerals of the iron and copper mines which are too rare to search for are **apatite, atacamite, bowlingite, brucite, faujasite, fluorite, galena, goethite, gold, heulandite, ilmenite, powellite, pumpellyite, rutile, scapolite, silver, sphalerite, stilbite, titanite, zircon, zoisite.**

Several rare minerals are in the dikes and veins of the crystalline rocks. **Sheelite** and **Wolframite,** the ores of the strategic metal **tungsten,** are found in many places, but no large commercial deposits have been located.

Should you return from the Upper Peninsula by way of the Southern Route (U.S. 2) attractive mineral specimens can be obtained in the marble quarries at Randville and Felch, Dickinson County. Slender white satiny-looking prisms of **tremolite** and grass-green blades of **actinolite** are found in the white crystalline dolomitic marble. At Felch a pink **feldspar** can be obtained from a dike rock which cuts across the marble. Where the dike is in contact with the marble, brown and blackish **serpentine** is found.

We will assume that you are now back at your home, we hope with a good collection of northern Michigan minerals. Very few minerals are to be found in southern Michigan in crystals or masses large enough to collect because, as we have said, the rocks are of the sedimentary type and the minerals of which they were made were ground into fine grains and particles by water, wind and ice. However, where cracks, hollows, caves, and other openings have formed in the sedimentary rocks, percolating water has dissolved mineral matter from the rocks and then redeposited it as crystals in the hollows and cracks where there is space for the crystals to grow. The mineral localities of the Lower Peninsula are scattered and collections should be made the object of special all day or all week end trips rather than a continuous tour.

The limestone and sandstone quarries of Monroe and Wayne counties are perhaps the best mineral hunting grounds in the Lower Peninsula. **Calcite crystals** (dog tooth spar) are abundant in quarries near Monroe. Small geodes containing rhombic crystals of **dolomite** may be found and one of Michigan's most beautiful minerals, the sky blue **celestite, is** abundant in the Sylvania Sandstone quarries at Rockwood, Wayne County. Attractive specimens of transparent blue **celestite** and yellow **calcite** in geodes in sandstones are common. **Sulphur** has been found in some of the Monroe County quarries. Celestite contains strontium, an element used in making red flares and fireworks. Another **strontium** mineral is **strontianite** which is not nearly as common as celestite.

Calcite crystals are common in the limestone quarries near Bayport, Huron County, and Omer, Arenac County. Specimens of **chert** and **flint** can be obtained at the same localities.

Calcite and pyrites may be found in the sandstone quarries, and crystals of galena, and sphalerite in the concretions and clay ironstones of the Coldwater Shale quarries. **Rock salt** or **halite** as it is known to the mineralogist, is mined at Detroit. The **gypsum** at Alabaster, National City, Grand Rapids, and Grandville has been mentioned. Very large crystals found in the mines at Grand Rapids are collected for some museums in the state.

The southern Michigan mineral collector is handicapped by the fact that he does not have free access to hunting grounds such as the abandoned mining dumps of the Upper Peninsula. The best searching places in southern Michigan are generally active quarries or quarries kept free of water where freshly broken rock exposes mineral-filled cracks and cavities—mineral veins and geodes. Furthermore, some quarry owners are not inclined to give collectors permission to have free run of the quarry, because of dangers involved.

The Lower Peninsula, however, offers excellent opportunities for studying and collecting specimens of the various types of sedimentary rock formations, and in the deposits in gravel pits igneous and metamorphic rocks may be found. Localities are mentioned in the discussion of rocks.

Michigan's Colorful Minerals

By Robert W. Kelley

Color photo by John R. Byerlay and Robert W. Kelly

Have you ever wondered what our world would be like without color — if everything Jul appeared in shades of gray? To what extent would this appearance affect our thinking and our way of life?

But the world we know abounds with color, particularly in nature. Most of the time we take it for granted, being awed only by the spectacular — like rainbows, sunsets, and aurora borealis in the panorama of the sky, or on a smaller scale, the vivid flowers and birds of the field. Whence this lovely color?

The most familiar colors in nature are exhibited by the living things. Yet our understanding of this category of color is meager. The chemical and physical relationships are very complex. Yet long before plants and animals evolved, mineral substances were displaying colors on a lifeless earth. Eventually living things developed colors by re-constituting the basic components of no-living things.

Minerals are important agents of color. Altogether, about 2,000 different minerals are known today. Briefly defined, they are natural inorganic chemical compounds having certain characteristics — color being the most obvious.

Although minerals are relatively pure or homogeneous, slight impurities often impart variations in color. Generally, however, a given mineral occurs in predictable colors. For example, sulphur is always yellowish. Amethyst, a variety of quartz, is always violet or purple. Halite (rock salt) and pure quartz (rock crystal) have no color, being transparent.

The main reason these colorful objects are not very familiar is because occurrences that would otherwise be easily recognized are usually mantled by vegetation and water, or else deeply buried within the earth. Furthermore, when they are exposed on the surface, weathering processes inevitably reduce them to exceedingly minute particles incorporated in soils.

The purpose here is to show that even the commonest minerals are colorful and attractive. The small group of randomly selected nonmetallic specimens in the color photo illustrates the range and variety of colors found in our own state. Several of them also demonstrate another trait of minerals — crystallinity. No attempt was made to gather unusual rare, or otherwise showy specimens; these are often-found Michigan minerals. In fact, pink gypsum, another of our important industrial minerals, would also have been appropriate. All express a form of beauty and loveliness that can hardly be expressed in words.

If these examples are fascinating, then a wonderful new world of color awaits you in the mineral halls in Michigan museums. Outstanding exhibits may be seen at Cranbrook Institute of Science, Bloomfield Hills; University of Michigan, Ann Arbor; Michigan State University, East Lansing; Michigan Technological University, Houghton; and Grand Rapids Public Museum, Grand Rapids.

Specimens are illustrated at roughly two-thirds their true size. Numbers appearing on the color plate are keyed to the following descriptions:

1 — SULPHUR. Also spelled sulfur. A basic chemical element (S) that occurs frequently in native form. An important industrial chemical used in making sulphuric acid. In Michigan, dispersed in very limited quantities in limestone formations. Specimen from Monroe County.

2 — CELESTITE. Sulphate of strontium ($SrSO_4$). This mineral forms tabular or platy minerals and is the chief source of strontium compounds needed in refining beet sugar, as well as imparting the intense red glow to fireworks and flares. Specimen from Wayne County.

3 — CALCITE. A sharp-pointed crystal variety called "Dogtooth spar." Carbonate of calcium ($CaCO_3$). The chief constituent of limestone, an important industrial mineral, comprising a large part of the earth's crust. Specimen from Monroe County.

4 — CALCITE. Same as specimen No. 3 except this unusual crystal is pointed at both ends. It is also "twinned".

5 — CALCITE. Same as specimen No. 3 except crystals are small.

6 — CALCITE. Though these crystals superficially resemble cubes, they are actually blunt-pointed "dogtooth." This specimen associated with celestite in sandstone formation in Wayne County.

7 — CALCITE. Same as specimen No. 3 except crystals are exceedingly small and stained with sulphur.

8 — FLUORITE. From Latin "to flow," because of low melting point. Fluoride of Calcium (CaF_2). Known as fluorspar in industry. Commonly occurs in cube-shaped crystals. Important in making steel, glass, and hydrofluoric acid. In Michigan, occurs in cavities in limestone but rarely found. Specimen is from Lucas County, Ohio, a few miles south of Michigan boundary.

9 — STRONTIANITE. Carbonate of Strontium ($SrCO_3$). The other source of strontium though not as important as celestite. In Michigan, occurs with celestite, sulphur, and fluorite in limestone formations, but seldom found. Specimen from Lucas County, Ohio, a couple miles south of Michigan boundary.

10 — AMETHYST. From Greek "not to intoxicate" because sobering effects were attributed to it. The most valuable gem variety of quartz (see No. 11). Violet to dark purple color is due to inclusion of iron, manganese, or boron. Specimens are from Keweenaw County.

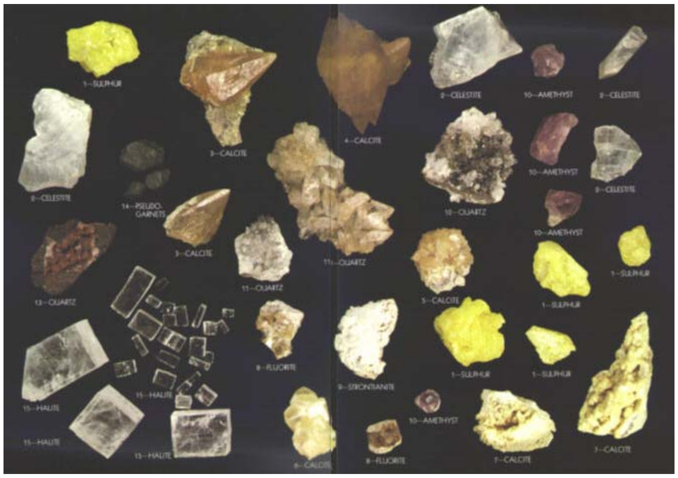
11 — QUARTZ. Oxide of Silicon (SiO_2). Pure and crystalline form called "Rock Crystal." Quartz is one of the most abundant minerals in the earth's crust. Crystals are usually pointed prisms. Occurs in all types of rock formations but these specimens came from Precambrian basalts in Houghton County.

12 — QUARTZ. Same as specimen No. 11 except this cluster is colored with an olive green mineral called epidote. Specimen from Houghton County.

13 — QUARTZ. Cluster of crystals stained red by the metallic mineral, hematite, an Oxide of Iron (Fe_2O_3). Specimen from Marquette County.

14 — PSEUDO-GARNETS. These 12-sided crystals are composed of a very complex iron-magnesium silicate mineral called chlorite. Originally garnet, but replaced by chlorite. Specimens from Marquette County.

15 — HALITE. The mineral form of pure rock salt, Chloride of Sodium (NaCl). Many minerals have a tendency to break or cleave smoothly in definite directions. Halite is a good example of cubic cleavage. Probably no other industrial mineral has as many uses as rock salt. It occurs extensively in deep-seated layers throughout southern Michigan. Specimen from Wayne County.



GEM MINERALS

Although no precious stones have been found in Michigan, some of the minerals found in the Keweenaw Peninsula and on Isle Royale are attractive enough when cut and polished to be classed as gem minerals.

If your vacation includes a trip to Isle Royale you should look along the beaches for a number of these minerals.

The most sought for stone is **chlorastrolite,** a green mottled mineral forming pebbles in the lavas similar to chlorite. It is very attractive when polished. Chlorastrolite was first discovered on Isle Royale and the island is the principal known locality for it, so you are searching for a real native Michigan mineral. The best places to look are along the beaches on Smithwick and Mott islands off the shore of Isle Royale, and along the south shore of Siskiwit Lake.

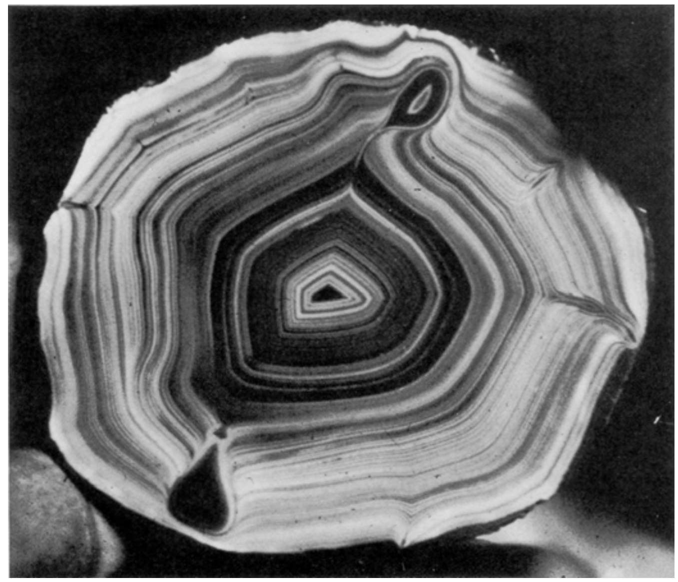
Thomsonite is another sought-for gem stone found on the Keweenaw Peninsula and on Isle Royale. It is also among the pebbles along the shores and when polished shows attractive white, pink, green, and yellow mottlings and “eyes.”

Several varieties of **quartz** found on the Keweenaw Peninsula and on Isle Royale are classed as gem stones. Attractive specimens of the purple crystal variety known as **amethyst** have been found on Isle Royale, but it is not so common on the mainland of the Keweenaw Peninsula.

Several of the fine-grained varieties of chalcedony quartz are very attractive when polished. **Agate** is a variety of chalcedony made of layers of colored mineral. If the layers are straight and parallel instead of wavy and concentric, the stone is called **onyx.** Cameos are made from agate, the figure or head being carved from one layer, leaving a background or base of darker or lighter color.

The best place to find agates in Michigan is along the shores of Lake Superior, on the Keweenaw Peninsula, or on Isle Royale. You may occasionally find one in a gravel pit.

Carnelian is a red form of chalcedony, the color being due to finely mixed iron oxide. Carnelian Beach at the head of Siskiwit Bay, Isle Royale, is the favorite hunting ground for carnelian and also for agate. **Datolite** and **prehnite,** also are attractive when polished. Inclusions of copper enhance the beauty of these minerals.



A cut and polished agate.

METEORITES

A streak of light speeding across the starlit sky, the display of “shooting stars” in mid-August, the report of a meteor, flashing, crashing to the earth, always excites our interest. The “stars” shoot overhead across the sky and disappear, or they are directed downward toward the horizon and seem to reach the earth. About a million do reach the earth each year according to the astronomers, but most of them fall in the oceans. Those that fall on land are occasionally found and give us an idea of what some of the stars are made. They are meteorites or fragments of cold shattered stars which become red hot by friction with our atmosphere as they flash through the upper air at a speed of many miles per second. Even the smallest fragments of meteor appear very large when red hot and their glow magnified by radiating light rays. Because “finds” of **meteorites** are so often reported we include a brief description of them.

