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THAT HAVE
PRESENT OR FUTURE SIGNIFICANCE IN MONTANA

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The collection of stories compiled in this pamphlet were originally written for radio broadcast over Montana radio stations. It must be understood that these stories do not cover the whole field of ceramics nor do they in any sense give a complete historical or technical summary of any one field or subject discussed. In each case, those subjects have been treated that apparently have present or future significance in Montana.

The subjects discussed are eleven in number and are written in a popular style, each being told as a separate story. They are titled as follows:

1. The Story of Ceramics
2. The Story of Brick
3. The Story of Roofing Tile
4. The Story of Wall and Floor Tile
5. The Story of Fire Brick
6. The Story of Pottery
7. The Story of Electrical Insulators
8. The Story of Glass
9. The Story of Abrasives - "The Jewels of Industry"
10. The Story of Insulation - "Feather Gold"
11. The Story of Cements, Lime and Plasters
Montana has many natural resources and raw materials that may some day place the state in as enviable a position among the ceramic industries, utilizing non-metallic minerals, as it now holds in the field of metal production.

The name "Ceramics" was derived from an early Greek word "Keramos" meaning "pottery" or "potter's earth". However its derivation is still more ancient than the Greek, for a related Sanskrit root has been found meaning "burnt stuff". From these two conceptions the modern definition of ceramics has been evolved; that ceramics is the utilization of earthy, non-metallic materials which are subjected to high temperatures during the process of manufacture.

The ceramic industry is perhaps the oldest of all man's arts except the making of weapons. Some authorities think that basket weaving preceded the working of clay but the majority of archeologists think that the making of pottery, the first of the ceramic industries, is the older of the two. One thing is certain, the industry was born at the beginning of the New Stone Age some 10,000 years ago in the plains regions of Asia Minor or perhaps in Asia itself. It was there that early man found he could scrape up the mud of certain localities, fashion it into a brick or urn, bake it in the sun, and thus have a hard porous object which was one of the milestones in Man's climb to modern civilization as we know it today. And it was in those ancient times, long before the annals of Ur or Babylon were written on sun-baked clay, that the first circular or rotating machinery evolved, for it was there that the potter's wheel was first used. We know, therefore, that a wheel was used to mold clay into urns long before it was ever used for chariots or for instruments of warfare.
And yet for all its ancient history the ceramic industry has few names or terms that date back beyond the Latin and the old Anglo-Saxon languages. Some of the terms used today have a meaning opposite to that which they had in the beginning. For instance the word "cement" was derived from the Latin word meaning "to cut", and today it means to bind together. From the Latin we have such words as "refractory"; from the Latin "re" and "frangō" meaning to break back, from whence comes the modern meaning; "terra cotta" meaning "cooked earth"; "furnace" meaning "oven"; "insulate" from the word for island; and many others.

The Anglo-Saxon tongue has contributed "tile" meaning cover; "pipe" meaning pipe or reed; "pottery" meaning push; "glass" and "glaze" meaning the same as today; and "clay" meaning earth. Pottery has another derivation from a Latin word given to Roman drinking vessels. The word "kaolin", a white clay used for pottery and chinaware, was derived from two Chinese words "kao" meaning high, and "lin" meaning hill, and dates from the twelfth century A.D., when the Chinese found the white clay that made their ware so famous.

Clays are the principal raw materials used in the ceramic industries. Impure clays find their widest usage in the manufacture of structural products such as brick, tiles, sewer pipes, etc.; the purer varieties are used for terra cotta, stone ware, fire brick and pottery. The white clays, kaolin, find a very wide use in the making of chinawares and chemical porcelain ware. However the greatest use for the white clays is in the manufacture of paper.

Incidentally Montana may have the nucleus for a paper industry utilizing white clays and wood pulp. For there are thousands of acres in the timber in the state which might be used for wood pulp.

There are many other uses for white clays which are not strictly ceramic uses. They may be used as fillers for rubber, oil cloth, linoleum, paints, asbestos products, plasters, kalsomine, and crayons.

A form of clay known as bentonite has a phenomenal variety of uses
extending from the ceramic industry to the purification of sugar, oils and fats. It is used for the manufacture of cosmetics, medicines and for many other modern products. In fact volumes have been written describing the uses of clays in industries other than the ceramic industry.

Next in importance to clays in the ceramic industries is white sand which forms one of the basic materials of the glass industry. Other materials used in ceramics are feldspars, limestone, gypsum, and large quantities of fluxing and coloring agents. The materials used in ceramics embrace most of the more common non-metallic minerals. The variety must necessarily be large because of the diversification and wide field covered by the branches of the industry.

There are eight major groupings or divisions of the industry. Briefly these groups consist of (1) structural clay products such as common, face, paving and sewer brick; floor, wall, roof and drain tile; sewer pipe; and architectural terra cotta; (2) refractories or heat resisting brick and cements used for lining furnaces; (3) pottery, including chinaware and tableware, art pottery, large porcelain sanitary ware for baths, garden pottery; chemical porcelain ware and baking dishes; (4) glass such as window, plate, bottle, optical, table and ornamental glass; (5) abrasives such as artificial abrasives of corundum and silicon carbide or "carbonundum" used in a great variety of grinding operations; (6) insulators, both thermal and electrical; (7) enameled metals such as used for cloisonne art objects of brass, and enameling on steel used for bath room fixtures, refrigerators and electric ranges; and (8) cements, lime and plasters used so extensively in the building trades. Thus the term ceramics may be likened to a pair of pants, it begins singular and ends plural.

There is practically no place in the state where some of the materials used in the ceramic industry are not found in abundance.

Of prime importance to all the ceramic industries is abundant and
cheap fuel. Montana is fortunate in having large supplies of all types of fuels: oil, gas, coal, wood and electricity. In fact few states in the Union are so fortunate in having such a wealth of all the fuels. The Treasure State has one seventh of the total coal supply of the United States and about one twelfth of the coal supply of the entire world. Montana has 15 petroleum and natural gas fields. The state has nearly three million potential hydro-electric horse power of which only about 400,000 has been developed.

Since gold was first discovered in Montana in the 1860's, the state's fame came chiefly from her wealth of metals. For 75 years the non-metallic resources which form the basis of the ceramic industry have been practically undeveloped. Today the non-metallic industry totals only about 5 percent of the value of the metallic industry. It is a conservative estimate that the non-metallics could be developed to produce eight times as much as at present. The state has vast deposits of clay and other minerals for ceramics, as well as great resources of fuel.

Modern science has found a way to use coal deposits in ways other than as a direct fuel. In our next article we will show how much of the 409 billion tons of coal known to occur in eastern and other parts of Montana can be used as the basis for a great industry as yet unknown in this state. This new industry, the result of a triumph of modern chemistry, can not be classified as a branch of ceramics. However it can be classed as a non-metallic industry and is so important that it cannot be omitted from a summary of Montana's non-metallic possibilities.
Millions of bricks are made in Montana each year adding many thousands of dollars to the annual wealth of the state, continuing an industry which legend says a God taught mankind more than six thousand years ago; an industry which has provided nearly all the nations and races of the earth with a building material that has survived in many places for centuries. According to the legend, the great Fish-God Oannes taught the Chaldeans that clay, scooped from a river or lake bottom, dried in the sun, and burned would make a strong and beautiful material from which to build their walls and temples. Because it was a gift of a God the Chaldeans venerated clay tablets on which they wrote their proverbs, their contracts, their dates; a sun-dried brick was stamped with the earliest recorded date of history, 3800 B. C., by Sargon of Akkad, founder of the Chaldean empire. Historians say that one of mankind's greatest discoveries ranking with the discovery of fire and the wheel was the burning of clay to produce the hard, resistant brick. Just when the Chaldeans discovered this art is lost in antiquity. Archeologists have found perfectly preserved bricks in the ancient city of Ur, Abraham's home town; bricks were used in the Tower of Babel, and in the Great Wall of China. By the time of Nebuchadnezzar in the seventh century, B. C., bricks were not only burned but beautifully glazed and ornamented.

It is a far cry from the primitive methods of manufacture employed by the Chaldeans to the power machinery and technical and scientific control
used by the American manufacturer, but the basic principles are the same. Three processes are widely used today: slop - or sand-mold, stiff mud, and dry press methods. In the first the clay is made into a soft mixture and pressed into the mold by hand or machine. In the second method the clay is mixed into a stiff mud, forced through a die into a continuous bar which is then cut into bricks by rotating piano-wire cutters. As many as 100,000 face bricks or 250,000 to 300,000 common bricks a day may be made by these machines. In the third method the nearly dry, granular clay mixture is molded under great pressure into the desired shape. The first two methods require a period of drying. After drying the bricks are burned in the intense heat of the kilns until they reach the desired color, hardness, and durability. The temperature of the kilns vary from 1500 to 2500 degrees Fahrenheit.

