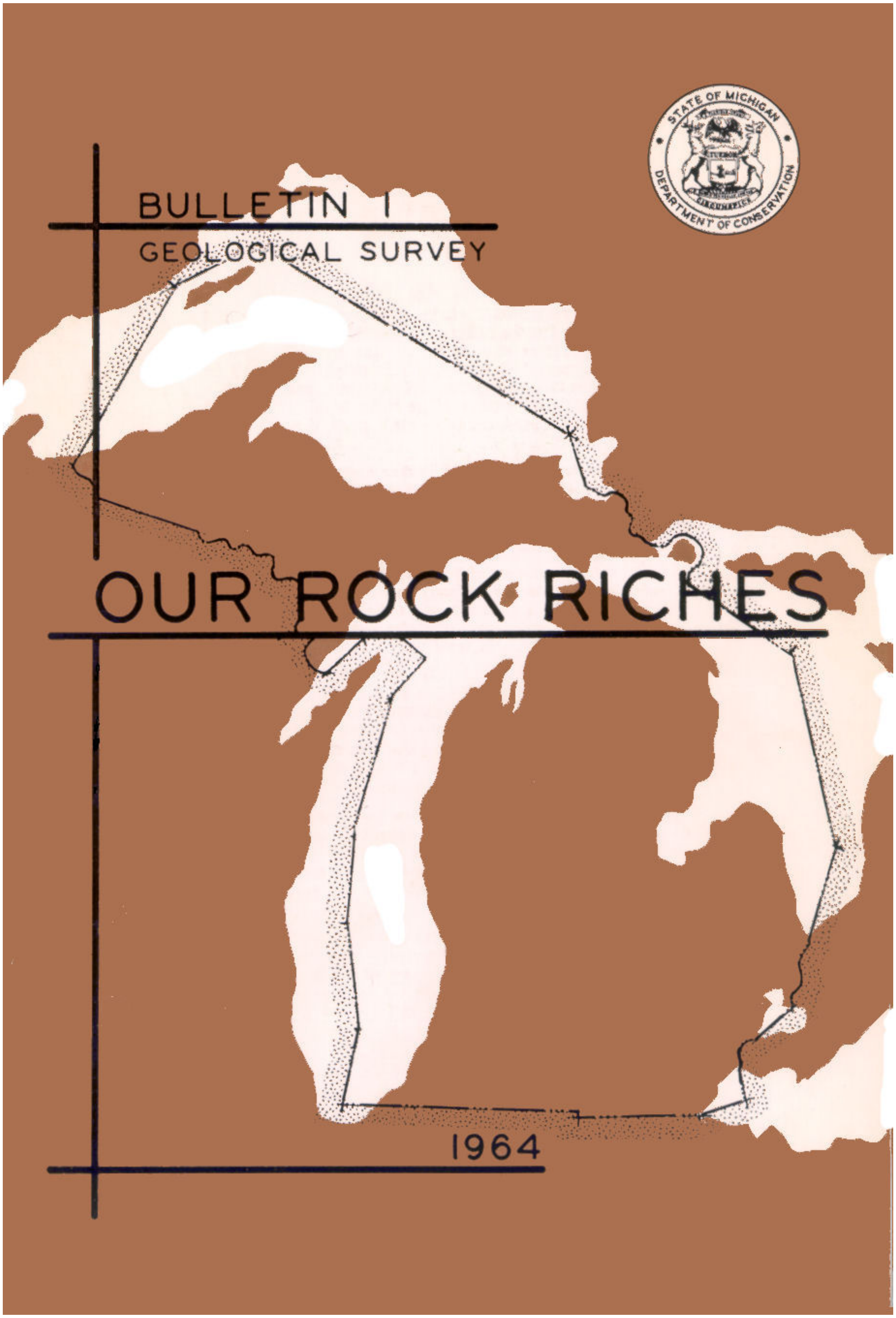
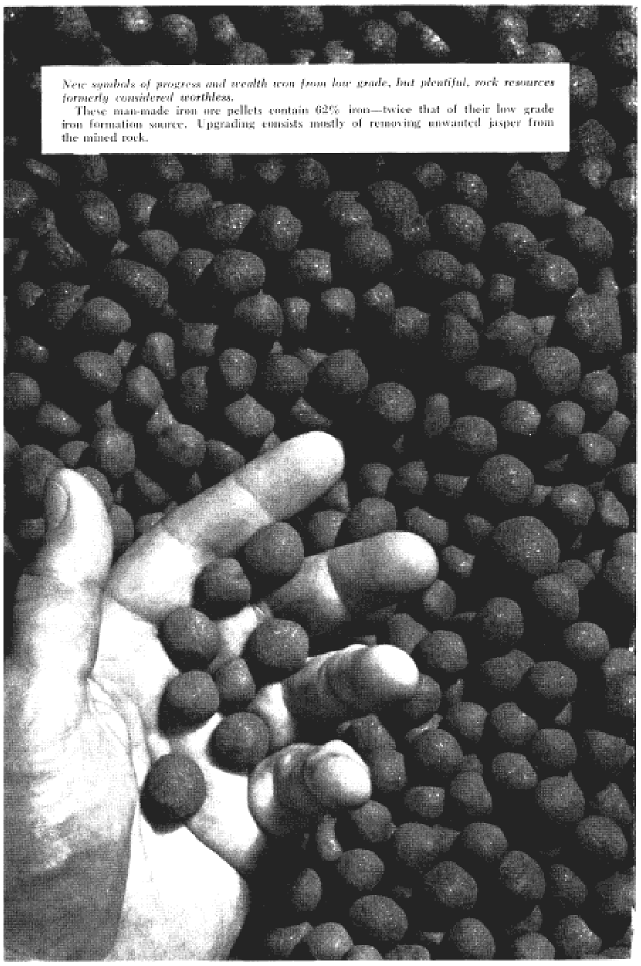


on the [original] cover

The ink contains copper — Michigan's "honor metal". Nothing remotely resembling the native copper deposits of the Keweenaw Peninsula is known anywhere else on this planet. This remarkable resource aided materially in the growth and development of the Nation. Featured also is the legal state boundary marking Michigan's sovereign jurisdiction. The impressive situation here, affirmed by former Governor Chase S. Osborn, is that no political subdivision on earth is comparable to Michigan on the basis of proportion of fresh water to land.



New symbols of progress and wealth won from low grade, but plentiful, rock resources formerly considered worthless.

These man-made iron ore pellets contain 62% iron—twice that of their low grade iron formation source. Upgrading consists mostly of removing unwanted jasper from the mined rock.

Frontispiece. Iron ore pellets

Geological Survey

Bulletin 1

OUR ROCK RICHES

A SELECTED COLLECTION OF REPRINTED ARTICLES ON MICHIGAN'S MINERAL RESOURCES BY VARIOUS AUTHORS

LANSING, MICHIGAN 1964

Contents

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PREFACE

The importance of our mineral resources is being re-discovered today, as indicated by the number of Michigan citizens seeking information on these valuable assets. Much has been written on the subject but, unfortunately, little is readily accessible.

The purpose of this volume, therefore, is to provide a handy general reference devoted to mineral resource topics of particular interest to the people of this state. To accomplish this aim, we have brought together a diverse collection of twenty-two separate articles embodying basic information. These articles vary widely in form, content, and length, inasmuch as all were prepared originally for other uses. Nevertheless, each author has a worthwhile message and is informative in his own way. Doubtless, readers will appreciate the change of pace from one article to another.

Because this publication was prepared essentially as a reference source, illustrations have been held to a minimum. The special reading list appearing at the back will prove especially helpful to anyone wishing to delve into the subject further.

The willing cooperation and courteous permission of all our contributors made this publication possible.

	Robert W. Kelley, geologist
Lansing	Lansing Geological Survey
Aug., 1964	Dept. of Conservation

SKETCH OF MICHIGAN'S GEOLOGIC HISTORY

By Kiril Spiroff[1]

The state of Michigan is richly endowed by Nature with varied geologic phenomena. There is evidence to show that within the state there were active volcanoes, that prevailing westerlies ruffled the waves of the shallow seas that once covered it, and that in turn, deserts, jungles and ice ruled where now the genus Homo ekes out a living.

In the Upper Peninsula the bedrock formations include some of the oldest rocks known. Many of these were originally gravels, sands, marls and silts, deposited in shallow seas or on great outwash plains that existed in this region a billion or more years ago.

Life was not abundant in those ancient times, but humble forms of the plant and animal kingdoms were present. Some of these lowly organisms formed reefs that are similar to deposits of a much later date; other remains formed carbonaceous or graphitic layers, but nothing like coal.

A unique feature of these oldest rocks is the occurrence of the iron formations. The total quantity of iron-bearing minerals deposited in the shallow seas of this era was never repeated. A comparatively small amount, much less than 1%, of this iron formation was later concentrated into commercial iron ore by natural processes. For many years the iron deposits of the Lake Superior region yielded 80-90% of the iron produced in the United States.

After great thicknesses of the iron formation and associated deposits were laid down, the district became the site of a profound crustal disturbance. The beds were contorted and broken, high mountains were formed, and great masses of molten rock surged within the earth's crust and broke out to the surface in the form of volcanoes. In the center of Lake Superior, where deep cold water now conceals the remnants of this activity, large fissures poured forth lavas that flowed outward beyond the vicinity of the present shores of this great lake. Intermittently, layers of gravel and sand spread over the laval flows. Spent by all this activity, the area then sank, leaving the outer part of the volcanic series as rims around the present Lake Superior.

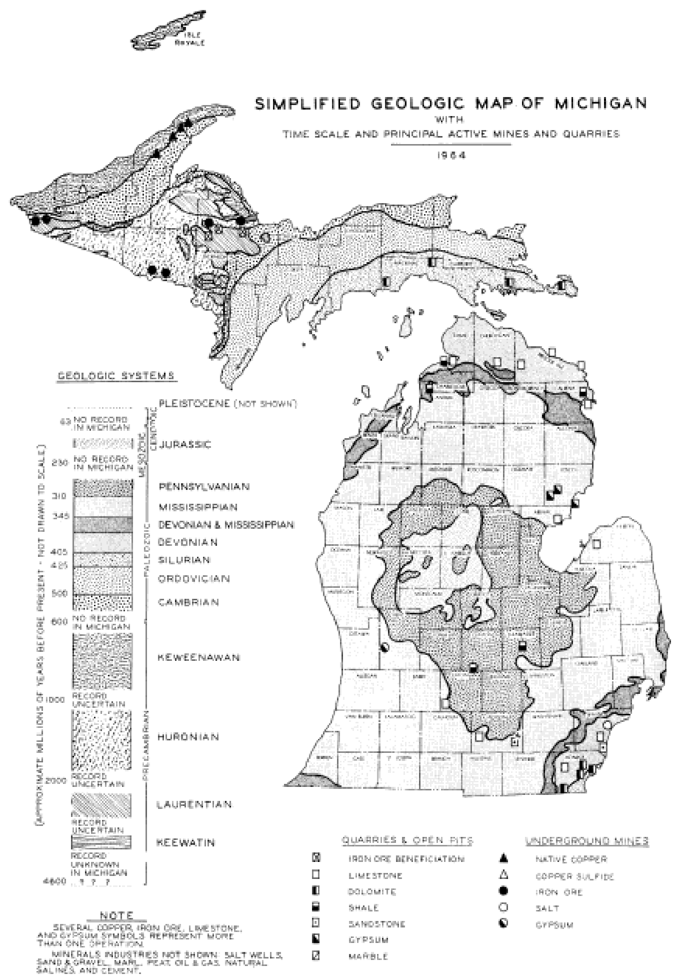

Figure 1. Geologic map with time scale and principal mines.

Within the porous and fragmental part of the lavas and the interstratified conglomerates of the Keweenaw peninsula, native cooper was deposited in veins, long famous for their unique character — the only large deposits of native copper known in the world today. The purity of the copper is such that it required minimum metallurgical treatment. The lodes are among the most persistent known in the world, continuing down along the incline for a distance of 10,000 feet and horizontally for distances measured in miles. How much farther they go down into the earth is unknown. Workings are limited by mining and economic factors rather than by the continuity of the deposits.

This copper lured man of the Stone Age, evidenced by crude implements found in shallow pits where shafts now go a mile or more deep.

Several of the mines in the Upper Peninsula have the distinction of being the deepest in the United States. The Quincy at Hancock attained a depth of 9,009 feet along the incline, or 6,254 feet vertically. The Red Jacket of the Calumet and Hecla Company at Calumet had a 5,690-foot vertical shaft. Auxiliary shafts reach to 9,500 feet along the incline.

A million years or more after the eruptions of the Keweenawan epoch the Michigan basin began to develop. During Paleozoic time this large basin intermittently and gradually filled with sediments from nearby landmasses, along with chemical precipitates and shells of an infinite number of marine creatures.

In shallow bays and arms of the seas, toxic conditions prevented complete destruction of accumulating remains of animal micro-organisms and vegetation. Natural distillation of some of these organic materials formed crude oil and natural gas. Oil and gas, being mobile, migrated into structures developed in the more porous rock beds.

Strata of gypsum and salt, interbedded with various other sedimentary rocks, were precipitated during several of the many floodings of the basin. These sediments furnish raw material for such important industries as Portland cement, gypsum, salt and brine. One large chemical plant alone produces several hundred products from natural brines.

By the end of Paleozoic time, the basin became a broad flood plain of low swampy nature. Life had made enormous strides in development. Fishes, crustaceans and mollusks were abundant. Plant life was very conspicuous. The luxuriant vegetation of tree ferns, giant mosses and horsetails growing in the warm moist climate transformed this lowland into jungle swamps exceeding those today.

A very significant economic product of these former swamps is coal. It represents accumulation of vegetation under conditions that did not allow complete oxidation. As vegetation accumulates on the surface it forms peat, composed of partly decayed stems, leaves, and woody materials along with an amorphous black jelly-like substance which results from complete decomposition. When buried and covered with mud and sand, however, the partially decomposed substance is compacted to form lignite coal at first, and after long burial, bituminous or soft coal.

After the disappearance of the last of the Paleozoic seas, Michigan may not have been submerged again. However, the state was covered several times by enormous sheets of ice as Greenland is today. These glaciers modified the appearance of the land. They grooved and polished the resistant rock outcrops, picked up and carried away the residual soil and acted as large ball mills which pulverized the granite, forming "rock flour" rich in potash and phosphates — ideal plant foods. As the glaciers retreated the materials they were carrying were deposited in chaotic fashion, leaving hills, gravel beds and shallow lakes.

As a result of geological processes, the Upper Peninsula of Michigan is favored with enormous deposits of iron ore and copper, while the Lower Peninsula can boast of its salt, oil wells, gypsum beds, coal mines and good farming lands. The scenic wonders, sandy beaches, forests, streams and lakes beckon the traveler, fisherman and hunter, and the state is one of the nation's favorite playgrounds.

So reads the fantastic tale, the terse natural biography of our state. To the little boy who might ask, "Do you expect me to believe this?" I reply, using the phrase of another little boy, "You are blind in one eye, and can't see with the other." Nevertheless, come be a good sport. Master the alphabet so you can read the things you see.

It may be that a crystal, a fossil, a pebble, or perhaps a scenic feature is waiting to be described or interpreted. Their underlying causes are found in the records of the past. The ability to properly interpret these records depends upon the knowledge of the forces which produce them. Thus, the study of the records of the past leads one to the understanding of the natural laws which contribute to our daily welfare, for these processes have been in operation from the beginning and are in operation now and will continue.

[1]Professor of Geology, Michigan Technological University. (1964)

MINERAL RESOURCES AND MAN

By Charles M. Riley[1]

The average citizen gives little thought to the many cultural and technological advances that play so great a part in the high standard of living which he is enjoying. Evolution of language, religion, ethnology, and philosophy through the ages has created a social environment for Mr. Citizen which he feels is essentially right. Medical advances have given him a life expectancy which is double what the average worker could expect in the Middle Ages. Great strides in the knowledge of agriculture, animal husbandry, and food preparation have given our modern man a diet of a quality and variety never before enjoyed on this earth, even by the richest kings of old. If we were to ask Mr. Citizen about his standard of living, he might mention some of these less-obvious blessings, but more likely he would talk of the wealth of physical and mechanical things which make his life easy and enjoyable. His modern home, automobile, refrigerator, radio, television, telephone, electric lights, and a host of other modern inventions would probably be first on his lips. It would, perhaps, not occur to him to think further to the raw materials without which he could have none of these necessities and luxuries of his modern world. Let us point out some of the basic mineral substances which he uses daily without realizing it.

In the construction of his home a variety of metals are used, including iron, copper, zinc, lead, aluminum, tungsten, and perhaps, alloys containing manganese, cromium, nickel, and molybdenum. Stone or bricks may be used on the outer surface, or perhaps a shingle siding made of asbestos and cement. The asphalt roofing paper is covered with stone chips, and the inner walls are of plasterboard, made mostly from gypsum. Glass is generously utilized in his modern home, but it must be manufactured from quartz, soda, lime, and a variety of other materials. The basement and footings are concrete in which is cement (limestone, clay, gypsum) mixed with sand and gravel. The house is insulated with mineral glass fiber and is painted a snowy white with paint that contains lithopone (zinc sulfide and barium sulfate mixture) and titanium oxide pigment. His heating plant burns natural gas, but his friends use fuel oil and coal, all mineral fuels. Water is piped to his house from a municipal system that relies upon surface water or ground water sources. His electricity is generated in a plant which burns coal or gas, and it travels to the many outlets in his house through networks of copper wire.

When one starts to enumerate for Mr. Citizen all of the mineral raw materials used in his automobile or the train in which he rides to work, the list becomes even more impressive. In his office building and in the city around him are things made with mineral products from mines, wells, and quarries all over the world. Even his food and clothing, products of agriculture, would not be as good or as inexpensive were it not for the great quantities of mineral fertilizers used each year by the farmer. In the following pages the reader will be constantly reminded of the great quantity and variety of minerals that are required in our complex industrialized world.

Distribution of Mineral Resources

Any student of economic geography is soon impressed with the fact that for every important mineral resource there are "have" and "have-not" nations. It is necessary that the nations with an abundance of a certain mineral share this resource with less-fortunate countries through the avenues of international trade. This is not done through any altruistic motive, for in return the supplier nation receives minerals or goods which it cannot produce within its political boundaries. There is such a variety of mineral raw materials needed today and they are so unequally distributed on this earth that no country is completely self-sufficient. Even the great industrial nations, United States, England, and Russia must rely upon imports of many minerals from all over the world.

United States has become a world power largely because of her bountiful mineral resources, which include nearly 50% of the world's reserves of coal, about 30% of all the iron ore, 25% of the copper, 50% of the phosphate rock, and abundant reserves of petroleum, sulfur, zinc, lead, and other vital minerals. The United States is producing most of the substances at a prodigious rate for domestic consumption and for export, yet she must import additional supplies of some others to meet the growing demands of her industries. There are many essential mineral substances for which she is wholly or almost entirely dependent upon imports. Tin, nickel, manganese, chromium, industrial diamonds, quartz crystals, and sheet mica are a few of these.

The mineral resources of the U.S.S.R. may ultimately prove to be more varied and plentiful than those in America. There are great areas that have been only poorly examined, and many regions are so remote that mineral resources they contain could not easily be exploited at the present time. However, the potentialities are great and, even now, known deposits of iron ore, manganese, chromium, coal, mineral fertilizers, and a variety of other metallic and nonmetallic minerals are sufficient for her present needs and for export. The possibilities for extensive petroleum reserves are good, but little has been found so far. U.S.S.R. is deficient in and must import such mineral commodities as copper, lead, zinc, mercury, sulfur, tin, and many others.

In contrast to the two great nations best endowed with mineral wealth, there are the many countries which may have a few or several mineral substances in great abundance but do not have the industrial development to make use of them. Many backward but mineral-rich African and Asian countries are in this position, suppliers of raw materials and markets for manufactured goods.

The unequal distribution of minerals on the earth has in the history of mankind led to wars of conquest, colonialization, and purchase of vast undeveloped holdings by other countries. With mineral wealth has come economic power, particularly since the Industrial Revolution when coal and iron ore became the major factors in the industrial growth of a nation.

The days of colonialization are past, and no longer will nations sell land to other countries. Unfortunately, wars of conquest still take place, but now the issues involved are more complex than the simple desire to steal the resources of a neighbor.

Military Importance of Mineral Resources

War is a reality that seems to be threatening or with us all the time, despite a seemingly universal desire for peace. In the last 20 years the world has seen at least four wars as well as several revolutions and "police actions."

In olden times a country could train and simply equip a few thousand soldiers who could live mostly off the land. Such an army could win a war with a neighboring country by its fighting skill and the clever leadership of an experienced general. Modern wars can only be won by countries who produce the most and best armament and military material of all kinds. Valorous soldiers and excellent leadership are important, but great industrial potential is essential, coupled with the maximum efforts of soldiers and civilians alike. Such military efforts create extraordinary demands for minerals. Metals of all kinds are consumed in vast amounts during war-time, and the drain on the world's reserves of mineral fuels is increased many times in order to keep the factories producing at maximum capacity and to propel the many military ships, planes, and vehicles. In short, a country with the most military power is one with the greatest available industrial potential, and this is greatly dependent upon the mineral resources which it controls. History has showed that a large well-trained and even well-equipped military machine is not enough to win a major war against an enemy with higher industrial potential. Germany, Japan, and Italy learned this again in World War II.

In recent years it has become more and more apparent that a new factor must enter into a determination of the military strength of a nation. This is the number and quality of trained scientists which the nation can direct to studies and research on new weapons and defenses. It was a cooperative scientific effort on a large scale that created the first atomic bomb, and today teams of scientists in many nations are perfecting the terrible hydrogen bombs, working on guided rocket missiles powerful enough to penetrate outer space, and developing other new weapons that we will perhaps never hear of until they are used.

Of course, industrial or military developments of this kind result in shortages and demands for new mineral materials. The discovery of atomic weapons created an unheard of demand for uranium, a metal that was previously considered little more than a curiosity yet was a rather plentiful byproduct from the recovery of radium. Extensive explorations for uranium deposits by trained geologists and hopeful prospectors reached into every corner of the earth. The search was stimulated by government subsidies and other enticements. Many new discoveries were made, and this potent metal is flowing into the atomic arsenals of the world in greater and greater tonnages. Now an evaluation of military might must take into account the tonnage of uranium ore owned or controlled by a nation and the ability of the nation to transform the raw material into nuclear weapons.

Exhaustibility of Mineral Resources

Our agricultural resources can be considered everlasting, provided that we take care of the soil. Fields will yield crops year after year, and even forests can be cut again within a few decades. This is not true of our mineral resources. When a copper deposit is mined out, all that remains is a hole in the ground, and there is no possibility that more copper ore will form in the same place. Many great ore deposits have reached this state, and ghost towns are all that are left of what were once bustling mining communities. As long as new deposits are found to replace those that are exhausted, industry will continue to get the minerals it needs. For most minerals geologists and prospectors have been able to replenish our proven ore reserves by new discoveries. However, the rate of consumption of many of these minerals has increased so much in the last 20 years that our reserves will completely vanish in a short time if we fail to uncover even more and larger deposits. None of us is so optimistic as to believe that we can continue finding minerals as fast as we consume them. After the more exposed deposits are used, the deeper deposits can be discovered only by much financial risk and expensive exploratory programs. Not even the greatest of human ingenuity can find new ore deposits where none exist.

No one can exactly foretell when supplies of minerals will run out, because we do not know how many new discoveries will be made or what the demands of the future will be. Many predictions have been made in recent years, all taking into account the possible relief of the situation by new discoveries and by diminished demands upon mineral reserves when they become critically low. Although these experts do not agree in their forecasts, they are all in accord that the long-range outlook is gloomy and that within a few centuries we are going to be completely without, or suffering severe shortages of, some minerals which are not considered essential to our economy.

The mineral fuels and many nonmetallic minerals present the most serious problems because they are "expendable" and cannot be used more than once. Coal is the mineral fuel that occurs in the greatest abundance, but even it will be depleted in about 2000 years if used at the present rate. Long before this, however, the costs of mining deeper less-profitable deposits may make it impossible for coal to compete with other sources of energy. The position of the world with regard to petroleum is more serious, because oil products are being consumed at an ever-increasing rate. In 1946 the world was burning each day 7,778,000 barrels of petroleum. In 1955 the consumption was 16 million barrels per day, and in 1957 the rate was 17.5 million barrels. New discoveries continue to keep up with the rate of depletion of known reserves, but exploration costs become greater as less-promising areas are tested. Even at today's consumption rate 200 years may see us without oil.

Nearly all minerals are required in greater quantities today than ever before. This is due to increased industrialization, higher living standards and a larger population. The United States alone, since 1914, has used more metals and mineral fuels than were used by all of the world in historic time preceding 1914.

There is no solution to the problem of the world's exhaustible mineral resources. We can delay the day of reckoning in many ways, but, so long as we use any mineral material, a time will come when there will be none left or when it will become uneconomical to recover it.

There are four things that can be done to stave off the unpleasant realities of this problem: (1) We must increase our programs of exploration, train more and better geologists to carry them out, and employ and develop the best geophysical and geochemical tools to aid in the search. (2) For the nonexpendable minerals we can increase the efficiency of scrap recovery so that these materials may be reused to a greater extent with less waste. (3) Researchers must find substitutes for each mineral when it can no longer be produced in great enough quantities or at low enough costs to meet the demands of industry. (4) We can restrict the uses of some minerals to those applications where they are most critical.