We have said that very little metallic iron is found in our earth rocks, but it does come to us from the stars in those heavy *nickle-iron* meteorites known as **siderites** which are made of metallic iron with grains of nickle so small as to be invisible except under a microscope. We can distinguish the iron of meteorites from the iron of earth rocks because some meteorites when polished and etched with acid show fine lines arranged in an eight-sided pattern, known as "Widmanstätten figures" after the man who first studied them. These lines have not as yet been found on the metallic iron of the earth.

A rather rare type of meteorite is made of dark minerals meshed in a spongy network of light-colored alloys of nickle and iron. These *stony-iron* meteorites are known as **siderolites.**

About ninety percent of the known meteorites are made of rock materials like volcanic ash and sand and contain spherical shot-like bodies known as *chondrules*. These are the *stony* meteorites or **aerolites,** and when crystalline are so similar to some of our earth rocks that it is difficult to determine their origin.

Only five meteorites have been reported found in Michigan:

> The Grand Rapids meteorite was found in an excavation in the city of Grand Rapids in September, 1883. It weighed 51.9 kilograms or 114.2 pounds.
>
> The Reed City meteorite (a siderite) was found on a farm near Reed City in 1895. It is composed essentially of iron (89.38 percent) and nickel (8.18 percent) and weighed 19.8 kilograms or 43.6 pounds. Iron contained in the meteorite is octahedral in character and well marked with "Widmanstätten figures."
>
> The Allegan stony meteorite (an aerolite) was observed to fall near Allegan on July 10, 1899. The body was badly shattered on striking the ground but probably weighed about 70 pounds. The main mass of the aerolite weighed 62½ pounds.
>
> On November 26, 1919, a meteor was observed from many points through southwest Michigan. It apparently fell somewhere in Berrien County but it was never located.
>
> Three stones with a total weight of 10½ kilograms or 23.1 pounds were recovered from a fall observed at Rose City, Ogemaw County, at 11:00 P.M. on October 17, 1921.

ROCKS

In Part I of this book you were told about minerals, and about the minerals which may be found in a handful of sand. Part II points out how the minerals of the handful of sand may also be seen in pebbles, cobblestones, or boulders, and explains how sand is made. Many other minerals which may be studied in a gravel pit or stone pile are described and localities given where specimens of the minerals suitable for collecting may be found in Michigan. Some of the specimens that may be collected in these localities are crystals, others are simply larger fragments of the minerals that are to be found in gravel pits, and are more or less free from mixture with other minerals. For example, a specimen of feldspar collected in a gravel pit would undoubtedly be in a pebble in which the pink feldspar is associated with quartz and mica or hornblende, but in the localities described crystals of free feldspar may be found. To aid you in making a mineral collection we took you on a tour of Michigan because it is impossible to make a really good collection of minerals from a gravel pit, although you can study many of them there.

You can, however, make a good collection of rocks from a gravel pit or stone pile. As we have said before, the pebbles or cobbles are called by the geologists "rocks." We have said that a gravel pit is not the best place from which to make a mineral collection because the minerals are not free. But for this very reason it is a good place to collect rocks because all but a few *rocks are mixtures of minerals*. **Limestone, dolomite** and **quartzite** are examples of rocks made almost entirely of one mineral.

Most common of the rocks, **granite,** is a mixture of light-colored quartz, pinkish feldspar, and a dark mineral—mica, hornblende, augite.

Most of the stones we see in cemeteries are of **granite,** because granite is the most enduring and everlasting thing we have on earth. In any cemetery you will see markers that have a very old appearance, the polish has disappeared and the stone is no longer attractive. These lusterless stones are of marble which was beautiful when newly polished but which is so much softer than granite that it is dulled much more quickly by the scratching of the often invisible dust particles in the air.

You can see several varieties of rock or stone in almost any village or city street. Many bank and office buildings are built wholly or in part of stone. The lower part of the building is generally of granite because it has the great strength needed to support the remainder of the building. Granite, however, is too costly to cut and polish to use in the entire building, so *limestone*, *sandstone* or *marble* is used for the upper stories. Notice the steps. These are nearly always of granite because little hollows are soon worn in steps made of the softer varieties of stone. You surely have noticed the green marble used in banks and below so many store windows. This is known as **verde antique marble,** and is the mineral serpentine containing streaks or veins of calcite, dolomite, or talc.

Marble is more "showy" or imposing than granite in its variety of color combinations and few people fail to admire the striking effects produced on the interior of large buildings by the use of beautiful, highly polished, varicolored marbles.

IGNEOUS ROCKS

Granite is an **igneous** rock, that is, was formed by a cooling of molten rock (magma) deep in the earth. But granite is only one of many igneous rocks formed in this manner. Igneous rocks do not all look alike. Molten rock, or *magma*, does not always have the same chemical composition. Some magmas have more silica, or more iron, or more magnesium, or any of the other chemical elements which make up all things living or non-living. Magmas with much silica make light-colored rocks, but if iron is abundant the rocks are darker. Iron coloring the rocks is never in the form of metal but is in combination with silica, calcium, aluminum, and other chemical elements forming dark-colored minerals. *Minerals are combinations of chemical elements; rocks are combinations of minerals*. Hornblende, mica, and augite are the minerals which give dark color to igneous rocks; quartz (pure silica) and orthoclase (silica, aluminum, and potassium) are responsible for the light color in igneous rocks. *Common igneous rocks, other than granite are syenite, diorite, gabbro, peridotite, pyroxenite, rhyolite, basalt, obsodian, pumice*. Some of these rocks are *intrusive* and some are *extrusive*. Limestone and sandstone are **sedimentary** rocks; marble and slate are **metamorphic** rocks.

To learn about these three main classes of rocks and to make a collection of the different varieties it is hardly necessary to go far from your back yard, especially if you live in the country. A gravel pit, stone pile, excavation for a cellar, an abandoned house foundation, or even a vacant lot will supply material for your study. Perhaps you have a collection of rocks made from a gravel pit or collected on some trip around Michigan, or have noticed the rocks in the stone houses of your town and parks, or maybe the foundation of your house or school; perhaps you know a rock garden made of interesting stones and have wondered what they are.

In the following pages we tell you about the different kinds of rocks and the places in Michigan where thick ledges or beds of such rocks are at the surface. The pebbles, cobbles, and boulders of gravel pits are pieces of rock which were torn off the ledge rock by the glacier thousands of years ago. The fragments of rock were often made as round as marbles by being rolled along by streams of water running out from the melting glacier. Much of the rock was ground into sand which was mixed with the round stones and spread out into beds of sand and gravel. Most of the rocks of the gravel pits are igneous or metamorphic because the softer sedimentary rocks are destroyed; they are broken up into sand and clay. However, some sandstone, limestone, and shale fragments may be found.

Intrusive Igneous Rocks

Most common of all igneous rocks, the rock most valuable for building and monumental purposes is **granite.** Because it is very hard, its crystals uniform in size, and its color permanent, granite takes a beautiful and enduring polish. The rock is dark to light gray or pink and reddish depending on the color of one of its minerals—feldspar, the mineral which shows flat shiny crystal faces when a mass of granite is broken. The other minerals in granite are quartz, the black mica biotite, and/or hornblende.

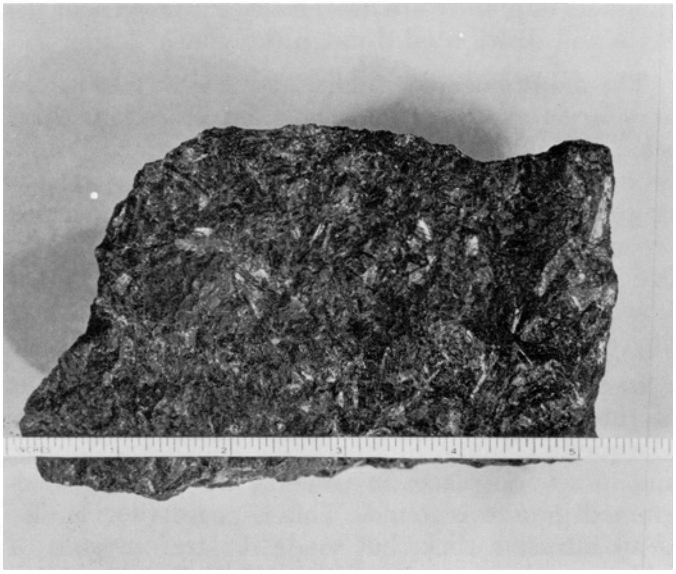
No granite quarries are operated in Michigan although attractive varieties of granite are found in Dickinson, Marquette, Iron, and Gogebic counties. Boulders of granite are universally scattered over the State and distributed through the glacial drift.

The granite near Republic, Marquette County, has very large crystals of feldspar, some an inch or more wide, imbedded in a finer ground mass or background of granite. This rock is **porphyritic granite** or **granite porphyry.** The large crystals (phenocrysts) are of feldspar, and were the first minerals to crystallize out of the cooling granitic magma. In the Lower Peninsula large boulders of granite and porphyritic rocks are in the glacial drift.

In the areas of granitic rocks in the western part of the Upper Peninsula, especially near Republic, Marquette County, Metropolitan, Dickinson County, and in several places in Gogebic County, a coarse-grained granite is found. This is **pegmatite.** It also is an intrusive rock, but made of large crystals of feldspar, quartz and mica showing that it cooled slowly. Some pegmatite contains rare and valuable minerals such as tourmaline, beryl, topaz, and others. The mineral crystals of pegmatite are usually very laree, many of them from several inches to a foot or more in diameter. This rock is the natural source of the feldspar mined for commercial purposes, and also the parent rock of many gem stones. Feldspar has been mined from pegmatite dikes near Republic and Metropolitan.

Granite

Pegmatite is seldom in large masses but is usually in veins or dikes cutting through other kinds of rock. Frequently a mass of granite or diorite may have a thick vein of pegmatite running through it. Many glacial boulders contain streaks of pegmatite. Such boulders are prized as the odd stones of rock gardens. Pegmatite should not be confused with porphyritic granite as the two can be distinguished by the relative size of the mineral grains. In pegmatite the crystals are uniformly large, but in a porphyry usually but one mineral is in large crystals, the others making the fine ground mass in which the large crystals are embedded.



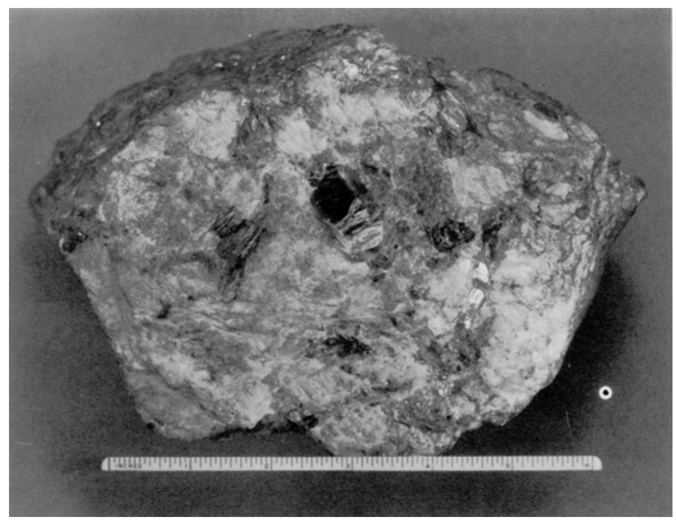
Gabbro

Porphyry

Another, but fine-grained rock similar to pegmatite is aplite. A dike of **aplite** cuts through the marble of the quarry near Felch, Dickinson County.

Quartz is an important mineral in the granites, but is lacking in a rock often confused with granite, **syenite.** Syenite also is an igneous intrusive rock. It resembles granite, but careful examination will show that the syenite has no quartz, but is composed of long prisms of the dark mineral hornblende (rather than the scaly biotite mica) and feldspar which is the chief constituent of the rock. As a building stone, syenite compares favorably with granite but is superior to granite in resistance to heat. The quartz grains of granite contain minute bubbles or inclusions of liquid or gas, which expand and cause the rock to rupture when exposed to intense heat. Syenite is not a common rock in Michigan although small masses of it are found in the granite areas near Marquette and syenite pebbles are common in the conglomerates of Keweenaw County. Syenite boulders are not as common as granite in the glacial drift because the glacier did not pass over any large outcrops of the rock.

Granite cut by a diabase dike.



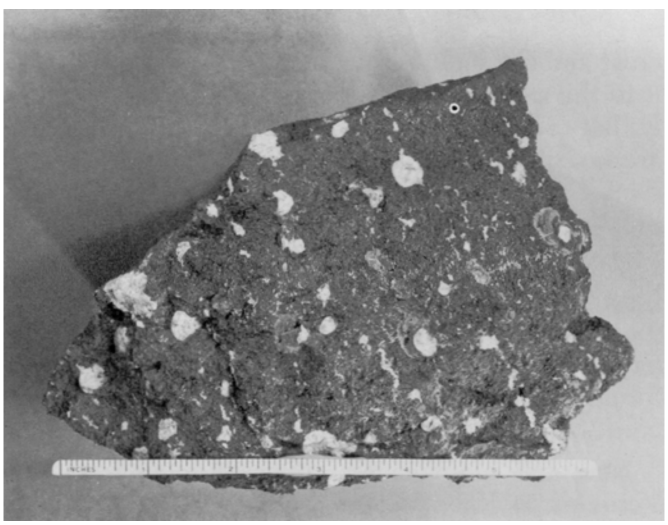
Pegmatite with mica crystals.

If you find a dark-colored boulder having about equal amounts of hornblende and feldspar it is probably **diorite.** The hornblende makes it darker than syenite and granite. It has little quartz except in certain varieties known as **quartz-diorite** and **grano-diorite.** The feldspar of the diorite is a cousin of the orthoclase feldspar of granite, but is darker in color and made of sodium and calcium rather than of potash. Masses of true diorite are not found as outcrop rock in Michigan but boulders are common in the glacial drift as the glacier scraped diorite off the ledges in Canada. The so-called diorite sills near Ishpeming and Negaunee are in reality altered gabbro.