Clay has the mysterious property, even to this day not thoroughly understood, of plasticity, acquired through some chemical change when the original lava or granite was disintegrated and laid down by prehistoric seas or rivers. When the clay has been burned or heated the plasticity is lost and cannot be regained. The clays derived from lavas generally burn to a red color; those from granite burn to a buff or white. The colors are due to the impurities in the substance.

Montana has vast deposits of clay but little or nothing is known of the extent or the uses to which most of the deposits of the state may be used. For that reason Montana School of Mines started a survey of the clay resources of the state three years ago. The survey is being carried on by the ceramics department of the mining school under the direction of President Francis A. Thomson, director of the State Bureau of Mines and Geology. In the great rush for the more precious metals such as gold, silver, copper, lead, and zinc, the non-metallics such as clay have been largely overlooked
in the past. With the continued growth and development of Montana, these little-known deposits of non-metallic minerals will become more and more valuable, and important. Clay products of Montana have proven their quality by having been shipped and utilized in surrounding states, even as far as the Pacific coast.

Montana has some nine brick manufacturing plants. In normal years from six to seven million bricks are made and marketed. The value of these products totals many thousands of dollars annually. It is interesting to note that 70 per cent of the value of the finished product represents money paid to employes, and other local overhead, by the manufacturer. Other industries pay out only 20 per cent of the final value of their product in wages, etc.

Although there are many millions of bricks made for special purposes such as fire brick in metallurgical and other furnaces, acid-proof brick, sewer brick, and others, the bulk of the industry is in making common and face brick used in building. The latest development in the use of brick as a building material has been reinforced brick work, combining the grace and thinness of reinforced concrete with the beauty of brickwork. It is said that no other building material offers so great an opportunity for a builder to show his individuality of pattern. Many different colors which mellow and become more beautiful with age have made bricks one of the most attractive building materials down through the ages.
The Story of Roofing Tile

This is the second of a series of articles on the utilization of Montana's abundant but neglected nonmetallic minerals in the ceramics industry. These articles have been specially prepared by W. Wurth Kriegel, instructor of ceramics, and John D. Keyes both of the faculty of Montana School of Mines at Butte.

One of the branches of the clay products industry that may in time add thousands of dollars to the production of wealth for Montana people is the manufacture of roofing tile, an art which has been practised for many centuries in other parts of the world but which is a comparatively new industry in the United States.

Our primitive ancestors were quick to discard their roofs of leafy boughs and flimsy wood when they discovered that a roof covered with thin slabs of burned clay afforded greater protection against the violent vagaries of nature and endured for many generations. Like the discovery of the arts of making bricks and pottery, the discovery of the art of making roofing tile is lost in the dim past of antiquity. When recorded history began the Babylonians, Assyrians, and Egyptians employed burnt clay slabs for their roofs. Later the Greeks and Romans whose architects built so that their castles, temples, and homes would stand for generations, covered their roofs with tile. China and Japan made use of tiles for countless centuries. And for centuries past European roofs have been made chiefly of burned clay tiles. These warm colorful roofs which have stood the test of time for generations, are one of the chief points of interest for the traveler abroad.
It is a strange thing that American architects, knowing the beauty and enduring qualities of tile roofs, neglected the art. It was not until 1875 that the first advance in manufacturing this material was made with the establishment of a modern plant more than a hundred years after the Spanish Padres introduced the art in California and Mexico.

Credit must be given to those trail-blazing priests of two centuries ago for introducing the first successful tile manufacturing in North America. Their ancient missions, standing proudly against hurricane, flood, and earthquake are among the most colorful relics of the arts of the first white men who conquered the western world. The Spanish missions attract thousands of tourists each year who marvel at the fact that the buildings remain today much as they were when the Black Robes carried the white man's science, skill, and religion into an unknown world.

The human thigh was the mold from which the Padres and the native Indians to whom they taught their art fashioned the roofing of the missions. The clay was made into a plastic mass and shaped by the hands over the maker's thigh. This influence is still seen today throughout the southwest. Much of the tile of that region is still shaped by hand and even the machine made product is made to resemble this early work. The resulting tapering effect adds greatly to the beauty of the roofs of that region.

Almost every country has its own distinctive style of roof, but American manufacturers have been able to reproduce each type. As a result we have the straight flat shingle, smooth or roughened like aged wood shakes; the "S" shaped Spanish, the straight and tapered Mission, the tapered Cuban, the flat English, the ribbed French, ancient Greek, and ancient Roman type of tile. Each type is made in a variety of textures.

A recent triumph of skill was obtained recently in California with the production of a tile which had the appearance of a moss-covered clay slab hundred of years old; another product gave the appearance of age by simulating the droppings of sea gulls.
Most of these types are included in the exhibit of ceramics products at Montana School of Mines, one of the most extensive collection of ceramics products in the western states.

Three methods of manufacturing are common used: hand pressing in plaster of paris molds; machine pressing in steel molds, and a third method by which a stiff clay-mixture is forced through steel dies into a long bar and subsequently cut into the desired units. For Montana manufacturers the third method would probably be the best because ordinary brick making equipment can be used with certain minor modifications of the machinery.

Tile is usually made from shale, wherever it is present in sufficiently large deposits. The shale must be such that thin slabs made of the ground material will burn to a dense vitreous substance without warping or twisting. Shales abound throughout Montana but may not all be of the desired quality. Shales are clays which have been subjected to great pressure by nature but which have not lost much of their plastic quality. Plasticity of clay is lost when it is heated to very high temperatures.

By all three methods of manufacture the shales or clays are ground to a coarse powder, mixed or tempered with water, shaped, carefully dried, and then burned in kilns similar to brick kilns. The finished product has one of the natural colors of burned clay, such as yellow, buff, red, brown, purple, or black, depending upon the impurities in the clay and the conditions of burning. Unusual colors or effects are produced by covering the tile with a glazing material and then burning. Most tile, however, are not glazed.

Visitors to Montana have commented on the peculiar lack of color and the drab appearance of the majority of homes and building in the state. Much of this impression could be eliminated if people realized that a third to a half of the exterior of the average building is made up of the roof and that therefore the roof should be given greater consideration. Roofing tile, with its multitude of colors, textures, and patterns, can always reflect the individuality of the builder.
History and archeology has shown that as nations become more mature
the architecture of that nation becomes more lasting. Nearly all the cities
and buildings of ancient races which still stand were built in the hey-day of
that civilization. It has been one of man's characteristics since his beginning
that he has been proud of his ability to create and to build permanently against
the destructive forces of nature. Until comparatively recent times Montana,
together with most of the western part of the United States, was a frontier
in which wood was plentiful and hence the chief building material. In the
older parts of the country stone, brick and tile are gradually replacing more
perishable building material. It may be expected that this effect will be
felt in Montana and the surrounding western states and that there will exist
in these regions a steadily increasing market for burnt clay products as
building materials.

wk-JK
Crete, one of the most noted islands of the Mediterranean sea, became famous within recent months as the home of a leader in the abortive Greek revolution. However it is not unusual to have this beautiful little island attract the attention of the world. It was noted as an outpost of warring Christians and Mohammedans during the Crusades; it was famous during the days of Roman occupation 20 centuries ago; and again when the Greeks and Trojans fought their war on the plains of Asia Minor.

But Crete is famous for another phase of history that has seldom found its way into the histories of the world, for it was one of the earliest places where man first began to decorate the drab sun-dried brick walls of his home with vari-colored bits of burnt clay 1,800 years before the Christian era, thus founding a great industry, the art of making floor and wall tile.

Historians agree that the art of burning clay originated on the Mesopotamian plains in very ancient times, spreading eastward into Persia, India, and China; and westward into Egypt, Asia Minor, Greece, and Rome. The most ancient burnt clay tablet of which we have any knowledge was stamped with the date of 3,800 B.C. at the time of Sargon of Akkad, the founder of the Chaldean empire. But the art in ancient Babylon was restricted chiefly to the making of brick for building purposes, while the art of decorating interior of the walls with mosaic patterns probably was unknown until many centuries later, perhaps originating in Crete.

The art of forming small bits of different colored tile into intricate mosaic patterns for floors and walls was an achievement of which the ancients were justly proud. A mosaic floor uncovered at the site of ancient Carthage revealed that the art at that time had reached a high point of
beauty of design and technique. Prior to this period some attempts had been made in Egypt, the most noted relic of the Egyptian art, the doorway of the Abusir pyramid of Meketkhet in the Third Dynasty. This example is in the form of a mosaic pattern and is thought to precede the Cretan art but is not as highly developed as the latter.