Substitution seems to be the only way man can forestall or significantly postpone the day when an industrial mineral will no longer be available for human use. Already many important advances have been made in a quest for other sources of energy to take the place of our mineral fuels. Solar energy has been utilized on an experimental basis, and it is entirely conceivable that much of our electrical power will some day be generated by great plants located in the arid regions of the world where there is a high incidence of sunshine. Solar energy may even be used to distill fresh water from sea water which will help create productive agricultural regions out of what now are deserts. Studies are also being made to find ways of harnessing some of the enormous energy of the tides, and increased usage of river water power will certainly take place.

Uranium is a new source of energy that is already being used as a substitute for coal and oil. Power from the atom will become more important in the next few decades, yet, as a substitute, it can only prolong our use of mineral fuels, for it too is an expendable mineral resource. Of course, any substitute for coal and petroleum should be welcome, for these fuels of today may mean far more to mankind as sources of organic chemicals than as sources of energy.

The most important kinds of substitute materials for our diminishing mineral resources are those that come from agriculture and are thus replenishable or those that are minerals so abundant in nature that we need never fear for their depletion. Plastics offer examples of agricultural substitutes that have taken the places of metals in a number of uses. Metals, ceramic materials, and rock products produced from sand, gravel, clay, limestone, and other plentiful rock materials must be used wherever possible, for such sources of mineral substitutes can never be used up. Minor amounts of a number of valuable metals and nonmetals occur in common granite, a source that could supply our needs indefinitely if only there were ways to extract these minerals economically. The ocean is an inexhaustible source for a variety of mineral substances such as magnesium that will become important substitutes in the future.

[1]Reprinted with permission from "Our Mineral Resources," 1959, John Wiley & Sons.

BOSTON AND KEWEENAW

— An Etching in Copper

By J. R. Van Pelt[1]

It was a strange but highly fruitful marriage — that union of hardy explorers seeking the rich treasures of copper in the Lake Superior wilderness, with Boston's aristocracy of brains, capital, and enterprise. This historic wedlock, which has continued happily to the present day, was the means by which the wealth of Lake Superior's copper was won for the use and benefit of an expanding America.

One branch of this family tree, the western branch, begins with prehistoric Indian miners, embraces the early French explorers of the Upper Lakes, and finally includes the British and American pioneers who reduced the vague rumors of copper to known fact and actually began the mining of copper in the wilderness. The other branch, the New England line, begins with the Mayflower, runs down through three centuries of Massachusetts history, and includes not a few of Boston's financial and intellectual leaders of the eighteen-seventies, -eighties, and -nineties.

The fecundity of this union of east and west has been remarkable. Since its consummation less than a century ago, its issue has included America's first great mining boom, her first major copper-producing district, many important engineering developments, much pioneering in enlightened labor relations, one of the world's greatest colleges of mining and technology, and generations of mining men who have opened and operated important mines in every corner of the globe.

Lake Superior, largest of the world's fresh-water lakes, sweeps four hundred miles from its head at Duluth to the outlet at Sault Ste. Marie. Near the center of the south shore a rugged, rockbound peninsula juts out nearly a hundred miles into the lake. This great finger of land is the Copper Country; its name, the Keweenaw Peninsula. Fifty miles northwest of the peninsula, across the lake, is Isle Royale, a forty-five mile sliver of rock lying close to the Canadian shore. Isle Royale and the Keweenaw Peninsula are twins geologically, though the copper deposits on the island are too lean to be worked with profit.

Prehistoric Mining

By a lucky chance, the copper of the Lake Superior district occurs in the pure metallic state. Pieces large enough to serve as tools or weapons could be pried out of soil or rock by primitive men and hammered into spearheads, axes, or tomahawks, without any smelting. Almost everywhere else in the world the copper is locked up in chemical compounds, chiefly copper sulphides, the utilization of which had to await the discovery of rudimentary smelting methods to extract the metal. So it happened that long before Columbus — the date is known only by archeological inference — an unidentified race, presumably of Indians, found this metallic copper, discovered its malleability and strength, and from it made many thousands of copper implements. No doubt they first used loose or "float" copper found in river beds, along the beaches, or in the bouldery glacial soil that covers most of the area; but when the visible supply of "float" had been exhausted, these primitive men attacked the solid rock itself wherever large pieces of the metal could be seen. Hundreds of pits were thus dug by prehistoric miners on the Keweenaw Peninsula, and more on Isle

Royale. We shall presently hear more of one of these Indian pits.

Early Explorations

Franciscan and Jesuit missionaries were the first white men to explore systematically the vast region of the upper lakes. Imbued with religious zeal, with which was mixed a keen eye for commercial possibilities and an understandable ambition to enhance the power of the French throne in the New World, these explorers from 1660 onwards persistently related to their superiors the stories of copper deposits which they heard from friendly Indians. In 1667 Father Claude Allouez actually saw copper on the shore of the lake — possibly the first white man to do so. But neither he nor any other Jesuit ever tried seriously to mine the copper. These Frenchmen were missioners and explorers, but not miners; and they left this bonanza untouched from their earliest arrival until, more than a century later, the region passed from French to British sovereignty.

No sooner was the British flag hoisted at the Sault in 1763 than English traders and adventurers began to cast an appraising eye on the fabulous deposits of copper. In eight years they did what the French had failed to do in a hundred; a mining company was organized in London, a group of English miners was sent to the New World, and actual mining operations were started. Working through the long, cold winter, these men drove an adit into a clay bank at a point where they had observed a trickle of green copper-bearing water, and found a number of pieces of float. But with the warm days of spring their roof of frozen clay thawed and caved in, and the miners, unfamiliar with the geology of the area and tired of their lonely life, returned to the Sault. The next year they drove some thirty feet into the solid rock not far from their site working along a copper-bearing vein. But the vein narrowed down and nearly disappeared in this short distance, and the project was abandoned. Thus ended the first abortive effort of white men to develop the area. It was the last serious attempt under the British flag, for a dozen years later, in 1783, the south shore of the lake, and Isle Royale as well, were ceded to the United States.

In the early years of American sovereignty, the energies of the young republic were occupied with urgent problems nearer home, and the legends of Lake Superior copper were virtually ignored. But a change came eventually, and here as in many another turning-point in history, it was brought about by one strong man, working with single-minded devotion for a cause. This man was Douglass Houghton.

Douglass Houghton, State Geologist

Douglass Houghton had been graduated in 1828 from Rensselaer, America's first engineering college, and soon thereafter had been invited by General Lewis Cass, Governor of Michigan territory, to come to Detroit and give a series of lectures on botany, chemistry, and geology. Finding the community to his liking, he settled in Detroit and soon became a leader in the state of his adoption, to which he was destined to render services of immense and lasting value. In 1830 he joined the Schoolcraft expedition to the sources of the Mississippi, and his imagination was fired by the limitless possibilities of the north country and by the opportunities to develop the mineral wealth of the Keweenaw that had been talked of for nearly two hundred years.

Houghton foresaw that the youthful science of geology might be the key that would unlock these mineral treasures; and when Michigan became a State, his enlightened and contagious enthusiasm led to the establishment of a state geological survey and to his appointment as its first chief. In 1840 he began his exploration of the Lake Superior region, and his report of 1841, though written with all the caution appropriate to a scientist working in an almost unknown field, aroused widespread interest. Few documents in scientific literature reveal better balance between caution and courage, between proof and intuition.

Houghton said in this report, "I am fully satisfied that the mineral district . . . will prove a source of eventual and steady increasing wealth to our people." But he cautioned that this would depend upon "the most judicial and economical expenditures of capital at those points where the prospects of success are most favorable . . . I would caution those persons who would engage in this business in the hope of accumulating wealth suddenly and without patient industry and capital, to look closely before the step is taken." Similar warnings were expressed in a letter which supplemented the report. "I know full well," he wrote, "the many difficulties and embarrassments which will surround the development of the resources of this district. That it will eventually prove of great value to our citizens there can scarcely be a shadow of doubt, but the time when this can be done must in a great measure depend upon the general policy of our government." He went on to advocate policies that would stimulate individual enterprise, and to urge the building of a canal at the Sault as a necessary first step to opening up the mineral lands. Even as early as 1841 the relation between private enterprise and government seems to have been a vital issue. Houghton was 31 years old when he wrote this penetrating analysis.

America's First Mining Boom

But the sober judgment of the State Geologist could not prevail against the mad rush that soon followed the publication of the Houghton reports. On March 23, 1843, the signing of the treaty with the Chippewas opened the country to settlement, and America's first mining boom was on. Adventurers poured in by schooner from the Sault and by pack train from Green Bay. Towns mushroomed at Eagle Harbor and Copper Harbor, where vessels would unload in protected waters, and even at Eagle River, where the crude pier was at the mercy of every storm. These were the roistering days when hopes were high, when whispers of new finds filled the air, when a prospector of two weeks' standing was an old-timer, and any new arrival in a black frock coat could pass as a mining expert.

The Keweenaw, in the early forties, was still public domain. Mining was carried on under federal permits which, however, could not be bought at any government office nearer than Sault Ste. Marie, two hundred miles away. Soon a brisk local trade in permits sprang up to accommodate, at a price, those adventurers who had neglected to secure them before leaving the Sault. Needless to say, any resemblance between the price of the permit and the value of the tract it covered was purely coincidental. A promoter had only to display a few choice specimens of copper, and the fatal magic of hidden treasure would soon get in its work.

David Henshaw, a solid man of Boston and the Secretary of the Navy under President Tyler, was one of the first to buy permits. He and his associates organized the Lake Superior Copper Company in 1844 and appointed Dr. Charles T. Jackson, a conspicuous figure in science in Boston, as the first manager. In his first annual report, Dr. Jackson quoted an assay showing values in copper and silver of more than $3,000 per ton of rock.

The effect of this incautious announcement was electric. Few people stopped to inquire whether this one test was typical; they simply assumed that their luck would be at least as good as Henshaw's. And so another crop of eager pioneers set out for the lake, many of them devoid of mining experience, equipment, or even proper clothing.

Succeeding annual reports of the Lake Superior Copper Company were just as optimistic; the second stated that there was "an adequate quantity of rich ore to render the work very profitable," and that there was no danger of exhausting the ore for "generations to come." Copper was, indeed, produced in moderate amounts, but at a net loss. By 1849 the mine had accumulated a deficit of $105,000, and the Lake Superior Copper Company gave up the ghost. From the ashes of this inauspicious beginning rose a new corporation, known most appropriately as the Phoenix Copper Company; but the mine proved just as unprofitable under the new name as under the old. All told, the Lake Superior Copper Company and its successor companies, the first strongly financed and systematically prosecuted venture in the Copper Country, cost the investors nearly two and a half million in paid-in capital and yielded just $20,000 in return.

The Cliff Mine

This disastrous record, which even the august sponsorship of Henshaw and the scientific reputation of Jackson could not conceal, might well have discouraged other investors and postponed for many years the development of more profitable mines, if another company, the Pittsburgh and Boston, had not had a far happier history. In August 1845, this company found a small vein high up on a greenstone cliff some three miles south of the village of Eagle River. The vein widened toward the bottom, and on the advice of Dr. Jackson and of another Bostonian, J. D. Whitney, United States geologist, an adit was driven in the vein. Some 70 feet from the mouth, the miners encountered the first mass of copper to be found in the district by systematic mining — a discovery of the greatest importance, for it restored waning confidence throughout the district, and it also settled the basic question as to whether the vast amount of "float" copper that had been found on the surface was derived from near-by sources which might be found and worked, or had been transported, as some people argued, by iceburgs or some other agency from Isle Royale, fifty miles away. This find marked the beginning of real mining in the district as distinguished from prospecting. The mine, known as the Cliff, was the first in the world to mine native copper as its sole product.

The company, however, was not yet out of the financial woods. By the following year all available cash had been exhausted, and receipts from the sale of copper could not yet support the growing mine. The Boston stockholders, sobered perhaps by the disappointments of the Henshaw enterprise, refused to vote further assessment. Fortunately, the Pittsburgh shareholders felt more optimistic. The president of the company, Dr. Charles Avery of Pittsburgh, whose bank credits at the time amounted to $82,000, offered $80,000 of that sum as a loan to allow the company to open the vein at greater depth. When $60,000 had been spent without return, rich shoots were found which made the mine self-supporting. A year and a half later the loan was returned and the first dividend paid — first not only from this mine, but from the whole district; first of the flood of wealth which was destined to flow into the coffers of the shareholders of this and other successful mines in the district. This one mine, the Cliff, in its productive period from 1845 to 1880, produced 38 million pounds of copper and returned to the investors slightly more than 2,000 percent on the paid-in capital.

Dr. Houghton's Death

These two companies were the conspicuous pioneers; one a dismal failure; the other a spectacular success. Meanwhile, prospecting went on actively all over the mineral belt, and Douglass Houghton, now in the employ of the federal government, was vigorously pushing his surveys in order to complete the gradually unfolding picture of the basic geology that controlled the location of copper deposits. But on a stormy night in October 1845, while trying to complete his season's field work before the onset of winter, Houghton risked a dangerous coasting trip in an open boat and was drowned near Eagle River at the age of 36. A monument composed of typical Upper Peninsula rocks stands beside Highway M-26 on the outskirts of the village of Eagle River, a fitting memorial to Michigan's first State Geologist.

Houghton's career, brief as it was, made him easily the most distinguished man of his generation in the Lake Superior region. In a few short years he had discovered and mapped the major geologic structures of the area. He had made painstaking observations of the relation of the copper in the fissures to the other minerals present, and the relation of the fissures to the broader geologic structure. He had used his data as the basis for a tentative hypothesis of the origin of the ore bodies. Even in this early day he seemed instinctively to use the methods of research which later became commonplace in the scientific world. Though diminutive of figure and not very robust of constitution, his keen eyes, his resolute and decisive manner, his boundless energy, and his unswerving devotion to his scientific studies as a tool for developing the region, made him both a natural leader and a great scientist.

In May of the next year Congress put an end to the clumsy permit system and offered the land in the Keweenaw for outright sale, first at $5.00 an acre and later at $1.25. With this improvement the copper rush gained new momentum. In 1848 the exploration fever reached its height, and the old-timers, the real pioneers and true prospectors, began to feel crowded. That autumn the air was full of the news of gold in the creek bottoms of California; and when spring came, these frontiersmen shook the dust of the Keweenaw from their feet and headed westward. Many a California '49-er first caught the mining fever in the Keweenaw and learned the rudiments of mining in the clear, sharp air of Superior.

Small, Rich Fissures vs. Large, Lower-Grade Lodes

The chief problem facing every prospector in the district was, of course, to find ore bodies. Douglass Houghton's exploration had shown that the mineral belt of the Keweenaw Peninsula consisted of several hundred lava flows and beds of sandstone and conglomerate, laid one upon another like a great deck of cards miles in length, and then turned steeply on edge. The stresses that accompanied this mighty upheaval also caused the rock to break here and there in cross fissures.

In places, these fissures contained broken rock fragments separated by cavities through which a liquid could readily percolate. The conglomerates also were porous in some localities. The lava flows were generally dense except near their upper surfaces, some of which contained myriads of almond-shaped holes caused by the expansion of steam within the lava before it solidified. Because of these cavities, such beds were termed amygdaloids. Thus porosity, one of the requirements for deposition of copper, was provided in favored spots in all three environments — fissures, conglomerates, amygdaloids. After these rocks were formed, copper-bearing solutions filtered upward into the porous parts of the structure and deposited their metal in the favored zones. Not every bed, nor every part of any bed, was rich in copper, but only those areas where nature provided just the right environment. Copper masses, sometimes weighing tons in a single piece, were characteristic of the cross fissures, but in the conglomerates and amygdaloids most of the copper was in small particles.

The early miners worked almost entirely in the cross fissures. As they followed these "veins" across a succession of conglomerates and amygdaloids, they must have noticed scattered particles of copper in the exposed edges of these beds; but they were looking for great masses of the metal, and seem to have paid little or no attention to the possibility of mining the other beds for their less spectacular contents. The factor they overlooked was the vital one of tonnage. The fissures might be profitable for a few hundred feet at the most, but the conglomerates and amygdaloids ran continuously for miles, and might carry copper in far greater total amount than the fissures. The first discovery of copper in an amygdaloid bed was the next great development.

The Pewabic Lode and the Quincy Mine

In the center of the Keweenaw Peninsula and far to the south of the mines thus far described, there is a gap occupied by Portage Lake. Prospecting in the cross fissures of this locality had been fruitless; but in 1856 the great Pewabic lode was discovered, not in a fissure, but in one of the great lava flows just north of Portage Lake. Though not so rich as the best of the cross fissures, the Pewabic was far greater in extent, and thus lent itself to more systematic mining. As the Quincy Mining Company, which controlled much of this find, settled down to steady production, the miners throughout the area began to realize that the greatest bonanzas might be found, not in the small cross fissures, but in the much more extensive lavas and conglomerates.

The Quincy development took place just before the Civil War. When that conflict broke out the company was in a position to furnish the federal arsenals with all the copper needed for military uses. The Quincy and its associated companies began to pay dividends in 1862 and continued to pay at least one dividend a year, almost without a break, until the 1920's — a record which gave it the nickname among mining men of "Old Reliable."

The underground operations of the Quincy have now been closed down, but the remains of the surface plant, including some once-superb equipment, may still be seen along U.S. 41, the highway between Hancock and Calumet.

This changeover from fissure to lode mining soon revolutionized the industry. The fissures, no matter how rich, were too small to provide the basis for a stable, permanent community. Their development was essentially the gamble of the small speculator. But the lodes soon proved to be immense in tonnage, of great depth, and uniform in character over considerable distances.

Hulbert's Discovery of the Calumet Conglomerate

One of the men who witnessed this revolution was Edwin J. Hulbert, a young civil engineer. Reaching the Copper Country in 1853, he first acquired a little practical mining experience and then received, with several others, a contract to survey a military road from Portage Lake to

Copper Harbor, near the tip of the peninsula. He soon became a prominent figure in the Keweenaw, known for his energy and shrewdness.

While conducting his survey for the military road in 1858, Hulbert came across a prehistoric pit which he naturally assumed to have been opened by the Indians on a rich copper-bearing outcrop. Searching for other evidence which might help to establish the strike of the outcrop, he found, a thousand feet distant, a great block of conglomerate, the pebbles of which were cemented together by copper.

Hulbert concluded from its appearance that the huge copper-bearing boulder had not been moved far from its original bed, and that the ancient pit was also on the same bed. He thus had two points which could be assumed to be on the outcrop. Drawing a line through the two points, he determined the hypothetical position of the conglomerate below the soil. Keeping all this strictly to himself, he went on with his road survey, and as soon as possible made quiet attempts to buy the land on which the discovery had been made. This he was unable to do, but he did succeed in buying 1,920 acres a little farther to the northeast, on the continuation of the same line. In 1861, in order to get capital to develop his tract, he deeded a three-quarters interest in the property to J. W. Clarke, Horatio Bigelow, and other Bostonians, and together with them formed the Hulbert Mining Company. Later that year he bought 200 additional acres on the same line, and by a similar arrangement formed the Calumet Mining Company. On the land of this latter company, Hulbert's theory seemed to be vindicated, for in 1864 workings actually disclosed the Calumet conglomerate, which proved to be by far the richest lode in the district.

All this was based on the tenuous assumptions already mentioned, one of which was that the ancient pit discovered by Hulbert was, like all the others then known, an old Indian mine. When the pit was finally explored, some years after these purchases, it was found to contain some twenty tons of copper fragments deeply altered to green copper carbonate, evidence that they had been placed there many centuries earlier. But there was not a single stone hammer or other prehistoric tool, and the surrounding rock was found to be barren of copper. Some believe, therefore, that this particular pit may not have been an ancient mine, but was a kind of primitive safe deposit vault. Others seeking an explanation not dependent on the activities of prehistoric men, have speculated on the possibility that continental glaciers might have concentrated heavy copper in a natural depression. These theories can never be verified by a study of the pit, for the pit and its surroundings were soon destroyed by mining operations. Be that as it may, Hulbert was probably wrong in assuming that the pit was an ancient mine. But by the most improbable chance, it was located only a few feet to one side of the rich conglomerate! Hulbert's carefully drawn assumption turned out to be without foundation, but the results were just the same as if he had been right. Surely the gods of chance were on his side.

Hulbert as Mine Manager

Hulbert now had two promising mines, the Hulbert and the Calumet, but realizing that some of the best land carrying the extension of the conglomerate was still in the hands of others, he went to Boston, already the center of copper finance, and in 1865 met Quincy A. Shaw. From him he borrowed $16,800 to finance further land purchases for the Calumet Mining Company, and in return for his services Hulbert received enough Calumet stock to give him a controlling interest. In order to give Hulbert, as the manager, the greatest incentive to bring the property into profitable operation, the mine was leased to Hulbert and Shaw as operators, under a contract designed to be profitable both to the company and to the lessees. Hulbert, acting as resident manager, promptly began mining. Every foot of opening in the conglomerate seemed to be richer than the one before, and all would have been well if Hulbert had kept his head. But the amazing wealth that Dame Fortune had practically laid in his lap was too much for him. He threw caution to the winds, and forgetting the dictates of ordinary business judgment, he tried to mine the narrow and steeply dipping lode by opening great surface pits which filled with water in the summer and with snow and ice in winter. Instead of building at the first opportunity a treatment plant of his own, he ordered the ore hauled by wagon thirteen miles to a mill owned by others. Living only for the moment, he failed to lay in adequate supplies at the mine, so that the winter of 1866-67 found him dependent on such supplies as could be purchased at inflated prices in the towns of Hancock and Houghton. With good tonnage, the income from the mine might have paid even the fantastically high expense which he was daily incurring; but Hulbert's ability to maintain production was no greater than his skill at holding costs down. At the very time when his energy and shrewdness were most needed, Hulbert became a spendthrift.

Meanwhile, the Huron mine, a property fifteen miles from further south which Hulbert also managed for Shaw, was in serious financial straits from poor ore as well as from dubious management; Hulbert either had to raise money to pay its debts, or else admit its failure. He seems to have had high hopes for the Huron, for when assessments were called which were too large for him to pay, he chose to retain his Huron stock and sacrifice his Calumet holdings. With Hulbert no longer in a position to dictate, the directors in Boston terminated the Hulbert-Shaw lease, ousted Hulbert, and in March 1867 sent Shaw's brother-in-law Alexander Agassiz, to the Lake to try to rescue the rich but desperately mismanaged mine. Shaw and his friends meanwhile had purchased the land to the south of the Calumet and organized the Hecla Mining Company, and this too passed from Hulbert's to Agassiz's management.

Born in 1835 and the son of the famous Louis Agassiz, originator of the theory of continental glaciation, Alexander had been reared to follow in his father's footsteps as a scientist. Zoology did, indeed, become his principal lifework. It seems almost incredible that he could have been a great leader in two fields so dissimilar as scientific investigation and the management of a large mine. Yet he did play this double role, and played it well. Before leaving Boston for the Lake, this young naturalist, 31 years old, said to his friend Charles W. Eliot, then a professor at Boston Tech, "Eliot, I am going to Michigan for some years as superintendent of the Calumet and Hecla mines. It is impossible to be a productive naturalist in this country without money. I am going to get some money if I can, and then I am going to be a naturalist. If I succeed, I can then get my own papers and drawing printed." How well he brought these things to pass can be recounted here only in so far as the mine is concerned. For the rest, suffice it to say that with the fortune built on his management of the mines, he produced a quantity and quality of scientific research beyond the fondest dreams of many a scientist.

Alexander Agassiz as Mine Manager

Then began one of those notable chapters of human fortitude and determination which have so often illumined the annals of mining and given it the color of picturesque adventure. Agassiz arrived at Calumet none too soon. Everything was in confusion. Supplies were exhausted and cash was low. Lines of authority were tangled, and no one was willing to accept responsibility. Worst of all, there was nearly unanimous sympathy for Hulbert and distrust and suspicion of the inexperienced intruder from Boston. Not one man in the Copper Country could Agassiz count as a trusted friend and confidential adviser; and with Shaw a fortnight's journey away in Boston, Agassiz had to meet every daily problem alone.

Agassiz quickly realized that lieutenants must be found and trained. But this would take time, and meanwhile copper must be produced to keep the sheriff at arm's length. Someone had to stop the incredible waste and confusion and create a passion for productivity. These were tasks that could not be delegated. Working day and night, Agassiz tried to inspect frequently every major operation to make sure that nothing lost momentum. "The thing that I drive and look after," he wrote Shaw, "is the only thing that goes." Through many weary months the two brothers-in-law, one in Boston and one in Calumet, strove against heavy odds to rescue the mine from disaster. Shaw, loaded with debts, was struggling to obtain more funds from an increasingly skeptical community. Agassiz, with inadequate capital and forced to work with a staff that neither understood nor trusted him, was trying to bring order out of chaos at the mine, and at the same time to train a few men to carry a share of responsibility. Men less determined would have given up a dozen times. Years later, Agassiz remarked, "If Quin had known when he was beaten we should never have pulled the thing off."

A few months after Agassiz took charge, Shaw visited the Lake and satisfied himself that the mine was a rich one and could be rescued. To provide the needed working capital, more assessments were levied on both the Hecla and the Calumet. Agassiz prepared new plans for the development of both mines, and in less than a year the Hecla became the largest producer in the district.

