University of Arizona
Bulletin

LIME ROCKS
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Entered as second class matter November 23, 1915, at the postoffice at Tucson, Arizona, under the Act of August 24, 1912. Issued weekly, September to May.

PUBLISHED BY THE
University of Arizona
Bureau of Mines
CHARLES F. WILLIS, Director
TUCSON, ARIZONA
1916-17
BIBLIOGRAPHY.

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INTRODUCTION

Lime rocks were probably the first rocks that found a large demand among ancient peoples, and this demand has continued through all the ages down to the present time. The demand first arose because of its value as a building and ornamental stone, and as a binder for structural purposes.

A classification of lime rocks, with a general description of the sources, methods of manufacture, uses, industry, and of Arizona deposits may be of interest, and it is hoped that this bulletin will be of both interest and value.

CLASSIFICATION OF LIME ROCKS

There are two methods of classifying lime rocks: first, by structure and second, by composition. Lime rocks occur in a great variety of forms, differing in origin, color, texture, hardness, structure and composition. These types all have one common property in that they consist largely of the mineral calcite (calcium carbonate, CaCO₃) or the mineral dolomite, (a combination of calcium and magnesium carbonates, CaCO₃, MgCO₃). No natural limestones are absolutely pure; in fact, they are as a rule, quite impure. The most common impurities are magnesium carbonate (MgCO₃), iron oxide, and carbonate, silica (SiO₂), alumina (Al₂O₃), clay, carbonaceous matter, and various other minerals. Limestones derive their wide variety of colors, as a rule, from these impurities.

While reading this classification, it should be remembered that the varieties are very apt to mingle, and that it is quite seldom that one finds any one variety in its purest form.

Structural classification:
1. Compact, dense, fine-grained limestone.
2. Crystalline limestone (non-metamorphosed).
3. Crystalline limestone (metamorphosed).
4. Oolitic and pisolithic limestone.
5. Fossiliferous limestone.
6. Shell limestone (fragmental, including corals).
7. Chalky limestone.
8. Conglomerate limestone.
9. Cherty limestone.
10. Fresh water marl.
11. Travertine, or calc sinter.
12. Stalactitic and stalagmitic limestone and onyx marble.

Chemical classification:
1. High calcium.
2. Magnesium limestone.
3. Dolomite.
4. Argillaceous limestone.
5. Arenaceous and siliceous limestone.

ORIGIN OF LIMESTONES

Limestones belong to the class of rocks known as sedimentaries. Sedimentary rocks are generally composed of materials derived from older rocks, either by mechanical or chemical decomposition. These materials are deposited (1) under water, forming marine sedimentaries, and (2) on land surfaces, forming terrestrial sedimentaries. The chief agent of transportation of these materials is water in motion; wind also is an important transporting agent. When material is carried in solid form, the deposits are said to be mechanical. When carried in solution, and precipitated without the aid of organisms, the deposits are said to be chemical. There is another type of sedimentary rock known as organic rocks. As the name implies, these rocks are formed from an accumulation of the remains of various organisms; the type also includes deposits formed from solution with the aid of organisms. Limestones may include all three types of sedimentaries.

Origin of varieties based on texture:
1. Dense, fine grained limestone: This type of limestone has been formed by deposition in quiet waters, at some distance from the shores, where only fine grained particles would be carried. In some cases, however, this type may be formed by chemical precipitation.
2. Non-metamorphosed crystalline limestone: These rocks were probably formed by a mixture of mechanical and chemical processes of deposition. The crystalline structure is due to re-crystallization through the agency of water.
3. Metamorphosed crystalline limestone: (Marble.) Marble is a granular crystalline limestone, or dolomite in which re-crystalliza-
tion has resulted from the effects of heat and pressure, usually aided by the action of water to some extent. This change is affected with practically no chemical change.

4. Oolitic limestone: This is a granular limestone, composed of small, rounded, concretionary grains, cemented together. When these grains are very small, the rock is called oolitic limestone; as they become large, the rock is called pisolithic limestone. These types are formed by the deposition of calcium carbonate about pre-existing nuclei, such as sand particles.

5. Fossiliferous limestone: This type is so named from the presence of a noticeable quantity of remains of organisms. The origin and general structure may correspond with any other types.

6. Shell limestone: This is a form of fossiliferous limestone, in which the rock is made up of shells, shell fragments and shell sand. Coquina is an example. Coral limestone is similar, except that it is made up of fragments of corals.

7. Chalky limestone: Chalk is composed of microscopic shells of foraminifera. It was probably deposited in quiet seas, far enough out to escape foreign debris.

8. Conglomerate limestone: As the name implies, this is merely a conglomeration of limestone fragments. It is a rare type.

9. Cherty limestone: This is limestone containing nodules of chert. Chert bands are deposited alternately with bands of limestone. Chert nodules are probably most commonly secondarily deposited, although they may be nodular inclusions.