Not until the 12th century of the Christian era did the use of tile for floors or walls receive much favor in Europe. Until then the tile occurred only as small fragments of classic mosaic. Gradually however the floors of churches and other important buildings were tiled in small squares of two colors: a dark reddish-brown and pale orange or brownish-yellow. One of the earliest European examples was in Fountains abbey, England in the 13th century. At the close of the 12th century the abbey church of St. Denis, near Paris, was built with a richly colored tiled floor. By the 15th and 16th centuries this early type reached its highest development only to be superseded by the painted majolica pavements of the Renaissance.

Some of the most attractive tile of the Middle Ages was made and used by the Moors in Spain. The classic work in the famed Alhambra at Granada was an outstanding example. The Moors became the chief makers of tile but their ware, coated with soft glazes, soon wore out and few tile of that period remain today. They perfected the famous Azulejas ware. Their tile was made in eight and ten pointed star designs as well as other geometric figures, colored blue, green, and brown with white lines. Notwithstanding the fact that Moors and Christians were constantly at war with each other the Moors became the chief potters for Christians and manufactured tile for Christian consumption.

Moorish tile reached such a state of perfection in style and design that one California company recently sent a tile expert to Spain and Morocco to study these tile for the purpose of reproducing Moorish tile in
American manufacturing plants.

During the 16th century the English caused a revival of the gothic type tile, glazed for the most part with simple lead silicate glazes. They developed the encaustic process which is at present widely used in the United States and Germany. This process is the pressing of powdered material into steel dies instead of shaping wet, plastic clay to make the tile.

In Colonial times in the United States the most attractive tile was the famous Delft ware, a Dutch product on which the designs were in relief. This tile, mostly of a blue color, is evident in many of the buildings of the eastern part of the United States. It is highly prized. These Dutch tile were contemporaneous with the famous blue Delft pottery.

It is interesting to note that the tile industry in the United States, though comparatively unknown in Montana, is one which in 1927 produced more than 90 million square feet of floor and wall tile valued at more than 27 million dollars. And yet Montana has the materials with which to make attractive tile which might find a market throughout the United States. Montana is sparsely populated but a good quality tile can be shipped to distant markets. An example of this is Seattle tile which has been shipped as far as Porto Rico.

Tile is usually classified as belonging to one of two types: those made from artificial or synthetic bodies, and those made from natural bodies. In the first case a mixture of 50% plastic clay and 50% feldspar and flint is used. In the second type the raw material is taken directly from the natural clay and is not mixed with any other substance. Sometimes a ground talc is mixed with the synthetic type. The ground materials are forced under great pressure into steel dies, fired, glazed in automatic glazing machines and then again fired to fuse the glaze. Another type of tile is the so-called non-slip tile such as is used in stair treads. For this type
clay is ground, mixed with water and the aluminum mineral corundum, and then shaped and fired similar to the other methods.

Wall tile as it is made today is a triumph of modern skill. The individual pieces are usually small, the usual size being about four inches square. The tile used in walls is manufactured with great care; an automatic machine sorts the various pieces so that the thickness of each piece will not vary more than 1.32 of an inch. These pieces are passed through a machine that automatically coats them with a glazing mixture, usually a lead silicate. The pieces are then fired. Any desired color can be produced by varying the composition of the glazing mixture.

Most famous of the wall tiles are the "Faience" and the "Mosaic" types. The former are manufactured much in the same manner as ordinary tile but the glazes are applied by hand painting. The tiles are first burned to produce the hard "bisque" body. The required design is then imprinted on the tile by a carbon imprint. Lines of the design are painted with a manganese paint which prevents the various colors of the design from running together. The different colors are then squeezed on the tile. The Mosaic tiles are much smaller than ordinary wall tile, the units being about 3/4 of an inch on a side. They are generally square or octagonal in shape. Setting of these small pieces in a wall requires considerable skill. One of the recent advances in Mosaic tile has been the fastening of large groups, already arranged in desirable patterns, in units on a sheet of heavy paper. The entire unit can then be applied to the wall or floor and after it has set firmly in the binding cement or mortar the paper is removed.

Mosaic patterns are also used in floor tile in much the same manner as in wall tile. The principal type of floor tile, however, is the so-called "quarry" type. This is a thick tile about four to 12 inches on a side and is generally made in square, rectangular, hexagonal, or octagonal
shapes. The quarry tile is usually made from a natural clay body unmixed with other substances.

Quarry tiles are used widely as an imitation of stone flagging and in the western part of the United States has found its widest use in the patios of the Spanish type houses in southern California.

Undoubtedly some of the Montana clays now being used by the state's clay products manufacturers could be used to make "quarry" tile. This type of tile can be made in modern clay products plants with the minimum modification of present equipment; on the other hand, mosaic and faience tiles using synthetic bodies of clay, feldspar and flint would require new machinery and other equipment.

wk and jk.
Modern civilization with its towering steel skyscrapers, massive iron machinery, great warships and guns, automobile, radio, and telephone, might be said to rest entirely upon a humble, prosaic brick.

For it is only by the use of the "fire" brick from which the great metallurgical furnaces are made that the high temperatures ranging upwards from 1,600 degrees Centigrade can be attained. And the rapid growth of the steel industry has resulted in a phenomenal growth in the manufacture of refractories, or fire bricks, in the ceramics industry. The manufacture of refractories, growing from a negligible value a few decades ago to an annual production of nearly $60,000,000 in the United States in normal years, holds probably much promise for Montana ceramics manufacturers in the future. For Montana abounds in some of the raw materials needed for this important product.

Montana people in the past have been interested chiefly in gold, silver, and the other valuable metals, but it is possible that many gold mines literally exist in the common unromantic clay beds of the state. Fire bricks made from clay having little value in the raw state have a ready market at prices ranging from $40 to $1,000 a thousand.

Man's emancipation from the misery and drudgery of the prehistoric Stone Age began some 6,000 years ago with the Age of Metals. Perhaps accidentally some primitive man discovered that iron could be smelted from ore over an open fire; iron from which he fashioned weapons, and implements with which to build and to write. But the crude iron he melted out of the ore so many centuries ago is a far cry from the alloys of steel made today. And much of the credit for the structure of our modern world belongs to the ancient potter who discovered that clay could be burned to make a granite-
like, fire-resistant brick. Modern metal alloys are made in furnaces of brick.

Like so many of the significant milestones of human civilization, no records exist to tell the identity or the locality of this forerunner of the Metal Age. An iron blade, 5,000 years old, has been found in an Egyptian pyramid. The blind minstrel, Homer, told of the steel working and hardening of ancient Greece, 3000 years ago. Historians know that the use of metals preceded all recorded history; and it is known that the manufacture of fire bricks was necessary for the utilization of metals.

Manufacture of fire bricks in the United States dates from about 1825 when they were traded by the makers for goods. But the scientific manufacture of a high quality brick is of recent date – 1910. The period from 1910 to 1915 was characterized by the development of bricks which would successfully withstand higher and higher temperatures. When the World War began the American manufacturers sacrificed quality for quantity to supply the warring nations, with the result that the industry received a temporary set-back. Since 1920 the manufacturers are again producing bricks of increasing quality.

Montana, with only one manufacturer in the state, is in the last place, among 19 states which manufacture fire brick. Four other western states which also produce refractories are California, seventh; Colorado, ninth; Washington, eleventh; and Utah, eighteenth.

Fire bricks are generally classified under three different types: basic, acidic, and neutral, depending upon the material from which they are manufactured. They are made with the same general technique as the common brick and cost about the same to produce. The value of the finished fire brick, however, is from four to 70 times as great as the value of the common brick.

Refractories made from fire clay are classed as acidic brick. They
are the most extensively used of all three types, having a large market in the steel plants. Acidic refractories are so-called because they are not destroyed by acid slags such as the slags of the steel industry. They are used in the crowns of nearly all metallurgical furnaces.

Silica Brick - a special acidic brick is made from silica ores such as quartzite, which is crushed, ground with water and hydrated lime, molded under pressure, dried and burned at temperatures ranging between 1300 and 1500 degrees centigrade.

Basic bricks are made chiefly from magnesite, the largest bodies of which are found in northeastern Washington. The process of manufacture is similar to that of the other fire brick except that the magnesite is burned or calcined before being fashioned into brick. These refractories are used in the basic open-hearth steel process and wherever basic slags are encountered.

Neutral bricks are made chiefly from Chromite ores molded under heavy pressure and burned at high temperatures. In the past the principal use for this type has been to separate basic from acidic bricks. They have a very high fusion temperature sometimes up to 2,250 degrees centigrade. In Montana the value of Chromite bricks ranges as high as $1,000 a thousand.