By the late summer of 1868, Agassiz had trained a small management staff, put the daily work into a sensible routine, and stopped the fiscal wastage. He decided that he could leave the mines in the hands of his mining boss, Captain Hardie, and prepared to sail for home. But Hulbert, according to legend, had one last fling at revenge. Men reputed to be in his employ caused the Calumet dam to be cut, thus depriving the mill of necessary water. Now, however, the spirit of the community was very different from the suspicion which had greeted Agassiz on his arrival at the Lake. The break was promptly repaired before Hulbert could get the injunction with which he had sought to embarrass the company for a longer time. Soon thereafter Agassiz left for Boston, though for many years he continued to give general direction to the Calumet and the Hecla through lengthy visits every spring and autumn. In 1869 the Hecla paid its first dividend, and the Calumet followed in 1870. In 1871 these two companies were consolidated, with two others, to form the Calumet and Hecla Mining Company. Shaw continued to serve on the Board until his death in 1908, and Agassiz as president from 1871 until his death in 1910.

Hulbert, on the other hand, seemed doomed to ill fortune. After his ouster from the Calumet and the Hecla, he continued for a time to operate Shaw's smaller venture, the Huron. But its ores, though plentiful, were too lean, and once again Hulbert drank the bitter cup of failure. After the Huron was closed, Shaw established a trust for Hulbert consisting of 2000 shares of Calumet and Hecla stock in recognition of his discovery of the Calumet conglomerate. The stock was worth more than $200,000 at the time, and later reached much higher values. Hulbert later moved to Italy and dropped out of Copper Country affairs except for an occasional attack upon his former associates in vituperative letters and through the columns of newspapers. He died in Rome in 1910, embittered by his firm belief that he had been defrauded of a fortune by the directors of the Calumet and the Hecla.

The growth of the Calumet and Hecla exceeded all expectations. In 1906 it produced nearly 100 million pounds of copper, and in 1907 the price of the stock reached $1,000 a share. Dividends have amounted to about $250 million, or some 10,000 percent on the original capital invested. After the company's bonanza days it settled down to steady production. Under Endicott R. Lovell as general manager, then as president and now (1957) as chairman of the board, well-designed geological explorations revealed two new lodes; old mines were reopened and modern, economical mining techniques were adopted; and the company also acquired important fabricating plants so that it is no longer dependent on mining alone for its continued existence.

The Copper Range Enterprise

Most of the developments thus far mentioned took place north of Portage Lake. The southern part of the district has a history no less interesting, though its large producing mines were developed a little later and never reached the proportions of the Calumet and Hecla. The Copper Range Company has dominated the southern portion of the district. As early as 1884 W. A. Paine of Paine, Webber and Company conceived the idea of building a railroad along the undeveloped southern part of the mineral belt where ore bodies might be found. In 1899 the Copper Range Company was organized, and Dr. L. L. Hubbard, state geologist of Michigan, was invited to join the new organization as chief geologist. Within five months he found one of the best copper showings in the entire district. Here the Copper Range Company established the Champion mine. Adjoining the Champion property Thomas W. Lawson, a Bostonian of more spectacular hue, controlled a property known as the Tri-mountain mine. It appeared to be workable, but under Lawson's control had never made any money. It did, to be sure, pay one dividend under his direction, though the company was deeply in debt at the time. In 1903, soon after this dividend payment, the Copper Range secured control of the Trimountain and also of another adjoining property, the Baltic, and soon the Copper Range Company's production and profits were second only to those of the great Calumet and Hecla.

Reclamation Operations

In 1898 a young scientist from Cornell, C. Harry Benedict by name, joined the Calumet & Hecla staff as a metallurgist. Probably no one then guessed that under the leadership of this young man a process would soon be developed whereby the company's gross dividends would be increased by many millions from material hitherto discarded as waste. In crushing and treating the copper-bearing rock for the purpose of extracting the copper, it is inevitable that some of the copper should remain in the waste sands thus produced. In the early days, these losses were high. The idea of recovering the wasted copper was an old and favorite dream, but the technical difficulties were great. It was under the guidance of Harry Benedict that a process was finally evolved that made such recovery both a technical and a financial triumph.

Waste sands from the early operations are dredged up from the lake bottom, finely ground, and their copper extracted by modern metallurgical processes. On the conglomerate waste sands, by means of an ammonia leaching process invented by Benedict and developed by Calumet & Hecla engineers, some 504 million pounds of copper have been recovered from material formerly thrown away. The net profit from this reclamation work was in excess of $35 million in 1949 when the conglomerate sands were exhausted.

Since that time, with plants already in existence, it has been possible to treat the much lower grade amygdaloid tailings by a cheaper process, eliminating leaching and recovering the metal by flotation following adequate grinding. Up to the summer of 1957, Calumet & Hecla in its Tamarack plant on Torch Lake has recovered in excess of 40 million pounds of copper from these amygdaloid tailings. Also on Torch Lake the Quincy Mining Company has a very successful operation, the plant constructed as a World War II project. It has recovered in excess of 70 million pounds of copper at a profit of some $5.5 million. The Copper Range Company, working on a smaller scale, has treated tailings from its mills located on Lake Superior.

These reclamation plants during periods of abnormal copper prices as experienced in 1956, when large quantities of copper sold at 46 cents per pound and higher, proved to be very valuable assets and adjuncts to depleted mines.

The Outlook for Future Production

The Copper Country, after a century, is still producing copper, though on a greatly reduced sale. What will happen to this historic mining district when the presently known ore bodies in the amygdaloids and conglomerates are exhausted? Is there any chance of finding more great ore bodies? The answer to these questions brings us face to face with the most important problem in metal mining — that of where to invest venture capital, where to look for ore.

There are, of course, only two places to look: either in virgin territory where no great ore bodies are known, or around the margins and in the unexplored gaps of established mining districts. Geologists are interested in both; capital should be interested in both.

It happens that ore bodies are gregarious in habit; if you find one, others are likely to be near. It follows that the re-examination of old districts is a promising activity. In the Keweenaw, most of the potential ore-bearing ground has been investigated only by widely spaced drill holes; only a very small fraction of the area where an ore body might lurk has been exhaustively explored. Every great mining district is being or will be re-examined as known reserves are consumed, and in some of these districts, perhaps in the Keweenaw, great ore bodies may yet be found. If they are not found by present methods of scientific exploration, they will yield to the higher powered prospecting tools of the future. To be sure, these comments are only speculations; but it would be contrary to all the laws of chance to assert that every ore body in the Copper Country has been discovered. The problem is how to find those that remain at a reasonable cost.

Another factor influences the future of the Copper Country. The district includes vast tonnages of low-grade deposits. These provide a second and very important answer to the question of the district's future. Advances in technology and changing market conditions may at any time convert a sub-marginal deposit into a profitable ore body. This has already happened in the Copper Country in the case of the White Pine.

The White Pine Development

For many years it has been known that the Nonesuch shale contains finely disseminated native copper and copper sulfides near the Porcupine Mountains, at the southwest end of the district. In the period of high prices during World War I, the White Pine mine actually produced copper from this deposit, but ceased operations soon thereafter. Starting in the mid-1930's the Copper Range Company explored the area by diamond drilling and vastly extended the area of known mineralization. From these studies it became certain that here was an enormous deposit of low-grade chalcocite which might be workable at a profit. The key to success, however, would be found in large-scale mining, which would require a large initial investment.

In 1950 the Federal Government became interested in this property and asked the Copper Range Company to submit estimates of White Pine ore reserves and possible production from the deposit. The results were so attractive that the Government granted loans totaling over $64 million to develop the property, to which the Copper Range Company agreed to add working capital of $13 million. The Government also entered into an agreement with respect to the purchase of copper from the mine. In 1956, the first full year of operation at the new mine, 3.9 million tons of ore were mined and over 37,500 tons of refined copper were produced. The White Pine thus takes its place among the country's greatest mining developments of recent years.

Such low-grade mass-production mining ventures are increasingly typical of modern mining. The White Pine was the first major development of this kind in the Copper Country, but it may not be the last. Great low-grade copper resources undoubtedly remain, awaiting the proper time for their use.

Photo 1. White Pine Copper Company, subsidiary of Copper Range Company, White Pine, Michigan. Tailings pond in right background. Lake Superior in distance.

The Hazards of Mine Finance

Mining is well recognized as a hazardous financial venture. There must be a possibility of occasional great gain to justify the risk and to compensate for the frequent losses. The Keweenaw has been a spectacularly successful mining district. Let us look at the record, now that hindsight is available, and see what our chances would have been if we had been looking for a mining investment when the Copper Country was new.

The Keweenaw Peninsula together with its southwestward extension to the White Pine area comprises some 3,000 square miles of hills and valleys, largely drift-covered and forest-clad. To the early prospector all of it must have looked much alike geologically. It is a tribute to Douglass Houghton that in the limited time at his disposal he delineated so well the area of about 400 square miles which might be considered possible copper-bearing ground.

But 400 square miles is still a large tract within which to find evidence of mineralization, particularly when most of the district is covered by glacial drift. The district contains some 400 lava flows, conglomerates, sandstones, and shales, but only sixteen of these have produced copper commercially. There are also many fissures, some barren, some mineralized. Twenty-three of these were worked by the early mining companies, but only seven of them paid anything back to the investors. It is clear, therefore, that discovery of ore was in the early days, as it still remains, the most crucial problem for the investor. The early prospectors naturally found all the easily discovered outcropping ore bodies. Such undiscovered deposits as still remain are likely to be found, not by accident nor by casual surface prospecting, but by painstaking scientific analysis coupled with the use of the most modern prospecting tools and techniques.

The record summarized above seems discouraging at first glance. It is significant, however, that most of the unsuccessful companies were small and died young. They were only a minor factor in the history of the district. In view of the primitive state of geological science in those days, it is surprising that the unprofitable ventures were no more numerous or expensive.

It is interesting to speculate on the probable history of the district if the rich ore body in the Calumet conglomerate had not been discovered. About half of the ten billion pounds of copper thus far mined in the Copper Country has come from the Calumet conglomerate. Financially, however, its contribution has been ever larger. Dividends derived from it amount to about $200 million, which is some 60 percent of all the dividends from the district.

If the Calumet conglomerate had never been discovered, the district would still have been famous for the efficient and profitable development of other deposits such as the Kearsarge, Pewabic, and Baltic lodes, but it was the Calumet conglomerate which lifted the Copper Country into the select group of "billion-dollar mining districts."

With the opening of the White Pine, however, a new giant has emerged. The total production from this ore body, without any allowance for tonnages not yet discovered or announced, is expected to be about 60 percent as great as the production of the entire district up to 1956, or at least 20 percent greater than that of the Calumet conglomerate. Thus it must be regarded as one of the nation's most important copper assets.

It is too early to estimate the net profit from the White Pine; its low grade naturally creates many problems and narrows the profit margin. But if we take the long view and consider its probable life of about a century, there is every reason to believe that this giant ore body will yield a substantial return to the investors.

Social Dividends

The benefits of the Copper Country development did not end, however, with a money profit of some three hundred millions, useful as that has been. Certain intangible assets of great worth have also accrued. Among these were many engineering triumphs, such as the development of safe methods of opening and working mines at great depths. On the surface of the ground, too, these companies achieved some of the finest engineering in the world. Hoists, air compressors, and pumps of leviathan proportions and unprecedented efficiency were and are characteristic of these mines. Some of these machines were among the first great steam engines to utilize the principle of triple expansion. Agassiz retained the Boston engineer, E. D. Leavitt, to design the earlier engines. Later, in the nineties, the Finnish engineer, Bruno V. Nordberg, settled at Milwaukee and blazed new trails in efficient steam machinery of giant size. The Nordberg hoists, pumps, and compressors scattered through the Keweenaw made the Copper Country one vast monument to Nordberg's genius. The last of the large steam hoists to be installed in the Copper Country served the Quincy Shaft No. 2. Its mammoth revolving drum, as high as a three-story building, is designed to hoist from a shaft depth of 13,300 feet. The main shaft of this hoist, driven by four huge steam pistons, is a steel forging weighing 410,000 pounds.

Many another pioneer step in engineering was taken in the Copper Country. It was at the suggestion of Mabbs, a copper mine manager, that Rand developed the portable compressed-air drill for use in mines; and half a dozen important inventions for the concentrating of ores first saw the light of day in the mills along the Copper Country lake shores.

In the fields of labor relations the progressive and humanitarian record of the Lake Superior copper companies deserves much more attention than we can give it here. Early in his career Alexander Agassiz and other Copper Country mine operators set a high standard in such matters as housing, medical care, industrial safety, and employee welfare. The major companies have thus built an attractive community whose happy surroundings have been reflected in over a century of productive effort seldom interrupted by industrial strife.

Mining, especially when carried on in large scale, is a job for engineers. Precision, efficiency, freedom from breakdown, are the order of the day; and these qualities do not thrive where the management follows rules of thumb. To meet the growing demand for mining engineers and metallurgists, the State of Michigan in 1885 established what is now the Michigan Technological University in Houghton. Her graduates run many of the greatest mines, mills, and smelters in all parts of the world. Since 1927 "Michigan Tech" has been a large general engineering college, serving all branches of industry with marked success.

Like every other great enterprise, the copper mines of Lake Superior are a reflection of men — of the prehistoric miners, the Jesuits, the pioneers and sourdoughs, the scientists and engineers of later years. The mines are in no small measure a reflection of such men as Quincy A. Shaw, the man who refused to know when he was beaten. But most of all, they are a reflection of two remarkable men, Douglass Houghton and Alexander Agassiz: one the geologist, the seeker after truth, whose ambition was to lay a sound scientific foundation for systematic mining, and who, in the few fleeting years before his death, paved the way for all the developments that were to come; the other a zoologist at heart; but in Calumet, the planner, the doer, the practical operator, who learned intellectual integrity in the uncompromising school of science, and through sheer strength of will built a great mine where for a time most men would have said the odds were impossible. Both were men of indomitable spirit; both had their eyes fixed on bright and distinct goals. To the world of practical affairs, and no less to the world of science, they have left a rich and enduring heritage.

[1]President, Michigan Technological University. (1963)

ECONOMIC ENVIRONMENT OF THE MICHIGAN COPPER INDUSTRY

By James Boyd[1]

Michigan as a copper state, although the original home of the copper industry in America, began to attain real importance only when the electrical industry started its phenomenal growth in the early 1900's. Today copper production in the deep Michigan mines is operating with certain disadvantages in costs, but current developments in the world's copper production and markets give promise of more profitable operations for the industry in this state and consequently better times for the Upper Peninsula.

It is no coincidence that the development of mines in the Upper Peninsula came with the rapid expansion of the electrical industry. Indeed, it is unlikely that the one industry could have grown without the other.

In time, of course, the electrical industry's requirements, together with those of other copper consuming industries, outgrew the ability of the mines to satisfy them. The high-grade mines of the west began to overshadow the relatively low-grade deposits that remained in the area of the Keweenaw Peninsula. Eventually low-grade, open-pit mines of the west and South America dominated the copper supply. Underground mining, unless the grades were high, faced stiff competition. Because of the increasing depth of the ore, which means higher production costs, the deep mines of Michigan are facing difficult times. These mines are operating today with ores averaging less than one percent. The underground mines, such as Braden in Chile, have ores averaging almost two percent, and they have less expensive mining methods, and the African mines are working with grades in excess of three percent.

As the open-pit mines become deeper, their costs will rise. Future discoveries are more likely to result in underground operations, as the obvious surface indications of large low-grade deposits have been fairly well explored. Large copper deposits seem to be accompanied by massive changes in rock composition which are not readily hidden, so that the likelihood of finding many more large deposits close to the surface is not great. Hence, an era of underground mass production mining is probably just beginning, although it will be some time before we shall see the return to dependence upon underground mining for most of our supplies of copper.

The discovery of the Nonesuch deposits in Michigan, therefore, bodes well for the copper industry of the state. As the discoveries so far are running about one to one-and-a-half percent copper, it must be borne in mind continually that, for the time being at least, they are low-grade as underground copper mines go, and cannot compete on an equal basis with the low-cost surface mines or the high-grade underground mines previously mentioned, which provide most of the copper today.

If the copper industry of the Upper Peninsula of Michigan is to survive, the mines must be operated with the highest order of efficiency, and they cannot be expected to provide bonanza-type dividends for their owners, or easy, highly paid jobs for their workers. It will take the kind of pioneer spirit that typifies the people of the Upper Peninsula to make these deposits pay enough to keep them in operation until the preponderance of production returns to the underground mines.

If, in fact, these higher cost underground mines cannot compete directly, why is it that they continue to operate more or less profitably? The answer lies in the total world market for copper. This has been in the past a fluctuating business with wild swings in consumption, accompanied by even more exaggerated swings in price. The lowest cost mines do not have today, nor are they projected to have, the total capacity to satisfy the needs of the market in periods of high demand. Therefore, if the consuming industries are to be provided with all the copper they need, the increment supplied by the higher cost producers must continue to be available. It is this factor that helps to maintain the price high enough to keep these mines in production, even in periods of poor business.

The history of the Michigan copper deposits is well known, and I shall not dwell on it except to place it in perspective. Michigan coppers have an important part to play in the copper industry of the Free World. Copper is indeed an international commodity. Except for that produced in the United States, most of the Free World's copper is produced in countries that currently consume only a small part of their production. Conversely, a large part of the consumption is in areas that produce little or no copper. Therefore, copper flows in international trade and is subject to the economic variations of such trade. Copper is also produced in large part from areas where it is the dominant factor in the economy. This is true in Chile, in Africa, in Arizona and in the Upper Peninsula of Michigan.

These are all elements that contribute to some of the copper industry's strength and some of its weakness. A stable market for copper is vital to Rhodesia, the Congo, Chile and Michigan. The wide fluctuations in price and demand in the past have had serious economic and even political implications in all of those areas. With the decline of industry derived from forest products, and other local industries, copper — at least so far as White Pine contribution is concerned — is of vital importance to the economy of the Upper Peninsula.

What, then, is the environment in which White Pine and the Keweenaw mines operate? As I have pointed out, it is affected by economic forces throughout the world. We in Michigan have very little control over world economic forces; we must study them and be prepared to live with them. In concert with other producers, however, we can, through research and promotion, do a great deal to improve the climate in which we operate. In the past two years companies representing 95 percent of the Free World's production have formed the Copper Products Development Association, through which they are combining their efforts toward developing stronger and more enduring markets. They are seeking ways to compete with substitute materials, which have encroached on the traditional copper markets in recent years.

In the meantime, however, there have been some marked changes in the industry, most of which tend to strengthen it and in so doing to strengthen the Michigan copper industry. In the past decade the center of gravity of consumption has moved from the United States to Europe. Ten years ago the U. S. consumed 51.6 percent of all copper used in the Free World; Europe consumed 37 percent. Today the U. S. consumes 31 percent and Europe 51 percent — but the total market is one-third larger.

A similar change has come about in the extractive side of the industry. In the first place, total production has increased from 2,535,323 tons in 1950 to 3,932,719 tons in 1960, but whereas the U. S. produced 36 percent of the 1950 figure, she produced only 28 percent of the 1960 figure. The proportion produced in Chile now is about the same as in 1950 — around 15 percent — but Africa has increased its share of the production from 23 percent in 1950 to 27 percent in 1960, and the rest of the Free World from 26 percent to 30 percent. Although Europe and the United States together still consume 82 percent of all copper produced, both the sources of copper and the consumption of the metal have become more massive and more widely distributed.

The wide variations in market and price, which have proved to be so difficult for the higher cost producers and the economics of the areas in which they operate, have resulted from a combination of many factors. The history of these has a bearing on the Michigan copper environment. It is not necessary to go too far back. The inordinately high demands of the war period and the immediately post-war decade were almost impossible for the mines then in production to meet. As the reconversion requirements began to level off, they were replaced by those of the Korean War. Therefore, both open market and subsidized prices remained fairly high until 1956, and the high-cost, deep mines of the Peninsula were able to continue in production. White Pine, together with such western mines as San Manuel, Silver Bell, Yerington, etc., were Korean War babies. They were put into production at the request of and with the aid of the Government, probably some years before they would have been under normal economic growth. Most of them, including White Pine, and excepting San Manuel, got into production in time to help meet the demands of the 1953-56 boom and to take advantage of the unusually high prices that prevailed from 1954 through 1956. During the following two years consumption dropped. The 1958 recession saw the price drop to 25 cents, a price at which the relatively young White Pine mine could not operate profitably without the floor price the Government contract provided. (The Keweenaw mines had similar difficulties.) These contracts have now expired, and the company is on its own to compete with all others.

The prolonged strikes of the 1959-60 period did immeasurable damage to the White Pine operations. This type of operation requires large numbers of skilled workers, many of whom were lost during the strike, and it took months to train new crews. Despite this difficulty and the low ebb of the copper consuming industry in the United States, the mines were kept in production throughout the remainder of 1960 and early 1961 but inventories accumulated. Production is now 30 percent higher than it was during most of this period, but the total output is being sold and the inventories have been liquidated. It was not without trepidation that the mines were kept in production while inventories accumulated. Many of the larger companies curtailed production in order to avoid inordinately large industrial stock accumulation. This restraint was a major factor in preventing a drastic drop in price which could have been disastrous to the Michigan copper industry.

There are a number of factors involved in the economic environment which are helpful to the new Michigan mines. Once considered the standard grade of copper, the Lake Coppers lost their place when they were available in only relatively small quantities. The higher silver content of the Lake Coppers imparts some desirable qualities for a number of important uses. Once Lake Copper became available in steady supply and in larger quantities, these qualities began to be recognized, and it is again in demand from widely scattered areas. Lake Copper is being sold on its own merits from India to Japan, and in both the domestic and European markets. Its specific physical properties have been scientifically determined and made available to designing engineers and purchasing agents.

The Michigan copper mines have again become regarded as a reliable source of supply in appreciable quantities, since operations have been uninterrupted for nineteen months. Although our labor contracts expire in ten months, we see no reason for further interruptions. Continuing supply is a vital factor in marketing and it is also a vital factor in job security. It is most important to both management and labor that long interruptions do not occur again.

The current political unrest in Africa and Chile, the other two important producing areas, encourages European and domestic customers to turn to the United States, including Michigan, for assurance of a steady supply.

All of these factors combine to give strength to a burgeoning resurgence of the copper industry in Michigan. It is perhaps too much to hope that efforts of the entire industry to stabilize its activities will be wholly effective for a few years yet and that there will be no more difficult periods for the copper industry in Michigan. The industry is gaining strength with time, however, and many factors are working in its favor.

[1]President, Copper Range Company. Reprinted from: 6th Annual Conference, Michigan Natural Resources Council, 1961.

800,000,000 TONS OF IRON ORE

By Harry J. Hardenberg[1]

The "barren wastes" it was called — the land which is now Michigan's Upper Peninsula. It was once a part of the Territory of Wisconsin, but was awarded to Michigan by an act of Congress as compensation for giving up The Toledo Strip. Tales of rich mineral resources and vast forest brought a northward movement of civilization into the Upper Peninsula, with the inevitable competition for land ownership. The federal government at that time commissioned several land surveyors to survey the territory.

It was such a survey party, headed by W. A. Burt, which on September 19, 1844, discovered iron ore — the first in the Lake Superior district — in what is now the town of Negaunee. The following summer the first location of iron ore lands was made by P. M. Everett, who, with others from the City of Jackson, organized the Jackson Mining Company. The first iron ore was mined from this "Jackson Pit" in 1846. Two hundred pounds of ore was "packed" to Jackson and there converted into iron in a blacksmith's forge — the first iron derived from Lake Superior ore.

During the next few years a limited amount of ore was mined. Small sample cargoes were shipped to furnaces in Pennsylvania, but most of the ore was smelted in local forges. In either case, costs of sending the product to market proved too great because of the Sault portage. The iron ore industry in those years was kept alive more with a view to the future than for immediate returns.

With the opening of the first ship canal around the rapids of the Sainte Marie River at Sault Sainte Marie, it became possible to ship iron ore to southern Great Lakes ports without the costly portage. From the day the first ore cargo of 135 tons shipped through the locks aboard the brigantine Columbia in August, 1855, the iron industry of the Upper Peninsula progressed with rapid strides. By 1873, annual production from the Marquette Range reached one million tons.

For more than 30 years after the discovery of this valuable ore at Negaunee, the Marquette Range was the only producing area in the Lake Superior district. In 1877, its first competitor came into existence — the Menominee Range of southern Dickinson County. Iron ore had been reported near Lake Antoine as early as 1849. Some exploratory work was done in that area in the 1860's but nothing of importance was found. By 1874, prospecting had shown enough ore to warrant mining, but transportation facilities were lacking.

It was not until a branch of the Chicago and Northwestern Railway was extended from Powers to Quinnesec in 1876-77 that the ore of this area could be mined to advantage. In 1877 the first ore was shipped from the Menominee Range — 10,405 tons from the Breen and Vulcan mines. Two years later eight mines shipped a quarter-million tons.

In the western part of the Menominee Range in 1851, iron ore was noted by Harvey Mellen, a government surveyor, in the vicinity of the present-day cities of Iron River and Stambaugh. As in the East Menominee district, development was delayed by lack of transportation. A further deterrent was the lower grade of ore as compared with the other known districts. Originally only the hard specular hematite and magnetite ores, such as were mined on the Marquette Range, were considered by the furnace men to have any real value. By 1874, however, the more courageous furnace operators were beginning to use the "soft" ores and these soon came into favor.

Ore production in the Iron River-Crystal Falls area began immediately upon the completion of the railroad to that area in 1882. Thus, in that year, the entire Menominee Range shipped more than one million tons.