10. Marl: Fresh water marl is a fine grained, loose, earthy material, largely composed of calcium carbonate. It is found in lake basins and marshes, and has been precipitated from solutions either chemically or by means of vegetable and animal organisms.

11. Travertine: Travertine, or calc sinter, often called calcarous tufa, is a massive, porous to compact limestone, deposited by waters of springs or streams along their courses.

12. Stalactitic and stalagmitic limestone and onyx marble: Stalactites are pendant columns of calcium carbonate, deposited by water dripping from the roofs of caverns in the earth. Stalagmites are the forms that rise from the floor towards the stalactites and are, of course, formed in the same manner. Onyx marble is a chemical deposit of calcium carbonate, usually considered as precipitated by deep seated hot spring waters.

Varieties based on composition:

(1) High calcium limestone: This is an exceptionally pure variety, being almost free from magnesium, as well as other impuri-
ties. It carries from 93 to 99 per cent or more of calcium carbonate, and may embrace all the structural varieties excepting cherty limestone.

2. Magnesian limestone: Magnesium limestone is that containing magnesium carbonate in any quantity up to 45.65 per cent. In most cases the percentage is either small or large. This variety may include practically all structural types, excepting organic limestones.

3. Dolomite: Dolomite is a mineral composed of the double carbonate of calcium and magnesium (CaCO₃, MgCO₃). It contains 54.35 per cent calcium carbonate and 45.65 per cent magnesium carbonate.

4. Argillaceous limestone: Argillaceous limestone contains a varying proportion of clay materials, usually and mainly silicate of alumina.

5. Arenaceous and siliceous limestone: Arenaceous limestone contains fine particles of siliceous sand deposited with the calcareous sediments. Or silica may be deposited as quartz in the form of grods and veins, and again, the limestone may have a siliceous cement.

USES OF LIME ROCKS

Lime rocks are used for structural purposes, including building stones, paving, crushed stone; for ornamental purposes, in the case of marble and onyx marble, and sometimes travertine; as a furnace flux; for the production of lime; as a component of various cements; and for various minor purposes, including its use in sugar refineries, alkali works, glass factories, paper mills, carbonic acid plants, and as a fertilizer.

Lime rocks find their most important use in the production of lime. This product finds a wide variety of uses, which may be grouped as follows:

1. Building lime, used either alone or with cement in making mortar for masonry work, or for plaster or stucco.

2. Finishing lime, used either alone or with plaster of Paris for the white coat of plaster.

3. Agricultural lime, used as a fertilizer.

4. Chemical lime, used in the various chemical industries. Here it finds a wide use, because it is the cheapest base known. It is used in making sand lime bricks, glass, as a water softener, in the manufacture of soda ash, caustic soda, bleaching powder, calcium carbide, illuminating gas and ammonia, sugar, insectides, paper, paints, and many other things.

Probably the most important use of lime rocks is in the cement
industry. Limestone is widely used in the manufacture of Portland and puzzolan cement. A natural mixture of limestone and clay found a wide application as a cement material until the perfection of Portland cement.

As a structural material, limestone is not so important, as it was formerly. It is still used for exterior construction work to a considerable extent, however, and also as crushed stone for road building. Some varieties of lime rocks, particularly marble and onyx marble, are in great demand for interior construction, ornamental and monumental stone.

Lime rocks also find a wide use in the metallurgical field; as a furnace flux for the reduction of various metals.

MINING AND PREPARATION OF LIME ROCKS

Lime rocks are so plentifully distributed over the surface of the earth that it is not necessary to dig under the ground for it. It is in every case produced by quarries. The care taken in quarrying the rock depends, of course, upon its intrinsic value, and the use to which the product is to be put. Fine marbles, and limestone for monumental and ornamental purposes, is carefully sawed out, in blocks of enormous sizes. Or, owing to jointing and bedding structures in the limestone strata, it is often possible to blast the rocks without materially injuring it. For ordinary structural and lime-producing purposes, the rock is blasted out without much regard to the shape of the product.

In preparing lime from the various lime rocks, the raw stone is crushed to a proper size, placed in kilns, and burned. The size to which the stone is crushed depends upon its hardness and density, and varies from 3 or 4-inch blocks up to large pieces requiring the full strength of a man to handle. Kilns vary greatly in design and size. The size is largely controlled by the market the kiln must supply. The simplest type of kiln is built of an outer shell of sheet steel and an inner stack of fire brick, with a large fire box near the bottom, extending on both sides of the stack and through the outer shell. The bottom of the kiln is elevated above the ground, is conical in shape, and is constructed so that the burnt lime may be drawn from the kiln through it. Kilns of this type may be built to almost any required dimensions.