Montana has extensive deposits of quartzite from which a high grade silica brick is being made at the present time. These deposits occur chiefly in the mountainous regions of western Montana. Large chromite deposits are known to be present in the southwestern part of the state but up to the present time have not been used in the making of chromite bricks or refractories. An investigation is to be made by Montana School of Mines of these deposits to determine whether or not they can be utilized.

Although Montana has only one plant making refractories today, in
former years a plant at Butte produced a refractory of such quality that it
was shipped as far as Tacoma, Washington, and to many western states. The
brick was made from fire clays occurring near Whitehall. These clays are
unique in that they are the only deposits in the United States which have
been found in pre-Cambrian rocks.

Fire clays may be expected to be present wherever there are large
masses of granite rocks, although sometimes they are found in association
with coal beds.

Wherever man produces high temperatures he lines his furnaces with
fire brick for these bricks withstand temperatures that will reduce the best
steel alloy to liquid. Fire bricks are used in the home furnaces, in the
fire boxes of locomotives, and in the ocean liners and battleships. They are
an integral part of our modern civilization and an important feature of the
ceramics industry of the world.
The Story of Pottery

Man is living in a Golden Age of achievement and progress; he has conquered the air, the surface of the earth, and the depths of the ocean. And yet, with each year bringing changes that have revolutionized industry, science, and society, it is a strange truth that in each housewife's home are articles that have changed but little during the past ten to twenty thousand years.

Pottery such as the most fragile chinaware to the beautiful vase or lamp may be made today by great iron machines in vast factories, but there has been little change in the technique that was ancient before Caesar was born or before the Trojan wars had been fought, even before Abraham led the "Chosen people" from Ur. In fact the great machines themselves would not be possible if it were not for the same material that goes into the most delicate urn. For the iron was melted in a clay-lined furnace.

The making of pottery is one of the oldest of man's arts; perhaps its antiquity is exceeded by the making of weapons from stone. Its discovery was a great day in the history of the human race, for it meant that man could store grain and water, that no longer would he have to follow the wandering game herds for food. Wherever prehistoric man found plastic clay, he mixed it with water and fashioned it into pottery, needing only the pressure of his hands to make any shape his skill could command. Shaping of wood or stone or metal require hard and sharp tools.

Pottery is the product of no one people. Archeologists find fragments of broken pottery in the ruins of the most ancient civilizations and use these fragments to piece together the story of these long forgotten races.
Part of our knowledge of ancient Egypt, Assyria, China, Peru, comes from the mute particles of broken pottery. Discovery of pottery was first made perhaps in the last part of the Stone Age, 15,000 or 20,000 years ago, at the time that man first discovered that he could produce his food from the earth by agriculture. No key has been found that will unlock the full story, and perhaps it will never be found. Some authorities believe the first burned clay jar was the result of an accident. A basket lined with sun-dried clay to hold water was perhaps placed too near the fire and the basket was burned off. The resulting jar was then found to be harder than an ordinary sun-dried clay. This basket design has survived to the present day.

By the time recorded history had begun, in the valleys of the Tigris and the Euphrates, the Sumerians, or Babylonians had a highly developed art of pottery. It is here that we also find the first principle of circular motion machinery, the potter’s wheel. Sometime during the thousands of years that preceded some primitive man had discovered that a flat rock, pivoted in a hole of another rock, enabled him to mold a perfectly circular bowl more easily. So it is probably that ancient potter to whom must be given the credit for the second of mankind’s great achievements, the invention of the wheel.

Egyptians knew and practised the art of glazing burnt clay bodies to produce the glassy luster of their bowls and dishes. During the reign of Hoang-Ti in China, 2698 B.C. earthenware was being made from clay. About 200 B.C. the Chinese discovered a clay that made, in later centuries, the highest grade porcelains the world has known. This clay they called kaolin (kay-o-lin) from the two Chinese words "kao" meaning high, and "lin" meaning hill. The modern world still calls this fine clay Kaolin. And so excellent were the Chinese products that dishes are still called chinaware. Some authorities claim that the Chinese porcelains were produced during the
tenth and eleventh centuries, 700 years ahead of the Europeans, instead of 1,700 years as others claim. Marco Polo brought the first definite knowledge of the Chinese art of pottery to Europe in the 13th century A. D.

The art, like the civilization fostering it, waxed and waned with the civilizations. Thus the Chinese art reached its zenith during the Ming dynasty from 1368 A. D. to 1643 A. D. Since 1736 the Chinese porcelain degenerated to a cheaper commercial product and today no longer leads the world in its excellence. In Italy the famed Majolica ware, so named from the Island of Majorca off the coast of Spain, was highly developed by Luca della Robbia in 1440, but the art declined and nearly disappeared in the 17th century. In the 16th century French potteries assumed world leadership with the work of Bernard Palissey who became the favorite potter of Catherine de Medici. Palissey's ambition and poverty was so intense that he found it necessary to burn his household furnishings in his kiln that he might complete his experiments. Palissey died in prison taking his secrets with him, and setting the industry back many years. In England the famous Wedgewood brought the mantle of greatness to English ware in the middle of the 18th century.

During the 18th century a tidal wave of pottery broke over Europe. Importations of the Chinese porcelains by Dutch traders created a demand for the ware and a search for clays that might approach the Chinese product. Fantastic legends were formulated as to its composition until Bottcher discovered that a wig powder coming from Strassburg contained the precious material. Previously Europeans had believed that the translucent Chinese wares were made of glass, and the French Sevres (pronounced Sayv'рю) china was an imitation. Another attempt at imitation gave rise to the Chelsea (Chel-sey) and Bow porcelains of England. These wares contain about 40 per
cent of the ashes from burned bones. Some day, perhaps, some gruesome-minded person will conceive the idea, with the aid of our present day crematory service and a renegade potter, will preserve for posterity the dust of Uncle Ben, Aunt Minnie, and little Willie, in the form of a piece for the parlor mantle.

Pottery making in the United States started in 1601 on Long Island. Pennsylvania and the Ohio river valley became the center of the industry. White clays were imported from England beginning in 1873, in spite of the fact that enormous deposits are present in North Carolina and Georgia. Trenton, New Jersey, beginning in 1852, became the second important china center. Here the famous Lennox "Belleek" ware is made. This ware has attained historical note with the furnishings of 1700 pieces for the White House at the time of President Wilson. The presidents since Wilson have all used this chinaware.

Modern pottery is a queer combination of the old and the new. Here we find the potter's wheel of 10,000 years ago, dressed up in modern style, side by side with the latest electrically powered and controlled, modern automatic machinery. The wheel is still a flat rotating dish on which the plastic clay is shaped.

Much of the art pottery today is made of a dark burning clay to which colored glasses are added for surfacing. In the finer products such as porcelain and chinaware the body is made up of kaolin, feldspar, and flint or quartz. Indications are that Montana contains large deposits of all of these materials.

The materials are ground together in water and then allowed to age. The resulting creamy material is fashioned in one of three ways. In the first two methods the water is pressed out of the mixture leaving a plastic body which is kneaded into shape or fashioned on the potter's wheel
or some modification of the wheel. In the third method the creamy material or "Slip" is poured into plaster of paris molds which absorb the water. After standing for several minutes the liquid is poured out, leaving a skin of the material clinging to the mold. This skin is allowed to dry and is then removed. The ware is then carefully dried and fired in a kiln at about 3,000 degrees Fahrenheit, known as the "biscuit" fire. The chinaware is now ready for decoration or glazing. This is a glass that is applied to the surface. In art pottery the glass is generally colored. In table-ware it is usually a clear glass which allows the color of the body to show through. Further decorations, such as flowers and geometric designs, are applied by one of several methods either under or over the glaze. Colors in the glazes are obtained from certain metallic salts such as blue-cobalt, green-copper or chromium, red-iron, brown-manganese, etc. The glazes are either sprayed on, or dipped. The pottery is then again fired in what is known as the "ghost" fire. Another type of decoration is the goldwork often seen on table-ware and ornamental pieces. Very fine gold is mixed in an organic solution and applied by hand painting, and the piece is then again fired but at a much lower temperature.

As it has been indicated the three chief materials needed to produce pottery and chinaware are kaolin, feldspar, and quartz. The latter two of these materials occur in great quantities, throughout western Montana but no significant kaolin deposits have as yet been found. However Montana School of Mines, in cooperation with the State Bureau of Mines and Geology is conducting a thorough investigation of the state clay deposits with the expectation that deposits not previously reported will come to light. It is known that kaolin deposits are the result of residual weathering of granite rocks and hence that deposits might be found in association with some of the massive granite formations of the state. Clay samples which
have been assembled from various parts of the state are now being tested in the School of Mines ceramics laboratories to find whether or not they will be suitable for this product.