Gabbro is an intrusive igenous rock much darker than diorite because the black minerals are more abundant in it than the lighter feldspar. The dark mineral is augite rather than hornblende. Gabbros are found in the Upper Peninsula of Michigan, but they have been changed or altered from their original composition as the augite has been generally altered to a fibrous form of hornblende known as **uralite** and the rock is incorrectly called diorite.

In grading from granite to gabbro rocks become increasingly darker colored as the quartz content decreases. If we chemically analyze the darker minerals we will find that the amounts of iron, magnesium and calcium are much greater than the silica (quartz) hence the darker color.

A dark rock may have light-colored lath-shaped crystals in a mass of finer dark crystals. This rock is **diabase.** Diabase is common in the western part of the Upper Peninsula generally in dikes cutting across other rocks and in sills and sheets between layers of rock. Diabase is an intrusive rock almost like gabbro but is classed as a separate rock because of its peculiar lath shaped crystals of lime feldspar in a ground mass of augite crystals. A variety of diabase is **ophite,** a rock which has the mottled appearance because the crystals of augite seem to wrap themselves around the feldspar laths. Good specimens of ophite may be found in certain parts of the copper region, but the drift boulders show the diabasic and ophitic character of the rock better than the fresh rock of the Copper Country because weathering in the drift has etched the crystals into relief.



Amygdaloidal basalt (trap).

Other igneous intrusive rocks are **peridotite, pyroxenite** and **hornblendite.** We started with the granites having quartz, feldspar, hornblende and/or mica, then we described the syenites made of hornblende and feldspar, no quartz, then the diorites and gabbros with little or no quartz, now we come to the peridotites, pyroxenites and hornblendites which have little of either feldspar or quartz. Peridotite is a heavy dark-colored rock composed largely of augite or other minerals related to it (the pyroxene group) and olivine, or of olivine alone. Pyroxenite and hornblendite are made principally of pyroxene and of hornblende respectively as their names imply. Because of the high content of iron in these rocks they are easily attacked by weathering when exposed to the atmosphere and soon crumble into heavy dark-colored soils.

An altered peridotite near Ishpeming is cut by gold-bearing quartz veins. In the Kimberley region of South Africa diamonds are mined from a “blue ground” which was formed by the weathering of a variety of peridotite known as kimberlite. Diamonds found in the glacial drift, including one found near Dowagiac, Michigan, are believed to have been gathered by the glacier from outcrops of peridotite which the ice passed over somewhere in Canada.

Extrusive Igneous Rocks

Some of our rocks are very fine textured and some are glassy. These are the extrusive igneous rocks, formed when a crack or crevice opened in the earth’s crust and the molten rock or magma poured through it to the surface. There the magma cooled so quickly that crystals did not form or are so small that they are invisible to the naked eye. Some types of extrusives have many small “blow holes” caused by the bursting of the gas bubbles in the cooling rock.

Volcanic material under high gas pressure is often blown out of volcanoes in the form of large bombs (boulder-like masses of lava), fine nut-like lapilli (lava pebbles), or very fine ash. These are extrusives formed by explosive volcanic action through a comparatively small opening.

New and old volcanic cones or mountains—like Vesuvius in Italy, Crater Lake in Oregon, and the volcanoes of the Philippines and elsewhere, are the result of this sort of earth activity.

The 1943 explosion of the new volcano Paricutin in Mexico is a recent earth activity of this sort. In some parts of the earth layers or strata of volcanic ash and lapilli have collected and been cemented into sedimentary rock. But most of the extrusive igneous rocks in Michigan were formed from quiet lava flows which reached the surface through long cracks or crevices.

The first intrusive igneous rock we described was granite. But if the magma which slowly cooled to crystalline granite had come to the surface and cooled quickly it would have made a rock we call **rhyolite.** This rock was a light-colored **lava** made of silica (quartz) and feldspar which cooled so rapidly that the crystals are so small as to be indistinguishable without a microscope.

In some rhyolites glassy feldspar or quartz formed somewhat larger crystals than the body of the lava and so gave the rhyolite a porphyritic texture. Rhyolite is a common type of rock in the Copper Country of the Upper Peninsula. The copper-bearing conglomerate of the Keweenaw Peninsula is made of pebbles and fragments of rhyolite porphyry which have been cemented together by copper and other minerals. Occasionally pebbles or cobbles of rhyolite may be found in gravel pits.

An interesting volcanic rock which is not found as bedrock in Michigan although rare fragments of it are found in the glacial drift is volcanic glass or **obsidian.** It was formed by quick chilling of a granite magma which was poured on the surface. It is dark and glassy and breaks with a peculiar shell-like fracture, like glass. In the Rocky Mountain and the Pacific Coast states whole mountains are made of obsidian. Because it is very hard and glassy, obsidian was highly prized by early man for making arrowheads, knives, and other implements and ornaments.

Much of the native copper mined in the Keweenaw Peninsula fills cavities in the lava we call **basalt.** The cavities are amygdules and the copper is referred to as amygdaloidal copper. Basalt is a fine-textured (or grained), dark-colored rock formed by rapid cooling of magmas which would have formed gabbro if they had been cooled slowly below the surface. So basalt is the extrusive equivalent of the intrusive gabbro as rhyolite is the extrusive equivalent of intrusive granite. You will often hear these rocks of the Copper Country called **trap,** a word that refers to the massive lower part of the lava flows. The upper frothy part of the flows is known as the amygdaloid.

Basalts differ considerably in appearance. Normally, basalt is extremely fine-grained with crystals of microscopic size. Frequently when a basaltic magma is poured out on the surface it contains much gas which is released by bursting of bubbles as the lava cools.

The explosion of the gas bubbles causes "blow holes" or openings to form in the cooling rock. If the cooling lava is not flowing when the gas bubbles burst the blow holes will be roughly spherical in shape and form a sponge-like rock called **scoria** or **vesicular basalt.** But if the lava is in motion when the blow holes are being formed the holes may be drawn out and elongated into tear-drop or almond-shaped or even pencil-shaped openings called *amygdules*. Basalt containing such openings is usually termed amygdaloidal basalt. **Pumice** is a light-colored spongy lava. Extrusives are reaching the surface of the earth in volcanic regions now active, but the extrusive igneous rocks of Michigan are very old and their cavities have been filled with minerals to form amygdules, geodes, agates, as well as the amygdaloidal copper and some gem stones.

The igneous rocks of Michigan are the remnants of ancient lava flows and the cores of ancient mountain ranges whose peaks have been worn away. Just how the mountains were formed is another chapter of geology, but the materials worn from them were carried away and deposited to form the type of rocks found east of Marquette in the Upper Peninsula and underlying all the Lower Peninsula — the sedimentary rocks.

SEDIMENTARY ROCKS

In our gravel pit or rock garden we found a hard rock, seemingly made from many pebbles cemented together. This is a **conglomerate.**

Conglomerate is a sedimentary rock composed chiefly of rounded fragments which range in size from fine gravel to large boulders. Conglomerates are formed usually by the cementation of gravel and cobble deposits along the shores of large bodies of water. Conglomerates consisting of rhyolite, partly cemented by copper are found in the Keweenaw Peninsula and southwestward along the Copper Range. Conglomerates of different types are exposed near Marquette and in the vicinity of Munising. In the Lower Peninsula conglomerates are found as pebble bands in the Marshall Sandstone near Port Austin and Grindstone City in Huron County. The pebbles in this formation are smooth and polished and resemble peanuts set into a matrix of firmly cemented sand. The term "peanut conglomerate" is often applied to these pebbly zones. The Parma formation near Jackson also has zones of conglomerate.

The Romans built high stone walls that through the centuries have broken up. The mass of angular rock fragments collected at the foot of the walls have become cemented together and are called **breccia** (pronounced bret-chi-a). Geologists have adopted the descriptive word to describe a rock similar to conglomerate except that the pebbles, cobbles, and boulders are angular rather than rounded in shape. The angularity of the fragments seems to indicate that the material was not washed very much nor transported very far before it was cemented into rock. Some breccias may have been formed at the base of cliffs through the cementation of broken rock material (talus) which builds up at the base of the cliff. Ridges of cherty limestone breccia are found near Mackinaw City and St. Ignace and also on Mackinac Island. It is now believed that the breccias of the Mackinac Straits region were formed by collapse of the limestone into subterranean openings that had been formed when ground water dissolved limestone and salt, making caves and cavities.

Graywacke is a dark-colored breccia usually composed of broken fragments of shale, slate, basalt, granite. In Michigan it is found only in a few areas in the western part of the Upper Peninsula. A few boulders of graywacke are found in the glacial drift.

Great masses of our sedimentary rocks are **sandstone,** a rock formed from the cementation of deposits of sand laid down in the shallow waters of seas and lakes. The greater abundance of sand and the fact that grains of sand, being lighter than pebbles and gravel, are carried out greater distances from shore, explains why deposits of sand are much more extensive than deposits of conglomerate.

Sandstone is composed of grains of sand, mainly quartz, which are held together by various forms of cementing material. The color of sandstone is generally due to the character of the cement. Iron oxide cement gives yellow, brown, and red colors to the rock. Silica and calcium carbonate are common cementing materials, but do not usually impart color to the rock. Clay is another common cementing material.

The durability of sandstone depends almost entirely upon the nature of the cement. Sedimentary rook can be no stronger than the cementing material which holds the grains together. In some sandstones the cement between the particles is so weak that the rock crumbles between the fingers. Other sandstones are so firmly cemented that it takes a strong blow with a hammer to break them. Deposits of sandstone are not so extensive as limestone, yet it is a common rock in Michigan. Sandstone is most prominent in the Upper Peninsula where it forms the famous "Pictured Rocks" along Lake Superior. The rapids of St. Marys River near Sault Ste. Marie and numerous waterfalls throughout the Peninsula owe their existence to sandstone ledges which in many places are capped with a harder dolomite. In the Lower Peninsula outcrops of sandstone are found chiefly in Calhoun, Huron, Jackson, Eaton, Shiawassee, Wayne, and Monroe counties.

It is possible that we may find a rock in the gravel pit that breaks into thin plates and is a fragment of **shale.** Shale is compacted clay formed from deposits of mud laid down in the deeper parts of the ocean basins or deposited near shore by rivers having gentle currents. Mud deposits usually begin where the finest sands, washed out from shore, leave off and may extend for several hundred miles offshore into deep water. Shale may be white, blue, grey, red, green or black, depending on impurities and cementing material.

Another important sedimentary rock is **limestone** which is composed principally of the mineral calcite. It is formed by the accumulation of the remains of sea animals which become buried in "graveyards of the sea" and also by chemical precipitation of calcium carbonate from solution. Marine animals such as corals remove calcium carbonate from the sea water and build it into their shells and skeletons. Upon death the remains sink to the sea floor and help to build up beds of **limestone.**

Pure limestone is formed in the clear sea at a considerable distance from shore, hence is relatively free from sand and mud. Limestone formed closer to the shore becomes intermingled with sand and mud carried out by variable currents and tides and is therefore sandy or shaly.

Dolomite is very similar to limestone. It is a chemical admixture of approximately equal amounts of calcium and magnesium carbonates. It is somewhat more dense and slightly harder than pure limestone and is dissolved much more slowly with dilute hydrochloric acid. The powder, however, fizzes more freely than does the massive rock, hence in making the acid test it is advisable to scratch the surface of the rock into a fine powder with a knife blade, before applying the acid.

Dolomite is an important rock in the sedimentary formations of the Upper Peninsula. It forms a belt bordering the north shore of Lakes Michigan and Huron, extending from the Garden Peninsula in Delta County to Drummond Island. It is the chief kind of rock in the Niagaran (Silurian) Series which may be traced eastward beyond Rochester in New York. It is in this same formation from which the Niagara Falls and Gorge have been sculptured.

The Engadine Dolomite is a very pure member of the Niagaran Series, quarried in Mackinac and Chippewa counties. Pure dolomites such as the Engadine are potential sources of magnesium, a very light metal.

In the Lower Peninsula, dolomite forms a narrow strip along the shore of Lake Erie in Monroe and Wayne counties. The formation which contains the various dolomite beds in the southeast corner of the State was long known as the "Monroe formation," but is now named the Detroit River and Bass Islands formations.

Gypsum, anhydrite and **rock salt** are important sedimentary rocks. They are the residues left where the water of ancient seas and lagoons evaporated as the climate became arid, and are rocks which may contain but one mineral. Gypsum rock contains the white mineral gypsum — calcium sulphate plus water— but is colored gray, yellow, buff, pink, red, brown, by clay and iron oxide impurities. It is a soft rock, can be scratched with the fingernail, and occurs in thin and massive beds and as lenses in limestone and shale.

Anhydrite rock is made of the mineral anhydrite, — calcium sulphate. It is pearly white but may be tinted red, blue, brown, by impurities. It is harder than gypsum and can be scratched with a knife. On exposure anhydrite takes up water and becomes gypsum.

Rock salt is formed of the mineral halite, common salt. It is in thick massive beds of pure salt or may be in thin layers interbedded with limestone and/or shale.

Sandstones

"Marquette brownstone" (Cambrian), a dark reddish-brown, ferruginous (iron-cemented) sandstone was formerly quarried at Marquette and shipped to various cities on the Great Lakes. It was used extensively as a building stone in the era when "brown-stone fronts" were in vogue. Many of the older buildings in Marquette and other Upper Peninsula towns were constructed of this sandstone.

"Jacobsville redstone" (Cambrian) forms a rather wide belt through the eastern part of Keweenaw, Houghton and Ontonagon counties. Its bright red color is due to the presence of a highly oxidized iron cement which binds together the grains of quartz of which it is largely composed.