Lime is sold as "quick" lime, and as "hydrated" lime. Hydrated lime is prepared by crushing quick lime to pieces of one inch size, and then mixing with water in special hydrating machines. As placed on the market, quick lime is sold in lump form, or as pulverized lime.
It may be shipped in bulk, barrels or in casks. Hydrated lime is sold in sacks or in paper bags.

Lime rocks for structural purposes are either cut or blasted from the formations. The product so obtained is marketed as “dressed” or “rough” stone. The “dressed” stone is further cut into desired shapes, and often polished. “Rough” stone is sold without further treatment, unless it be to reduce the size of the product.

Lime rocks for use in the cement industry need not be pure, that is, high calcium rocks. In fact, argillaceous limestone is commonly used for this purpose. The stone is quarried, crushed to the proper size, mixed with the other ingredients of the cement, the mixture burned to a clinker, which is ground to a very fine condition, and marketed in barrels and sacks.

When used as a furnace flux, lime rocks are crushed to moderately small sizes, and mixed with the rest of the furnace charge.

THE LIME ROCK INDUSTRY

Lime rock is one of the most widely quarried rocks. The production of limestone in the United States in 1913 was valued at $38,745,429, an increase of over $2,000,000 over 1912. Every state in the country produced to some value, varying from $6,328 in Arizona, to $6,200,000 in Pennsylvania. These figures do not include the production of limestone which was burned for lime.

The total value of lime produced in 1914 was $13,247,676 with a tonnage of 3,380,928. This is less than the 1913 production and also less than 1912. Imports of lime in 1913 were valued at $48,438 and exports of the same year at $212,345, both the imports and exports showing an increase in value over 1912. No figures giving the value of lime produced for the various purposes for which it is used are available.

Limestone produced for structural purposes in 1913, excluding marble, but including building, road making, railroad ballast, paving, etc., had a value of $26,159,036.

Limestone produced for furnace flux in 1913 was valued at $11,103,989. That sold to sugar factories, used for agricultural purposes, and for various minor purposes, was valued at $1,932,504.

The total value of marble produced in 1913 was $7,870,890. Vermont, Tennessee, and Georgia are the most important marble producing states.

LIME ROCKS IN ARIZONA

Lime rocks occur in many parts of Arizona. The formations in general are of two geologic ages. In north central Arizona occur
the Redwall and Kaibat formations, both of Carboniferous age. Limestone formations of the southern part of the state are both Carboniferous and Devonian. The best known of these formations are the Naco and Escubrosa at Bisbee, and the Modoc at Clifton-Morenci.

Some limestone is quarried locally in Arizona for the production of lime. In 1913 there were three plants in operation, which produced 18,292 tons of lime, valued at $99,550. This lime is used almost entirely for building purposes.

No limestone in any important quantity was quarried in Arizona for structural purposes in 1913. Limestone used as a furnace flux was valued at $3,628, and that sold to sugar factories at $2,700.

There are several deposits of marble, and also onyx marble in Arizona. So far as known to the author, these deposits are not actively worked at present, although commercial production has occurred in past years. Probably the most important and best known marble is that found near Bowie. Marble of good quality also occurs in the Santa Rita and Santa Catalina mountains, near Tucson; in the Chiricahua Mountains, near Dragoon; and near Bouse in the Colorado River region. Onyx marble is found in Yavapai County, at Mayer and Cave Creek; and near Greaterville, in Pima County.

PRICES AND ECONOMIC CONSIDERATIONS

No definite price can be set on lime rocks in general, but approximate prices will be quoted for various products.

Building stone is worth from 20 to 35 cents per cubic foot for rough stone, and a minimum of about 50 cents per cubic foot for dressed stone. The price of dressed stone is, of course, very variable.

Crushed stone brings an average price of about 54 cents per ton. Furnace flux was worth about 50 cents a ton in 1913. Ground limestone, used as a fertilizer, was worth about $1.56 per ton in 1913.

The average price of lime in 1913 was $4.07 per ton, but it was slightly less in 1912, and also in 1914, both of these years falling below $4. The price of Arizona lime was higher, being $5.44 per ton in 1913.

Limestone in Arizona is a rather uncertain money-maker. Its largest use is in the production of lime; after that, its chief value is as a furnace flux, and some lime is sold to sugar factories.

There is plenty of limestone, and of good quality, not to mention the high grade marbles found, but the greatest difficulty is to secure a market.
There is no danger that the demand for limestone will ever cease. Its application to the building industry, particularly in the making of cements and mortars, would alone be sufficient to call for a large production. The variety called marble, and onyx marble, are assured of a strong demand as ornamental and monumental stones. The demand for lime for chemical purposes will always be great, due to its cheapness.

In Arizona there will always be small local markets for lime, and so long as the smelters continue to operate, limestone will be in demand as a furnace flux.