Pottery manufacture has begun in Washington and Oregon, some plants are operating in California using imported English kaolin. It is possible that Montana will be able to take part in pottery manufacture in the future if the kaolin deposits are found.

Pottery, though a specialized combination of art and science in the modern plant, is one thing that each person can do with more-or-less skill. The ease with which plastic clay can be molded rouses the creative instinct in man, a creative instinct that has its roots back 15,000 years or more. Perhaps some of the pride of our primitive ancestors in their ability to mold clay into any shape has come down to most people living today. Few things hold the fascination that plastic clay holds. And there are few of man's many occupations that offer a greater field for man's creative instincts and imagination as the making of pottery or the molding of clay.
The Story of Electrical Insulators

Of Montana's nearly 3,000,000 potential hydro-electric horse power only about 400,000 has been developed at the present time. All of the power already developed, as well as the immense quantities that may easily be developed in the future must be transported, like any other commodity, from the place of manufacture to the place or places of utilization. Hydro-electric power is manufactured in power plants located usually beside dams or waterfalls far back in the mountains; the places of utilization of the power are in more or less distant cities, industrial plants, and factories. Transportation of electric power is accomplished by means of copper or aluminum transmission wires which are strung across the country side on tall steel towers. In order that the electricity isn't lost by passing through the steel towers to the ground or by short circuiting to the other wires on the tower, each wire must be suspended from the towers on high quality electrical insulators.

It is a well known fact that the greater the voltage of electrical pressure, the farther a spark will leap between two wires. On these high-tension transmission lines from power plants to cities where voltages as high as 220,000 volts are carried, very large and long insulators are used. These insulators, as well as all others whether they are used in home lighting, the work shop, the factory, or the automobile, are nearly always made of either porcelain or glass, both of which are ceramics products.

One of the most interesting stories of prospecting for a finding of valuable mineral deposits in recent decades, is the story of the discovery of a mineral claimed to be essential to the high quality spark plugs necessary in airplane and automobile motors. The World War created so great a demand for spark plugs that would withstand the terrific strain of the combat airplane that American manufacturers were constantly searching for a new process which
would turn out a better spark plug. After much research it was found that a porcelain of the required standard could be manufactured by the addition of an aluminum silicate mineral called "sillimanite". As a result of this work the United States Bureau of Standards advised the manufacturers that the mineral should be artificially. Difficulties of making this mineral however were so numerous that a nationwide scientific prospecting search was made for the three minerals of the sillimanite group that under high temperatures change into the compound found in the high-quality porcelain insulator. Although the final compound was at first called "artificial sillimanite" it was found later to be "Mullite" a very rare mineral found in only one place in the world: on the Island of Mull in the Hebrides near the coast of Scotland. However three minerals are known to change into mullite at high temperatures. These minerals are sillimanite, cyanite (kyanite), and andalusite. Another mineral known as dumortierite also produced similar results but has a slightly different composition.

The romance of the discovery of a large body of andalusite, the first commercial deposit to be found in the world, is one that rivals some of the classic tales of old such as discovery of a bonanza through the kick of a mule, or through a broken wagon wheel. For two fruitless years Dr. J. A. Jeffrey, president of the Champion Spark Plug company, had prospected through the likely mountainous regions of the United States. One night, in the depths of the Inyo mountains of California, Dr. Jeffrey and his prospector guide were pitching camp after dark. In moving rocks to make room for his blankets Dr. Jeffrey was impressed by the weight of one of the boulders. The next morning he examined it and found it to be nearly pure andalusite. After considerable search he discovered that the boulder must have fallen from an overhanging cliff which could be examined only by swinging over the top on the end of a rope. This cliff of andalusite is now being mined, the mineral is hauled on
the backs of burros to the valley 6,000 feet below, transported several miles by trucks, and then shipped by railroad to Detroit where it is incorporated in porcelain bodies used for the manufacture of spark plug cores and chemical porcelain dishes.

It is quite possible that deposits of one of the three minerals of sillimanite, syenite, or andalusite may be found in Montana. These minerals are known to occur in metamorphic rocks such as schists and gneisses, and also in association with pegmatite formations, all of which are typical of the mountainous regions of Montana.

For house wiring, most of the insulators are made of unglazed, quite porous, porcelain in the form of small tubes, knobs, and cleats. This porcelain is very similar in composition to the porcelain dishes commonly used for every day service in the homes.

The three main ingredients are white clay, quartz and feldspar. These insulators, however, are not coated with a glaze or glass such as the dishes, which is not necessary as they are protected from the weather by being used only on the inside of buildings.

For transmission lines, particularly those that carry the electricity for long distances at high voltages, require very large and long insulators. These are usually made of porcelain and in segments varying from three inches to twelve inches in diameter.

The common ingredients of pure white clay, pure quartz, and pure feldspar are ground together with water. The resulting creamy fluid is run through strong electro-magnets which remove any stray iron particles, and into massive filter presses which remove most of the water. The plastic mass or body is removed from the presses and is shaped into the flat, plate-shaped and long tube segments, in plaster of Paris molds and in gas or electrically-heated steel molds. The formed insulator is very carefully dried in automatic
dryers. They are then dipped into a glazing material which, after firing, imparts to the insulator its glossy and impervious surface. Many of the glazes used on these insulators is a natural low fusing clay known as "Albany slip" which may or may not be colored, however, colored glazes are more common. The common colors are brown from addition of manganese dioxide, and blue from the addition of cobalt oxide.

The insulators are then placed in clay boxes on special kiln cars which are run through tunnel kilns from 250 to 300 feet long. The temperature in the hottest section of these kilns is between 2,300 and 2,500 degrees Fahrenheit. This intense heat causes the mineral constituents of the insulator to react chemically to form a dense, hard, vitrified and impervious structure and causes the glazing materials to fuse to a fluid liquid which flows and uniformly covers the outside of the insulator. On cooling the fluid glaze becomes a thin glassy coating which is impervious to weather. All insulators or insulator parts that are used on transmission lines and under high voltages are individually tested with electric currents at very high voltages and at 60 cycles of frequency before they are sent out of the factory or assembled into the large two to five-foot length insulators that are so common on the high voltage transmission lines all over the United States today.

Many electrical insulators are made of glass, particularly, those used for the antenna of radios, and telephone wires on telephone poles. Many of the glass insulators are used for the relatively low-voltage wires in street transmission lines. They are all of the so called "pressed" glass, formed by pressing the molten glass into steel molds.

Insulators have many uses other than those that have been mentioned in radios, radio tubes, electric ranges, stoves, furnaces, thermal couples - in fact, wherever electricity is used. With the further development of the hydro-electric resources of Montana and with the ever increasing application of electrical energy to save man's energy, will the demand for electrical insulators increase.
The Story of Glass

Of all Man's products which have contributed to the development of modern civilization, few have been so important as glass, an article so common that it attracts little attention and yet which has given man his knowledge of the universe, and has enabled him to fight his most mortal enemy, disease.

It was once said that man's greatest achievement was the invention of the telescope; today the common statement is that man's greatest invention is the microscope. Both are made possible by glass. The advancement of nearly every science has been possible to a greater or lesser degree, through the use of glass equipment which can be easily constructed.

Of the many ceramic products used in the household there are none so common as glass. Consider the glass in your own home, the windows, electric light bulbs, table glass, insulators on your radio antenna, bathroom fixtures. There is no material, perhaps, that is with us more from life to death than glass in some form. Man, with eye glasses, can even correct the mistakes of Mother Nature in the human eye.

Although the presence of glass sands is said to be extremely rare west of the Mississippi river, an extensive deposit has been recently found in southwestern Montana of a purity that makes it likely the state may some day be able to join in this highly important part of the ceramic industry.

It is surprising what this transparent substance means to modern
civilization, and yet glass is not a product of modern civilization. Glass making, like so many of arts, has been known for more than 6,000 years. Examples of Egyptian opaque glass dating back to the fourth millennium B.C. are in existence. The Egyptians are believed to have invented the making of glass although its origin is unknown.

The wandering Phoenicians are credited with spreading the glass-making art. The Phoenician city Sidon became the center of the industry and it was there that the art of glass-blowing began about the time of the beginning of the Christian era.

Most of the civilizations of the period made glass, among them the Assyrians and the Greeks. One of the outstanding examples of the Greek glass making is the famed Portland vase, now on display at the British Museum. This vase, originally a cinerary urn, was discovered in the tomb of Emperor Alexander near Rome in the 17th century. While on display at the British Museum in 1845 it was smashed by a lunatic but was later repaired.