This sandstone, quarried rather extensively at one time, was used for building purposes in many cities in northern Michigan and elsewhere in the region of the Great Lakes. Some stone was shipped as far east as Boston and New York. The stone is obtainable in blocks up to thirty inches in thickness and the face of the stone can be carved into rather intricate designs.

Sylvania sandstone (Devonian) is a relatively pure sandstone made almost entirely of rounded grains of white quartz, loosely cemented together. Because of its high purity the sand is used in the manufacture of glass for milk bottles and for automobile and plate glass.

This sandstone is well exposed at Sylvania, Ohio, whence it receives its name. In Michigan, the outcrops form a narrow belt extending from the southwest corner of Monroe County northward to Rockwood in Wayne County. The sand was used for the manufacture of early Pittsburgh pressed glass, prized by some collectors of antiques.

Marshall sandstone (Mississippian) Outcrops are found chiefly in Jackson and Calhoun counties and in the northern part of Huron County where this sandstone forms the "Thumb Nail" of Michigan. The Marshall sandstone has been quarried for building purposes at the city of Marshall, whence it gets its name, and also near Battle Creek and Napoleon. It is now being quarried near Napoleon, Jackson County. At Grindstone City in Huron County, the rock was used in the manufacture of grindstones. An old quarry at Waverly near Holland, Ottawa County, supplied stone for many of the old buildings and foundations in Holland. Near its rim the Marshall sandstone is a source of fresh water and in the central part of the Lower Peninsula, in the deeper part of the bowl-shaped formation, it contains valuable brines which were formerly manufactured into salt and chemicals at Midland, St. Louis, and Saginaw. Because the dip (slope) of the strata is toward the center of the State, Marshall sandstone is found in wells at a depth of about 1,400 feet in these localities. Fossils of plants and shelled animals may be found in these rocks.

Ionia sandstone (Pennsylvanian) is a variegated or mottled variety with colors ranging from yellow and brown to shades of red and purple. It is composed largely of grains of quartz held together with a cement of iron oxide. When first removed from the ledge the rock crumbles rather easily. However, it hardens upon exposure to the air and eventually becomes firm enough to be used in building.

Outcrops of Ionia sandstone are prominent along the Grand River Valley in the vicinity of Ionia and Grand Ledge. The rock was formerly quarried along the river a short distance east of Ionia and was popular as a building stone in many cities of the central part of the Lower Peninsula.

Because it is a coarse quartz sandstone, the Ionia has been used in experiments in the manufacture of rock wool.

Shales

Antrim Shale (Mississippian-Devonian) is one of the most easily recognized of the rock formations underlying the Lower Peninsula. It is characterized by its universally dark brown or black color which is due to a high content of oily matter. In many places it contains thin veins, nodules, and crystals of pyrite ("fool's gold") and marcasite, and also large spherical concretions of clay ironstone, dolomite, and anthraconite or "stinkstone."

In certain areas, particularly in the vicinity of Atlanta in Montmorency County, Antrim shale is the source of small quantities of natural gas which seep to the surface. Also it probably is the source bed of the gas which farmers often report and occasionally use in Macomb, Oakland and Wayne counties. The shale was first seen and described in a small exposure in Antrim County, hence its name, but its larger outcrops are chiefly in Charlevoix, Cheboygan and Alpena counties. It is quarried at Paxton in Alpena County for use in the manufacture of Portland cement.

Interesting concretions of iron pyrites, anthraconite, and scattered fossils, chiefly fish teeth, may be found in Antrim Shale.

Ellsworth Shale (Mississippian) is a gray, greenish-and light-brown shale overlying the Antrim Shale. Exposures are found only in the Grand Traverse Bay region in Antrim and Charlevoix counties. The shale obtained from the Ellsworth quarry in Antrim County is used in the manufacture of Portland cement at Petoskey.

Coldwater Shale (Mississippian) is a soft, blue-gray shale named from the exposures near Coldwater in Branch County, where it was quarried for use in the manufacture of Portland cement. Coldwater Shale is exposed near water level along the shore of Lake Huron between Harbor Beach in Huron County and Port Sanilac in Sanilac County and in the valley of Willow Creek, Huron County. Interesting concretions and clay-ironstone nodules may be found in the Coldwater Shale which disclose crystals of other minerals when broken open. Fossils are occasionally found.

Coal Measure Shales (Pennsylvanian) of the Saginaw Sandstone are exposed in the vicinity of Grand Ledge, Jackson, Corunna and Williamston. They vary somewhat in color from gray to black and contain beds of coal. These shales are quarried for and are used in the manufacture of various kinds of tile products. Fossils of plants and invertebrates are common.

Limestones

Trenton Limestone (Ordovician) so-called from the place where it was first studied at Trenton Falls, New York, crops out in Michigan chiefly in the vicinity of Escanaba, Rapid River, and Trenary. It underlies a drift-covered belt which extends across the eastern half of the Upper Peninsula from Menominee to the Neebish Islands. The formation slopes to the southeast and in the central part of the Lower Peninsula is reached in wells at depths of 5,000 and more feet. The formation is quarried for road metal and concrete aggregates at Escanaba. In southern Michigan considerable oil and gas is obtained from the Trenton limestone at a depth of about 4,000 feet.

Good fossil collections may be made in Delta County at Bony Falls, and from the exposures along the east bank of the Escanaba River.

Fiborn Limestone (Silurian) is in a very pure bed of smooth-grained limestone in Schoolcraft and Mackinac counties. This seems to be the only pure bed of limestone found in the magnesium limestones and dolomites of the Niagaran series of rocks. It was formerly quarried at Fiborn and Hendricks in Mackinac County and near Blaney in Schoolcraft County but at present it is being quarried only near Port Inland in Mackinac County.

The stone is suitable for blast furnace flux in smelting iron ore; for lime, calcium carbide, paper and sugar manufacture and for other uses where a very pure limestone is required.

Manistique Dolomite (Silurian) crops out in arc across the southern part of the Upper Peninsula from Drummond Island to Garden Peninsula. It has been quarried at Manistique and used for riprap, and harbor and road building stone. Many beds of the formation are highly fossiliferous, containing beautifully preserved shells, chain and honeycomb corals, and other corals of the solitary type.

The Engadine Dolomite (Silurian) outcrop is a broken, northward-facing escarpment across the southern part of the Upper Peninsula from Drummond Island, Chippewa County, to Seoul Choix Point, Schoolcraft County. Quarries are near Ozark, Mackinac County and in western Drummond Island. Fossils of corals and shelled creatures are plentiful.

Bass Islands Limestone (Silurian) is quarried in Monroe County. During the early settlement of the country several small quarries were opened; the stone was used for building purposes and for lime burning. It is now sold as crushed stone.

Detroit River Dolomite (Devonian) forms the bed of the Detroit River below Detroit and the stone removed in deepening the channel was used for concrete, road metal, ballast, and building purposes. In its deep subsurface extension under Michigan the formation contains important reservoirs of brine and petroleum.

The **Dundee Limestone** is named from the village of Dundee in Monroe County where the stone was first quarried. Because of the dip of the rocks toward the center of the State with a corresponding rise at the margins, the Dundee crops out also in the northeastern part of the Lower Peninsula where it is overlain by the younger Rogers City Limestone. The most extensive outcrops of the Dundee-Rogers City formation are in Presque Isle County. The quarry at Rogers City is said to be the largest limestone quarry in the world. Limestone is used for blast furnace flux, road metal and concrete aggregates, in sugar and paper manufacture and for making Portland cement, calcium chloride, calcium carbide, sal soda, caustic soda, for “agstone” or lime fertilizer and for the manufacture of plastics, nylon, and dry ice.

In the central Michigan oil fields, because of the dip of the rocks, the Dundee Limestone is approximately 3,500 feet below the surface. It has been the chief oil producing formation in the State.

Fossils are abundant in the Dundee Limestone. Best hunting is in the shale waste dumps of the quarries.

Traverse Limestone (Devonian) so named from outcrops along the shore of Little Traverse Bay, is generally separated from the older Dundee by the Bell Shale which is named from Bell, Alpena County, where it was once quarried. It forms a narrow belt in the southeastern part of the State and a much wider belt below the drift in the northern part of the Lower Peninsula. The limestone crops out only in the northern belt and is well exposed in Alpena, Cheboygan, Emmet, and Charlevoix counties. It is quarried at Alpena and Petoskey for use in the manufacture of cement. In the Alpena region the limestone contains beds of shale, but in the Petoskey region there is very little shale. Abandoned quarries are in Cheboygan and Charlevoix counties.

Well records from the northwestern part of the Lower Peninsula show approximately 800 feet of limestone belonging to the Traverse formation. Large sinkholes which are among the scenic attractions of the State have been formed by underground water in the limestone areas of Alpena and Presque Isle counties. Two new sinks were formed in 1950.

Oil and gas is being produced from the Traverse formation in various fields of the State.

Fossils are abundant in the Traverse limestones, and may be found in any outcrop, but best hunting is in the refuse of the quarry dumps where the fossils “weather out” from the rock. The colonial coral *Hexagonavia*—called “Petoskey stone”—is one of the more abundant forms and has been designated as Michigan’s official State stone.

Bayport Limestone is buff-colored and is quarried near Bayport, Huron County; near Omer, Arenac County; and near Jackson, Jackson County, it is used chiefly as crushed stone for concrete aggregates and road material, but formerly some stone was used for blast furnace flux and railroad ballast. Small amounts are also sold for building stone. Near Jackson the deposits are almost pure and the stone is pulverized for use as agricultural lime. The Bayport was formerly quarried at Bellevue, Eaton County, for the manufacture of Portland cement.

Gypsum (Mississippian) quarries are near Alabaster and National City, Iosco County, and Turner Arenac County. Abandoned quarries are near Grandville, Kent County. Gypsum is mined at Grand Rapids.

The only **rock salt** (Silurian) mine in Michigan is under a part of Detroit. Rock salt is cut from massive salt beds in the Salina formation of the Silurian.

METAMORPHIC ROCKS

In our collections we find rocks which do not seem to fit the description of either sedimentary or igneous rocks. They are probably the metamorphic rocks.

We may have a peculiar banded rock in which the dark and light-colored minerals seem to be separated in layers, yet it is not a sedimentary rock. However, it may once have been a sedimentary rock, or it may have been an igneous rock, but now we know it only as a metamorphic rock called **gneiss** (pronounced "nice"). If the gneiss was made from granite it is composed of quartz, feldspar and biotite mica or hornblende but the process of metamorphism has rearranged the minerals in bands.

Gneiss may be found in Marquette, Dickinson, Iron and Gogebic counties. Boulders and cobbles of the rock are quite common in the glacial drift and gravel pits throughout the State. Gneiss is sometimes used in constructional work, but care must be taken in laying the rock so that the lines of banding are in horizontal rather than vertical positions, otherwise the rock may split.

The most common type of metamorphic rock found in the western half of the Upper Peninsula is **schist.** The rock is platy or scaly and boulders of it found in the drift crumble into thin flakes of mineral. The platy or scaly structure was produced by great compression which caused the minerals to be rearranged in layers. Schists differ from gneiss in being generally composed of one mineral and seldom possess feldspar, a common constituent of most gneisses. The feldspar of a rock which has been metamorphosed into schist has been generally changed to mica. The schist is usually named according to the mineral which is most prominent in its composition, i.e., **mica schist, talc schist, chlorite schist, hematite schist,** and others.

In gneiss the banding is much more conspicuous than in schist owing to the layering of the light and dark-colored minerals contained in the original rocks. Where mica is more abundant than other minerals gneiss may be difficult to distinguish from mica schist.

Mica schist is formed by metamorphic processes from fine-grained sandstone containing an abundance of feldspar; it may also be formed from shale and slate. Hornblende, chlorite, and talc schists are formed by pressure and heat on such rocks as diorite, gabbro, peridotite and basalt. It is probable that some types of schist may have been formed from impure limestone. A variety of schist composed largely of small flakes and scales and of shiny specular hematite and commonly called **specularite** is found in the region of Champion and Republic in Marquette County. Much of this rock contains sufficient magnetite to make it slightly magnetic. If the iron content is high, specularite is an important ore.

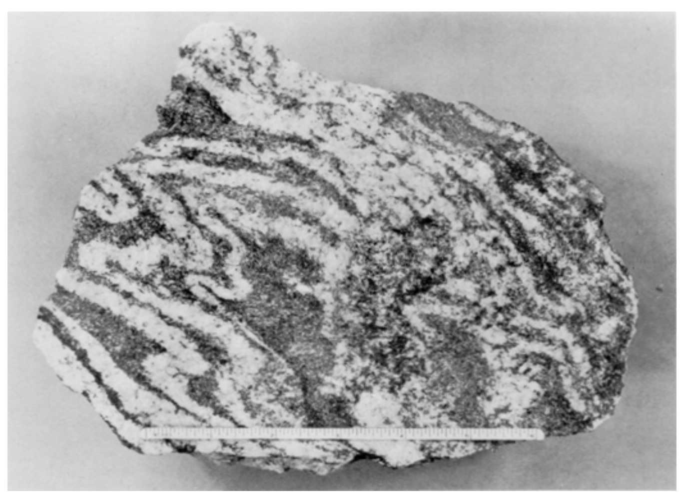
A hard, dense, greenish rock in the vicinity of Marquette has been so thoroughly metamorphosed that it is difficult to accurately classify it. This type of rock, one of the oldest on earth, is known as **greenstone** or **greenstone schist.** It is commonly found as large cobbles and boulders in the glacial drift.

A very beautiful common metamorphic rock in the iron-bearing formations of the Upper Peninsula, made of bands of bright red jasper, alternating with bands of specular hematite, is **jaspilite.** This rock is an abundant but low-grade material contributing an ever increasing tonnage of iron ore being produced in Michigan.

Small mountains of jaspilite form a portion of the rugged scenery in the vicinity of Ishpeming and Republic. Jasper Hill, on the outskirts of Ishpeming, is composed entirely of jaspilite. Jaspilite is probably the most attractive and interesting of Michigan rock formations. It is beautiful when polished.