Outcroppings of iron ore between Wakefield and Bessemer were mentioned in the United States linear surveys made about 1850. Here again lack of transportation facilities and the general early disdain for "soft" ores delayed development of the Gogebic deposits. However, earnest exploration began in the 1870's and by 1883 was in progress along the entire range. A railroad was completed into the range in 1884 and the first shipment of ore — 1,022 tons — was made by flatcar in that year. The first worked deposit, the Nipigon Pit on the Colby property, at Bessemer, was also probably the smallest deposit on the range, yielding a total of only 3,800 tons. But other discoveries were made in rapid succession. By 1885 seven additional mines were making shipments for an annual total in excess of one million tons from the Michigan portion of the range.

The spread of iron mining from Negaunee south to Iron Mountain and west to Ironwood was accompanied by a gradual evolution in mining methods and mining equipment, a change which has continued even to the present.

The early mines were nothing more than shallow pits. Manual labor and animals were chief sources of power. Little mechanical assistance was available for hoisting or pumping. Until about 1875 almost all iron mines were open to daylight, and mining operations were carried on primarily with pick and shovel. Hand drills and hammers were used to put down holes for blasting and black powder was used for breaking large chunks. The ore was then loaded into carts or wagons and hauled by horse, mule, or oxcart to the railroad.

About 1880, underground mining began. Shafts were sunk and mining done with the aid of rock drills powered by compressed air. Dynamite came into use for blasting. Moving the ore from the working places to the shaft was by hand or by mule-drawn cars. The electric motor was introduced for this ore "tramming" about 1895, but even as late as 1910 some of the mines still used mules.

Steam provided the power in those years for hoisting ore in these mines and also for pumping water. By the early 1900's, electricity was beginning to supplant steam for these purposes. When the mines were relatively shallow the miners gained entrance by climbing down ladders, sometimes as much as 500 feet. This practice was changed about 1885 by the use of cages to lower and hoist men in the shafts.

Electric lights for the surface plant appeared in the early 1880's and soon after were used in the shaft and main drifts. The miners' lights in the dark working places were first candles, then oil lamps, carbide lamps about 1908 and as late as 1925, and eventually electric head lamps.

Until the early 1900's, ventilation in the mines was natural; that is, it was induced by the difference in temperatures in the mine from that outside, a difference which produced a constant wind through the shafts. With increased depth it was necessary to install forced ventilation, air which had to be heated in cold weather and which was blown into the mines by large fans.

Thus the mining of iron ore in Michigan began in a primitive manner, but the simple methods of the early days have given way to the most improved and advanced systems of mining. Since the first "shipment" of 200 pounds in 1846, the iron ore industry of the state has shipped almost 800 million tons. And there's a lot more where it came from.

[1]Geologist, Michigan Dept. Conservation. Reprinted from Michigan Conservation Magazine, Jan., 1958.

BENEFICIATED LOW GRADE IRON ORE

By William L. Daoust[1]

The iron ore industry of Michigan has made a significant contribution to the national economy during the past hundred and fifteen years since the discovery of iron ore near Negaunee. The importance of this effort during recent major wars was outstanding. In recent peacetime years the industry in Michigan has averaged more than twelve million tons per year with a product value of near $100 million. In terms of value iron ore has been the leading mineral product of the state for the last 40 years.

Through the years the industry has passed from the early, rather primitive stage of hand mining of small tonnages of ore to the present modern machinery and mining methods which produce large amounts of material with considerably less labor per ton.

The high grade direct-shipping ores which got the industry off to a strong competitive start have become less plentiful during the last few decades, both in Michigan and the entire Lake Superior iron region. This necessitated a search for other reserves of ore if the industry were to continue in a healthy economic condition. Attention was directed to the vast deposits of low grade iron-bearing rock which might be processed to yield an iron ore concentrate containing possibly 65 percent iron compared to the 51 percent iron from the average "high-grade" underground operation.

After many years of costly research, beneficiation processes utilizing the low grade ores were developed which promised to supply the market with an excellent iron ore product at a cost which would permit economic operation. The first commercial beneficiation plant in Michigan, the Ohio, began production in 1952. In 1954, the first plant utilizing our jasper ores went into operation. These are the hard, red, lean ores which were held in reserve.

Briefly stated, the processing of jasper ore, which had heretofore not been commercially possible, involves the crushing and pulverizing of the rock to powder fineness to separate the particles of iron ore and waste rock. Then the iron ore particles are extracted by flotation methods and finally the iron powder is roasted into solid balls (pellets) about the size of a marble suitable for shipment to the blast furnace. Each step in developing the procedure held tough obstacles and meant costly new routines.

For example, at open pit mines, holes for the explosives are prepared by a "jet piercing" drill, using kerosene mixed with oxygen to create a 4500° Fahrenheit "blow torch." A stream of water breaks the hot rock and the steam blows the rock chips from the hole. The drill bores 15 feet per hour and consumes 1,000 gallons water, 37 gallons kerosene and 10,000 cubic feet oxygen for each 15-foot hole. One blasting operation requires about 30 holes, 40 feet deep, for an area 209 feet long and 65 feet wide, with 7½ tons of explosives necessary. Such work is obviously costly.

Grinding the hard jasper ore to a fine powder to separate the hematite which will be coated with chemicals in the flotation process is another of the high cost factors. The "froth-flotation" process employed in the concentration of the lower grade ores is one by which the finely ground rock is treated with chemicals and oils having an attraction for the iron minerals and little or no effect on the much greater amount of waste material. The chemicals form a water repellant film over the iron oxide mineral. In a mixture of properly conditioned ore and water, air bubbles are generated. The water repellant iron minerals attach themselves to the bubbles and rise to the surface. They are then skimmed off as iron ore concentrate. The waste material remains submerged and is carried away in a fluid form to disposal areas especially prepared for the waste. Not to be overlooked is the important task of providing an adequate supply of suitable water to keep the concentrating process functioning. It has been estimated that 50 tons of water are required to process each ton of concentrated ore. The process ends up with an ore that is materially improved but which must be baked into solid balls suitable for shipment and use in blast furnaces.

Michigan now has two open pit, low-grade ore mines with beneficiation plants utilizing jasper ore. The first to start operations was the Humboldt Mine in 1954, followed by the Republic in 1956. Both are west and south of Ishpeming in the Marquette Range. The current capacity of the two mines and plants is about one million tons of processed ore annually. A new mine and plant is under construction near Randville in central Dickinson County. The pelletizing plant for the Republic operation is at Eagle Mills, Michigan, east of Negaunee.

With the ever increasing demand for higher grade ores, which materially reduce processing costs at the furnaces and steel mills, the ores from underground mines are becoming less in demand, while the richer ores from the newer processes are gaining the more favored market. It has been estimated that Michigan has some two billion tons of low grade iron ore reserves. Some of these reserves are of the type now being utilized; others cannot now be economically processed by known methods. Continuing development of the more readily treatable ores and perfection of new techniques to allow use of remaining reserves provide the best chance of retaining the market for Michigan's iron ore industry.

Competition from foreign ores, many of which are of higher grade than Michigan ores, offers a constant threat to the continued economy of the industry. The nation's steel industry consumed more than 33 million tons of foreign ores in 1957 contrasted to less than a fifth of that amount imported just a few years earlier. Our mining industry to survive must keep all mining costs at a minimum and be prepared to supply the steel industry with high quality products as needed.

Continuing exploration and research by the iron mining companies and in cooperation with the universities and colleges have done much to keep the industry in a strong competitive position. The recently established Ores Research Laboratory at Michigan College of Mining and Technology should serve as an ideal source of assistance in problems confronting the industry.

[1]Former State Geologist of Michigan. Reprinted from Michigan Conservation Magazine, Sept., 1958.

ECONOMIC ROLE OF MICHIGAN IRON ORES

By Stanley W. Sundeen[1]

The Michigan iron ranges are the oldest of the major Lake Superior district iron ore producing ranges. Production from the Marquette Range started in the early 1850's prior to the development of the Sault Ste. Marie canal and locks. It was followed by the Menominee Range in the 1870's and the Gogebic Range in the 1880's.

The earliest of the iron mining operations appear to us today to be almost ludicrous but you can be assured the problems besetting the industry then were, both in detail and in broad scope, very real. In the report of the Geological Survey of Michigan for 1873 Major Brooks wrote: "If ever there comes a period when our mines do not pay, it may be due largely to horses." Major Brooks referred, of course, to the uneconomic continued use of horsepower in mines that had outgrown the one-horse operation size. Why did such a situation arise? Because capital was lacking for transition to steam power. As you know, the capital was ultimately supplied by very earnest, hard-working, intelligent men engaged in a complex struggle to solve problems such as "too many horses" to bring about the development of the very appreciable iron mining industry in Michigan. I shall later recall for you this illustration of one early iron mining problem, for we are plagued now by some very formidable modern problems.

To appreciate and understand these problems we need a little historic and world-wide perspective. Michigan iron mining developed into big business starting in the 1880's. As the steel industry burgeoned with the country's rapid industrialization, so Michigan mining prospered and grew. Most of Michigan's iron ore mines were underground and could only compete with the much more cheaply won Mesabi open pit ores, because furnace men considered it more desirable and because of the transportation advantage. Carnegie and Schwab, great steel men of their day, opposed the use of the newly discovered Mesabi ores because of the undesirable fineness of the Mesabi ores. Use it they did, however, because its abundance and low cost constituted a tremendous economic incentive for its utilization. It took furnace men 15 years to learn how to use these different ores. There is, in this history, a lesson to remember and it is this: Furnace men have firm convictions about what constitutes a good furnace ore and these convictions can be and are molded by the cost of the ore.

Starting after World War I and becoming full blown after World War II, there was steel company alarm that the vast Lake Superior district ore deposits would become exhausted in the foreseeable future. There was, in addition, change in market area demand such as expansion of steelmaking at the coast plants. Rising costs were also a stimulus to the search for better ore to raise furnace efficiency. In the year 1948, 100,700,000 tons* of iron ore were consumed in the United States. The production to supply this tonnage came from the geographic iron areas in the amounts set forth as follows:

Lake Superior District	83,723,000
Southeastern District	8,362,000
Northeastern District	4,422,000
Western States	5,104,000
Total	101,611,000**
Imports	6,109,000

Unquestionably there was need for concern in light of this big annual exhaustion of U.S. ore reserves. To assure a continuing supply of iron ore for the furnaces as a replacement for the rapidly depleting Lake Superior district ores, steel companies and iron mining companies instituted a world-wide investigation of iron ore deposits. These were examined in a new framework of reference — the air transport age, the age of new geophysical tools of prospecting, the age of bigness in machines and ships, the age of growing automation and mechanization. The search and examination that was made was too successful from the standpoint of the Michigan iron mining industry. We knew iron was the fourth most abundant element on the earth but we now really had it hammered home that iron ore is abundant to the point of profligacy. From a famine of ore the world suddenly went to a feast. The ample supply is shown by the following table of estimated world reserves taken from the Engineering and Mining Journal of February, 1960:

World Reserves (Million Metric Tons)

% Iron	*World Total*	*Free World Total*	*U.S. Total*
50+	34,000	31,444	986
25 to 50	88,000	70,302	20,416

At a consumption rate of 100 million tons or more per year, there is obviously enough ore available.

In addition to the finding, exploring and developing of high grade iron ore bodies in Canada, South America, and Africa, there was carried out at the same time a very formidable research program on the domestic and foreign low grade ores. Again, success in terms of techniques and available tons of high grade product was phenomenal. You are familiar with the roster of low grade developments or projected developments — Reserve, Erie and Pilotac in Minnesota; Humboldt, Republic, Empire, Groveland in Michigan; Grace Mine in Pennsylvania; Pea Ridge in Missouri; and Atlantic City in Wyoming. Across the border there are Hilton, Marmora, Moose Mountain, Wabush, Quebec Cartier, Carol Lake and many others that are being studied. Collectively, these are good for hundreds of millions of tons in their life spans. To say that the shortage of iron ore is now an over-supply is an understatement.

In the year 1948 which was prior to any big-scale fruition of development of foreign ore deposits and prior to the beneficiation plants for low grade ores, imports amounted to 6,109,000 tons. In 1960 we imported 34,600,000 tons out of a total consumption of 102,200,000 tons. This trend is going to continue upward for imports. Mr. H. S. Harrison, President of The Cleveland Cliffs Iron Company, predicts 85 million tons of iron ore imports out of 190 million tons total consumption by 1980. In a talk to the New York Society of Security Analysts, April 12, 1960, Mr. Harrison clearly outlined the dilemma of the domestic iron ore industry as dependent on three major problems, viz.:

1. Foreign competition
2. The change in character of the iron and steel business
3. Over-supply of iron ore

Paraphrasing his comments: "The key is the growth of high grade ore usage either from foreign direct shipping or beneficiation sources." This points up problem No. 2 — the changing character of the steel and iron business where high capital replacement or expansion costs (from 7½ million to 25 or 40 million for a blast furnace) and increased labor costs (from 65¢ an hour in 1927 to $3.45 an hour in 1961) has provided the powerful stimulus that sent the steelmen out into the market places for a better ore raw material. A 62% iron ore will put production up 20% over a 52% iron ore with substantial cost saving.

To illustrate more precisely what is meant, I quote Mr. Carl Jacobs of Inland Steel in a paper he gave before the American Mining Congress in Seattle this past month. "What do these improved products mean to the blast furnaces? — Inland's eight blast furnaces in 1947 were rated at 7,350 tons of pig iron per day. Today, with only minor mechanical improvements and enlargements, the same furnaces can produce 10,500 tons per day. The increase is more than 1.1 million tons of pig iron production each year, mostly from improved iron ore. This is more than the capacity of the largest U.S. blast furnace costing $60 million to build. To avoid this capital expenditure, Inland, like all other steel companies, will continue to push for ever better raw materials, including iron ore."

Mr. Harrison sounds some note of optimism concerning the over-supply of iron ore given time for steel capacity to expand and assuming some stabilization of iron ore property development. This, however, will take a fairly long time.

Now, we should put Michigan in this picture. I could almost do so parenthetically because I'm sure you have gathered by this time that the underground iron mining picture is painted in grays while the future of open pit products in the form of beneficiated ores is brighter. In 1948, the first year I quoted for production, Michigan ranges produced almost entirely from underground mines 13% of 100 million tons consumed, or 13,100,00 tons. In 1960 they produced 11,800,000 tons or 13.5% of 87,300,000 tons consumed. You may wonder what I am trying to establish in a comparison that shows Michigan's percentage share increasing. But to understand my point you must appreciate that underground mines, by their very nature, do not lend themselves to on and off production schedules. For this reason operators are reluctant to take the decision to close an underground property because it is so difficult and expensive to reopen an underground property. In 1960 Michigan's underground mines did work but in 1961, it is sadly true, many have closed and probably for keeps in some cases. The basic reasons are that their ore is not as desirable as foreign higher grade ores or as high grade pellets and only the most efficient mines enjoy costs low enough to compete.

Iron ore has become a world commodity and its price results from a balance between costs of delivered product and the urge of competition. Michigan underground iron ore is not particularly high grade. The old standard for these ores was 51.50% Fe natural. Foreign ores are 60% Fe natural ranging to 68% Fe natural as in Liberia and Brazil. This means less slag volume, less coke consumption, and more iron with the same labor and equipment for the furnace using the higher grade ones. The mining industry in Michigan has introduced such measures as more selective mining, drying, screening and heavy media beneficiation for the underground ores that has resulted in the improvement of natural iron content of the ore to approximately 55% iron. This sounds small but is no mean accomplishment. It is exasperatingly true that the so-called high grade soft iron ores practically defy further beneficiation except through smelting or semi-reduction schemes. What can be achieved is at the cost of irrevocably lost reserves in the ground or process costs that are out of proportion to the degree of improvement achieved.

Michigan underground iron ores are expensive to produce. An underground mine utilizes up to five men for each one man engaged in an open pit operation producing equivalent tonnage. Almost without exception Nature blessed the foreign iron fields with exceptionally high grade ore and placed it at the surface. To further aggravate the disparity between Michigan underground ores and foreign open pit, there are very great differences in labor costs. These vary from country to country. For Venezuela, for example, the labor cost is not so disparate as for Chile, Liberia, or Brazil, but it constitutes on the whole a large factor of cost differences in favor of the foreign ore.

Most foreign countries have less onerous local taxes on raw material extraction than Michigan. In addition, they may extend special considerations such as Canada's three-year income tax exemption. Many countries allow more liberal depreciation rates than the U.S.

A few years ago, all of the above mentioned factors were not enough to make foreign ore a serious competitor of Michigan ores in the Lake Erie, Ohio Valley and Chicago districts because foreign ore transportation costs were too high. There has been, however, a revolution in transportation and now all of the foreign ore cost advantages are cumulatively effective with a vengeance. Mr. Wilbur, Senior Vice President of The Cleveland-Cliffs Iron Company, in his presentation entitled "Lower Lake Railroads and the Iron Ore Industry," given before the University of Minnesota Symposium on Mining in January of this year, points out that the combination of greatly reduced ocean freight rates and lower eastern railroad rates for ore moving inland is a big factor in the reduction of Lake Superior ore usage in the Youngstown-Pittsburgh area. Huge ocean carriers, 40,000 tons and up, running under low wage foreign registries makes rates possible of $4.25 from Brazil and $2.95 from Liberia for distances of 3300 to 4500 miles, compared with $1.80 from Marquette to Lower Lake ports, a distance of 500 to 800 miles.

I should like to summarize, then, what all of this has done to Michigan iron mining and give my prognosis of the future. Coming to a swift culmination in this year of 1961, the competitive impact of finding their ores unsalable at a profit has resulted in the closing of several underground mines — The Morris, Champion, Sunday Lake, Cary, Peterson, Geneva-Newport, Mather A and Buck. Some may (or will be) reopened, but it is apparent that some of these are closed for good and such final decision may be eventually extended to others. The obvious inference to take is that the more marginal mines are the first to succumb to the competition and with some exceptions this is likely the case. These are the mines that are probably down for good.

While the underground mining industry in Michigan is maimed, it is not yet dead. It is putting up a real fight for immediate survival and there are some helping hands. The companies are improving the grade of their product as best they can and offering several kinds of structures and combinations as inducement to steel users for individual customer needs and desires. The industry has made progress with the cooperation of fee owners in getting royalty costs reduced. The industry is working hard on mechanization and methods of improving labor efficiency. A constant effort is being directed toward creating an understanding in the mind of the public that taxes need to be equitably shared. The upper lake rail carriers have foregone rate increases and indeed lowered rates. You may well say: "If all of this has gone on and mines are closing, the case is hopeless and the patient is not only maimed but completely crushed." It is possible for this to happen, but I remind you of Major Brooks' prophecy that if the mines close it will be because of too many horses. The problem in 1873 and today are in essence the same — too high costs. Hard working, earnest, intelligent men built changes into the industry then that kept it tough and vital until now. Today's problems are more complex and tougher but the seeds of a change are already growing. Low grade development, for example, is rapidly under way and much of the tonnage lost from closing of underground mines will be replaced by pellet tonnage. There are, at this time, three Michigan properties — Groveland, Humboldt and Republic — operating on low grade ores using fine grinding beneficiation schemes. A fourth, Empire, is being engineered. The agglomerated product from this type of plant is greatly desired by iron makers and costs for these developments are, as of now, competitive — thanks to the fact the mines are open pit and thanks to an enlightened policy of state taxing for low grade mining.

Management, transportation agencies, fee owners, labor and you, the public, can collectively do much more than has been done to cut delivered cost of traditional Michigan underground iron ores. The better underground mines should, with such cooperation and understanding of needs, be able to survive. All segments of the industry economy have to want it, and want it enough, to submerge individual wishes.

Looking beyond Humboldt, Groveland, Republic and Empire to the more distant future, I hesitate to be a prophet but I can point to possibilities. There are some billions of tons of iron formation available to open pit mining on the Michigan iron ranges. In a technical sense, we know of a way to win usable iron from this material by chemical and pyrometallurgical-mechanical beneficiation schemes. In an economic sense we have not yet been able to do this cheaply enough to have a substitute for our present mining and beneficiation. Here is a fertile, albeit expensive, field for public financed fundamental research into better use of Michigan iron resources.

Photo 2. Mather "B" shaft, Cleveland-Cliffs Iron Co., Negaunee, Michigan. Aerial view looking west. Teal Lake is just off right margin.

[1]Manager, Research and Ore Development, The Cleveland-Cliffs Iron Company. Reprinted from: 6th Annual Conference, Michigan Natural Resources Council, 1961.

*American Iron and Steel Institute Reports.

**U. S. Bureau of Mines Minerals Yearbook.

MICHIGAN'S MYTHICAL GOLD MINES

By Franklin G. Pardee[1]

The one genuine gold mining myth in Michigan goes back to the days of the first State Geologist. As we have the story, Douglass Houghton left camp one day in the company of an Indian. Upon returning Houghton carried with him some specimens of rich gold ore. A short time after this Douglass Houghton was drowned and he either did not make any notes of the location of this gold ore, or they were destroyed with him. In any event, no one ever knew where he found this rich ore.

Without doubt this legend contains grains of truth because over $600,000 in gold has been taken from the Ropes Mine in Marquette County, and a spectacular specimen of gold ore from the Michigan Mine in the same locality was exhibited at the 1893 World's Fair in Chicago. There have been many explorations for gold in the hard rocks of the Northern Peninsula, but this article is concerned with the gold mining "myths" of the Southern Peninsula.

In 1914, R. C. Allen, then State Geologist, wrote a paper on "Gold in Michigan." After reviewing the gold mines and prospects in the hard rock areas, he listed the reported occurrence of gold in about thirty places in the southern part of the state. All these so-called discoveries were from the sand and gravel beds above the solid rock and represented the location of one or two samples of material containing some small amounts of gold — for example, a small nugget, or perhaps a few colors in a pan of gravel. Since that time there have been many other reports of gold found in the glacial drift, but, like the former ones mentioned by Allen, none were commercially important.

The glacial drift of Michigan doubtless carries a tremendous amount of gold worn off the hard rock hills of northern Michigan and Ontario, but, by the very nature of these glacial deposits, this gold has been scattered and distributed all over the state. It is possible to imagine that somewhere there may be a concentration of gold of commercial importance in the Southern Peninsula, probably along some glacial river bed, but to date no occurrence of this sort has been reported. The chances for a concentration of this character are remote, and it would be like looking for a needle in a haystack.

The underlying rock strata of the Southern Peninsula are essentially undisturbed sediments. Gold mines in rock formations of this type are usually found where the sediments have been broken or altered by a once molten rock material which forced its way into other rocks. With no signs of igneous activity of this kind in this part of the state, however, the reporting of gold occurrences in Southern Michigan in large quantities is always looked upon with a great deal of skepticism.

About 1924 the State Geological Survey received reports on an "important gold" occurrence in Alpena County. At first it was thought that someone had hit a pyrite concentration in shale. Pyrite is a mineral that is a brassy yellow, mistaken for gold so often it is called "fool's gold." When it was determined that gold was reported from the limestone in that area, a careful check was ordered. This investigation was started and finished (so we thought) by a thorough examination of the district. Accurate sampling was followed by reliable chemical assays. Unfortunately, the negative results obtained by this work failed to quiet the gold excitement. Not only was the gold absent in the original rock, but the only real gold found was dental gold forced into the rocks. It took time to bring this condition to light. In the meantime, we had to deal with a "wonderful method" for the extraction of gold. The chemist for the Alpena group reported a "new process for recovering the extremely finely divided gold" that had been missed in the assays by the best laboratories in the country. This idea of a finely divided gold explained why the gold could not be seen in the rock, and offered a plausible story to the uninformed investors. Before the smoke blew away, a lot of drilling was done, an experimental mill set up, and a shaft sunk — expending over $200,000 to get down about 230 feet. This shaft found nothing but a large amount of water and the money spent to sink it had been completely wasted. Furthermore, this expenditure was only about one half of the total sum wasted looking for gold in that area.

After a year, excitement at Alpena died down. The reports of all the investigations, the lack of funds, and the departure of certain individuals from Michigan all contributed to this end. The "Alpena Rand", appeared to be dead. The economic depression, along with the increase in the price of gold, however, had a marked effect on the renewed search for this metal. Once the price of gold went up, it became obvious the "Alpena Rand" would revive, but no one anticipated the rash of "gold fields" that were to break out all over the Southern Peninsula. Gold was reported in "astonishing quantities" from the so-called Vernon, the Ortonville, the Perry, the Montrose, and the Grand Rapids "gold fields", to mention just a few. In no place, however, had accurate sampling shown any gold.

The renewal of activity at Alpena was spurred, as near as can be determined, by the report of an engineer claiming to have been in all the large gold fields of the world. His presumably learned report, when analyzed carefully, consisted of a log of geological terms put together in such a way that they meant absolutely nothing. He was followed by, and probably worked with, another engineer who prepared an impressive looking report on this district. This second engineer had an address on lower Broadway near the financial district of New York City, and a list of previous jobs and titles that made him appear to be one of the pillars of the mining profession. He did not even visit the district but based his whole report on one or two samples. His report also contained a lot of geological "double talk" — for a stipend of $2,500.

He also worked with a chemist who not only discovered another new process for the recovery of this very fine gold, but also described this particular type of gold ore by the suggestive name of "micronic" gold. We were able to get this chemist into an assay laboratory where we were sure of the purity of the chemicals and where he could direct the procedure for the analyses of the samples according to his method, without touching any of the materials or chemicals. He obtained no gold either natural or "micronic" by his new process, nor did we get any by the standard method which was run on these samples at that time. This chemist left Michigan rather abruptly without leaving a forwarding address. Needless to say, no gold mine has ever been developed in the Alpena area. The money spent in this venture has all been lost.