The Romans learned their art of glass making from the conquered peoples. However they brought the art to a high state of perfection, mastering most of the technical processes and producing a crystalline product which was ranked with the precious metals in value. They perfected the "Cameo" glass, similar to that of which the Portland vase was made. The Romans invented the process of applying gold leaf to glass, and are believed to be the first to invent window glass.

During the 11th century Venice became the leader in the art. They perfected "Lace" glass, and "Mosaic" glass, with its marvelous coloring. They enameled their products and imitated precious stones, the forerunner of our modern cheap jewelry.

Bohemia became the rival of Venice in the 16th and 17th centuries with their invention of cut glass, after which the Venetian art declined. England contributed much to the art in 1673 with their invention of "Flint"
glass, which though fragile has great brilliance and is used today in our finest table and cut glass. The Romans established the art in England, also in Spain and France.

In America little glass was made until the 18th century. Casper Wister and Henry William Stiegel were very prominent among the early producers. One of America's contributions was the making of "Favrile" art glass by Louis Comfort Tiffany in 1890.

Though glass is exceedingly common, the main ingredient is more common. It is sand. The sand must be pure, clean, and white, having a very high content of silica and a very low content of iron. The other ingredients vary according to the type of glass to be made. Three general classes of glass are made: soda-lime, such as used in window glass, plate glass, bottles, etc; lead glass, such as used in table and ornamental ware of great brilliance; and boro-silicate glass such as used in the manufacture of ovenware like "Pyrex".

One of the most interesting properties of glass is its great strength. It is said that a railroad freight car could be suspended from a piece of glass two inches square, and eight freight cars, or 350 tons, might be balanced on a two inch cube without crushing it. Another interesting property is its refraction of light; it is this property of glass which causes its use as imitation diamonds. However no glass can approach the diamond in the dispersion of light from its cut faces.

Glass making is essentially a simple process but one in which a high degree of technique has been developed. The glass sand and the fluxing materials are mixed together in a furnace and heated to from 2,500 to 2,600 degrees Fahrenheit.

The Romans, who were the first manufacturers of window glass, cast it into the required shape by pouring the molten materials into a mould. In
the 12th century the Anglo-Saxon monk, Theophilus, gathered the liquid on the end of a pipe and blew out a bubble which he split and flattened out while hot, with paddles. This is usually known as the Belgian process and was used until the end of the 19th century. In 1894, J. H. Lubbers, an American, mechanized the process drawing out cylindrical bubbles about 40 feet long. These cylinders were cut into five or six feet sections by scratching the large cylinder with a diamond and wrapping it with an electrically heated wire. They were then cut lengthwise and flattened after heating. At the present time two processes invented shortly after the beginning of the 20th century by a Belgian, Fourcault, and an American, Coburn, are in use. By these methods the glass is drawn upwards in a flat sheet from a tank of the molten material. For plate glass a method used by the Ford Motor Company consists of fusing the material in a tank and passing it continuously through rolls. The glass is then cut, annealed, ground, and polished. Safety glass is formed by laminating plate glass with transparent plastic materials. Bottles are blown by intricate machinery, supplanting the old hand methods.

Colors are produced by the addition of various minerals and mineral compounds. Red glass is produced by the addition of gold, copper oxide, or selenium; amber and yellow by uranium oxide or cadmium sulfide; green by the addition of iron; blue by copper or cobalt; violet by manganese dioxide; milk or opal by bone ashes of alumina and flourine minerals.

Color has a commercial significance other than the beauty of the product. As an example of this beautifying of the prosaic, one glass manufacturer added a small amount of selenium to his product for the making of mayonnaise jars. The resulting pinkish-amber cast gave the mayonnaise a better appearance and increased the sales of the mayonnaise.

Glass making is no small industry in the United States, varying
in value between two and three hundred millions of dollars annually. The volume of glass used is increasing annually. New uses are being found or created daily. One of the recent developments is the placing of glass windows in tin cans used for foods so the purchaser can see what he is buying.

If the desire to see and to know has been, as some believe, Man's dominant characteristic throughout the time his species has inhabited the earth, then surely glass has been his greatest aid. For it is through glass that he sees the greatest and the smallest things of all creation. With it he has separated the colors of the sun, has built great lighted places in which to live, and has stored away his treasures to be seen and admired by those who follow centuries later, but safe against the ravages of time and element.
For nearly thirty years, one of the important industries of the modern age has been allowed to lapse in Montana, so that certain resources of the state have lain idle while other parts of the nation have produced millions of dollars of wealth in which this state might share. In fact thousands of dollars' worth of a mineral, which occurs in quantities in Montana, has been imported from foreign lands capturing a part of the American market.

This mineral, an aluminum oxide known as "corundum" is the chief material used in the abrasive industry in which all kinds of grinding stones, powders, and wheels are manufactured. Next to the diamond, corundum is the hardest known mineral, and like the diamond it is the source of the world's most valuable gems such as the sapphire and the ruby.

In Gallatin county, are deposits of corundum which are reported to extend for miles throughout an easily accessible country containing thousands of tons of ores of this material. Some of the possibilities of these resources can be calculated from the fact that corundum is valued at $78 a ton. Corundum is mined chiefly in two localities in the world today: Naxos, Asia Minor, and New York state. The New York deposits are an impure mineral called "emery", a mixture of corundum and magnetite.

Prior to 1906 Montana was noted for being one of the few places where corundum ore was mined. It is reported that large tonnages were mined, milled, and sold to eastern markets at a value of $200 a ton and a thriving mining industry depended upon the deposits for its existence. Discovery that the compound could be manufactured caused the price to be
lowered to less than half that amount and terminated the Montana production. Since that time the deposits have been neglected, the mines ceased operations and the mills were finally dismantled and sold. Today, however, the improved techniques of mining and milling are causing a revival of interest in the deposits. There is a possibility that Montana in the future may be able to share in an industry that produced more than 31 millions of dollars in 1933.

The scintillating beauty of the crystal forms of corundum, together with the fact that the mineral is the source rock of the precious sapphire and ruby, have caused them to be called the "Jewels of Industry". In fact one industry, watch making, uses millions of sapphires annually. The chief use of the mineral, however, is in the manufacture of abrasives for grinding and polishing.

Chief among the precious gems composed of corundum are the Oriental sapphires, found in many parts of the world, and the ruby. Both these stones have values greatly exceeding the diamond. Montana has become famous as the producer of the blue Montana sapphire; the value of these stones prior to 1929 was more than half the total value of gems produced in the United States. In fact Montana is the only state in the Union where gem mining has been a definite industry. The principal gem areas of the state are the Yogo district, about 75 miles northwest of Helena; Dry Cottonwood gulch, about 12 miles northwest of Butte; and Rock Creek, near Philipsburg.

Lapse of corundum mining in the state was due to the discovery in 1897 by Charles B. Jacobs that the crystal compound could be produced artificially from bauxite, an aluminum oxide chemically combined with water. By 1901 the artificial product was developed in large commercial quantities and gradually supplanted the natural mineral.
The process of manufacturing artificial corundum though simple is quite unusual. Carbon electrodes are suspended in a furnace in which the previously heated bauxite is packed. Electric current is passed through the electrodes for 24 hours producing temperatures exceeding 2,000 degrees Centigrade which melts the bauxite. The molten material is allowed to cool slowly for a week, causing the corundum to form in massive crystals. The melt is then crushed, passed under a magnet to remove iron compounds and screened.

While corundum and its impure relative, emery, form the bulk of the materials used in abrasive manufacture, several other minerals are also important, namely garnet, silica sand, volcanic ash, and pumice. In addition to these natural minerals are "carborundum", which is artificially made from silicon and carbon, and boron carbide. Both these artificial products are harder than corundum.

Large quantities of garnets have been found in Montana. Early day placer miners found these semi-precious stones in gold bearing gravels in many parts of the state. The region near Virginia City in the Ruby valley is particularly noted for garnets. Garnet is the name given to aluminum silicate chemically combined with iron, magnesium, or calcium.

That man could produce in his laboratories a substance harder than any natural substance except diamond is one of the interesting facts in the discovery of "carborundum" by Doctor Edward G. Acheson in 1891 at Monongahela, Pennsylvania. Doctor Acheson assisted the late Thomas A. Edison in developing the carbon filament of the original incandescent lamp. While experimenting with electric currents he fused a mixture of clay and coke and discovered in the melt a few tiny, bluish, diamond-like crystals. He found these crystals to be harder than corundum and sold a small vial of them, about 10 carats, at the rate of $880 a pound. Since then the substance, to which the discoverer gave the name "carborundum", has been produced in
large commercial quantities and sells for $103 a ton. Today the substance is made by a method similar to that used in the manufacture of artificial corundum, except that the furnaces are of different types.