In general the banding in jaspilite is parallel but where pressures causing metamorphism were extremely great the bands have been contorted and twisted into a variety of shapes. Specimens of the rock show intricate patterns of folding as well as the effects of shearing and faulting.

Chlorite schist with garnets.



Folded gneiss.

Slate is rock which was once mud or silt or very fine silty sand but is now a metamorphic rock formed by pressure and heat applied to shales and very fine-grained sandstones. It is harder than shale, extremely compact, and splits readily in flat plates with smooth surfaces. Because it resists weathering, slate is widely used for roofing and other building purposes. It is also used for school slates, blackboards, and billiard-tables.

Quarries for the production of roofing slates were operated years ago near Huron Bay in Baraga County and also in the northwest corner of Iron County. Many of the roofs in Greenfield Village are of slate from the Arvon quarry, Baraga County.

Slate is widely distributed in the western half of the Upper Peninsula. The color of the rock depends upon the impurities present. An abundance of organic matter and graphite produces a black slate, iron oxide colors it red, and chlorite makes it green.

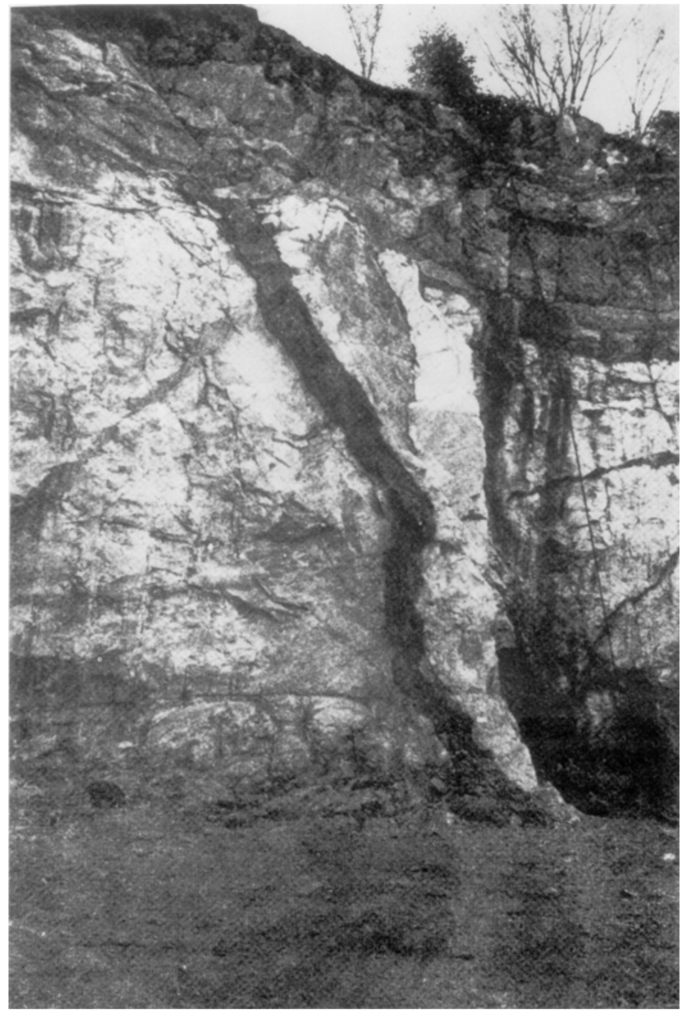
Many of the slates of the Upper Peninsula are **phyllites** rather than true slates. Phyllite is a metamorphic rock which possesses properties common to both schist and slate. It may be described as a fine-grained platy slate containing sufficient mica to be visible to the naked eye.

Many foundations contain white stones which look like white glass. No crystals can be seen and the stone looks more like a mineral than a rock. It is **quartzite,** a metamorphosed sandstone. It is a very hard rock composed almost entirely of quartz grains which are melted by heat and pressure and recrystallized in interlocking fashion. Quartzite differs from sandstone in that it absorbs little or no water and is much harder. In sandstone the grains are held together by cementing material of varying degrees of firmness. When sandstone is struck a blow with a hammer it usually breaks around or through the cement which is the weakest part of the rock. In quartzite the crystals are so thoroughly interlocked that the rock breaks through the quartz grains as easily as around them.

Quartzite, when pure, is white or gray, but impurities may color it various shades of red, yellow, and green. The rock never cleaves along smooth lines; rather it breaks with a shell-like or conchoidal fracture.

Quartzite is a common rock in the “iron ranges” of the Upper Peninsula. Because of its extreme hardness it has resisted weathering more than softer rocks near by, and in many places stands out in rather imposing bluffs and ridges. The rock is scattered abundantly through the glacial drift, and as pebbles, cobbles, and boulders forms a prominent constituent of most of the gravel deposits in the State.

Marble is a metamorphic rock which was once something else. Limestone or dolomite which has been recrystallized by heat and pressure is known as marble. The texture of the original rock is usually changed to one that is crystalline and granular and the new rock looks very much like lump sugar. Any fossils originally contained in the limestone or dolomite are changed in the heating and crushing process into formless grains of calcium carbonate.



Metamorphic rock in the Metronite Quarry near Felch, Dickinson County.

Marble can be recognized by its relative softness, by its sugary appearance, and by the numerous pearly light-reflections from the grains of calcite. It may be scratched easily with a knife blade, and when pure fizzes freely with dilute hydrochloric acid. Marble is one of the most widely used stones for monuments, buildings, and for statues and ornamentation. Some of the rock is stained by various impurities which act as pigments to produce pink, red, purple, gray, green, brown marble, and mottled and streaked varieties.

Recrystallized dolomite or dolomitic marble crops out in Dickinson, Iron, Marquette, and Gogebic counties. It is quarried in the vicinity of Randville and Felch in Dickinson County, where it is known geologically as the Randville Dolomite. Owing to the generally fractured condition of the stone, large blocks suitable for building purposes are difficult to obtain. The marble quarried in Michigan is usually crushed and used in the manufacture of paint, stucco, and ornamental concrete.

Much of the so-called marble of commerce used as interior paneling in public buildings is a firm limestone which takes a good polish. The fossils are plainly visible.

We called your attention to a green marble and said it is serpentine or verde antique. Serpentine results from the alteration of rocks which are composed largely of olivine, hornblende, and augite. When the dark green serpentine is mottled with, or has streaks and veins of calcite, talc, magnesite, or dolomite it forms a rock known as **verde antique** or **serpentine marble.** This rock takes an excellent polish and is used extensively for interior decorating and for ornamental purposes.

Deposits of serpentine and verde antique near Ishpeming in Marquette County have been used in the past for making terrazzo. Slabs or blocks for building and ornamental purposes have not yet been produced from the Michigan deposits. Many cracks and joints in serpentine rocks contain some small veins of fibrous, thread-like green serpentine asbestos (chrysotile).

Epidosite, another of the altered rocks, is a yellowish-green, fine-grained rock composed chiefly of grains of epidote mixed with quartz, garnet, and other minerals. It is associated with the copper-bearing amygdaloidal basalts of the Keweenaw Peninsula, and probably was formed from the basalt by alteration processes.

COMMERCIAL MINERALS AND ORES

Iron ore (Hematite) had been searched for from the days of earliest settlement in the Lower Peninsula. Bog iron was found in small widely separated deposits and the ore supplied several small furnaces until the discoveries in the Upper Peninsula.

The earliest discoveries of commercial deposits of iron ore were made at Negaunee, Marquette County, in 1844. A party of government surveyors under the direction of William A. Burt encountered difficulties in surveying owing to deflection of their compass needles. It was soon determined that the deflection was caused by the magnetic attraction of beds of iron ore. The Jackson pit, located near Teal Lake on the north edge of Negaunee, is the site of the first iron-mining operation in Michigan. The first shipments of iron ore from the Jackson mine were made in 1852 and regular shipments were begun in 1856, following the opening of the locks at Sault Ste. Marie. Until about 1900 Michigan was the leading state in the production of iron ore. With the development of the large open pit deposits in Minnesota, Michigan was forced into second place.

Native copper was mined in Michigan by prehistoric man but copper mining as an industry did not actually begin until 1845. Evidences of early mining in Michigan are preserved in the old “Indian pits” which have been found scattered through the region of Isle Royale and the Keweenaw Peninsula. The prehistoric miners and artisans of copper in Michigan used the metal in the making of crude implements.

The copper district of the Keweenaw Peninsula is world famous. Some of the mines were more than a mile in vertical depth below the surface. From 1847 to 1887, Michigan was the leading producer of copper among the states. The district is unique in that its copper is free and not combined with other elements. The metal occurs in the amygdaloid lavas as a filling in the amygdules or gas-bubble cavities which were formed by steam escaping as the rock cooled. The copper was carried in and deposited by heated water solutions arising from deep-seated magmas. Copper-bearing solutions also deposited copper between and around the pebbles of conglomerates which had been formed during the quiet periods between times of extrusions of the basaltic lava flows, and also in sheets between the layers of lava. Small quantities of native or free silver are mined with the copper.

Masses of “float copper” are sometimes found in the glacial drift in the Lower Peninsula. These were carried southward by the ice sheet which moved across the copper-bearing outcrops of the western part of the Upper Peninsula.

The Ontonagon Boulder is perhaps the most famous erratic found in Michigan. It is a copper boulder weighing about 6,000 pounds. The romantic tale of its wandering from its place of origin to the forks of the Ontonagon River in the Upper Peninsula, to the Smithsonian Institution in Washington is too long to recount here. However, it is not the largest copper boulder found, as two larger masses were discovered in the old Minesota Mine, Ontonagon County. One mass weighed 527 tons and another weighed 480 tons and was 46 feet long, 12 to 18 feet wide, and four feet thick. But these masses were found in place—they had not been moved by the glacier.

Gold is found in quartz veins which cut the serpentine and talcose rocks in an area of very ancient rocks northeast of Ishpeming in Marquette County. Prior to 1900 more than $600,000 worth of gold was mined in the district, principally from the Ropes mine.

Gold is characterized by certain specific properties which serve to distinguish it from other minerals such as pyrite and bronze mica which are frequently mistaken for it. Gold is much heavier than most substances which resemble it. The luster is metallic and the color ranges from golden brassy to light yellow, depending upon the amount of silver present. The metal is capable of being pounded into very thin sheets (malleable) and can be drawn into wire (ductile). When pure it is sufficiently soft to be scratched slightly with a copper coin. Gold has been reported in the glacial drift but never in commercial quantities.

NONMETALLIC MINERALS

Thick sedimentary beds of **rock salt** underlie a large part of the Lower Peninsula. Individual beds of almost pure salt ranging from 50 to more than 400 feet in thickness are not uncommon. In the deepest well in the State, in Ogemaw County, the Detroit River formation is 1,066 feet thick and has nearly 300 feet of rock salt in 13 salt beds, ranging in thickness from 6 to 78 feet. In this well the Salina formation is 3,144 feet thick and has 39 rock salt beds ranging in thickness from 2 to 463 feet, with a total of more than 1,360 feet of rock salt. In the second deepest well in Michigan, Bay County, the Salina formation is 2,790 feet thick and has more than 1,700 feet of solid rock salt beds, which range from 30 to more than 400 feet in thickness.

The Salina formation in Ogemaw County is from 5,393 to 8,547 feet below the surface; in Bay County, it is from 5,480 to 8,270, but in Wayne County, it is from 1,000 to 2,000 feet below the surface, and has some 550 feet of rock salt in 17 beds that range in thickness from 20 to 90 feet. These figures will give you an idea of the variability of our rock formations, and also an indication of the bowl shape of, and slope of the formations. The salt underlying Wayne County is nearer the rim of the Michigan Basin than salt in the other wells.

Michigan is a leading salt-producing state. The salt is obtained in several ways. At Detroit, St. Clair, Port Huron, Manistee, and Montague, salt is manufactured from artificial brines which are made by dissolving beds of rock salt in the Salina formation; also at Manistee and Midland, from the Detroit River formation. Water forced into wells dissolves the rock salt, and the resulting brine is then pumped to the surface and evaporated. Rock salt is mined in but one locality in the State, at Detroit in Wayne County. The salt in this mine is obtained from the Salina formation at a depth of approximately 1,150 feet.

Gypsum (Calcium Sulphate and water) is similar to rock salt in its origin and mode of occurrence. The commercial beds, however, are not nearly as thick as the salt deposits, the average being from 8 to 12 feet. Wells drilled for oil in central Michigan penetrate beds of gypsum ranging in thickness from 30 to 50 feet. It is quite probable, however, that these thick layers contain partings of shale or limestone.

Deposits of gypsum are found at depths of less than 1,500 feet in wells drilled anywhere within that portion of the Michigan "Basin" which is underlain by the Michigan Formation. Because of the basin type of structure, however, the mines and quarries are located at or near the borders of the formation. Gypsum is quarried at Alabaster and National City, Iosco County, and is mined at Grand Rapids, Kent County, where the beds are from 75 to 100 feet below the surface. The beds rise to near the surface at Grandville, a few miles southwest of Grand Rapids, where quarries were formerly operated.

Gypsum, when ground and heated sufficiently to drive off a portion of the contained water, possesses the property of resetting to a hard plaster when water is again added. This property makes gypsum valuable for the manufacture of wall plaster, plaster board and various types of construction, insulating and soundproofing materials.