The chemist referred to above was also mixed up in the development of some of the other so-called "gold areas" of the Southern Peninsula. In fact, all these mythical gold developments are inter-related and a complete discussion would be rather lengthy. They all follow a similar pattern in that somewhere in the story a chemist or assay office obtains results that cannot be checked by reliable laboratories. To say that these assays showing large amounts of gold were due to improper sampling or improper work in the assay office would be charitable. The difference between the results obtained in these assays and those by reliable laboratories, however, compels one conclusion: reported figures were much higher than actual results. The reason is obvious. Charges for making a gold assay are fairly high. If a person receives an answer that the sample contains no gold, he pays his bill and forgets the whole thing. If, however, gold is reported in the sample, he starts looking for other samples and runs up a sizable bill. The laboratory may or may not go through the motions of making analyses before the misleading results are sent out. Multiply this procedure by even a small number and you can see how an unscrupulous laboratory can make money even in an area where gold mining is not an important industry.

It has been said that the discovery of gold or oil will disturb the equilibrium of the most conservative Scottish banker. The people of Michigan who put their money into these "gold" enterprises with the hope of getting rich cannot be blamed when many businessmen also invest their funds with little investigation. We hope, however, that anyone finding "gold" on his farm, or receiving assays showing large amounts of gold in samples will stop and look over the situation very carefully, and listen to the advice of persons who have spent some time in the study of deposits of this character.

[1]Former State Geologist of Michigan. Reprinted from Michigan Conservation Magazine, Nov., 1945.

CEMENT AND GYPSUM GIANTS[1]

Because of its vast supplies of materials that go into the manufacture of cement and gypsum products, Michigan has attracted major producers of these wares. Materials in most cases are located near the shores of the Great Lakes which give the added advantage of low cost shipping to the major industrial areas of the nation. Unlimited water supply is a further asset.

Grand Rapids Gypsum Company is one of the oldest manufacturers of gypsum products in the United States; the company being incorporated in 1860. The company mines and processes gypsum at its plant at Butterworth Road in Grand Rapids, Michigan, and sells in a marketing area of ten states surrounding the Great Lakes.

The principal products produced are various types of wall plasters, gauging plasters, industrial plaster for the plate glass industry and plaster stucco for the core of gypsum wallboard and gypsum lath. Construction in general, in the marketing area, has been down this year but the company is looking forward to a substantial increase in construction volume for 1962.

For National Gypsum Company with headquarters in Buffalo, New York, Michigan is a very important state. National began operations here in 1927, just two years after its inception, when it opened a quarry and gypsum plant at what was then called Emery Junction — now National City. National now has more employees in the State of Michigan than in any other state of the Union.

These people are in the paper plant at Kalamazoo and at the huge Huron Portland Cement subsidiary at Alpena, the world's largest cement plant. At Tawas, National's original home base in this state, local people are engaged in producing rock at the huge Tawas quarry, at the loading dock which ships this rock to lakefront plants, and at the National City gypsum plant which is still an important part of its overall gypsum operations after 34 years.

Last July National Gypsum Company announced plans to invest $72 million in the next 14 years to double the capacity of its huge Huron Portland Cement mill at Alpena.

The vital key to the present $25 million-plus Great Lakes production network of the National Gypsum Company of Buffalo, New York is the mother deposit of gypsum near Tawas City, Michigan.

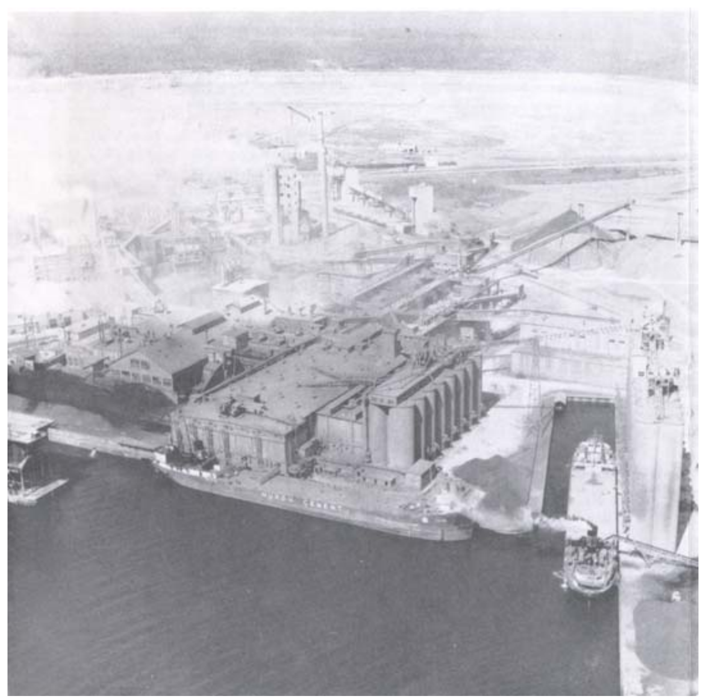

Photo 3. Huron Portland Cement Company, subsidiary of National Gypsum Co., Alpena, Michigan. Aerial view looking west.

Discovery of this immense deposit — accessible to Lake Huron — opened up the possibility that National at last could fill two gaps in its distribution pattern and build plants for the Milwaukee-Chicago and Greater Cleveland markets. The mineral could be transported at low cost by lake ship to manufacturing plants that might be erected near each of the big and growing markets.

The gypsum find also guaranteed that the company's plant at nearby National City, Michigan would have ample gypsum ore for uninterrupted operations. The National City plant supplies gypsum products throughout the State of Michigan.

At about this same time, the St. Lawrence Seaway was becoming a reality. Chairman Melvin H. Baker was convinced that the Seaway would usher in a period of accelerated economic growth for the area bordering the Great Lakes.

He directed that plans be drawn for a four-part Great Lakes network with a mining operation at the new deposit, dock and loading facilities on six-mile-distant Tawas Bay and plants for Milwaukee-Chicago and Cleveland and Ohio markets.

In the spring of 1956, National raised $19 million for the project through the sale of common stock.

Development work got underway promptly at the quarry site. Thousands of tons of earth were moved to uncover the gypsum. Giant crushers were installed. Railroad tracks were laid from the quarry to Tawas Bay where a 1100-foot dock was built and a deep channel dredged.

Waukegan, Illinois, halfway between Chicago and Milwaukee, was chosen as the location from which to supply the growing northern Illinois and Wisconsin markets and Lorain, 60 miles from Cleveland, was picked as the site for a plant to supply the Greater Cleveland and Ohio markets.

The Great Lakes Gypsum network complements the chain of cement plants of National's Huron Cement Division which ring the lakes. They are supplied by ship from the company's huge mill at Alpena, Michigan, the world's largest.

The reason for the specific plant location of the Dundee Cement Company just north of Dundee in Monroe County, was because a huge deposit of Dundee limestone was discovered near the surface in this area. Although Dundee limestone exists under most of the state, there are few outcrops and this one was ideally situated in many respects.

Underneath the 1600 acres obtained for the plant site, is a 40-foot stratum of Dundee limestone which contains over 95 percent calcium carbonate and less than three percent magnesium carbonate. Below the 40-foot level, the magnesium content increases to a point which makes its use for the manufacture of cement impractical. This remaining 125 feet of limestone may be usable for aggregate.

Above the limestone is 40 feet of overburden and clay. Approximately 20 feet of the clay is used in the process to provide the silica, iron, and alumina required for combination through burning with the calcium from the limestone to form the portland cement clinker. The remaining clay is wasted with the overburden.

Limestone is used at the rate of about one million tons per year. Not only is there a sufficient supply of raw materials for more than 100 years of capacity production, but the necessary oxides are in exactly the right proportions for the manufacture of cement.

Gypsum is purchased and secured from deposits in the Alabaster area and is used at the rate of about 40,000 tons per year.

As soon as an adequate supply of raw materials was confirmed, Dundee Cement Company began looking at other important factors. An enormous quantity of fresh water is necessary in the manufacture of cement and Michigan has the greatest supply of fresh water of any state in the union. Michigan has a great supply of skilled labor and this is a condition that simply does not exist in many states. Transportation facilities were found to be of the very best, with water transport just a few miles away at the Port of Monroe, more than 200 truck lines operating on the finest highway system in the country and 32 railroads servicing the state. Electric power was in good abundance nearby and fuel was no problem.

And, in addition to all these factors on the plus side, Dundee Cement Company's chosen plant location was in the heart of the Great Lakes area — an area with a dynamic economy, 20 percent of the country's population with predicted population increase of 50 percent in the next 20 years.

The Peerless Cement Company, founded in 1897 — and since 1958 a division of the American Cement Corporation — operates three cement manufacturing plants (one in Port Huron and two in Detroit), as well as two bulk cement distributing plants (at Grand Rapids and at Schoolcraft). It is the only multiple plant cement producer in the state. Its three manufacturing plants have a productive capacity of 6½ million barrels annually. Peerless cements are sold within an area of approximately 200 miles of its plants, with 90% of the sales being in Michigan.

Six other companies also operate cement plants in Michigan. These, along with Peerless, make this the fourth largest cement producing state in the country. Only California, Pennsylvania, and Texas outrank Michigan.

Three basic raw materials are used in the production of cement — clay, limestone, and gypsum. All three of these underground elements — in ample quantity and of suitable quality — are readily available in Michigan.

Peerless obtains clay of the proper chemical composition from an excellent 268 acre deposit at Smith's Creek (near Port Huron), and from a 260 acre pit located in Allen Park, a Detroit suburb. Limestone is delivered by boat from the famed Rogers City quarries owned and operated by the Michigan Limestone Company, while high grade gypsum comes from mines at Alabaster.

[1]Reprinted from Michigan Challenge, Michigan State Chamber of Commerce, November, 1961.

BOUNTIFUL BRINE[1]

A very abundant supply of natural resources in Michigan provides the raw materials for Wyandotte Chemicals Corporation, but ironically it was the lack of a natural resource in Michigan that led to the founding of the company 71 years ago.

Searching for an adequate supply of rock salt deposits near which he planned to manufacture soda ash, Captain John B. Ford, Wyandotte Chemicals' founder, was attracted to Wyandotte by word that a natural gas drilling operation had been thwarted by a layer of rock salt in the area.

Capt. Ford took an option on the land and when tests proved the salt layer was vast, formed in 1890 the Michigan Alkali Company, forerunner of Wyandotte Chemicals.

The company became the second United States soda ash plant, producing, less expensively, the basic material for a rapidly expanding American glass industry.

In addition to salt, limestone, clay, crude oil and, in unlimited ways, water plays an irreplaceable role in Wyandotte Chemicals' daily life.

The salt used in the basic chemicals processing at Wyandotte still comes from the layer, fourteen hundred feet beneath the surface, that first attracted Capt. Ford.

So vast is that layer that even the most conservative Wyandotte official will tell you that the supply will satisfy needs for the next century.

In Capt. Ford's day soda ash was the principal product of this newly formed company. But science and research and new markets demanded other chemicals.

The manufacture of allied alkalies, caustic soda and sodium bicarbonate was begun in 1896 and 1897.

Salt, limestone from Michigan's plentiful supply in the northern section of the state, and "imported" coal are some raw materials from which Wyandotte products are made.

Of the chemical products soda ash, to the average layman, is one he's not likely to recognize because he seldom sees it in its natural form. Yet soda ash is such a basic chemical that everyone benefits from the products made with and from it.

The glass industry, largest single soda ash consumer, produces electron tubes for television, radio and industry; mirrors, windows and thousands of other everyday items we use.

Soda ash also finds its way into the manufacture of phosphates for detergent formulations; in the processing of materials in the textile industry; paint, metal, paper, and, in fact, almost very man-made product has at some time required soda ash in its manufacture.

Sodium bicarbonate, or "bicarb," at this very moment somewhere in America is helping a housewife in her cake baking, relieving indigestion, putting out a fire and cleaning teeth. These are just some of the uses man has devised for this salt by-product.

Michigan's salt and limestone play an important role in many other ways. Calcium carbonate is used in the manufacture of paper. Calcium chloride is invaluable in the construction and maintenance of highways. Carbon dioxide keeps your soda pop "alive," fights fires, and freezes perishables as dry ice.

Another by-product produced by Wyandotte with Michigan's raw materials is caustic soda, basic to the manufacture of soap, making aluminum and cellulose. Another is chlorine, used in medicines, drugs, sanitation, refrigerants, paper, dyes, rubber, plastics and others.

The manufacture of cement at Wyandotte requires many tons of Michigan's limestone and clay. In 1960 alone, Wyandotte consumed more than 1,300,000 net tons of limestone in its overall production.

Modern day needs of petrochemicals, those products for which petroleum or natural gas has served as the starting raw material, and the discovery and supply of crude oil from the central section of lower Michigan gave Wyandotte another need for Michigan's natural resources. In 1960, 800,000 barrels of Michigan crude oil served Wyandotte needs in the production of glycols, ethylene and propylene dichloride.

Through it all, Wyandotte Chemicals uses Michigan's most famous of all natural resources . . . water. Wyandotte ships ply the Michigan waterways, its plants utilize every known application for water in daily operations.

For 71 years Michigan's natural resources have provided the raw materials that helped Wyandotte Chemicals Corporation become the state's second largest employer in the basic chemicals industry, one of the nation's major basic chemicals producers and the world's largest producer of specialized cleaners for business and industry.

[1]Reprinted from Michigan Challenge, Michigan State Chamber of Commerce, November, 1961.

BRINE - SALT OF THE EARTH[1]

In the world of Herbert Henry Dow, brine was the stuff that dreams are made of. That was in 1889. Today, brine is the stuff that literally hundreds of chemical products are made of.

The subsurface strata of most of the state of Michigan have been likened to a stack of saucers, having their maximum depth near the center of the state and gradually curving upward around the edges.

A number of these strata hold the remains of ancient seas in the form of brines. Some contain only common salt, while in others, in addition to sodium and chlorine, are varying concentrations of magnesium, calcium and bromine.

It was these brines that led Herbert Dow to Midland, for while in college he had experimented with them and worked out a process for recovering bromine from brine. Midland already had both salt and bromine industries, but when he arrived in 1890 they were dwindling because their processes depended on evaporation which, to be economic, depended on cheap fuel. The sawmill scrap which had provided this was becoming unavailable as the lumbering industry moved on.

Just why Dow chose to locate in Midland specifically is not known, for he had worked also with brines from other areas and states — perhaps because he could obtain brine from existing wells and avoid the cost of drilling his own. In any event, his decision proved to be almost uncanny.

Geologists today have a vastly greater knowledge of Michigan's substructure than in 1890. This new knowledge indicates that the Midland facilities of The Dow Chemical Company are in an almost ideal location for recovery of the chemical wealth that lies below.

For example, at the present time Dow is taking brine from more than 50 wells, scattered in a rough oval only about 30 miles across. These tap the Sylvania stratum at a depth of about 5,000 feet, where the brine is considerably richer in content than the Marshall brines at 1,200 feet which the company largely depended on for many years.

The location presents another advantage, too. Since brines in several strata are available and vary in their content of different chemicals, the company, at its option, can alter its source of supply to obtain the optimum brine in terms of production needs.

Thus, more than 70 years ago, Herbert Dow, through chance or sixth sense, placed his finger on a focal point for chemical production the full potential of which was not to be known until years later.

The first few years were marked more by struggle and frustration than success. In fact Dow's first venture was so flimsily financed that it never really got off the ground. But he was not one to give up, and he could always learn something from failure.

Somehow he got additional backing, started over, this time with a larger though still modest plant built of the cheapest materials possible, and though it was an uphill struggle, by 1895 the business was making money.

By this time also, he was experimenting with ways to recover the chlorine present in the same brine. Because this activity was not looked upon with favor by his board of directors, he found new backers — and this led to the formation of the Dow Chemical Company in 1897.

The years since then are a record of constant expansion, constant research, combining and recombining the chemical elements in the brine to form new useful products. And with the rise of Michigan's oil industry, the company began exploiting another underground resource — petroleum —extracting its chemical wealth and, often as not, combining petroleum chemicals with brine chemicals to form entirely new products never before in existence.

Today the Dow Chemical Company has some 30 manufacturing operations, from the Atlantic coast to the Pacific, and from Washington State to the Gulf coast, yet its Midland plant is, and for some years has been, the largest chemical complex in the United States. By itself, it would rank as about the 12th largest chemical company in the country, and it manufactures some 600 different chemical products. With the exception of benzene, all the major raw materials from which these products are evolved come from the brine, salt, oil, and gas deposits of Michigan.

Two of Dow's other Michigan installations likewise are based heavily on the state's oil and mineral deposits. At Bay City, its Saginaw Bay Division operates an oil refinery and manufactures petrochemicals and polyethylene, including the plastic household film, Handi-Wrap. Crude oil, of course, is its principal raw material. About half of this is obtained from Michigan wells and the other half from the Canadian pipeline.

Across the state at Ludington another Dow plant manufactures such products as lime, calcium chloride, magnesium hydroxide and bromine. The raw material for its lime kilns is limestone from the Cedarville area of the Upper Peninsula. The other products are based on underground brine deposits similar to those in the Midland area. Some of the Ludington brines are especially rich in magnesium. In fact, the original portion of this plant was built and operated by Dow for the government during World War II to recover magnesium chloride for the production of magnesium metal.

Chlorine and bromine, Herbert Dow's first two "targets," are still among the most basic chemical building blocks of the company's Midland Division. And "building blocks" they are, for while tremendous quantities are recovered very little of either is sold in its elemental form. Instead, they are combined with other chemicals, most often petroleum chemicals, and the letter combinations "chlor" and "brom" show up in the names of product after product — as in carbon tetrachloride, perchloroethylene, chloroform, ethylene dibromide, methyl bromide and scores of others.

The chlorine is recovered from salt brine by electrolysis, with hydrogen and caustic soda as companion products from the process. Bromine is recovered from the mixed brines by a "steaming out" process. Chlorine is bubbled through the brine to liberate the bromine which is then steamed out of the solution and collected as free bromine.

Like the sodium, both magnesium and calcium are present in the brines in the form of chloride salts. If slaked lime is added to the brine, magnesium will precipitate out in the form of magnesium hydrate (milk of magnesia) which can be removed by filtration.

Magnesium hydrate itself has a considerable market. In fact, at both Midland and Ludington it is piped as a slurry to adjacent plants of customers who use it in the manufacture of industrial ceramics such as fire bricks and other furnace linings. Some of it, however, is reconverted to magnesium chloride, and likewise it can be converted into other products — as, for example, Epsom salts. After being filtered and dried, magnesium hydrate is treated with sulfur dioxide to produce magnesium sulfite, which is then oxidized to yield magnesium sulfate — Epsom salt.

Calcium chloride is recovered by evaporation and drying and is marketed by the company in flake and pellet form as Dowflake and Peladow.

The products of brine alone are numerous, as are products based on petroleum, but the largest number have some combination of brine and petroleum, brine and benzene or petroleum and benzene in their ancestry.

Among the major products of Dow's Midland Division in terms of sales volume are ethylene dibromide, Styron (Dow polystyrene), phenol, synthetic latexes and saran, (including the well-known household roll, Saran Wrap). And they serve to illustrate the significance of these combinations and the chemist's ingenuity in exploiting the various raw materials available to him.

Ethylene dibromide, used chiefly in anti-knock gasoline fluids, is based on petroleum and brine as its name implies. Polystyrene, the company's most important plastic, is based on petroleum and benzene, while saran, another major plastic, has petroleum and brine for parents.

Phenol, a large volume industrial chemical and intermediate in the manufacture of plastics and adhesives, has its roots in benzene and brine. Of the various latexes, used in paints and as coatings for paper, textiles and other materials, some are based on petroleum and benzene, others on petroleum and brine.

Thus are Michigan's abundant "treasures," buried for eons of time and useless in themselves, reclaimed and converted through the magic of chemical science into hundreds of useful and beneficial products. Without man's vast accumulated knowledge they would not be treasures at all.

[1]Reprinted from Michigan Challenge, Michigan State Chamber of Commerce, November, 1961.

GRAVEL-COMMON STUFF

By Helen M. Martin[1]

Long ago in the Ice Age, glaciers crept slowly from Labrador and Hudson Bay. As the cold advanced, animals and plants moved southward before it. Cold and changes of temperature cracked up the rocks even more than vegetation had done. Streams from summer melting of the advancing glaciers washed them clean. The glaciers froze onto rocks large and small and carted them southward. They picked up granitic rocks filled with garnets, mica, jasper. They froze onto limestone, sandstone, shale. They plucked off far northern granites, lavas with their agates and carnelians, iron-bearing rocks, even a few diamonds and gold-bearing quartz. They jumbled all these old rocks with younger rocks they plucked off the petrified cemeteries of corals, moss animals, shelled creatures that had helped to build up the limestones which the glaciers smoothed and polished when they couldn't rob any more. They shoveled up sandstones and shale and fragments of old petrified sea floors and beaches. That's why you can find almost any kind of rock in a gravel pit. In the mill of the glacier the rocks were ground to sand and gravel, cobbles, and boulders with rounded edges.

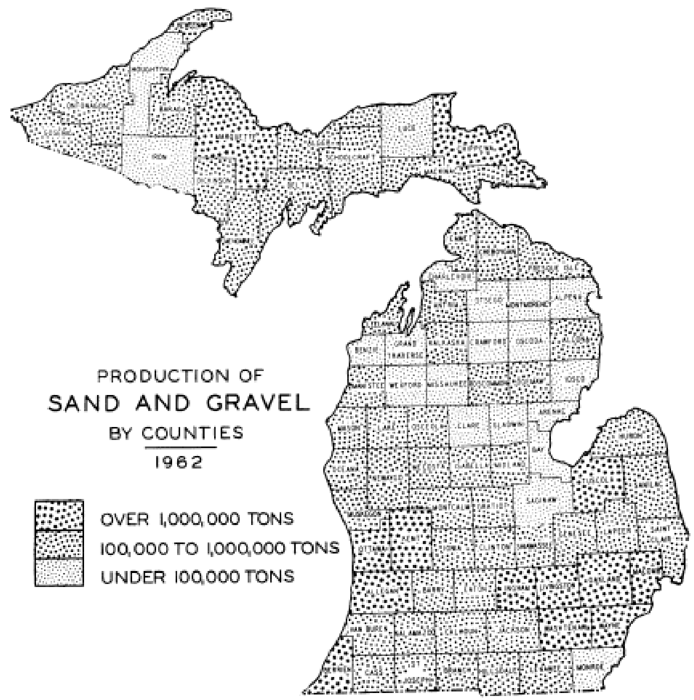

Figure 2. Production of sand and gravel by counties, 1962.

The ice at the front of the glaciers melted, rapidly at times, and made torrential rivers that washed gravel from the ice, sorted, scoured and polished it and, when the torrents ceased, dumped it in thick deposits and banks scattered over the land where the glacier had been. Cracks and gorges in the bedrock were filled with sand and gravel and trapped some of the meltwater of the ice. Other rivers carried glacial gravels far south of the glaciers' halting places. Lakes formed in front of the glaciers and, in them, rivers dumped great deltas of gravel. On their shores, great beach ridges of sand and gravel were built by wind and waves — beaches that were man's highways when he walked or rode a horse westward to new lands and that he dug up later to make concrete for the highways he laid where the beaches had been.

When the glaciers were not moving, the meltwater fell in waterfalls and cascades into the cracks of the glaciers and carried, sorted and washed gravel into the cracks, piling it up layer on layer. Rivers formed in the ice and carved tunnels for their flow, tunnels that became choked with sorted sand and gravel the icebound streams washed from the ice. When the last of the ice melted away, conical hills (kames) of sorted gravel were left where the ice cracks and waterfalls had been. The gravel choking the old stream tunnels was let down in long sinuous ridges (eskers) of sorted gravel that the early settlers called hogbacks or Indian trails. Stream channels that pushed their heads northward also became filled with gravel. Where the glaciers readvanced, all these gravel deposits were buried under later glacial deposits.

All these vast deposits of sand and gravel of the glacial drift that covers the bedrock became filled with water from the melting ice and the rains of the centuries that followed the disappearance of the glaciers, and thus were made some of Michigan's aquifers — the great buried reservoirs of water.

Some of this gravel is in pockets and banks at the surface, covered only with thin vegetation, and on this common stuff a basic industry has been developed. Our early "good roads" were gravel and crushed stone made of the larger cobbles. Then came Portland cement and the old glacial gravels were mixed with it to make our modern concrete. A new day in construction dawned. Good hard roads demanded by the newly arrived automobile became possible. Dams, culverts, bridges, construction of all sorts called for more concrete, more sand and gravel.

Power shovels took off the overburden of soil and vegetation that nature had so carefully built over the gravel deposits. Larger power shovels bit into the largesse of the glacier. Conveyor belts, crushers, screens were erected. Great piles of gravel washed free from sand and sorted to size were heaped up. Busy trucks hauled away the sorted gravel to build roads, dams, culverts, bridges. A gravel pit was made.

All too soon the edges of the deposit were reached, too soon the ground water became a problem and the shovels could go no deeper as the bottom of the deposit was reached. Only the best of the gravel was taken. The less-washed and sorted gravel around the edges of the pit was left to be used some day when the sand and gravel industry may utilize wastes and re-work the edges of old pits. The shovels and crushers and conveyor belts moved away, the trucks started to haul from elsewhere and only an ugly scar was left on the landscape; a scar that for a time in its deeper parts held water for a swimmin' hole.