Abrasives are used for the manufacture of all kinds of grinding wheels and equipment, from the small dentist drill to the massive wheels used in pulping wood for the paper industry. The abrasives are crushed and screened to obtain uniform sizes. These grains are then cemented by one of five types of binding material: clays, sodium silicate or water glass, shellac, rubber, and bakelite. If clay is used as a binding agent the material is shaped into wheels and then fired. This is the most common method. Abrasive grains as fine as 600 mesh are widely used for polishing and grinding powders. Some of these fine powders are coated on paper and cloth. Abrasives are also used in the manufacture of non-slip floor tile and stair-treads. Of late years super-refractories have been made from both the alumina and silicon carbide abrasives.

It is said that Man's need for a grinding stone has been imperative ever since the first weapon was shaped from iron found in meteors. Without a substance which could sharpen the metal the weapon was less effective than a crude stone arrow or spear head. This would give the art of grinding an antiquity extending back for more than 6,000 years. But historians claim that grinding was practised even 20,000 years ago when human beings first fashioned stone axes, spears, and arrows.

Grinding, instead of becoming a lost art with the progress of the human race, has been found to be one of the most essential parts of our modern metal and machine age. It is only by the use of hard abrasives that cutting edges can be applied to tools and weapons. Without abrasives the most common of our everyday instruments would be impossible; it would be impossible to produce optical instruments such as telescopes or microscopes;
it would be impossible to manufacture the surgeon's knife, the mechanic's drills and lathes, the ordinary razor blade, the automobile, the clock.

It is a queer paradox that as machines are developed to withstand greater and greater wear from abrasive substances, man has developed harder and harder abrasives to make the machines.
The Story of Insulation - "Feather Gold"

Within the past few years Montana has achieved national prominence as a leader in an industry that should in the near future become a vital concern to homeowners everywhere. Growth of a demand for air-conditioning of dwellings, business offices, and even railroad cars, has caused industrial leaders to search for and develop various types of insulating materials. Montana's mineral deposits of some of these materials are claimed to be among the most important in the United States.

The trend toward air-conditioning while not apparent to the casual observer is revolutionizing the building industry. Air-conditioning requires that the walls and ceilings be built to prevent heat from passing through, thus retaining the heat in the winter, as well as keeping the building cool in the summer. This desirable effect has been attained by the use of insulating materials. Not only is the preserving of a constant temperature comfortable and economical, but according to medical science, is essential for health. In most buildings, when the mercury outside has gone down to 30 or 40 degrees below zero, much fuel is consumed to produce warmth that is lost. Where does it go? It is common knowledge that heat rises. It has been observed that in the spring when the housewife's fancies turn more or less heavily to thoughts of spring housecleaning, stained streaks are prominent across light colored ceilings. The location of each board and lath under the plaster or paper is evident from these streaks: the lighter spots mark the overlying boards while between are dirty strips that show where much of the heat from the winter's fuel passed through.

Insulation has two principal functions: retention (or exclusion) of heat, and sound control. In order that a material be suitable for use as
an insulator, it must contain confined or entrapped air spaces. These spaces may be the space between small fibers, threads, flakes, or particles of a fluffy material.

Montana has many deposits of three of the minerals from which insulating materials are made: vermiculite, an altered mica; asbestos, a fibrous silicate; and diatomaceous earth, a material composed of the skeletons of millions of minute water plants. Of these vermiculite is by far the most important in Montana. In fact Montana is chief producer of vermiculite in the United States, other significant deposits being found in North Carolina and Colorado.

Although vermiculite was known to mineralogists as early as 1824, more than a hundred years passed before its commercial significance was realized and the substance marketed. That it was finally marketed was due chiefly to a Montana man, the late E. N. Alley, who accidentally discovered the large deposits of the mineral at Libby in 1916.

Mr. Alley, while examining a quartz vein for the presence of gold and other minerals, found that the heat from his candle against the side of a mine drift caused a flake of a mineral substance to unfold and turn a golden color. At a loss to explain this phenomenon Mr. Alley gave the substance the name of "Feather Gold" because it resembled flaky gold but was light as a feather. Mr. Alley was quick to realize the commercial significance of a mineral which would swell to 16 times its original volume upon heating and experimented with it for several years. In 1925 he began to market the substance on a small scale and today vermiculite has found a market throughout the country.

Vermiculite was so called from the Latin phrase "to breed worms" because of its property of curling and assuming worm-like shapes upon heating. It is said that in Japan it was a popular amusement to throw vermiculite on hot coals to see it unfold and expand.
The mineral weighs about 100 pounds a cubic foot before heating and about 6 to 20 pounds a cubic foot after heating. The Libby deposits are very extensive. A report in 1929 stated that the deposits appeared to be at least 100 feet wide, 100 feet deep and 1,000 feet long. Several smaller bodies of the mineral and also of asbestos occur in the same region.

At least three other large bodies of vermiculite occur in Montana: one in the Bearpaw mountains in Hill county; one in the Sapphire mountains, near Stevensville; and another in the Tobacco Root mountains, near Pony in Madison county. The first two are known to be of commercial size, but little is known of the third deposit.

Because of its golden color, vermiculite has a number of other uses besides as an insulator. It is one of the components of gold or gilt paint. Another use has been in the making of plaster. Experiments at the University of Kentucky proved that plaster of 60 percent of vermiculite and 10 percent of asbestos made a plaster that would not disintegrate when placed in a red hot furnace. Fireproof insulating board made from vermiculite will withstand 1700 degrees Fahrenheit without appreciable contraction or expansion. For these reasons the substance is widely used as an insulator for fire-proof vaults, for fireless cookers, for refrigerators, and so on. Insulating bricks and cements are also made from it. It is also used as a lubricant and is said to be similar to graphite.

The asbestos minerals are of varied composition, being hydrated silicates of calcium, magnesium and iron, but are generally termed amphibole asbestos. They are all of a fibrous structure such that they shred into a soft pulpy mass. Purity, length, and flexibility of fiber are important both in value and variety of uses. The bulk of the asbestos in the United States has been produced from Georgia with small amounts from Maryland, Virginia, North Carolina, California, Idaho and Washington. The mineral is reported to occur in the same locality as the Rainey Creek
vermiculite deposits and in the Cliff Lake District near West Yellowstone in Montana. Asbestos finds its widest use in the manufacture of steam pipe coverings, fire-proof roofing materials, insulating plasters, cements, and boards. It is also made into thread and woven into cloth. The known deposits of asbestos in Montana appear to be adapted mainly to local uses. The greatest local use might be in the insulation of houses by the use of the powder or ground material.

Diatomite, sometimes called diatomaceous earth, is found in ancient shallow seas and swamps. The material is usually quite soft, and occurs in beds of varying thickness from a few feet to several hundreds of feet. The material is made up of the deposited skeletons of very minute water plants which may be seen only with the aid of a microscope. The most extensive deposits found in the United States occur at Lompoc, California. The manufactured products of these deposits are sold under the familiar trade name of "Sil-O-Cel". With the many recurrences of seas and lakes in Montana during the millions of years of geologic time, it would seem very likely that bodies of this material would be found. In fact, deposits have been described as occurring along the Missouri River in the Townsend Valley district, in west central Montana. Diatomaceous earth finds its greatest use in the insulation of furnaces, both in the powdered form and as bricks. At Lompoc some of these bricks are cut directly from the bank by means of gang saws. Other bricks are made by combining the powdered material with plastic clay, shaping and burning in a method similar to that employed in the manufacture of common brick. As a suggested use in Montana, powdered diatomaceous earth would make an admirable insulator to be poured between the studding of a frame house, and between the ceiling joists on top of the plaster in all houses and buildings.

Another mineral insulating material that someday may become important in Montana is the manufactured product, mineral wool.
are known by two names, rock wool and slag wool. Rock wool derives its name from the fact that certain clay-lime rocks are used as the raw material. Slag wool, as the name implies, is made from steel furnace slag. The process of manufacture is the same in both cases. The rock or slag is charged with coal or coke into furnaces where it is melted. A stream of the molten material flows into a room where it is struck by a jet of high pressure steam, breaking it up into small globules. As these small globules are driven through the air by the impact of the steam, they leave a tail following behind much like the tail of a tadpole. It solidifies in the form of thin glassy threads which are utilized in this form or made into insulating pads and blankets. Mineral wools find their most extensive use in insulating ovens, refrigerators, houses and buildings.

The prophecies of controlled living conditions within the home; that is, cool houses in the summer and well-ventilated, warm houses in the winter, are just beginning to be realized. As progress is made in this direction, Montana's insulation resources will find wider and wider usage, as Montana's "feather gold" is doing today.
The Story of Cements, Lime, and Plasters

During the past billion years much of Montana has been submerged by a succession of great oceans, each of which remained millions of years. Today the evidences of these pre-historic seas are found in thousands of feet of sediments that cover much of the area of the state.