Coal. The central part of the Peninsula is usually referred to as the "Coal Basin." Although many thin veins of coal are distributed throughout this area, the known workable beds lie in a belt with a maximum width of about 30 miles, extending from the region of Saginaw Bay southwestward to the cities of Jackson and Albion. Michigan coal does not form continuous beds but rather small disconnected seams or lenses, many merely a few acres in extent. This discontinuity of beds indicates that the coal was formed in small, scattered bogs or lagoons rather than in extensive swamps as were the coals of West Virginia, Kentucky, and other eastern fields. In some places as many as eight individual seams of coal are found in sinking a shaft for mining operations or in drilling test holes for exploratory purposes. Usually only one of the seams is sufficiently thick to be mineable. Many of the veins are merely a few inches thick. Rarely does a seam of Michigan coal run more than four feet in thickness; most of the commercial coal is obtained from seams which range from 30 to 36 inches. Some of the smaller mines, especially those in which the coal is near to the surface, found it profitable to work seams as thin as 16 to 20 inches. Most of the mines in the Saginaw Valley had shafts less than 200 feet deep. Some of the shallow deposits near Williamston, Mason, Jackson, Corunna and Grand Ledge were worked by open pit methods after the overburden of soil and rock of the glacial drift had been stripped off with steam shovels.

Michigan coal is a high volatile or "flashy" bituminous fuel. It can be used economically for domestic purposes and is generally considered to be a good steam coal. The U. S. Geological Survey reports 12,000,000 tons of coal reserves but most of it is in seams too thin to mine.

Michigan coal has given better results in small stokers than many of the higher rated coals from other states. This is because Michigan coal does not form the troublesome "trees" or "spires" of coke. The ash melts at low temperatures and makes clinker which is easily removable.

Coal was mined as a cooperative project from a mine near Swan Creek, Saginaw County, until early in 1952 when it was shut down and coal mining ceased in Michigan.

Petroleum and Natural Gas. Strictly speaking, petroleum is not a mineral but being a product obtained from the rocks of the earth, it is always included in textbooks dealing with economic geology. Petroleum is believed to have been formed from oils released by bacteria during decay of soft parts of marine animals on the ocean floor. The globules of oil became imprisoned in the soft muds deposited on the sea floor or in the pores of coral reefs and remained entombed in the rock which formed by compaction of the muds. After the muds and reefs became compacted into rock some of the oil and gas apparently was forced into the porous beds of sandstone or limestone. Salt water forced the oil and gas into the up-folds, arches or domes in the rock which trap the oil and gas and prevent its further movement. Other types of oil traps are being discovered as the search for more petroleum continues.

The secret in searching for oil and gas is to locate the traps and the upfolds or anticlines, which are also called "structures," "highs," in the rock formations. This is accomplished by measuring dips of rocks from outcrops or from information obtained from wells by test drilling, or by other scientific methods.

The first oil pool of any importance in Michigan was located near Port Huron about 1886. The next commercial pools were discovered in the vicinity of Saginaw in 1925 and in Muskegon in 1927. Other discoveries followed rapidly and at present oil is produced in some 40 counties in the Lower Peninsula. The oil is obtained principally from the Traverse, Dundee, Detroit River, and Trenton formations.

The history of the natural gas industry in Michigan is closely related to the development of oil production. Most of the gas has been obtained from the following formations: "Michigan Stray Sand", Berea, Antrim, Traverse, Dundee, the base of the Salina, or the top of the Niagaran, Trenton, and also from the glacial drift.

Deep wells in search for oil have been drilled in every county in the Lower Peninsula.

Natural Brine is salt water believed to be original sea water which saturated the sands and other porous sediments when the deposits were laid down on the sea floor and was trapped when buried by later sediments. Brine, or salt water, is found in several of the rock formations of the State, especially with increasing depth below the surface. Water in the shallow formations is generally free from salt unless it has become contaminated by seepage from deep wells or from crevices in the rock which permit the brine to come up from deeper formations and mingle with the fresh water above. Salt water is always found below oil in the rocks and large quantities are produced with the oil.

Brine is a valuable commercial product and a large number of important chemicals are obtained from it. One of these chemicals is bromine which is used in the manufacture of ethyl gasoline, and in photographic and motion-picture films. Calcium chloride, used for laying the dust on highways, is another important chemical. Epsom salts, aspirin, carbolic acid, dyes, perfumes and flavorings are some of the more than one hundred chemicals and medicines manufactured from the brines of Michigan. Many compounds for the making of the new plastics are also made from the brines and from limestone.

Natural brines are obtained from wells in the Dundee, Detroit River and Sylvania formations at St. Louis, Manistee, Ludington, and Midland.

GLACIAL DRIFT

The glacial drift which covers the bedrock surface of Michigan is a mixture of all types of soil and rock materials ranging from large boulders to very fine silt and clay. Drift consisting of an unsorted mixture of clay, sand, gravel, and boulders is known as *boulder clay* or *till*. A very stony subsoil is sometimes called "hardpan." Stratified or layered formations are made chiefly of sand and gravel which were sorted out and deposited by waters flowing from the melting ice. The materials of the drift were brought from the north by vast sheets of ice or glaciers which dropped their loads upon melting. So complete was the work of the glaciers in gathering their loads and so large the area over which they worked that practically every common type of rock may be found in the deposits of drift.

The soils developed from the glacial drift in the south half of the Lower Peninsula are mostly composed of clay and are well suited to agriculture. The glacial soils in the north half of the Lower Peninsula and throughout much of the Upper Peninsula are generally quite sandy and only in places are they adapted to agriculture. These same light soils, however, have produced a great wealth of timber.

Gravel and sand. The most important sources of gravel and sand are deposits formed by the work of water which flowed out from the ice during melting of the glaciers. The commercial gravels are obtained largely from stratified deposits which were laid down in the form of out wash plains, valley trains, eskers, kames and the beaches of glacial lakes. Most of the gravel produced in Michigan is used as aggregate in the manufacture of concrete for highway and building construction. Michigan owes in part its fine system of highways to the widespread distribution and abundance of gravel deposits in the two peninsulas.

Foundry sands. Deposits of sand, abundant along our coast lines and elsewhere, are used for foundry sands. It is necessary, however, to add a binder to hold the sand together so that it may be molded into the various forms used for shaping molten metal. Michigan sands are used principally for making cores which shape the cylinder bores, valve holes, etc., in motors. When the metal cools the sand can be easily removed thus leaving the rough cavities in the motor. Most of the core sand produced in Michigan is taken from the sand dunes along the lake shores or directly from the lake bottoms. Lake sand, because of long continued washing by the waves is not only purer than other sands, but is more convenient for low-cost water transportation to industrial centers.

Sand is also used in glass manufacture, and as grinding and polishing, engine, and ballast sand.

Bog iron (limonite) and **bog manganese.** Iron-bearing minerals are common constituents of most soils but in some areas they may be concentrated into fairly large deposits. Soluble iron minerals such as iron carbonates and iron sulphates are removed from soil by water charged with carbonic-acid gas. These minerals are carried in solution into bogs and pools of quiet water and deposited as iron oxide or iron rust. Where swamps and bogs have been drained by ditching the deposits of bog limonite have formed ridges or mounds because bog ore resists weathering and wash more than the surrounding material. Bog limonite is a source of iron but at present no iron is being produced in Michigan from this ore, although early in the history of the State, iron was made from the bog ore deposits in the southern counties.

The “hardpan” found beneath the soil in many places is a cemented mixture of iron oxide and sand. Manganese, although not as abundant as iron, is present in some soils and certain types of sedimentary formations. When manganese oxides become mixed with limonite in bog deposits, the “ore” usually becomes much harder, somewhat heavier, and darker in color. Manganese minerals are frequently mixed with the iron ore deposits of the Lake Superior region and have an important commercial use in the manufacture of steel.

Marl (calcium carbonate) is a form of limestone which, in small deposits, is of rather widespread distribution throughout Michigan. As ground water charged with carbonic-acid gas moves through glacial drift which contains an abundance of limestone either as finely ground “rock flour” or as pebbles and boulders, it dissolves some of the limestone. When the lime-charged waters flow into surface basins or depressions some of the carbonic-acid gas is liberated and the calcium carbonate is deposited in swamps, lakes and stream channels as marl. Certain types of plants and animals which need calcium carbonate for their shells or leaf structure help to build up the beds of marl.

Marl is used primarily for treating soils which are deficient in lime.

Peat is partially decomposed organic matter made up largely of remains of plant leaves, stems, roots, fiber, spores, etc. It is formed by the work of bacteria which live without air. Peat is a common deposit in all bogs, swamps, marshes, ponds and lakes where vegetation flourishes. Coal was formed from the peat of very ancient swamps. In the process of changing to coal the swamps or bogs gradually became buried under deposits of sediments which consolidated into rock. The pressure of these sediments upon the peat caused the water to be squeezed out and the plant remains to be transformed into soft coal. But the process was so slow and gentle that impressions of plants, even the most delicate, were not destroyed.

It is estimated that peat forms at the rate of approximately one foot in 300 years. The maximum thickness of peat deposits which have been measured in Michigan is 60 feet. Such a thickness of peat would require roughly 18,000 years for accumulation. About 20 feet of peat are required to form one foot of good bituminous coal. Thus, a seam of coal 36 inches thick represents an original deposit of peat 60 feet thick.

When swamps or bogs containing peat are drained sufficiently to expose the peat to the air, other types of bacteria attack the plant tissues and cause complete decay of the organic matter. The peat is then changed into a type of soil known as muck which usually contains mineral matter in addition to the black decayed plant remains.

Peat is used chiefly for soil treatment, as packing material and for insulation. In some countries it is used as a fuel.

Clays are widely distributed in Michigan. Relatively pure clays are found in old glacial lake beds. The clay of the glacial tills is usually mixed with pebbles, sand, silt and other impurities. Lake or river-laid clays are usually free of impurities and are suitable for and are used for making brick, tile and stoneware, as a base for insecticide sprays, and for other uses.

Vast deposits of high-grade clays in the northern part of the State are so far from possible areas of consumption that no attempts have been made to exploit them. They form potential reserves for future use.

In some of the northern counties of the State glacial lake clays mixed with calcium chloride and gravel are used in highway construction.

Boulders, cobblestones, “hardheads”. Boulders of igneous, metamorphic, and the harder sedimentary rocks are found throughout the State. These boulders have been used since the State was first settled, for foundations and for buildings, fireplaces, and chimneys, either as the uncut or cut (faced) stone. Many churches, houses and other buildings are veritable museums of igneous and metamorphic rocks used in their construction.

PART III
HOW TO IDENTIFY MINERALS AND ROCKS

MINERALS

Minerals may be identified in several ways: by their composition, shape, crystal or non-crystalline form, color, hardness; by their reaction to acid, heat, electricity; and by several other characteristics. So the brief key that follows should be supplemented by reference to textbooks on mineralogy.

Physical Properties

1. Note luster and classify as metallic, nonmetallic.
2. Determine *hardness*.

   The scale of hardness used by mineralogists is:

   1. Talc
   2. Gypsum (selenite)
   3. Calcite
   4. Fluorite
   5. Apatite
   6. Feldspar
   7. Quartz
   8. Topaz
   9. Corundum
   10. Diamond

A rough scale for hardness: Can be scratched by the fingernail, hardness to 2.5; can be scratched by a penny, hardness 2.5 to 3.5; can be scratched by a steel knife, hardness 3.5 to 5.5; can be scratched by glass, hardness 5.5 to 6; can be scratched by a steel file, hardness 6-7; scratches glass, hardness 7 to 10.

3. Arrange by *color*.

   If the specimen is metallic, determine color by its streak; that is, the mark it makes on a tile or unglazed porcelain.

4. Note *tenacity*, that is, how the mineral holds together.

   Does it hold together when pounded—is it *malleable* like gold, copper? Can you shave or whittle it with a knife—is it *sectile*, like gypsum? Will it bend—is it *flexible* like selenite? Does it spring back to shape when bent—is it *elastic* like mica? Does it fly to pieces when struck a sharp blow—is it *brittle, fragile, weak?*

5. Note the *shape* of crystals.

   As minerals crystallize they assume various shapes, and shape classification of crystal solids depends on the shape of crystal faces, the angle at which the faces meet and the length of the axes (axes are straight lines that go through the center of the crystal). Common crystal forms are cubes, like salt, prisms, pyramids, flat tablet-like (tabular) with rectangular faces like selenite, and six-sided crystals like quartz and snowflakes. No matter how difficult it may be for a crystal to form, no matter how distorted they may become in the forming, minerals always assume their own distinctive crystal form, a process known as *crystal habit*. Crystals may be stretched like hair, flattened, twisted, curved or hollow. They may have delicate patterns or straight lines (striations) on their faces. They may be twined, form rosettes, or be arranged like a net. In staurolite, the twining forms a cross; gypsum and barium form rosettes and some minerals form net-like masses.

6. Note how the mineral *breaks*.

   Does it split or fracture? A break or split parallel with one of the faces of the crystal is *cleavage*. Mica and feldspar have cleavage. Other breaks are known as *fractures*. Fractures are: *Conchoidal* or shell-like, like the surface of broken glass. Quartz, chert, flint have conchoidal fracture. *Uneven*—having no regularity or pattern of break. Jasper quartz sometimes breaks with uneven fracture. *Hackly* or jagged as if hacked with an ax—the fracture pattern of copper. Fractures may also be *earthy*, like chalk, and for some minerals, the fractures are *splintery*.

7. Note *structure*.

   If the mineral sparkles and seems to be full of little crystals, it is said to be *crystalline*, although no distinct crystal is evident. If it is composed of grains it is said to be *granular*. If no crystals or grains are evident, it is *compact*, (some datolite). If it crumbles easily, it is *friable*, (halite—rock salt). If it is built up in plates, it is *platy* or *laminated*, (mica). If the plates or leaves are easily separated (like mica), it is *foliated*. Minerals may have structure like a column—*columnar* (gypsum). If the column is flattened, the mineral has a *bladed* structure. If the columns are small like fibers, the structure is *fibrous* (asbestos). If the fibers radiate from a common center, the mineral is said to be *radiated* or *globular* (anthraconite).