But nature does not like scars, even for swimmin' holes. She makes the winds blow and birds carry seeds to the scar — seeds that can find food in the water solutions in the gravel — grasses, roses, shrubs on the higher banks, cattails, reeds, water-loving plants where the scar is deepest and water stands and where the redwing makes his home. In a few years the steel cables, discarded shovels, barrows and junk of the abandoned pit are covered. The steeper slopes slump to gentle inclines. Oaks and cherries move in; in time even the cattail marsh disappears. Nature does her best to restore the green face of the earth to man-made scenes of desolation.

[1]Geologist (retired), Michigan Dept. Conservation. Reprinted from Michigan Conservation Magazine, Nov., 1953.

SALT FOR A MILLION YEARS

By Helen M. Martin[1]

When man was a nomad, he needed and used few of the earth's minerals —a stone for his sling, a bit of flint for his dart, spear, arrow, and water for his person. But when he settled in one place and became an agriculturist his need for minerals increased. As his diet changed from meat to vegetable, his body cried out for that mineral essential to life obtained from meat but deficient in a vegetable diet — salt. Early man probably noted and became curious about the places where animals gathered to lick the ooze or the rime about certain springs and so discovered salt and its value in his food supply.

Salt then became an article of trade, a medium of barter, a commodity of commerce. As civilization advanced and the human race spread into regions of temporary seasonal abundance of food, salt was discovered to be a preservative and man learned to preserve and store food from one season to another.

One day someone discovered how to make soap — but it was slippery soft soap until some experimenter discovered that when salt was added to the mixture of lye and fat, soap separated out and floated on top of the brine — and a great industry was born. Cleanliness became next to godliness and perfumes became esthetic, not necessary, commodities.

Early Salt Industry

Gradually, as chemistry and medicine advanced, medicinal uses were found for salt. Salt is the chief inorganic constituent of the blood and it was discovered that in cases of severe blood losses, a solution of 1,000 grams of pure water with eight grams of salt injected into the circulatory system will maintain life for a short time. As chemistry advanced and entered more into daily living, great manufacturing industries grew up that used quantities of salt as a basic material. The mineral, salt, comes from many places on the earth, but in greatest quantities from the United States, and our state of Michigan, leads all the rest.

Long before the white settlers entered the Michigan Territory, wild animals had discovered numerous salt springs and had developed salt licks. The Indians supplied themselves with salt from these springs and from the time of earliest settlement brine springs were known in Macomb, Washtenaw, and Wayne counties. Small quantities of salt were manufactured on Salt Creek, Macomb County, but by 1837 "only an old hollow gum or sycamore sunk a few feet into the edge of the stream and a few bricks of the furnace showed where the industry had been." Near Saline on Saline River, Washtenaw County, a salt plant was using the salt brine from a depth of 15 feet in a nearby marsh, the salt spring "firmly set about with pickets of logs and the surrounding water excluded by an embankment." But though flourishing in 1823, the plant was in ruins in 1837.

In Section 27, Redford Township, Wayne County, the Indians and early French settlers had manufactured salt from a salt spring and had later abandoned it. For a time after 1812 the industry was revived by American settlers. As settlement increased, need for salt increased. It was imported from New York and Ohio at almost prohibitive prices. Therefore as the linear survey progressed over the Michigan Territory, the Surveyor General, at the request of the Michigan Constitutional Convention of 1835, reserved from public sale those lands on which salt springs were reported — the "United States Saline Reservations."

State Reserves "Salt Springs"

By the Act of Admission to the Union in 1837, Michigan was permitted to select 72 sections of these lands for state use, the selection to be completed by 1840. So it was that Act 20 of 1837, which authorized a geological survey of the state, included a provision that the state Geologist (Douglass Houghton) should first examine the salt reservations, select the 72 sections, and report on them at the end of the first season of field work. During the first season, Houghton, accompanied by Bela Hubbard, C. C. Douglass, and Mimi, a black and white spaniel, using canoes for transportation, with uncertain and often inadequate food supplies, tormented by mosquitoes and lazy, talkative French-Indian guides, visited the salt springs in Wayne, Ionia, Macomb, Washtenaw, Clinton, Gratiot, Kent, and Midland counties (Saginaw and Sanilac were deferred to a time of better weather). They came to the conclusion, as set forth in the first annual report of the State Geologist, that no springs examined discharged enough brine to warrant establishment of salt works, but that they did indicate salt bearing rock below the surface which would warrant boring the natural springs to a greater depth through the sandstone, limestone, and shale to bring a continuing supply of brine to the surface.

First Ventures are Failures

Acting upon the suggestion of the State Geologist, the Legislature authorized the improvement of the "state salt springs" and appropriated $3,000 for the work. A site was selected June, 1838 in the Tittabawassee salt reservation, and a salt house and wharf were erected on the right bank of the Tittabawassee, one-half mile below the mouth of the Salt River, where Houghton expected to find salt bearing rock at a depth of 700 feet. Similar work was started July, 1838 on the "state salines" three miles below the village of Grand Rapids. The ventures were beset with difficulties. Canoes and barges were the only means of transportation of the heavy drilling equipment to the Tittabawassee. Competent drillers would not be lured from Ohio as they feared the ague and malaria, said even as late as 1837 to strike down those who ventured into the "endless morass of the Saginaw Valley". The costs the first year were $886.19 more than the appropriation. The next Legislature appropriated $15,000 to continue the work. Michigan annually imported over $300,000 worth of salt from Ohio and New York. The Legislature expected that the development of salt springs within the state would not only supply all the salt the state needed but return a handsome revenue as well, since New York and Ohio imposed salt taxes of from 6 to 12½ cents a bushel and Michigan legislators sought similar revenues.

Both attempts, however, were failures. After four years of labor troubles, illness, delays in bringing equipment from Detroit, and intermittent drilling, the Midland "boring" struck a hard igneous rock at 139 feet that the drill could not penetrate. No one at that time knew that Michigan is covered by a mantle of glacial drift and that the rock was not "primary rock" in place, below which nothing but more igneous rock would be found, but only an "erratic", a glacial boulder in the drift, and that a boring 20 feet away in any direction would have missed it. The Grand Rapids experiment was drilled 400 feet without success although Houghton believed that stronger brine would be found at 700 feet.

Salt Bounty Act is Passed

The salt works were idle for a time, and then contracts for completion of the work were awarded to Lucius Lyon, Grand Rapids and Ira Farrand, Midland, the low bidders. In the meantime, Lyon had drilled farther east (near the Bridge Street bridge in Grand Rapids) to a depth of 661 feet and had obtained a brine from which he manufactured salt until 1850, or as long as manufacture was profitable at $3 a barrel.

During the years that followed, many private attempts were made to establish salt works and to persuade the Legislature to offer bounties for salt to encourage exploration. Houghton had discovered the "basin" character of the Southern Peninsula, and Alexander Winchell, the second State Geologist, had determined that the deepest part of the salt basin was in the vicinity of Saginaw. Through the efforts of Dr. George A. Lathrop of East Saginaw and James Scribner of Grand Rapids, the Legislature of 1859 passed an Act to encourage the manufacture of salt in Michigan. Dr. Lathrop organized the East Saginaw Salt Company which put down the first successful salt well in the Saginaw Valley. The well was completed in March, 1860 at 742 feet depth where a heavy flow of brine was struck. A plant was erected and manufacture of salt began in June of that year. The Salt Bounty Act provided that all property used in the manufacture of salt was exempt from taxation and a bounty of 10 cents a bushel was to be paid on all salt when at least 5,000 bushels were manufactured. Under such a stimulus it was not strange that the industry was revived in Grand Rapids by Mr. Scribner who remembered that Houghton had believed that a second salt source could be found below 700 feet and who started drilling six wells. Twenty-three companies were organized to drill wells in the Saginaw Valley, their activities also inspired by the success of the East Saginaw Company. The bounty law was revised downward and finally repealed in 1869, but by that time the industry was well established in the Saginaw Valley and, in 1886, 136 companies were making salt — the all-time high. The salt industry later spread to Bay, Huron, Macomb, Midland, Gratiot, Manistee, St. Clair, Mason, Wayne, and Isabella counties in that order.

Ancient Seas Deposited Salt

Geologically, Michigan is a rock basin filled with a huge nest of rock bowls fitted one into another. The largest basal bowl underlies the state from Lake Superior to beyond the southern, eastern, and western boundaries, the smallest top bowl is well within the Michigan basin. Each bowl was made from the sediments left at the bottom of ancient seas that once covered and then withdrew from the area. In those sediments, salt waters of those old seas were trapped and buried by the sediments laid down by the next returning sea. Each sea was smaller than its predecessor and left thin sediments around its rim. During the long ages after all the seas retreated from the Great Lakes area, the rims of the bowls were eroded away, exposing the underlying rocks, only later to be covered almost completely with a mantle of glacial drift. Therefore, as the salt industry moved toward the rim of the basin wells were bored into older salt formations. Conversely, wells drilled toward the center of the basin, down the slope of the rock formations, encountered heavier brines or bitterns containing minerals other than sodium chloride or salt. Thus the earlier wells produced first from the Parma sandstone of The Saginaw Formation; later wells successively reached the brines in the Marshall and the Berea sandstones, the brines and rock salt of the Detroit River Group, and then the rock salt in the Salina Group.

Salt Underlies 55 Counties

As the industry expanded and deep wells were drilled for other purposes, four great reservoirs of brine were outlined with beds of rock salt in the lowest. Below all is a great rock salt formation, the Salina, that underlies nearly all the Southern Peninsula except the southwestern corner and has beds of rock salt from 30 to 442 feet thick. In the Gulf Oil Company's Bate-son No. 1 oil well in Monitor Township, Bay County, the rock salt beds aggregate over 1,600 feet in thickness and are from 5,480 to 8,270 feet below the surface under Kawkawlin. In addition, salt brine is produced from the Traverse and Dundee petroleum-bearing formations.

Have we enough salt? We now know that 55 counties of the Southern Peninsula cover more than 32,687 square miles of known salt, probably 3,269 cubic miles plus the cubic miles of unknown extent in salt beds discovered in the Bateson well which are probably even thicker in the center of the Salina basin.

A cubic mile of salt would weigh 10,819,049,472 tons. And 10,819,049,-472 x 3,269 is an astronomical tonnage, enough for everybody for a million years.

In 1860, Michigan produced 4,000 bushels of salt (a little over 56 tons) and hoped to closely rival New York State, at least. In 1943 Michigan produced 4,284,685 tons, valued at $14,472,820 and continued to be the first state in production as it had been since 1907, with the single exception of the year 1910.

The Saginaw Valley did not continue to hold first place in the industry; at one time the plant at Ludington, now torn down, was the largest salt plant in the world. Today the salt and associated brine and chemical industries are in Gratiot, Manistee, Mason, Isabella, Midland, Saginaw, St. Clair, and Wayne counties.

A "By-Product Industry"

The industry has always been a "by-product" industry. In the early days salt was produced from brines evaporated in huge kettles by heat produced from the slab and sawdust waste of the lumbering industry; later the heat came from the exhaust steam from the lumber mills, plate glass, and other industrial plants. This cheap fuel supply accounts for the rapid rise and later decline of the industry in the Saginaw Valley as the lumbering industry departed.

With the discovery that the bitterns thrown away after the salt was extracted had more value than the salt, the salt itself became a by-product of the great and expanding chemical industry and the foundation of other industries — but that's another story. A well drilled for oil in Macomb County in the 1860's found no oil but did find salt brine that has certain curative properties, and the famed Mt. Clemens mineral baths were developed. The records of the salt well borings were used in the search for petroleum.

Petroleum and salt were found together and now salt and its associate minerals are by-products of, and a disposal nuisance to, the petroleum industry.

Today, Michigan salt is produced by evaporation of natural brines, and of artificial brines made by the introduction of water into salt formations with consequent dissolving of the salt. In 1882, rock salt was discovered under Lake St. Clair and the production of salt from artificial brines began. In 1906 a shaft was started in Wayne County to reach the rock salt and open a salt mine, but various difficulties prevented opening the mine until 1913. Since then, Michigan's only rock salt mine — the second largest in the United States — has been developed to include many miles of crystal passageways, 1,135 feet below the streets of Detroit and Melvindale, with man-made caverns 22 feet high and 50 feet wide cut into the 98.3 percent pure salt.

Vital to Industry

What is all the salt used for? Nearly every industry uses salt in some form: after water, it is the mineral that is most essential to human and some plant life, and it is the most essential raw product in the modern chemical industry.

There is more than a pinch of salt in every vital industry. Salt is used in the manufacture of high octane gasoline, synthetic rubber, explosives, steel plate, and many more. Salt tablets are imperative to replace the salt lost from the body by heavy sweating, and to combat fatigue, heat cramps, and sickness caused by heat and loss of body moisture. Salt is used for refrigeration, the manufacture or processing of chlorine and bleaches, dyes, soap, textiles, hides and leather, for meat packing, fish curing, dairy products, canning and preserving, for highway dust and ice control, and for stabilizing clay and gravel on highways, for water softening and purification, glass, ceramic and paper making, for household, table, laundry, and dry cleaning uses, in the manufacture of vegetable oils, for fertilizer, insecticides, cattle licks, for seasoning lumber, making rayon, soda, baking powder, plastics . . .

These are only a few of the 14,000 uses of salt. We may find other uses that will draw from Michigan's reserve of trillions of tons of the mineral — the clear white hopper* crystals made from the union of a corrosive gray-silvery metal, sodium, and the poisonous yellow-green gas, chlorine, that chemists call sodium chloride and write NaCl, which the geologist calls halite, and the epicure and you and I know as the best condiment of all — salt.

[1]Geologist (retired), Michigan Dept. Conservation. Reprinted from Michigan Conservation Magazine, Dec., 1944.

*Hopper crystals are like a series of hollow building blocks in which each succeedingly smaller block nests inside its immediate predecessor.

LIMESTONE AND DOLOMITE

— Nature's Mineral Jack-of-All Trades[1]

Michigan, in 1957, was the third largest producer of limestone in the nation, following Pennsylvania and Ohio in that order. The state's total limestone production was 34,259,000 tons in that year. Output in 1960 and '61 is at a somewhat lower rate.

In addition to the Michigan Limestone Division of United States Steel Corporation, the principal producers are Inland Lime & Stone Company, Mackinac County; the Huron Portland Cement Company, Alpena County; Drummond Dolomite, Inc., Chippewa County; the Cheney Limestone Company, Eaton County; the France Stone Company, Monroe County; the Michigan Stone Company, Monroe County; Penn-Dixie Cement Corporation, Emmet County; Presque Isle Corporation, Presque Isle County; and the Wallace Stone Company, Huron County.

Some 320 million years ago in the Devonian period of the Paleozoic era, shallow warm seas of the purest salt water covered the whole area where the Calcite quarry of the Michigan Dundee Limestone in Rogers City and the Engadine dolomitic lime stone quarry in Cedarville, both divisions of the United States Steel Corporation, now are situated.

Ancient streams emptying into the sea carried dissolved calcium carbonate, and the corals and shelled animals in this sea extracted this compound from the water to form their shells. When the water became saturated with calcium carbonate, it was precipitated as a lime mud which covered up the corals and other organisms, and the whole mass was slowly solidified into a high purity stone now known as the Dundee Limestone at Rogers City and after further alteration, the Engadine Dolomite in the Cedarville area.

The dolomitic limestone in the eastern section of the Upper Peninsula differs from limestone in the additional element, magnesium. It is a close kin chemically to the high calcium limestone at Rogers City. The Cedarville "dolomitic limestone," as this is called, approximates the ideal of 54% calcium and 46% magnesium carbonate.

It is thought that the coarse-grained dolomitic limestone started originally as limestone in the Silurian period of the Paleozoic era about 350 million years ago. What caused the recrystalization that resulted as a product of the "dolomitization" of the original limestone is not known. The remains of the marine life entrapped in the original limestone were partially destroyed or at least enveloped so completely as to be indistinct.

Photo 4. Michigan Limestone Division, United States Steel Corp., Port Calcite, Rogers City, Michigan. Aerial view looking south.

It is the great purity of both types of these stones that make them so valuable, especially since they are found in quarriable thicknesses next to bodies of water that permit economical transportation.

Steel, cement and chemical industries buy and use limestone. This complex rock, while consisting almost wholly of calcium carbonate, also contains small amounts of silica, iron oxide, aluminum oxide, magnesia, sulphur, phosphorous and moisture. Chemists and other skilled technicians maintain a quality control program which permits them to accurately satisfy customer requirements.

First note was taken of the outcroppings of the limestone in the area in 1864 by Francis Crawford, long before

Rogers City was established as a town site. He had gone to Presque Isle county to start a wood fueling station for boats plying the lake. Thinking these limestone deposits to be suitable for building purposes, he established "Crawford's Quarry."

It was around 1910 that Henry H. Hindshaw, a mining engineer and geologist from New York City, definitely established the commercial value of the stone. He also determined that limestone could be obtained in unlimited quantities and loading docks would be built and maintained at a nominal expense.

There followed a long and romantic story of pioneering, research, financing and development including the establishment of a steamship line which bore the name of its founder, Carl F. Bradley. The Detroit and Mackinac Railroad extended its lines to Rogers City about 1910 and the town no longer was referred to as "Sleepy Hollow."

Upon the death of Mr. Bradley in 1928 the entire operation at Rogers City and Cedarville was acquired by United States Steel and in 1951 the companies became divisions of that corporation.

During the Great Lakes shipping season approximately 98% of the output of the quarries is shipped by Great Lakes freighters. In the non-shipping season crews are kept busy removing the top cover and shale.

Innumerable stories could be told of the quarrying, crushing, sizing and washing of the limestone. Forty-five different sizes and chemical combinations of stones are shipped annually. In the reduction of iron ore into pig iron, it is used as a flux to aid in the separation of the metallic iron and the unwanted impurities.

Among other uses are production of lime by burning the stone in rotary and shaft kilns; production of caustic soda (lye) for soap making; making of soda ash for glassmaking; bicarbonate of soda for baking.

Through chemistry, it plays a vital part of literally hundreds of products in use in everyday life: bleaching powders, paper, strawboard, glass, leather sand brick, lime, acetylene, cyanamide, insecticides, fungicides, disinfectants, soaps, plastics, paint pigments, synthetics, filters, refining of beet sugar; and, of course, as a basic material in the production of Portland Cement.

Other uses include as an aggregate in road building and other concrete and bituminous construction.

Finely ground, it is used as agricultural limestone, a soil sweetner, and as an ingredient in both fertilizers and in stock foods.

The fleet of eight self-unloading freighters is still owned by the Division's Bradley Transportation Line. They carry limestone to various industries and ports for reloading. On their return trips, they carry coal cargoes to various Great Lakes ports.

[1]Reprinted from Michigan Challenge, Michigan State Chamber of Commerce, November, 1961.

CLAY PIPE[1]

Clay pipe has come a long way in 2,000 years (that's how long it's been used), and the American Vitrified Products Company, with home offices in Cleveland, has played a big part in the development of today's refined clay pipe products.

The Grand Ledge, Michigan plant, one of AMVIT's (short for American Vitrified) largest 12 nationally spread plants and also one of the industry's largest plants, produces a product made entirely of the fine natural resources of the State of Michigan. That product is clay pipe.

Photo 5. Clay products come in all sizes and shapes. Grand Ledge Clay Product Co., Grand Ledge, Michigan.

Carefully selected fireclay and shale are precisely blended and conveyed to vertical press extruders. The pipe is automatically cut to specified lengths as it emerges from the extruder and is then finished and stamped, and placed in the drying phase. Hot air is injected at predetermined times to build up humidity to a degree required for the particular size of pipe.

The pipe is then sent to the kilns for vitrification.

From the kilns, the pipe is ready for either the jointing operation or for shipment as plain pipe. The pipe is constantly checked at this point to insure that it measures up to the exacting specifications of AMVIT.

If the pipe is to be jointed, one of two methods can be used; either the conventional asphaltic compound joint or a special patented process joint developed by American Vitrified. This joint is known as AMVIT. In this process, a special adhesive is placed on the pipe and dies are placed at both the bell and spigot ends of the pipe. A conveyor then takes it to an area where plastisol is applied to exacting specifications.

The dies are removed and then the pipe is heat cured and subsequently cooled. The pipe is then ready for shipment.

Officials at American Vitrified say that good research facilities and men are perhaps their two most important assets. With the excellent research facilities they have, they've done much to not only advance the industry as a whole, but they've been able to build their own business to one of the country's leading manufacturers of vitrified products.

[1]Reprinted from Michigan Challenge, Michigan State Chamber of Commerce, November, 1961.

GYPSUM IN MICHIGAN

By Emery T. Carlson[1]

Michigan's $5 million-$6 million gypsum industry, for the last 12 years biggest in the nation, started in 1834 in an old Indian corn grinder near Grand Rapids.

A certain James Clark from New Jersey, a member of the 14th family of settlers at Grand Rapids, built a house for Louis Campau, one of the early traders of the region. Clark had heard of gypsum deposits at nearby Plaster Creek and decided to use some for ornamental stucco mouldings in the building.

He gathered the gypsum, pounded it with a hammer, then crushed it in a corn grinder and after an early failure, finally produced the mouldings he wanted.

During succeeding years, more use was made of the Grand Rapids deposits and in 1840, State Geologist Douglass Houghton wrote in his annual report:

"Closely connected with the iron ore of our state in importance is the subject of calcareous manures. Our citizens are already annually importing from the neighboring states, large quantities of plaster and the import must have a rapid increase unless means be taken to open the stores which are found within our own state. There is no point now known where gypsum can so readily be obtained, and where it is at the same time so advantageously situated for distribution over the surrounding country, as at the rapids of the Grand River. Here is an extensive deposit of this important mineral, which in quality is not exceeded by any in our Union, yet thus far it has been entirely neglected. This should not be, for the time has now arrived when it is required for use, and no contingency should be allowed to arise that will cause it any longer to lie dormant."

Soon after, commercial interests began to produce this gypsum for use as plaster, and in 1841 the following advertisement appeared throughout the Grand Rapids area:

"PLASTER! PLASTER! The subscribers have now completed their plaster mill on Plaster Creek, two miles south of this place which is now in operation. They respectfully inform the public that they have on hand at the mill or at either of their stores at Ionia or this place a constant supply. As the quality of the Grand Rapids Plaster is not equalled by any in the United States, they hope to receive a share of patronage as the price is less than it can be obtained for at any place in Michigan. Wheat, pork and most kinds of produce received in payment, (signed) Granger and Ball, Grand Rapids, December 21, 1841."

"The first week after the posting of this notice," wrote G. P. Grimsley in *The Gypsum of Michigan*, published in 1904, "40 tons of plaster were sold at the mill at an equivalent of $4 per ton" — with much of the exchange undoubtedly in ". . . wheat, pork and most other kinds of produce."

"However," Grimsley continued, "the demand became so heavy that by the winter of 1848-49 the mill was running night and day without equalling the demand, so that some teams coming 100 miles were forced to return without a load.

"A competing firm developed in 1860 a short distance away. After near failure, the founder, Freeman Godfrey, traveled to New York, visited the mills there and returned with their methods of calcining, namely a system of two-flue kettles, in 1871.

"By 1873, the railroads had entered Grand Rapids and the wagon traffic in gypsum over dirt roads had become of little importance. Godfrey and his brother had built docks on the Grand River near their works, and large amounts of plaster were shipped by water."

Farther on, Grimsley traced the history of the Alabaster deposits.

"The plaster beds near Alabaster were first discovered by early Indian traders who noticed the outcrop in the waters of Saginaw Bay. In the later 1850's, a mail carrier on his way from Alpena to Bay City by dog team was stopped by a squatter, who possessed some land near the present Alabaster quarry. He gave the mailman a piece of gypsum found in the region and the mail carrier took it to a Mr. George B. Smith in Bay City. On his return, the mailman bought the land from the squatter for two dogs and $10, and later resold it to Smith, who began commercial development of what is today the Alabaster plant of the U. S. Gypsum Company, south of Tawas City.

Thus began Michigan's important gypsum industry, which is today still centered at the Alabaster-National City quarries and in two underground mines near Grand Rapids.

The use of gypsum and the art of plastering dates back to 2,000 B.C. when it was used in construction of the Egyptian Pyramids. Early Roman laws required builders to plaster their constructions to prevent the spread of fire. Paris, France, is built on vast beds of pure gypsum and this when mined and processed became what is still known today as "Plaster of Paris."

The first plant in this country was that of J. B. King, in New York City, started in 1835, using ore from Nova Scotia. Because gypsum plaster was fire resistant, and because it produced a stronger wall faster, it replaced lime as an interior decoration material in the early part of this century. This, together with industrial uses of gypsum, enabled the gypsum industry to develop from a very meager beginning to what is today an important industry.

[1]Geologist, formerly with Michigan Dept. Conservation. Reprinted from Michigan Conservation Magazine, Sept., 1957.

MICHIGAN SANDSTONES

By Edward A. Kirkby[1]

Grindstones

A layer of unique sandstone is exposed along the Lake Huron shore of northern Huron County in Michigan's "Thumb" region. This tough sandstone, composed of fine angular quartz grains cemented together by softer clay and mica materials, is well suited for grindstones. The softer cementing matrix wears away just fast enough to prevent clogging or glazing. The best material occurs in a 25-foot layer near the base of a rock unit called the Marshall Sandstone of Mississippian geologic age. In the vicinity of the "Thumbnail" this unusual sandstone outcrops as the result of much erosion through geologic time.

According to local history, a Captain Peer, commanding a schooner on the Great Lakes, discovered this rock while seeking shelter from a storm. Through his efforts a company was organized here in 1835 to produce grindstones. In 1839, the first quarry was opened and a grindstone mill erected on land acquired from the federal government.