Among the sediments left in those periods so ancient that the hard-shelled forms of life were just beginning, are great deposits of the three non-metallic minerals which are the raw materials of an industry totalling more than 400 million dollars in the United States in normal years, the industry of manufacturing cements, lime, and plasters. These three non-metallics are limestone, clay, and gypsum.

Limestone is one of the most abundant of all minerals. In fact it is said that in Western Montana there is no place where thousands and thousands of tons of more or less pure limestone do not occur within a radius of 40 miles. The purest limestone in Montana is said to occur in the Madison formation, a sedimentary bed laid down about 300 million years ago. However other formations carry thousands of feet of limestone generally less pure than the Madison Limestone. One of the oldest limestone formations of Western Montana occurs in the Belt group which was deposited perhaps a billion years ago. Other formations of varying age include the Jefferson, Gallatin, Ellis, Amsden, Cherry Creek, and Kootenai formations.

Most of Montana's limestone was deposited through a chemical reaction on calcareous substances carried in the sea water, causing a precipitation of calcium carbonate. Still other deposits are made up almost entirely of the skeletons and shells of billions of organisms some of which are so tiny that 500 of them laid end to end would not measure an inch. This type of limestone is
very like that now being deposited in the coral reefs of islands in tropical seas.

It is a significant thing that the trails of most of the modern arts and sciences lead back to Ancient Egypt and beyond Egypt to Babylon; nearly all the foundations of modern life and work were laid 6,000 years ago by those remarkable civilizations. We know that the Egyptians burned lime and gypsum to form cement which they used in their great works, although it is likely that adhesive clays were the first cementing materials applied between large blocks of stone and smaller units of sun-dried clay. One of the very earliest descriptions of burning lime has been left us by Pliny, Roman writer of the first century of the Christian era.

However, for all its very ancient origin, the art of making cement as we know it today progressed but little during some 5,000 years. Very little is known of any progress before the 10th century when the English originated the modern art of manufacture. Efforts of John Smeaton to invent a cement with which to build the famous Eddystone lighthouse in 1756 resulted in what is called "hydraulic cement" today. Smeaton discovered that by adding some clay to the limestone before it was burned a cement was formed that would harden under water and would continue to harden for long periods of time. The "Roman cement" made by Parker in 1796 was similar to Smeaton's product. Vicat in 1813 and Frost in 1822 continued to improve the cement by various techniques.

Portland cement had its inception in 1824 when Aspdin assigned that name to a prepared mixture of limestone and clay which he said "equalled the best Portland stone in strength and durability." The Portland cement of today, however, was first made by I. C. Johnson in 1845.

Portland cement is made by an essentially simple process. Limestone and clay are ground separately, mixed in a ratio of about three parts limestone to one part clay and passed through a rotary kiln where the materials are
burned to form clinkers about the size of a small nut. The clinkers are ground to a powder, to which is usually added about two percent of gypsum; the resulting product is called Portland cement. The function of the gypsum is to retard the setting of the cement.

It is interesting to note that the machinery involved in making cement are among the largest units used in any manufacturing process. Rotary kilns are long steel cylinders, sometimes 12 feet or more in diameter and 300 feet or more in length. They are lined with fire brick to withstand high temperatures and are slightly inclined so that the ground limestone and clay will pass through as the cylinder is constantly revolved. The high temperatures, partially fusing the powdered materials, and the rotating motion form the small, round pellets.

Portland cement has the peculiar property of hardening under water because the water reacts chemically with it to produce a rock-like substance. This property of cement is its most important characteristic and has led to an infinite variety of uses for which other materials are so well adapted. Very strongly acid water or very alkaline water, however, tend to disintegrate cement unless some provisions are made to counteract or prevent such disintegration. One Montana company is now preparing a cement for use at the Fort Peck dam; the cement is of special composition to counteract strongly alkaline waters.

Cement is used chiefly in making concrete. Cement, sand, gravel, and water are mixed in definite ratios. Both the sand and gravel must be clean and free from clay. The sand should be quite angular. Generally speaking the amount of water is kept at a minimum in order to produce strong concrete. Since cement gains strength from a chemical combination with water, concrete should be kept moist while setting. Concrete is used chiefly in construction work, the greatest advance in recent years being reinforced concrete where the material
is strengthened by use of steel rods imbedded in the concrete. Other uses are the manufacture of tile, sewer and drain pipe, and bricks.

Montana has two cement plants, one at Trident which was erected in 1910, and one at Hanover, built in 1918. The Trident plant has a capacity of 2,250 barrels a day, and the Hanover plant has a capacity of 1,000 barrels a day. In 1929, 568,000 barrels of cement were made in Montana which were used in Montana and in four surrounding states, also in Canada. A Butte concern has recently begun production of concrete roofing tile and face brick of a variety of colors and textures.

Lime used in manufacture of plasters and mortars is obtained by the simple process of heating limestone to drive off some of the carbon dioxide gas. The resulting material is known as "quick" lime and may be marketed either in this form or in "slaked" form. Slaked lime is quick lime which has been mixed or hydrated with water. The present trend is to market the slaked lime in powder form, commonly called hydrated lime. Many plasterers, however, prefer to slake their own lime at the time they are mixing their mortar or plaster. To make mortar slaked lime is mixed with sand and enough water to make a plastic mass. This mortar is the cementing material between bricks, tile, or any other units of building material.

Mortar hardens because of the fact that the carbon dioxide gas which was driven off when the limestone was burned, again combines with the lime to form limestone as the mortar sets. Mortars may be made stronger and harder by adding some Portland cement to the mixture.

Lime has been manufactured at Elliston, Red Lodge, Dillon, Divide, Limespur, Butte, Lewistown and elsewhere. There are two operating plants at the present time, one at Elliston and another at Missoula. Missoula lime has been shipped as far as Seattle where it has successfully competed with the famous Deer Harbor lime of Puget Sound.
The mineral gypsum is the third mineral of the group which form the raw materials of a 400 million dollar industry. Gypsum, a calcium sulphate, was deposited from the waters of ancient seas. Most of the calcium in sea waters occurs as a sulphate and hence wherever great marine bodies existed large deposits of gypsum might be found. These deposits are frequently found in association with rock salt deposits.

Gypsum is sometimes called "selenite" from the Greek word "the Moon." According to an old legend the mineral was so-called because it could be found only when the moon was on the increase. It is more probable, however, that the name arose from the fact that light is reflected from the surface of gypsum in a soft, moon-like glow. Still another name for the mineral is alabaster, a particular form of the mineral having a characteristic color and appearance.

Gypsum is prepared for plaster by heating to drive off most of the water chemically combined with it. Three-fourths of the water of crystallization is driven off after which the gypsum is ready for use. If used in this form the plaster would set so rapidly that it would be difficult to work and shape. In order to retard the setting process some organic materials are added. Usually some slaughter house products are the organic substances used. For wall plasters some fibrous materials are added for strength, such fibers usually being wood or cattle hair.

When the prepared gypsum is mixed with water it forms a plastic mass which hardens as the water chemically recombines to produce a substance quite similar to the original gypsum. Most gypsum plasters are used in wall plasters and stucco, but a large part is marketed as "plaster of Paris" which finds wide use in surgical casts, molds, art casts, and similar work. Most of the art work in the interior of theaters is made by fashioning plaster of Paris into the required shapes which are then gilded.

The United States produces more gypsum than any other country in the world, producing two-fifths of the world's supply. Two-thirds of the amount
produced in the United States is used for the manufacture of plasters.

Montana has two gypsum plants, one at Heath and another at Hanover. Large deposits of the mineral are known to occur in Jefferson, Meagher, Cascade, Fergus, and Carbon counties. The layers of the mineral are from 5 to 30 feet thick in the Ellis and Quadrant formations. Other deposits, about 40 feet thick, occur in the Chugwater deposits but are not being developed.

When one considers that clays and shales make up about 60 percent, and limestones about 10 percent, of all the sedimentary rocks of the earth's surface it is small wonder that these minerals have been among the chief building materials of the human race for centuries. One of the phases of pioneer life in the United States was that lime kilns were so common that nearly every community had one. Here the early settlers burned lime for their plasters whenever the need arose. As time passed and cement and lime companies became more centralized the home kilns gradually disappeared until today only ruins of most of them exist. The home burned lime, although only a passing phase in the life of earlier days, was nevertheless a significant one. For it seemed as though Nature not only supplied Man plentifully with building materials, but made the art of refining the materials for ready use so simple that every man could manufacture his own.

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