8. Note the *form* assumed by mineral masses.

   Some assumed forms are similar to kidneys, bands, grape clusters, corals, peas, fish eggs. If you want to use the scientific name for such forms, they are: Reniform, agate, botryoidal, coralloid, pistolitic, oölitic. A cavity lined with mineral crystals is a *geode*. An almond-shaped cavity made by expanding steam in lavas and later filled with minerals is an *amygdule*. *Stalactites* are mineral icicles formed from the roof of a cavern downward. *Stalagmites* are built upwards from the floor of a cavern by mineral left from evaporated water that dripped from the stalactite. Some minerals replace others and take the form of the replaced mineral. They are called *pseudomorphs*. Minerals may replace organic matter and so *petrify* an object. Wood has been petrified by replacement of the organic cells by quartz.

9. Note the *effect of light* on minerals.

   If light rays pass through, and objects back of the mineral are visible, the mineral is *transparent*, (quartz, calcite, selenite). If objects are visible but dim, the mineral is translucent (mica); semi-translucent if light comes through only thin edges (obsidian). If no light penetrates, the mineral is opaque. All metallic minerals are opaque.

10. Note *luster* of minerals.

    We have divided the minerals according to luster as metallic and nonmetallic. But nonmetallic minerals have a luster or shine quite different from the shine of metals. Lusters are described as: *Adamantine*, like a diamond; *vitreous*, like broken glass (transparent quartz); *resinous*, or *waxy*, like resin or wax (sphalerite, sulphur); *greasy*, like soft suet (serpentine); *pearly*, with the sheen of the white inside of a clam or oyster shell (mica, talc); *silky* or *satiny*, with the shimmering sheen of silk (asbestos); *dull*, if it reflects little light; and *earthy* when no light is reflected (kaolin).

11. Note the *feel* of the mineral.

Gold, silver, some gem stones, feel *cold*. Talc is *greasy* or *soapy*; chalk is *hard*; gypsum feels *smooth*.

12. Determine *specific gravity*.

Minerals have different weight, or specific gravity. Specific gravity is determined by comparing with water. Minerals twice as heavy as water have a specific gravity of 2; if six times as heavy, the specific gravity is 6.

13. Other characteristics—*taste*.

Some minerals dissolve in water and have a characteristic taste. They may be saline (table salt), acid, alkaline, astringent (make your mouth pucker, like alum), metallic.

14. Other characteristics—*odor*.

Some minerals, when scratched, pounded, rubbed, heated, or breathed upon have a characteristic odor. Kaolin smells like clay when pounded; barite has a fetid, rotton egg odor. Minerals containing arsenic give off an odor of garlic when heated. Pyrite gives an odor of burning sulphur when heated, and selenium may be detected by its odor, when heated, of rotton horseradish. Anthraconite gives off an odor of petroleum when pounded.

ELEMENTS

Michigan minerals, according to the abundance of elements in their composition:

(1) Aluminum	(10) Magnesium
(2) Antimony	(11) Manganese
(3) Barium	(12) Molybdenum
(4) Calcium	(13) Sodium
(5) Carbon	(14) Strontium
(6) Copper	(15) Sulphur
(7) Hydrogen	(16) Titanium
(8) Iron	(17) Tungsten
(9) Lead	(18) Zinc Group

Some representative minerals of each group are:

(1) kaolin, turquoise	(9) galena
(2) Stibnite	(10) dolomite
(3) Barite	(11) pyrolusite
(4) calcite, gypsum	(12) molybdenite
(5) graphite, coal	(13) rock salt
(6) copper chalcopyrite, malachite, chlorastrolite	(14) celestite (15) pyrite, gypsum (16) rutile (17) scheelite, wolframite
(7) ice	
(8) pyrite, hematite	(18) Zinc

ROCK-FORMING MINERALS

1. **Amphiboles:** The commonest of the rock formers. Hardness 5-6. Color—black, green gray. Luster—vitreous pearly, silky, opaque. The amphiboles are complex silicates, always containing magnesium and usually calcium and iron. Hornblende is the commonest amphibole.

2. **Pyroxenes:** Hardness 5-6. Color—black, green, brown, white. Luster—vitreous, resinous, or dull opaque to transparent. Complex silicates with magnesium and calcium; may have iron, manganese and other metals. Augite is a common variety of pyroxene.

3. **Feldspars:** Hardness 6. Color—white, pink, yellow, gray, green. Luster—vitreous to pearly, crystalline. Silicates of aluminum and one or more other metals—potassium, sodium, calcium. *Most important rock-forming minerals*.

4. **Garnet group:** Hardness 7-7.5. Color—black, red, brown, green. Luster—vitreous; commonly having 12-sided crystals. Aluminum silicates with calcium, magnesium, iron, manganese.

5. **Mica group:** Hardness 2-3. Color—colorless, black to green. Luster—pearly to vitreous. Transparent, elastic, six-sided crystals, cleavage perfect. Cleave into thin sheets that can be bent. Silicates of aluminum and potassium, with water, iron, potassium, manganese.

6. **Olivine** or **Chrysolite:** Hardness 6.5-7. Color—green, yellow, olive green. Brittle, shell-like fracture. Luster-vitreous. Transparent to translucent. A silicate of magnesium and iron.

7. **Chlorite group:** Soft, like mica. Color—dull green. Platy, like mica but plates break, not hard. Silicates of aluminum, magnesium, and iron with water.

8. **Quartz:** Hardness 7. Rock crystal quartz is a clear, colorless, six-sided crystal variety. Color of other crystalline quartz—violet, pink, yellow, brown, blue, green. Color massive varieties—blue-green, red-black, brown, yellow, gray. The commonest mineral—silicon dioxide (Si O^2). More varieties than any other mineral; rock crystal, amethyst, agate, flint, onyx, and others

9. **Talc** and **Serpentine group:** Hardness 2-3. Colors—white, green, yellow. Luster—vitreous, silky, oily. Fibrous. Silicates of magnesium with water that do not crystallize.

10. **Staurolite, Tourmaline, Zeolites:** Silicates of aluminum, nearly always calcium, and with barium and strontium. They are also rock-forming minerals.
It is evident that the element silicon, when united with oxygen to form silicon dioxide, is the most important element in forming minerals that make rock.

MINERALS HAVING METALLIC OR SUBMETALLIC LUSTER

1. May be scratched by the fingernail—Hardness less than 2.5.

   Color: Lead-gray, streak blue-gray on paper, green-gray on tile. *Molybdenite*

   Color: Iron-black to dark gray. Shiny. Soils fingers. Marks paper. *Graphite*

   Color: Lead-gray, streak lead-gray, silvery. *Stibnite*

   Color: Iron-black to dark gray, streak black. Soils fingers. *Pyrolusite*

2. May be scratched by a penny—Hardness 2.5 to 3.5.

   Color: Pure lead gray. Shiny. Cubic crystals. *Galena* (lead ore)

   Color: Blackish lead-gray. Fine, granular. Breaks like a shell. *Chalcocite*

   Color: Silver-white, tarnishes gray to black. *Silver*

   Color: Copper-red. Irregular to crystalline. Shiny. *Copper*

   Color: Reddish brown when fresh, tarnishes to blue. *Bornite*

3. May be scratched by a good steel knife—Hardness 3.5 to 5.5.

   Color: Brass-yellow, streak green-black, tarnishes to rainbow hues. *Chalcopyrite*

4. Cannot be scratched by a knife—Hardness 5.5 and over.

   Color: Black. Breaks in one direction. Opaque. *Wolframite*

   Color: Steel-gray to iron-black, streak cherry-red to red dish brown. *Hematite*

   Color: Steel-gray to iron-black. Crystalline. Brilliant luster. May break into thin plates that appear red. *Specular iron*

   Masses of micaceous flakes. *Micaceous hematite*

   Fibrous or columnar, masses smooth, kidney-shaped. *Kidney ore*

   Pencil-shaped. *Pencil ore*

   Color: Brown or yellow. Luster dull. Never crystallized. *Limonite*

   Color: Iron-black. Brittle. Strongly attracted by a magnet, crystalline. *Magnetite* or *Lodestone*

   Color: Pale brass-yellow, streak greenish black, tarnish brown. Brittle, Cubic crystals. Dissolves in strong nitric acid. Harder than gold and chalcopyrite. *Pyrite* (fool's gold)

   Color: Pale bronze-yellow, iridescent tarnish. Tabular. Dissolves in nitric acid with residue of sulphur. *Marcasite*

   Color: Brown to reddish black. Brittle. Crystalline. *Rutile*

MINERALS WITHOUT METALLIC LUSTER

1. May be scratched by the fingernail. Hardness less than 2.5.

   Color: Snow-white. Six-sided crystal, many patterns. Melts above 32° F. *Snow*

   Color: Pale yellow, red, brown, flesh white, bluish, gray and black. *Gypsum*

   Silky or satiny luster, fibrous. *Satin spar*

   Pearly luster, crystalline, thin plates are flexible, transparent. *Selenite*

   Fine-grained, nearly translucent, easily carved. *Alabaster*

   Color: Gray, white, green. Soapy feel. Pearly luster. Marks cloth. Not attacked by acids. *Talc*

   Does not feel greasy or mark cloth. Breaks into flakes. *Chlorite*

   Color: Yellow. Luster resinous. Brittle. Melts a little above the boiling point of water. Burns with a blue flame giving off white fumes. *Sulphur*

   Color: Gray-white. Splits into thin translucent to transparent scales or sheets. Tough. Flexible. Elastic. *Muscovite* (light mica, isinglass)

   Color: Black, or dark brown. Splits into thin scales or sheets. Tough, flexible, elastic. Somewhat harder than muscovite. *Biotite* (dark mica)

   Color: Snow white to gray. Massive. Clay like. Smells like clay. Sticks to dry tongue. *Kaolin*

   Color: Colorless to white. Transparent to translucent. Hopper crystals. Dissolves in water. *Halite* (salt)

2. May be scratched with a penny. Hardness 2.5 to 3.5

   Color: Greenish, yellow, brownish red, blackish green. Oily luster. Tough. Never crystallizes, fibrous like asbestos. *Serpentine*

   Color: Blue-green, snow or yellowish white, brown. Brittle. Luster glassy. Cubic crystals. Transparent to translucent. Opaque in masses. *Barite* (heavy spar)

   Color: Bluish, gray-green to turquoise-blue. Brittle. *Chrysocolla*

   Color: Light yellow, shades of brown and of gray. Crystals. Fizzes with hydrochloric acid. *Calcite*

   Color: Brownish to yellowish red. Tabular crystals. Luster glossy to pearly. Transparent to translucent. *Celestite*

3. May be scratched by a knife. Hardness 3.5 to 5.5.

   Color: Cream to wine-yellow. Coarse fibrous, to six-sided crystals. Opaque to transparent. *Aragonite*

   Color: Pale yellow to white. Radiated crystals. *Strontianite*

   Color: Brownish yellow. Luster, pearly to glossy. Sheaf like crystals. *Stilbite*

   Color: Brownish yellow to blackish brown. Granular or platy. Brittle. Luster resinous. Transparent to translucent. *Sphalerite* (zinc blend)

   Color: Ruby-red, streak brownish. Shiny. Small cubic crystals. *Cuprite*

   Color: Pale to dark brown, tarnish red-brown to black. Brittle. Luster glossy to pearly. Crystalline. Opaque to translucent. *Siderite*

   Color: Gray, white, blue. Granular. *Anhydrite*

   Color: White. Coarse or fine. Granular or crystalline. Does not fizz with cold hydrochloric acid. *Dolomite*

   Color: Blue of many shades. Crystal masses. Luster glossy. *Azurite*

   Color: Green. Tufted. Banded *Malachite*

   Color: Pale to deep yellow, greenish white. Crystals. Luster greasy to dull. *Scheelite*

   Color: Reddish brown, blue, green. Large six-sided prisms, tabular. Luster vitreous to resinous. Brittle. *Apatite*

   Color: Pink, green, brown, white, banded "eyes." *Thomsonite*

   Color: Green. Star crystals. *Chlorastrolite*

4. Cannot be scratched by a good steel. Hardness 5.5 to 7.

   Color: Pale yellowish, pinkish, greenish to white. Luster vitreous. *Datolite*

   Color: Pale yellow to orange-yellow. Radiated masses of crystals, concentric banding. Luster pearly to glossy. *Natrolite*

   Color: Cream-yellow. Fibrous. *Amphibole, Asbestos*

   Color: Dark to blackish brown. Fibrous. *Goethite*

   Color: Reddish brown, gray, greenish black. Luster vitreous to dull. Opaque. Crystalline. *Pyroxene*

   Color: Black to green. Opaque. Prismatic. Platy. *Pyroxene, Augite*

   Color: Colorless or white. Luster vitreous. *Analcite*

   Color: Flesh to brick red, white, yellow, gray, green. Crystalline. Luster glassy to pearly. *Feldspar*

   Color: Dark gray, blue to green, coppery red changing colors. Luster vitreous to pearly on cleavage faces. *Feldspar, Labradorite*

   A common feldspar in eruptive rocks, no striations on cleavage faces. *Orthoclase*

   A common feldspar in granitic rock. *Microcline*

   Color: Ruby-red, pink, purplish red, green. Twelve-sided crystals. Luster vitreous. *Garnet*

   Color: Black, greenish black, yellow-green, pistachio-green. Lustrous crystals green or brown by transmitted light. *Epidote*

   Color: Colorless, pale apple-green, yellowish. Dull glassy crystals in barrel-shaped bundles. *Prehnite*

   Color: Bright to gray-green. Bladed. Opaque to transparent. *Actinolite*

   Color: Black, green, gray. Opaque. Crystals. Fibrous or bladed. *Amphibole, Hornblende*

5. Can scratch glass. Hardness 7 to 10.

   Color: Yellow, brownish red, brown, green. Opaque. *Quartz, Jasper*

   Color: Rose-pink. Seldom in crystals. *Rose Quartz*

   Color: White, blue-grey, brown, bluish. Compact. Luster waxy. Translucent to opaque. *Quartz, Chalcedony*

   Color: Blood-red. Compact. Translucent to semi-translucent. *Quartz, Carnelian*

   Color: Green. *Quartz, Chrysoprase*

   Color: Yellowish to smoke brown. Massive. Crystal line. Luster vitreous. *Quartz, Smoky*

   Color: Snow white. Massive. *Quartz, Milky*

   Color: Dull black. Thin edges translucent. Tough, breaks like a shell. *Quartz, Flint*

   Color: White to gray to black. Brittle. Splintering. Impure. Tough. *Quartz, Chert*

   Color: Purple. Crystals. *Quartz, Amethyst*

   Color: Colorless. Six-sided crystals. Transparent. *Quartz, Rock Crystal*

   Color: Various. Banded. Bands differ in color texture and compactness. *Quartz, Agate*

   Color. Various. Bands straight. *Quartz, Onyx*

   Color: Black, brown, green, red, pink. Luster vitreous to resinous. Large prismatic crystals. No cleavage. *Tourmaline*

   Color: Dark brown. Luster vitreous to dull. Opaque. Crystals-twined like a cross. *Staurolite*

KEY TO SOME COMMON ROCKS OF MICHIGAN

IGNEOUS

1. Coarse-Grained:

Coarse to medium-wine grained, even texture. Composed of pink to red feldspar (orthoclase) that has glistening cleavage faces; clear, milky or smoky quartz with no cleavage faces and silvery white muscovite and/or black biotite mica. *Granite*

Some granites have a small amount of white, pale green, and/or yellow plagioclase feldspar, and other coarse granites may contain crystals of magnetite. Some granites have greenish black, prismatic hornblende crystals, very coarsely crystalline, found only in veins or dikes cutting granite and/or schist.