Quarrying was a seasonal proposition inasmuch as the working face cracked with frost, necessitating protection with sawdust during winter. Most of the quarry work, therefore, had to be done during other seasons. Vertical holes, closely spaced, were drilled into the horizontal rock layers. Tabular-shaped blocks were then roughed out by forcing bars and wedges into these holes and along horizontal bedding planes. Explosives were not needed. The rough blocks were lifted by derrick onto flat cars and hauled to nearby mills.

At the mill, blocks were shaped with hand tools into circular slabs having a square hole at the center. Rough grindstones were then mounted in a large lathe and turned to finished size. Stones with pebbles or other imperfections were sent to the waste pile. Finished grindstones varied from one to seven feet in diameter with the largest having a 14-inch working face and weighing over three tons. Loose pieces of stone not large enough for circular grindstones were used for various types of oilstones, whetstones, and scythestones. Much of the remaining waste was used in building construction.

Finished stones were shipped all over the United States, Europe and even Australia. Chief uses were in the manufacturing of cutlery, hardware, and tools, as well as for dressing and sharpening tools. In the early days, the finished stones were loaded on barges at Grindstone City and Port Austin and floated out to ships anchored offshore. Later, a railroad ran to the mills. Toward the latter years of production, transportation was primarily by trucks. The impact of artificial abrasives and high speed grinding equipment, however, gradually brought on the obsolescence of the natural grindstone.

Annual production and value figures for Michigan's grindstone industry were often concealed because only one or two competitive companies were operating. In 1870, however, two companies with quarries near Port Austin and Grindstone City employed nearly 100 men and produced in nine months grindstones valued at $79,600. One company produced 1,600 tons of circular grindstones and 600 cords[2] of other stones. The heyday, however, was in the 1880's when apparently more than 800 men were employed in the quarries and mills. In 1895, grindstones produced by 230 men at one company were valued at $44,602. In 1911 the value of grindstone production by two companies was $150,000.[3] For a number of years grindstones were also produced from quarries at nearby Eagle Mills and Caseville.

For many years, grindstone production from Huron County was sufficient to rank Michigan second only to Ohio which produced five or six times as many as Michigan. West Virginia, the only other state in the nation producing grindstones, ranked third for many years but moved into second place in the 1920's after Michigan production became intermittent, with only one company producing grindstones at Grindstone City. In 1945, several train-car loads of grindstones were shipped to Cleveland, Ohio — probably the last major shipment of grindstones from the area. Today, the quarries are deserted but some of the larger discarded grindstones still line the Lake Huron shore near Grindstone City, while some of the smaller stones have been stacked for use as fence and gate posts.

Redstone and Brownstone

The Jacobsville Sandstone of Cambrian age, found in Michigan's Upper Peninsula, was not only considered an excellent local building stone but was also shipped to Detroit, New York City, Chicago, Denver, New Orleans, and even as far as Liverpool, England. This medium-grained sandstone could easily be cut, carved and sawed. It becomes harder upon weathering and is unaffected by frost. It is also characterized by permanent red and brown colors resulting from iron oxide within the stone.

Massive layers of Jacobsville Sandstone suitable in size for building purposes were quarried at Jacobsville, L'Anse, and Marquette. The stone that was quarried at Jacobsville and L'Anse is red, mottled with white streaks, blotches, and circular spots, while stone quarried at Marquette was predominantly brown. One variety of the latter was called "rain-drop stone" because its surface was covered with marks resembling spatter imprints caused by rain drops falling on sand long before it became hardened to rock.

Most of the stone was shipped via the Great Lakes. The first shipment was from Marquette in 1869. In 1877, 70,000 cubic feet were shipped from L'Anse and Marquette. Nearly 750,000 cubic feet were shipped from Marquette and Jacobsville in 1889. The red sandstone was valued at $.60 to $1.25 a cubic foot while the brown sandstone was slightly more. The maximum value of annual production, $188,073, was attained in 1902. The sandstone was marketed under such trade names as Jacobsville Redstone, Portage Redstone, Marquette Brownstone, and others. By 1911, Michigan sandstone production on Lake Superior had almost ceased, with output valued less than $13,000.

As early as 1895, some sandstone remained at the docks. Apparently architects had begun to specify less highly colored stone such as granite, marble, and light colored limestone. The Jacobsville Sandstone producers, however, felt this change was only a "fad" and that the architects would again call for Lake Superior sandstone because it was not only cheaper, but also as attractive as most building stones. As time went on, the real competitors were brick and other artificial rock products as concrete. Great distance from markets was also a deterrent to further development.

Today, very small amounts of this sandstone from the Keweenaw Peninsula are being used for flagstone under the trade name of Superior Natural Redstone.

Other Sandstones

During the last decade of the 19th Century, small quarries were operating in various sandstone exposures situated in the southern part of the Lower Peninsula. Sawed and rough building blocks were produced from the Marshall Sandstone in Jackson, Calhoun, Hillsdale, Huron and Ottawa counties. Sandstones of Pennsylvanian age were also quarried in Ionia and Eaton counties near Grand Ledge. Most of this stone is soft when quarried but becomes harder and more resistant to frost when allowed to season. Also, yellowish iron oxidization streaks and spots appear after a few years exposure. The stone quarried near Ionia, on the other hand, became mottled and streaked with red, orange, and yellow, giving rise to a trade name "Rainbow Valley Stone."

Most of the sandstone production in the Lower Peninsula was used in local construction, its quality being inferior to Indiana limestones and Ohio sandstones. The production peak was reached in 1902, coincident with that of redstone and brownstone. Subsequent decline in production was for the same reasons. Presently, production is limited to small amounts of the Marshall Sandstone quarried for flagstone at Napoleon in Jackson County.

Besides the building stones described above, another sandstone produced in Michigan deserves mention. It is called the Sylvania Sandstone. This crumbly white rock, composed almost entirely of clear rounded quartz sand grains, is exposed in Wayne and Monroe counties, Michigan, and at Sylvania, Ohio. Its unusual purity makes it useful for the manufacture of high quality glass.

[1]Geologist, Michigan Dept. of Conservation. (1964)

[2]Number of items in a cord is not stated.

[3]Labor force and production not known.

OIL AND GAS PRODUCING FORMATIONS IN MICHIGAN

By Garland D. Ells and Robert E. Ives[1]

There are many facets to Michigan geology and many of them are important in the search for oil and gas. Others are indirectly related and some not at all. To acquaint the non-geologist with Michigan geology as it relates to the petroleum exploration industry, a few important aspects are summarized and presented in brief.

Since the first geologic survey in 1837, a great amount of information has been accumulated on the geology of Michigan.

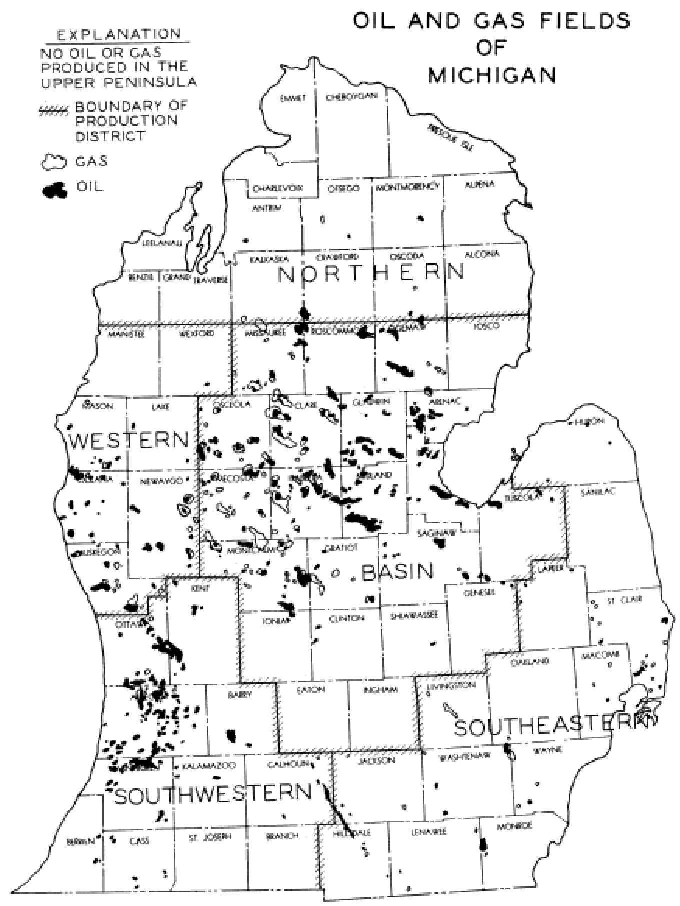

Figure 3. Oil and gas fields.

The general character of the province was recognized at an early date by observation and study of scattered bedrock exposures and, as early as 1860, it was recognized that possible oil and gas bearing rocks occurred in Michigan. However, most of our information has been afforded by the drilling of brine wells, deep water wells, and thousands of oil and gas well tests. Because the state is nearly everywhere covered with a thick blanket of glacial drift, and exposures of various formations are found at widely scattered localities, it is seldom possible to view more than two formations in contact at any one locality. The structure and lateral extent of the numerous formations is, in general, best confirmed by study of drill cuttings and electric logs from the thousands of wells drilled in the province.

The oil and gas bearing rocks of Michigan occupy a shallow depression of the earth's surface generally referred to as the Michigan basin. The basin is centered in the Southern Peninsula of Michigan and extends outward into the surrounding states and the Province of Ontario, Canada. The areal limits are defined by several geologic features which frame the region and help provide the basin characteristics. On the north the basin is bordered by the Canadian shield and to the west it is bordered by the Wisconsin arch. To the southwest and south, it is limited, respectively, by the Kankakee arch in northern Indiana and the Findlay arch in northwestern Ohio. To the southeast and east, the basin is bordered by the Algonquin arch in Ontario, Canada.

In area the Michigan basin encompasses 122,000 square miles. Geographically it includes in addition to the Southern Peninsula and the eastern part of the Northern Peninsula of Michigan, eastern Wisconsin, the northeastern corner of Illinois, northern Indiana, northwestern Ohio, and those parts of Ontario, Canada, bordering Lake Huron, Lake St. Clair and the western end of Lake Erie.

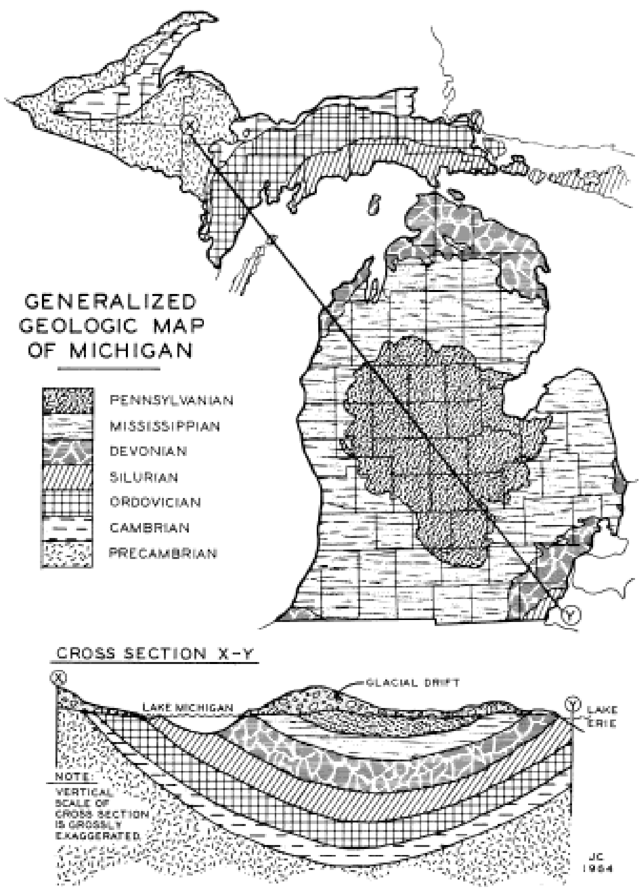

Figure 4. Generalized geologic map of Michigan.

Rocks representing the Archeozoic, Proterozoic, and Paleozoic eras are found in the Michigan basin. Rocks of the Mesozoic and Cenozoic eras, with the exception of the Pleistocene glacial deposits of late Cenozoic time, are not found in Michigan.[2] In Michigan, as in other eastern states, oil and gas are produced from specific beds of rock that are assigned to the Paleozoic era.

In Michigan there are rock units representing each division of the Paleozoic era from Cambrian through Pennsylvanian. Some rocks of possible Permian age are found beneath the glacial drift in the center of the basin. Figure 5 shows the geological terminology commonly applied to the rocks of Michigan.

The layers of rock representing the various Paleozoic divisions are situated in the basin in a manner analogous to a stack of shallow saucers of decreasing diameter (Figure 4). In plan the basin is somewhat ovate in shape in a general northwest-southeast direction. It is relatively shallow in reference to the areal extent and the deepest part is probably in the Clare-Gladwin County region west of Saginaw Bay. In this region the Paleozoic rocks are estimated to be about 14,000 feet thick. The oldest formations of the Paleozoic, those of the Cambrian System, are exposed at the surface in a few places or underlie the glacial drift in the Northern Peninsula of Michigan, eastern Wisconsin, and northern Illinois. The formations of the next youngest period, the Ordovician, are exposed at the surface in a few places or underlie the glacial drift in the same region but generally in a belt basinward from the Cambrian formations. From the outcrop area of the older formations bordering the Michigan basin, progressively younger rocks of the Silurian, Devonian, Mississippian, and Pennsylvanian periods are encountered beneath the glacial drift, or crop out as isolated exposures in circular belts of decreasing diameter toward the center of the basin. Possible Permian beds occur beneath the glacial drift in the center.

Producing Formations

The great bulk of oil produced in the Michigan basin has been from carbonate (limestone and dolomite) rocks of the Devonian System. Ordovician and Silurian carbonate rocks are next in the amount of cumulative oil production. A minor amount of oil has been produced from Mississippian sandstones of the Stray-Marshall and Berea formations and some is produced from sandy beds in Devonian rocks.

Most gas production has been obtained from Mississippian sandstones of the Stray-Marshall formations. Minor amounts of gas have been obtained from the Berea and Antrim formations of Mississippian age, and much smaller amounts from Pennsylvanian age. Some gas production has been obtained from the base of the glacial drift but the amount is very insignificant. In recent years the carbonate rocks of Ordovician and Silurian age have contributed large volumes of gas, much of which is associated with oil production.

There are several formations or intervals of rock in the Michigan basin that are potential oil and gas reservoir rocks but at present no production is obtained from them.

Examples are Sylvania Sandstone (Devonian) and the St. Peter Sandstone (Ordovician). Some carbonate formations such as the Manitoulin Dolomite (Silurian) are potential reservoir rocks in some areas but at present are unproductive. The significant known productive formations are briefly discussed in the following resume.

Mississippian

Michigan Stray and the Marshall formations. The rocks of these formations are primarily sandstones. Most gas production in past years has been obtained from the Michigan Stray and the upper part of the Marshall. Michigan Stray-Marshall fields are confined largely to the basin interior in the Central Basin District (Figure 3). Some oil has also been produced from the Stray in the same district.

SYSTEM-SERIES	PRINCIPAL ROCK UNITS (* GAS PAY, • OIL PAY)	LITHOLOGY
PLEISTOCENE	GLACIAL DRIFT	SAND, GRAVEL, CLAY, BOULDERS, MARL
PERMO-CARBONIFEROUS ?	"RED BEDS"	SHALE, CLAY, SANDY SHALE, GYPSUM
PENNSYLVANIAN	GRAND RIVER	SANDSTONE, SANDY SHALE
	* SAGINAW	SHALE, SANDSTONE, COAL, LIMESTONE
MISSISSIPPIAN	BAYPORT	LIMESTONE, SANDY OR CHERTY LIMESTONE, SANDSTONE
	•* MICHIGAN	SHALE, GYPSUM, ANHYDRITE, SANDSTONE
	MARSHALL	SANDSTONE, SANDY SHALE
	COLDWATER	SHALE, SANDSTONE, LIMESTONE
	SUNBURY	SHALE
	•* BEREA-BEDFORD	SANDSTONE, SHALE
	* ELLSWORTH-ANTRIM	SHALE, LIMESTONE
DEVONIAN	•* TRAVERSE	LIMESTONE, SHALE
	•* ROGERS CITY-DUNDEE	LIMESTONE
	•* DETROIT RIVER	DOLOMITE, LIMESTONE, SALT, ANHYDRITE
	SYLVANIA	SANDSTONE, SANDY DOLOMITE
	BOIS BLANC	DOLOMITE, CHERTY DOLOMITE
SILURIAN	BASS ISLANDS	DOLOMITE
	•* SALINA (SEE INSET)	SALT, DOLOMITE, SHALE, ANHYDRITE
	•* NIAGARAN	DOLOMITE, LIMESTONE, SHALE
	CATARACT	SHALE, DOLOMITE
ORDOVICIAN	CINCINNATIAN	SHALE, LIMESTONE
	•* TRENTON-BLACK RIVER	LIMESTONE, DOLOMITE
	ST. PETER	SANDSTONE
	• PRAIRIE DU CHIEN	DOLOMITE, SHALE
CAMBRIAN	TREMPEALEAU MUNISING JACOBSVILLE	SANDSTONE

DIVISIONS OF SALINA

G UNIT
F UNIT
• E UNIT
D UNIT
C UNIT
B EVAPORITE
• * A-2 CARBONATE
A-2 EVAPORITE
• * A-1 CARBONATE
A-1 EVAPORITE

Figure 5. Generalized chart of Paleozoic rock units and glacial drift.

Editor's note: "Red beds" have now been assigned to Jurassic age instead of Permo-Carboniferous. Also, for most up-to-date uses of all terms see Mich. Dept. Conserv., Geological Survey Chart 1 "Stratigraphic Succession in Michigan," 1964.

Devonian

Devonian age rocks have provided most of the oil produced to date in Michigan. The rocks of the Traverse and Dundee units have been the most widely explored while those of the Reed City and Detroit River units are next in exploration and productive importance.

Traverse Group. The Traverse Group is a limestone and shale sequence of varying thickness. Oil and gas are produced from several porous limestone or dolomite intervals. The uppermost pay is often referred to as Squaw Bay and production from this formation is confined mainly to the Central Basin District. A second and deeper pay is generally assigned to the Alpena Formation or its lateral equivalent. Throughout most of the Traverse oil producing districts in Michigan, the rocks containing the oil pays are generally referred to as "Traverse limestone", an informal drillers' term. Most Traverse production has come from the western and southwestern districts but production is not limited to these districts. In the western district some production is obtained from a porous interval called "Stoney Lake zone". Traverse Group rocks stand second in the amount of oil produced in past years.

Rogers City-Dundee formations. Oil and gas are produced from porous intervals within these carbonate formations. The "Reed City Zone" occurs in the western half of Michigan and is often included as part of the Dundee Formation by some geologists. Rogers City-Dundee production is largely confined to the Central Basin District but some occurs in the Western District and elsewhere. These formations have produced most of Michigan oil in past years.

Detroit River Group. The Detroit River Group rocks are generally divided into the Lucas Formation, the Amherstburg Formation and the Sylvania Sandstone Member of the Amherstburg. The upper part of the group, the Lucas Formation, contains dolomites, limestones, salt, and anhydrite beds. The salt and anhydrite beds are thickest and best developed in the central part of the basin. All oil and gas producing beds are assigned to the Lucas Formation. The producing formations or zones are as follows:

1. *Sour zone*. Oil and gas of high sulphur content are produced from dolomite beds associated with often thick salt beds near the base of the Lucas Formation. In Tuscola County, sulphur oil and gas are produced from a similar interval often called "Tuscola sour zone."

2. *Richfield zone*. This producing interval is often given formation status. Reservoir rocks are dolomites, sandy dolomites, or occasional lenses of sandstone. The producing intervals are below the "sour zone" at, or near, the base of the Lucas Formation. The oil and gas produced from the Richfield does not have the high sulphur content as does the "sour zone" crude.

In past years Detroit River rocks have ranked about third in contribution to the annual oil production totals. Most Detroit River pools are located in the Central Basin District but a few are found in the other districts.

Silurian

The Silurian rocks have been divided into three main divisions which are termed, from youngest to oldest, the Salina Group, the Niagaran Series, and the Cataract Group. Oil and gas are produced from carbonate reservoir rocks of the Salina Group and Niagaran Series.

Niagaran Series. The rocks of the Niagaran Series, where they occur at the surface in various places around the rim of the basin, have been divided into several formations. From well cuttings it is not always possible to identify all the Niagaran formations as they are known at the outcrop. Therefore these rocks are most commonly called "Brown Niagaran" and "White (or gray) Niagaran" by many drillers and geologists. The "Brown Niagaran" is the relatively thin brown or buff colored limestone or dolomite unit at the top of the Niagaran Series and the "White (or gray) Niagaran" is the white or light colored limestones or dolomites which lie below. Oil and gas are produced from porous intervals and from reefs which occur near the top of the Niagaran. Most Niagaran reef fields are located in the Southeastern District, but some are located in other areas.

Salina Group. The Salina Group is a sequence of carbonate, shale, and evaporite rock which has been divided into several formations (Figure 5). Oil and gas are produced from porous zones in the A-1 and A-2 carbonates. A small amount of oil has been produced from a dolomite bed in the E unit in one field in southwestern Michigan. In southeastern Michigan the A-1 carbonate produces gas and oil but the A-2 carbonate has been unproductive. In southwestern Michigan the A-1 produces gas and oil and the A-2 produces gas. Most significant A-1 and A-2 production is found in southeastern and southwestern Michigan.

Ordovician

The rocks of the Ordovician System have been divided into numerous formations. Those of the upper part called the Cincinnatian Series, are shales and carbonates. The middle division consists of the Trenton-Black River groups, and the Glenwood and St. Peter sandstone formations. The Glenwood and St. Peter formations are, respectively, a sandy shale and a sandstone. The lower division, the Prairie du Chien Group, is a dolomite and sandy dolomite sequence.

Trenton-Black River groups. Trenton-Black River rocks are predominately carbonates and are, with a single exception, the sole producing rocks of the Ordovician at the present time. The single exception is the Lime Lake field in southern Hillsdale County which produces some oil from the upper part of the Prairie du Chien Group.

Oil and gas production is associated with secondary dolomitization of fractured or faulted rock which, in the Trenton-Black River Group, is normally a limestone. Some limestone beds in the Trenton-Black River groups appear to be preferentially dolomitized more readily than others but, where fracturing and dolomitization has been intense, oil and gas can be found at various levels within the sequence. All Trenton-Black River pools in Michigan are located in the southernmost counties of the Southern Peninsula.

Oil and Gas Accumulations

Oil and gas accumulations are generally classified as to the type of trap or geological factors that causes the hydrocarbons to be localized. Many of Michigan's fields produce from several different formations and it is possible to have several kinds or variations of traps in a single field. Thus, the ensuing paragraphs cover only the general types of oil and gas traps presently searched for and exploited in Michigan.

Most known oil and gas accumulations in Michigan are related to relatively small areas where the formations have been folded into domes or structures of the anticline type. Oil and gas is generally localized on the highest part of these features but sometimes it is partially located on the flanks. Oil and gas accumulations in Mississippian and Devonian formations are mainly of the anticlinal type and are found throughout the basin. In some areas such as the Central Basin District, anticlines seem to be aligned in northwest-southeast trends.

Salina A-1 and A-2 formations often overlie Niagaran reefs. In these cases potential oil and gas traps similar to anticlines are formed in these rocks because of the underlying reef mound which causes structural closure in the A-1 and A-2 carbonates. Most eastern Michigan reef fields also produce gas and oil from the A-1 carbonate. Some Salina A-1 and A-2 gas pools such as Overisel and Salem in Allegan County produce from anticlinal features related to underlying beds of salt. In these examples, the anticlines are due to localization of salt beneath the closure rather than a reef as in eastern Michigan.

Accumulations of gas and oil are also localized in the porous parts of ancient reefs which are somewhat like those found in modern day seas and oceans. To date, the known producing reefs in Michigan are found in the Niagaran rocks of the Silurian System. Most producing reefs are located in the southeastern part of the state but reef development is known to exist in other areas, especially around and near the margin of the basin. Small reefs may play a part in Traverse oil accumulations in a few Traverse fields.

A few oil and gas accumulations in Michigan are related to porosity development associated with intense fracturing or with faulting of various magnitudes. In these cases, the oil and gas entrapment is not always directly related to anticlines or other types of structural features. Most Trenton-Black River production is associated with porosity traps related to fracturing and faulting and a few Dundee Formation fields such as Deep River and Pinconning can also be placed in that class.

Oil and Gas Production in Michigan

Although petroleum was produced in small quantities from the Port Huron field, St. Clair county, as early as 1886, Michigan's recognition as an oil province begins with the discovery of the Saginaw field in 1925. Most of the oil produced from this field was from the Berea Sandstone (Mississippian) which is found at a comparatively shallow depth. From 1925 through 1927 the Berea was the prime oil producing rock in the state. Production from the Berea amounted to about 4,000 barrels by the end of 1925 but climbed to an all time high of 434,000 barrels by the end of 1927. In 1927 Traverse rocks produced 482 barrels of oil and Dundee rocks produced 1,446 barrels. However, by 1928, as new fields were found which produced from deeper and older formations, production from the Traverse had increased to over 83,000 barrels and that of the Dundee to nearly 278,000 barrels a year. Meanwhile Berea production began a decrease which, with the exception of several slight upward trends, has continued downward since then. Traverse and Dundee oil production continued to increase and finally reached an all time high for Traverse (10,506,884 bbls.) in 1939, and an all time high for Dundee (16,194,612 bbls.) in 1938. Since the peak years, production from these rocks has steadily declined. In 1939, the first year of recorded Detroit River production, oil from these rocks amounted to about 14,000 barrels. As more Detroit River wells were drilled and more new pools found, production steadily increased and finally reached a peak in 1955. In that year over 3,100,000 barrels of Detroit River oil were produced but since then the annual recovery from these rocks has steadily decreased.