Coarsely crystalline, large crystals of feldspar and mica in veins or dikes in granite. *Pegmatite*

Gem stones-beryl, topaz (and others) may be found in pegmatite. Pegmatite dikes are in the rocks of western Northern Peninsula.

Coarse- to fine-grained. Light colored. Minerals: Chiefly feldspar and mica, no quartz. Rare. *Syenite*

Coarse to medium-grained. Even texture. Dark colored. Dark greenish to dark gray. Minerals: Hornblende or pyroxene, little feldspar, brown or yellow, no quartz. *Diorite*

The knobby hills around Ishpeming and Negaunee and diorite knobs.

Fine texture, greenish black, dark gray. Minerals: Hornblende or pyroxene, black mica, little feldspar, no quartz. *Gabbro*

Gabbros are found in the western half of the Northern Peninsula and as boulders in the glacial drift. It is difficult in the field to distinguish between diorite and gabbro.

Fine texture with lath-shaped crystals of feldspar with olivine and magnetite. May have small crystals of pyrite. *Diabase*

The greenstone and much of the trap rock of the Copper Country are diabase.

Coarse-grained, green to black, iron magnesium minerals with olivine, some pyroxene or hornblende. *Peridotite*

2. Fine-Grained:

Fine-grained, dense. Light color, gray, pink, red, green, yellow, brown. Dull stony texture. Conchoidal fracture. Luster horny, greasy. *Felsite*

Dark colored, black or very dark green. Stony. Luster velvety. Does not have conchoidal fracture. *Basalt*

Felsite and basalt are lavas. Porous basalts (pore spaces are gas-bubble cavities of the original lava) are *Amygdaloidal basalts*

Fine-grained rock in which minerals crystallized separately, giving spotted appearance. *Porphyry*

3. Glassy:

Lava cooled too quickly for minerals to form. Black. Conchoidal fracture. Sharp glass edge. *Obsidian*

Spongy structure. Light-floats on water. Gray brown. Can be ground to fine powder. *Pumice*

Coarse spongy structure. Glassy or stony. Red to black. *Scoria*

4. Fragmental:

Volcanic dust, cinders, “bombs” blown from volcanoes, may be cemented together to form *Volcanic breccia*

Broken lava crusts cemented *Trap* or *Basalt breccia*

SEDIMENTARY

1. **Rounded fragments of rocks cemented to a solid mass.** *Conglomerate*

   Original fragments moved by water, may have been of volcanic origin or broken from bedrock by weathering. Conglomerate being formed in the glacial drift by cementing of glacial sand and pebbles (induration). *Crag*

   Sharp-edged or angular fragments of rocks cemented together. *Breccia*

2. **Grains of quartz.** Worn, microscopic to coarse, cemented by silica, clay, calcite, iron. Creamy white to dark gray. Color depends on the cement. Breaks up to form sand. Rock breaks through cement, not sand grains, feels gritty. *Sandstone*

3. **Hardened, compacted (indurated) clay, mud, silt (decomposed mica and feldspar).** Black, blue-gray, red, whitish. Breaks into plates or sheets. Soft, can be cut with a knife, to very hard. Odor of clay when breathed upon. Weathers forming mud, clay. *Shale*

4. **Crystals and grains of calcite.** Various colors. Fizzes with cold acid. May or may not be crystalline. Easily scratched with a knife. *Limestone*

5. **Crystals and grains of calcite and dolomite.** Various colors. Fizzes in hot acid. Harder than limestone. *Dolomite*

Limestones were made of carbonate of lime, with or without magnesium carbonate, removed from sea water by very small plants and animals, deposited on the sea floor and consolidated into rock. **Chalk, travertine, tufa,** are forms of limestone. **Marl** is an earthy carbonate of lime that has not had time to compact to a rock.

All sedimentary rocks are in layers or strata. If the strata are thick, the stratification is *massive;* if in thin layers the rock is *thin-bedded*. Shale has the thinnest layers.

The plane surface or crack between two beds or layers is a *bedding-plane*.

A verticle crack in any kind of rock is a *joint*.

Joints and bedding plane cracks may be filled with minerals—*Veins*.

Cavities may be lined with minerals—*Geodes*.

METAMORPHIC

1. **Banded, light-colored, quartz, feldspar, mica.** Metamorphosed granite. *Gneiss*

2. **Banded, platy arrangement of crystals.** Commonest metamorphic rock. *Schist*

   If mica and quartz are the principal minerals, the rock is the second commonest metamorphic rock. *Mica Schist*

   Heavy, hard, not readily scratched by a knife. Dark green to black. Hornblende, the principal mineral. *Hornblende Schist*

   Easily scratched with a knife, green to dull grayish green. *Chlorite Schist*

   Scratched with fingernail, white to green and yellow, various colors but mostly white, pearly luster. Greasy feel. Coarse to fine scales. *Talc Schist*

3. **Metamorphosed sandstone or conglomerate.** Hard, firm, compact. Glassy. Conchoidal or splintery fracture. Breaks through grains and cement. *Quartzite*

4. **Metamorphosed shale.** Soft, dense. Red, blue, green, white, black, gray. Breaks into sheets. Mineral grain is indistinguishable. *Slate*

5. **Metamorphosed limestone and/or dolomite.** Soft to hard. Various colors. Crystalline. Fizzes with acid. *Marble*

SUGGESTED READING

HARDBOUND BOOKS

Field guide to rocks and minerals, by F. H. Pough, Houghton Mifflin, third Edition, 1960. 349 p.

Geology, by W. C. Putnam, Oxford University Press, N. Y., 1964. 408 p.

Geology of the Great Lakes, by J. L. Hough, University of Illinois Press, 1958. 313 p.

Getting acquainted with minerals, by G. L. English, and D. E. Jensen, McGraw-Hill Revised Edition, 1958. 336 p.

Our mineral resources: An elementary textbook in economic geology, by C. M. Riley, John Wiley & Sons, Inc., 1959. 338 p.

The rock book, by C. L. and M. A. Fenton, Doubleday & Co., Inc., 1940. 357 p.

PAPERBOUND BOOKS

Geology, Merit Badge Series, Boy Scouts of America, 1953. 84 p.

Geology and earth sciences sourcebook for elementary and secondary schools, edited by R. L. Heller, Holt, Rinehart, and Winston, Inc., 1962. 496 p.

Lake Superior copper and the Indians: Miscellaneous studies of Great Lakes prehistory, edited by J. B. Griffin, University of Michigan Museum of Anthropology, Anthropological Papers No. 17, 1961. 189 p.

Minerals and Men: An Exploration of the World of Minerals and its Effect on the World We Live In, by J. F. McDivitt, The Johns Hopkins Press, (for Resources for the Future, Inc.), 1965. 158 p.

Publications of the American Geological Institute, American Geological Institute, 1444 N. Street, N. W., Washington, D. C. 20005

Rocks and minerals: A guide to minerals, gems and rocks, by H. S. Zim and P. R. Shaffer, Simon and Schuster, 1957. 160 p.

Selected references for earth science courses, by W. H. Matthews III, Prentice-Hall, Inc., 1964. 33 p.

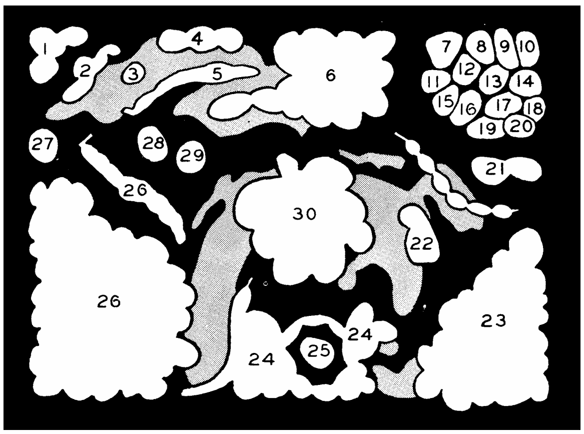
1001 questions answered about the mineral kingdom, by R. M. Pearl, Grosset and Dunlap, 1959. 326 p.

MICHIGAN BEACH STONES

REMINDER ABOUT BEACHCOMBING

If you are to walk along a Great Lakes beach, you should obtain permission of the property owner. His rights extend to the water's edge, regardless of water level fluctuations. Permission is not required, however, if you wade in the water, just off the beach. Submerged bottomlands of the Great Lakes are public owned.

GUIDE TO STONES SHOWN BELOW



1. AMYGDALOID (Greek: "almond")—Pebbles of basalt, or lava, with almond-shaped cavities created by gas bubbles trapped beneath the crust of a once molten rock flow. Green "amygdules" are *chrysocolla:* red, *analcite*. Note copper amygdules in pebble nearest upper left corner.

2. NATIVE COPPER — Michigan's "honor mineral." Specimens found in old mine waste piles usually have a green *patina* coating; when polished the bright copper color emerges.

3. NATIVE SILVER— Lake Superior copper is noted for its silver content that imparts "superior" qualities for many uses. Hammered nuggets of inter-mixed copper and silver are called *half-breeds*.

4. LAKE SUPERIOR AGATES—Typical beach specimens. Besides their inherent hardness and fine lustre, concentric banding is a definite clue to the identity of two of these specimens. The specimen on the right, however, might easily go unnoticed.

5. LAKE SUPERIOR AGATES—A string of tumbled round agates of the size most commonly found.

6. LAKE SUPERIOR AGATES—cut and polished gem stones collected at various beaches from Ontonagon to Sault Ste. Marie.

7. HONEYCOMB CORAL—the original limey skeleton of this fossil has been replaced by *silica* (quartz).

8. JACOBSVILLE SANDSTONE — not considered a lapidary material, but sometimes weathering processes cement the grains into a compact mass that takes a fairly good polish.

9. PREHNITE—a member of the *zeolite* mineral group, which also includes *thomsonite*, *chlorastrolite*, and an *alcite*, common to the Copper Country. See the minute flecks of copper?

10. BRECCIA (Italian: stone fragments)—Angular pieces of basalt fragmented in a zone of violent rock breakage and re cemented with other minerals, often quartz or calcite.

11. JASPILITE—a specimen of iron formation in which the usual red iron oxide coloring has been weathered to ochre-colored *limonite*.

12. CONGLOMERATE — an aggregation or "conglomeration" of rounded pebbles cemented together by other mineral matter.

13. RHYOLITE — red to brown fine-grained type of igneous rock.

14. QUARTZ—with green *epidote* and red *jasper*.

15. QUARTZ—with red *jasper*.

16. EPIDOTE—in basalt.

17. BRECCIA—Fragments of basalt cemented by milky *quartz* with traces of red *jasper*.

18. EPIDOTE—in basalt.

19. BRECCIA—Fragments of basalt cemented by milky *quartz* with traces of green *epidote*.

20. FINE-GRAINED GRANITE — contains small interlocked grains of clear *quartz* and flesh-colored *feldspar*.

21. JASPILITE—Interbanded red *jasper* and grey *hematite*. The ever-increasing production of iron from occurrences of this ore is a vital factor in Michigan's economy.

22. PETOSKEY STONE — fossil colony coral.

23. RAW BEACH STONES — a collection of various hard unpolished pebbles, typical of Lake Superior shores, but also found elsewhere to a lesser extent. True *cherts* are usually white, pale brown, brownish yellow, red grey, sometimes black, and occasionally green. In all cases, how ever, they consist of a dense, non-crystalline water-deposited form of silica that takes an exceedingly high polish. Colors are the result of other mineral impurities: iron oxide imparts the red color; green pebbles (basalts) are colored by *epidote;* glassy white to grey stones with frosted surfaces are usually *vein quartz*, a crystal line variety of silica.

24. THOMSONITE—Exquisite shades of pink and green with a radiant fibrous structure.

25. CHLORASTROLITE—the famous Lake Superior gem, "*greenstone*".

26. TUMBLED BEACH STONES—Same as in group No. 23, except the inherent beauty of their colors and textures has been enhanced by tumbling.

27. RHYOLITE — A fine-grained igneous rock shaped into a convex gem form known as a *cabochon*. The group of four banded reddish brown pebbles immediately beneath are also rhyolite.

28. CHERT—with small orbs of red *jasper*.

29. CHERT—just chert, but most unusual and pleasing gem specimens.

30. DATOLITE — often very colorful, and though not as hard as either agate or chert, takes a superb polish because of its very dense texture. Unusual, too, because it contains the element *boron*. Rarely occurs on beaches, but the two yellow pebbles were picked up on a Keweenaw beach fifty paces apart—and they're mates!