Prior to 1952 very little Silurian oil had been produced. Silurian production that year was nearly 2,600 barrels but as these rocks were more extensively explored and new pools discovered, the amount of oil from them steadily increased. In 1961 the annual production from Silurian rocks amounted to over 916,000 barrels.

In 1935 Ordovician rocks (Trenton-Black River) produced 162 barrels of oil. In 1940, over 108,500 barrels of oil were produced, most of which came from Deerfield pool originally discovered in 1920 but largely developed after 1935. From 1940 until 1953, Ordovician production declined to 7,187 barrels in 1953. In 1954, with the discovery of the Northville pool, Ordovician production increased to nearly 168,000 barrels but declined again until the discovery of the Albion-Scipio Trend in 1957. Since then, production from Ordovician Trenton-Black River rocks has increased annually, culminating in over 11,298,000 barrels in 1961. The bulk of this oil came from the Albion-Scipio Trend in southern Michigan.

Michigan's principal gas producing formations, the Stray-Marshall, Berea, and Antrim, show a similar increase and decline over the years. As the younger formations decline in productivity, the older and generally deeper formations have become more prominent as gas producers. Most gas produced from Devonian, Silurian, and Ordovician rocks has been incidental to oil production.

The regions of extensive drilling activity in the state have shifted from time to time. From the Central Basin District where much of the exploration has been directed toward Mississippian and Devonian formations, activity has moved in recent years to the basin margin areas. In these areas the older rocks of the Silurian and Ordovician systems are at a much shallower depth. As production is established in these rocks, an increasing number of deeper tests will be drilled in older producing areas which, at this time, are virtually unexplored as far as Silurian and Ordovician rocks are concerned.

ACCUMULATIVE OIL AND GAS PRODUCTION, 1925 THROUGH 1961

Barrels of Oil

Mississippian		Devonian			Sil.	Ord.
Stray Marshall	Berea	Traverse	Dundee Reed City	Detroit River	Salina-Niagaran	Trenton-Black River
66,523	2,172,814	89,100,216	309,809,813	34,394,701	1,907,139	23,134,622

Cumulative Total .... 460,585,828 bbls.

MCF° Units of Gas

Mississippian			Devonian		
Stray Marshall	Berea	Antrim	Traverse	Dundee Reed City	Detroit River
210,827,850	9,799,811	227,638	7,757,370	48,643,451	28,364,601

Sil.	Ord.
Salina-Niagaran	Trenton-Black River
58,883,169	20,260,782

Cumulative Total 384,772,692 MCF

°MCF means 1,000 cubic feet.

Formations of the Mississippian and Devonian systems have been the most widely explored and drilled over the years. Accumulative production figures show that most of Michigan's oil has come from the Devonian rocks and most of the gas from the Mississippian rocks. In recent years the Silurian and Ordovician have supplied an increasing amount of gas and oil as more pools are found in these older rocks.

[1]Geologists, Michigan Dept. Conservation. Reprinted from "The Michigan Story," published by Michigan Association of Petroleum Landmen, 1963.

[2]Current research indicates that beds long considered to be uppermost Paleozoic are probably of middle Mesozoic age.

HISTORY OF EXPLORATION FOR OIL AND GAS IN MICHIGAN

By Norman X. Lyon[1]

It can be documented that the first commercial oil well in North America was drilled in Ontario, Canada, and, it is not too wild to speculate that hard digging by historians could prove Michigan was the first oil state in the United States.

Few, if any, care to upset the romance of Colonel Drake's oil discovery at Titusville, Pennsylvania in 1859, but it is interesting to note in the unchallenged records that a number of oil tests were drilled in St. Clair County between 1861 and 1887. This play was enough to excite from Alexander Winchell, then Michigan state geologist, the statement that "oil possibilities are quite likely, but one should proceed with caution."

Records show that one C. A. Bailey drilled and produced a two-barrel per day oil well in St. Clair County — just across the river and international Ontario boundary line — in the year 1887. This was nearly 30 years after Drake's "gusher" in Pennsylvania and the first Ontario oil drilling activity. But the records are vague, if not absent, as to what drilling may have been carried out on the "Michigan side" during the early Ontario oil activity.

Michigan historians generally are satisfied to pin the start of the state's petroleum industry to the year 1925, with the advent of the Saginaw city development. This was followed in less than two years with a second "boom" on the opposite side of the state near Muskegon. Then, to silence for all times the pessimists' cries, "there can't be oil in Michigan," oil was discovered in the center of the state — and geological basin.

The basin discovery in 1928 near Mt. Pleasant did more than open "another field" in Michigan. It scotched thinking by many that the center of the basin had little to offer in the way of oil or gas traps. It was discovered, in part at least, by geological review and projection of shallow formation records (Marshall formation as logged on countless Dow Chemical Company brine wells).

Moreover, the basin oil strike immediately created interest throughout the Mid-Continent. Many major companies sent their representatives into Michigan for the first time. More successes followed in the Basin, and the oil and gas industry took firm enough root to stay on — during successive highs and lows in the years which have followed.

Many of the first oil men to reach Michigan moved up from Ohio and West Virginia. Independents were among the first to arrive, and, for one reason or another, independents have continued to the present time to play a significant role in the state's development. As a matter of fact, less than half dozen of the so-called major companies have "held on" in Michigan during the industry's low points. Some have pulled out only to return again at a later date. One reason for this can be credited to the state's still limited oil-gas reserves in terms of the United States as a whole. However, it is interesting to note that Illinois, Mississippi, and Kentucky are the only states east of the Mississippi River that have out-produced Michigan in recent years. All-time, Michigan has produced 460,585,828 barrels of crude (figured conservatively at $2.50/bbl., this is $1,151,464,570 to help fuel Michigan's economy) with runs of 18,900,948 barrels in 1961, about three million below the peak year in 1939.

Following the development rush in the 30's, which was concentrated in the center of the basin, (Isabella, Clare, Gladwin, Mecosta, Roscommon, Midland, and Montcalm counties) three major periods of emphasis as to area and geological horizons have taken place: (1) The west-side boom for 1,200 to 1,600-ft. Traverse production in Van Buren, Allegan, Kent, and Ottawa counties during the period 1937-1942; (2) the North-Central area boom in Arenac, Osceola, Roscommon, Ogemaw, and Missaukee counties in the 40's; and (3) the Scipio-Albion boom in 1958-60 that was followed quickly by a surge of development in eastern Michigan centering in St. Clair County.

Development in much of the 1940-50 period was for Traverse, Dundee, Reed City and Richfield zone production. The more recent era of high activity has been for Trenton-Black River oil/gas in the Calhoun, Jackson, and Hillsdale counties' district for Salina-Niagaran gas/oil in St. Clair and Ma-comb counties. This current activity has resulted in more major oil companies and independents returning to or entering Michigan for the first time since 1959 than in the previous 20 years. This has been reflected in both leasing and development.

Commercial oil or gas, or both, have been developed in 51 of Michigan's 83 counties — with all commercial production in the Lower Peninsula. Out of 36.4 million acres in the state, 327,000 acres have been proven productive with approximately 5 million acres now under lease but not tested.

It is noteworthy that the Michigan oil and gas industry has developed in step with good conservation practices. The Conservation Department and Geological Survey have worked in harmony with industry to the mutual benefit of all concerned. Conservation laws were broadened in 1939 to include proration regulations and Michigan was one of the early joiners of the Inter-State Oil Compact Commission.

Prior to 1939 most fields irrespective of depths or character of the formation, were developed in 10-acre units. There were a few "town-lot booms." Now 20- and 40-acre units are standard for oil and 40- to 160-acre units standards for natural gas.

Comparatively liberal well allowables have prevailed since the 1939 legislation. Generally, wells at depths of 2,100 feet or less fall in the 75-barrel limit and wells in the 4,000 foot class in the 100 to 150 barrel range. Depths, however, are not necessarily the factor of control.

A dozen or more independent oil refineries were built and placed in operation between 1930 and 1950, as well as a number of major company plants not keyed initially to Michigan oil production. Several of the smaller plants have been merged, dismantled or shut down in recent years. Total refining capacity presently is rated at 190,000 barrels per day with 125,000 of this rated thruput in four of the 14 operating plants.

The Albion-Scipio development brought the greatest use of rotary drilling rigs in the state's history. At the peak of the boom, 57 rotary rigs were active in the Trenton play alone. This year, however, the trend was reversed with 37 cable rigs and only 21 rotary rigs active at midyear.

The deepest test in Michigan was drilled in 1947 to 11,012 feet and only one other test has been put down as deep as 10,000 feet. This in itself is misleading because, due to the sharp dig of the geological basin to the center of the state, the Trenton that is produced at 3,500 feet in the

Hillsdale area cannot be penetrated until depths of 10,000 to 14,000 feet are reached in the Mt. Pleasant area. We should have deeper drilling in these areas at some future date.

Michigan moves into 1963 with prospects as good or better than any of its previous 5-year averages. Oil production is relatively steady at 1.5 million barrels per month; there are more companies and individuals with both immediate and long-range exploration plans; leased acreage is relatively high; crude and natural gas demand is strong, and development of both new and old reservoirs for gas storage is at a peak.

Whether or not Michigan historians can ever prove that this state was first, and not Pennsylvania, is questionable, but an analysis provides one thing upon which all can agree — Michigan has had, and now has, a vigorous oil and gas industry.

[1]Publisher, Oil and Gas News. Reprinted from "The Michigan Story", published by Michigan Association of Petroleum Landmen, 1963.

SCIPIO FIND BRINGS BOOM

By William Palmer[1]

Admittedly a toddler compared to its gigantic brothers in the southwest, Michigan's petroleum industry has, nevertheless, poured $835,312,000 into the state's economy during the past 40 years. Petroleum production currently represents slightly less than nine percent of all minerals taken annually from the state's underground warehouse of mineral wealth, but its contribution in crude oil and natural gas in 1960 amounted to $50,620,000.

Since its beginning, the Michigan oil industry has produced 523,558,000 barrels of available crude oil and 938,213,000 cubic feet of natural gas. Currently, there is estimated to be a proven state reserve of 79,441,000 barrels of crude oil and 585,758,000 cubic feet of natural gas — a figure which constantly varies — drawn down by production and added to by new discoveries.

The first major discoveries came in the Clare-Mt. Pleasant area but in the past few years equally important discoveries have occurred in the Albion area. This is the so-called Scipio trend which the newspapers like to call "the Golden Gulch".

Actually it is a gulch to geologists — a narrow, deep underground valley with tricky characteristics not common in Michigan — but it has given this industry a shot in the arm not experienced since the hey-day of Clare-Mt. Pleasant discoveries. It has brought a new and solid prosperity — new businesses, tight residential space, new residents, improved retail trade, more taxes — to the area surrounding Jackson, Albion, Hillsdale. More recently, there have been important new discoveries in the St. Clair area — indicating that even though the industry may have its gradual ups and downs there is still a steady future ahead.

From a peak production of nearly 23.5 million barrels in 1939, the oil industry output declined slowly for 20 years until the Scipio discoveries. Production was down to 25,800 barrels a day in 1958. Last year it was back to 43,600 barrels a day.

This is accomplished by production from 4,748 wells in the state, averaging 11 barrels a day. But all has not been beer and skittles; in the past 35 years or so, the industry has drilled 21,845 wells — and found 46.2 percent of them dry holes.

Fifty of the state's 83 counties benefit from this development of a natural mineral source and 13 percent of the state's surface is under lease for either

[1]Executive Secretary, Michigan Oil and Gas Assoc. Reprinted from Michigan Challenge, Michigan State Chamber of Commerce, November, 1961.

DEAD WELLS USED FOR GAS STORAGE[1]

Turning a depleted natural resource into an asset that is more valuable than it was to begin with is something of a trick . . . but it can be done and Michigan Consolidated Gas Company has done it.

Back in the 1930's natural gas was discovered in the central part of the state, north and south of a line running from Big Rapids to Mt. Pleasant. The gas fields, while not large in size compared to the great gas fields of the Southwest, were still important to Michigan and provided fuel to cities as far away as Grand Rapids for several years.

By the time World War II was over, the popularity of low cost natural gas for home heating had reached a point where the demand far exceeded the supply from Michigan fields and from the one pipeline from Texas to Michigan. The only answer was a new pipeline from the Southwest.

As a result, Michigan Wisconsin Pipe Line Company was formed as an Affiliate of Michigan Consolidated to bring gas here from Texas and Oklahoma. But there was still a flaw. The only way the pipeline could operate economically and provide enough gas for all the heating customers was to operate at full capacity every day of the year. This couldn't be done unless a way was found to store most of the gas delivered during the summer months for use in the winter when demands were seven to ten times greater than in the summer.

Michigan Consolidated engineers turned to the old gas fields for the answer. Armed with records showing every detail of the fields, they decided that a number of the fields could be utilized for storing gas underground at times when the supply from the pipelines would exceed the needs of customers.

Huge compressors were required to drive the gas 1,300 feet down into the earth where the sandstone, from which the gas had been originally produced, would absorb it like a sponge. The shale rock "dome" structure which had trapped the gas for millions of years would keep it from escaping if all the holes drilled in the fields were plugged or restored to operating wells.

The first gas fields to be converted into underground reservoirs were the Austin, Goodwell, Reed City and Lincoln Freeman, all within 30 miles of Big Rapids. These fields have a combined capacity of approximately 44 billion cubic feet of gas.

A 20,000 horsepower compressor station, known as the William G. Woolfolk Station after the late chairman of Michigan Consolidated, was constructed.

It has facilities to remove dirt and moisture from the gas as it flows in and out of the field so it arrives at the customer's home cleaner than the air he breathes.

Huge pipelines were constructed from Woolfolk Station at Austin Field to the three other fields and to Detroit, Grand Rapids, Muskegon, and other cities served by Michigan Consolidated. Michigan Wisconsin built its pipeline directly to the station, and Michigan Consolidated leased its storage fields and station to the pipeline company.

As the demand for natural gas continued to grow, another affiliated pipeline, the American Louisiana Pipe Line Company, was organized to construct a $130 million transmission system from southern Louisiana to Detroit, and additional storage facilities had to be provided.

Michigan Consolidated had anticipated the need and began the huge task of acquiring storage rights from hundreds of property and mineral right owners in the Six Lakes gas field, largest ever discovered in Michigan. The field, located 50 miles northeast of Grand Rapids, covers 23,360 acres in Mecosta and Montcalm counties. More than 50 billion cubic feet of gas can be injected and withdrawn from the field during its storage cycle, enough gas to heat 300,000 homes.

After drilling out or plugging the original gas wells, many of which were difficult to locate, Michigan Consolidated installed a 50 mile gathering system connecting each of the 200 wells with the compressor station. A block-long 20,000 horsepower compressor was completed in 1956 when the American Louisiana pipeline began operation. Another 20,000 horsepower was added last year, making Six Lakes the most powerful storage facility in the world. The company has now invested some $20 million in Six Lakes alone, but it is well worth it according to Hugh C. Daly, executive vice president of Michigan Consolidated.

He points out that nearly 60 percent of the gas delivered to customers during the winter comes out of the storage fields, making it possible to serve more than twice as many customers than would otherwise be possible.

[1]Reprinted from Michigan Challenge, Michigan State Chamber of Commerce, November, 1961.

MICHIGAN COAL BASIN

By Chester A. Arnold[1]

I frequently encounter people who do not know that coal was mined in Michigan, although some coal mining has been going on continuously within the state for more than one hundred years and only recently has ceased on a commercial scale. For a time it was one of the major industries in the Saginaw valley. However, Michigan has neither ranked high as a coal-producing state nor received recognition for coal as it has for automobiles, sugar beets, copper, or Kalamazoo celery. In 1942, one of the last good years in Michigan, less than one percent as much coal was mined as in Indiana, and Indiana produced only one sixth as much as West Virginia, which led the states in bituminous coal output.

The history of coal mining in Michigan goes back to the discovery of coal near Jackson, in 1835, when workmen were digging the foundation for a mill. Small mines were subsequently opened in Eaton, Jackson, and Shiawassee Counties, and in 1860, the first year for which records are available, 2,320 short tons were sold. The output went up to 135,000 short tons in 1882, at which time the state experienced a mild coal boom, but dropped to 46,000 short tons in 1893. From then it rose again, and with only temporary setbacks attained the peak of 2 million short tons in 1907. Production then began to drop off, and the decline through the years was steady but not quite as precipitous as the rise had been. When the Unionville mine ceased to operate in 1946, only one, the Swan Creek mine, northeast of St. Charles was left. This mine had been opened in 1941 by thirteen miners who pooled their savings of $40,000. For the next eleven years the daily output averaged about 80 tons. Even at that rate coal accumulated at the mine faster than it could be sold, and when the pile amounted to 2,500 tons in the late winter of 1952, the miners decided to quit. This event marked the demise of coal mining as an industry in Michigan. Nevertheless, small quantities continue to be uncovered in the clay pits at Grand Ledge. On Sundays and holidays the workmen return to the quarries with trailers and pickup trucks and haul out coal for home use.

Decrease in use of coal in Michigan is not the reason coal mining has gone out. As late as 1950 eight million tons were used annually for house heating, and this is enough to support a thriving industry, if the coal were of the right quality and available in sufficient amounts. But all of the coal seams in Michigan are thin as compared with those in many other states, and the total output of any one mine can never be very great. The coal contains much sulphur which produces odoriferous corrosive smoke. Never having been deep enough beneath the ground to be compacted by pressure, the coal is fragile and pulverizes badly during shipment. Shaft mining is necessary at most places, and since the coal is below the water table the mines flood rapidly unless constantly pumped. The heyday of coal production in Michigan was during the era of the steam boiler. Threshing machines, sawmills, and locomotives, especially those on branch lines, used large quantities of it. With all its faults, Michigan coal does produce a hot fire, but users complain that it burns violently for a short time, spews out clouds of smoke, and if the fuel supply is not immediately replenished the fire promptly goes out.

During the ephemeral coal boom in Michigan during the 1880's the usual flux of rumors spread through the areas concerned. Only a few options on land in any community were enough to set these rumors in high gear. Promoters circulated reports of the vast coal reserves that might exist in unexplored places. Land owners began to ponder over possible values of their holdings, but with results not always to their advantage. The following quotation from a Michigan farmer and reported by the late Dr. A. C. Lane is typical: "There was a fellow around here a while ago who wanted an option on my land, and offered to pay a little cash for it. But I was in no pressing need of money, and I thought if there was anything to be made, I might as well make it myself, so that I would wait and see what his explorations showed up. But that was the last I heard of him, and now I am sorry I did not take his money."

Those familiar with the geology of Michigan held reserved judgments of the coal potentials even at that time. This is shown by another story which Dr. Lane attributed to Dr. Carl Rominger. The eminent geologist was approached one day by a farmer who owned land along the Rifle River and who wanted to know what his property might be worth.

"Well," said Dr. Rominger, "your land is pretty sandy and not very good for farming. If you are offered ten dollars an acre for it, you had better take it."

"Ten dollars an acre! Why a man offered me forty already."

"Didn't you take it?"

"No."

"Then there were two fools instead of one."

The United States Geological Survey has recently made a comprehensive study of the coal reserves in Michigan and the prospects for renewal of the coal-mining industry. It is estimated that about 220 million tons remain underground, which is about three times the amount already mined. The prospects are rather bleak, because the only possibilities for the development of a profitable industry depend upon the discovery of thick beds in unexplored places, and on the invention of new mining techniques which would reduce the cost of working thin seams. During pre-inflation times the cost of mining a ton of coal in Michigan was about $4.00 as compared with $2.55 in Pennsylvania. These costs are higher today in both places, but they bear about the same relation to each other. A suggestion for possibly utilizing some of the thin coal seams in the state is to employ the underground gassification process, but this has not yet been highly successful in places where it has been tried. A major depression like the one we suffered during the 1930's would do more than anything else to stimulate local coal mining in Michigan. In times of economic stress coal mining would offer partial relief in communities where coal occurs.

Although coal mining is no longer a factor in the economy of our state, the great system of coal-bearing rocks is one of its major geologic features. These rocks fill the coal basin, which is a shallow depression in the central part of the Lower Peninsula. Having an area of 11,500 square miles, it extends from Higgins Lake to Jackson. Saginaw Bay lies across its eastern boundary, and the western boundary is an irregular line that at its westernmost limit swings a few miles beyond Big Rapids.

Coal mining during the past has been carried out almost exclusively in the eastern half of the basin, mainly within Bay, Saginaw, Tuscola, Shiawassee, Ingham, Eaton and Jackson counties. Exploratory oil test wells indicate that there is some coal in Montcalm, Isabella, Gladwin, Clare, Osceola and Mecosta counties, but there are grave doubts whether it is there in sufficient quantities to be profitably mined.

The rocks that occupy the coal basin were formed of sand, mud, and silt that accumulated in swamps during the Pennsylvanian period. Their total thickness is about 750 feet at the deepest place, which is in Midland County. These rocks have been divided into three groups. The bottom layer is the Parma sandstone which contains no coal. This supports the Saginaw Group, where the coal occurs. It is about 650 feet thick. Then on top, but only partially covering the Saginaw Group, is the Grand River Group, which, except for the glacial drift, is the latest geological formation in the state. Much of the Grand River Group was torn off by the movement of ice over it.

There are very few places in the state where the coal-bearing rocks can be seen in natural surface outcrops. Probably more than 90 percent of our knowledge of these rocks has been gained from mine shafts, deep wells, and quarries. Oil-well borings are especially informative because of their number and depth. The most extensive exposures of the rocks of the Saginaw Group are in the quarries west and northwest of Grand Ledge. At these places the glacial drift is sufficiently thin to permit quarrying of the shale for manufacture of brick and tile.

All of the Lower Peninsula was dry land at the beginning of the Pennsylvanian Period. The salt water had run off, leaving the sediments of the preceding Mississippian Period exposed to the elements. Erosion commenced again, but instead of much of the sand and silt being carried completely away, it settled in small bodies of water that formed in the low places in the broad and shallow interior. A few streams did flow out and this prevented the basin from becoming a large inland lake. The elevation above sea level was still not great, and several times during the succeeding ten million years slight lowering of the land permitted some salt water to flow in. But these invasions of the sea were temporary, and the last one was still during the first half of the period.

As a rule, the inland ponds and lakes that dotted the basin were not very deep, and the shallower ones developed into swamps. Because the climate was favorable, vegetation was lush and jungle-like in this wet environment. Tons of undecayed plant debris accumulated in the bottoms of the swamps and became pressed into peat, and later into coal. To judge from the extent of the coal seams, which are the best indicators of the size of the swamps, not many swamps covered more than a few square miles, and most of them could be measured in terms of acres. They were mostly confined to valleys between low hills. The water level in these swamps rose and fell intermittently, because of slight fluctuations in the elevation of the land and the huge quantities of sand and silt brought in by the streams from the surrounding hills. Concurrently with the filling and draining of already existing swamps, new ones formed. Streams would then cut channels through the older fillings, partially removing them, and then redepositing the material in other places. There were probably no permanent features within the basin. Even the hills were slowly leveled and the derived sediments were spread throughout the area as fine waterborne sand and mud.

We are not sure just when these swamps first developed or how long they lasted. The first ones probably appeared during the early part of the Pennsylvanian Period. There is evidence that they reached their maximum spread after about 10 million years, and that then they began to shrink and gradually to disappear. The early history of the basin is obscure because the oldest rocks are deep below the surface, and its late history has been partly obliterated by movement of ice over the loosely consolidated sediments. But we are reasonably certain that the ten-million year span, during which the bulk of the shales, sandstones, and coal seams of the Saginaw Group of rocks were laid down, came mostly within the middle of the first half of the Pennsylvanian Period. In addition, if we assume that an equal amount of time passed before the swamps finally disappeared, we find ourselves at or maybe just beyond the middle of the period. It is not impossible that a total of thirty million years elapsed from the time when water first accumulated in the basin until it drained out of the swamps for the last time.

The process of coal formation in the ancient swamps of Michigan was essentially similar to that which went on contemporaneously in Illinois, Indianan, Ohio, Pennsylvania, West Virginia, and other places. The actual situation is rather difficult to visualize, because conditions under which coal forms are totally different from those with which most of us are familiar. Incredibly large quantities of plant material must accumulate to form a coal seam sufficiently thick to have commercial value. It has been estimated that about twenty feet of plant tissue will become transformed into one foot of coal, and since the thickest seams in Michigan are four feet in depth, a layer of vegetable refuse about eighty feet deep had to accumulate in the bottom of the swamp to form this much coal. There are some peat beds in Michigan that are half that thick, but these are minor accumulations compared with what was involved in the formation of some of the very massive coal beds in regions of high production.

[1]Professor of Geology, University of Michigan. Reprinted from Michigan Alumnus Quarterly Review, Aug., 1954.

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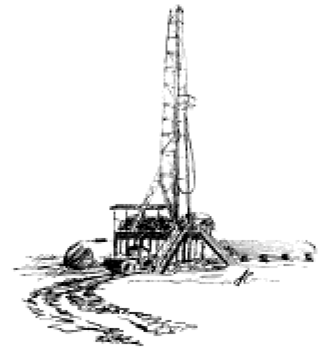

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