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The Geographical Review

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CORAL AND THE LIME INDUSTRY OF MAURITIUS*

H. J. WALKER

CORAL reefs provide one of the commonest, but nonetheless distinctive, types of coast in the tropical seas. The importance to man of these organically formed reefs has long been recognized, but almost entirely in an indirect relationship; the direct use of the coral itself has rarely been considered. The best-known use is probably as jewelry, which, along with the supposed magical and medicinal powers of coral, helped foster early intercontinental trade. In recent years less romantic uses have been developed. During World War II coral was dredged from the reefs of Pacific atolls and used as road metal in the construction of roads and runways and as the aggregate in concrete.[1] Another, though seldom reported, use of reef coral is as the raw material in the production of lime. Lime production by burning coral has attained industrial status in southern India[2] and possibly in Haiti,[3] but it is in Mauritius that the industry has been developed to the highest degree.

Physical and Cultural Base of Lime Production

Mauritius, some five hundred miles east of Madagascar (Fig. 1, inset), is a tropical volcanic island with a coast line 130 miles long. About 85 per cent

* During the Southern Hemisphere winter of 1959, a field study of the Mauritius coast was made by Dr. W. G. McIntire, Dr. Jonathan D. Sauer, and the writer under the auspices of the Coastal Studies Institute of Louisiana State University, with financial support from the Geography Branch, Office of Naval Research. The writer is indebted to the many people of Mauritius whose willing contribution of time and knowledge facilitated the preparation of this paper. Reproduction, in whole or in part, is permitted for any purpose of the United States government.

[1] See D. Lee Narver: Good Concrete Made with Coral and Sea Water, *Civil Engineering*, Vol. 24, 1954, pp. 654–658.

[2] N. Y. S. Knibbs: India's Lime and Limestone Industry, *Pit and Quarry*, Vol. 51, 1958, pp. 86–89.

[3] John M. Street: Historical and Economic Geography of the Southwest Peninsula of Haiti (Department of Geography, University of California, Berkeley, 1960), pp. 367–368.

➤Dr. Walker is assistant professor in the Department of Geography and Anthropology, Louisiana State University, Baton Rouge.

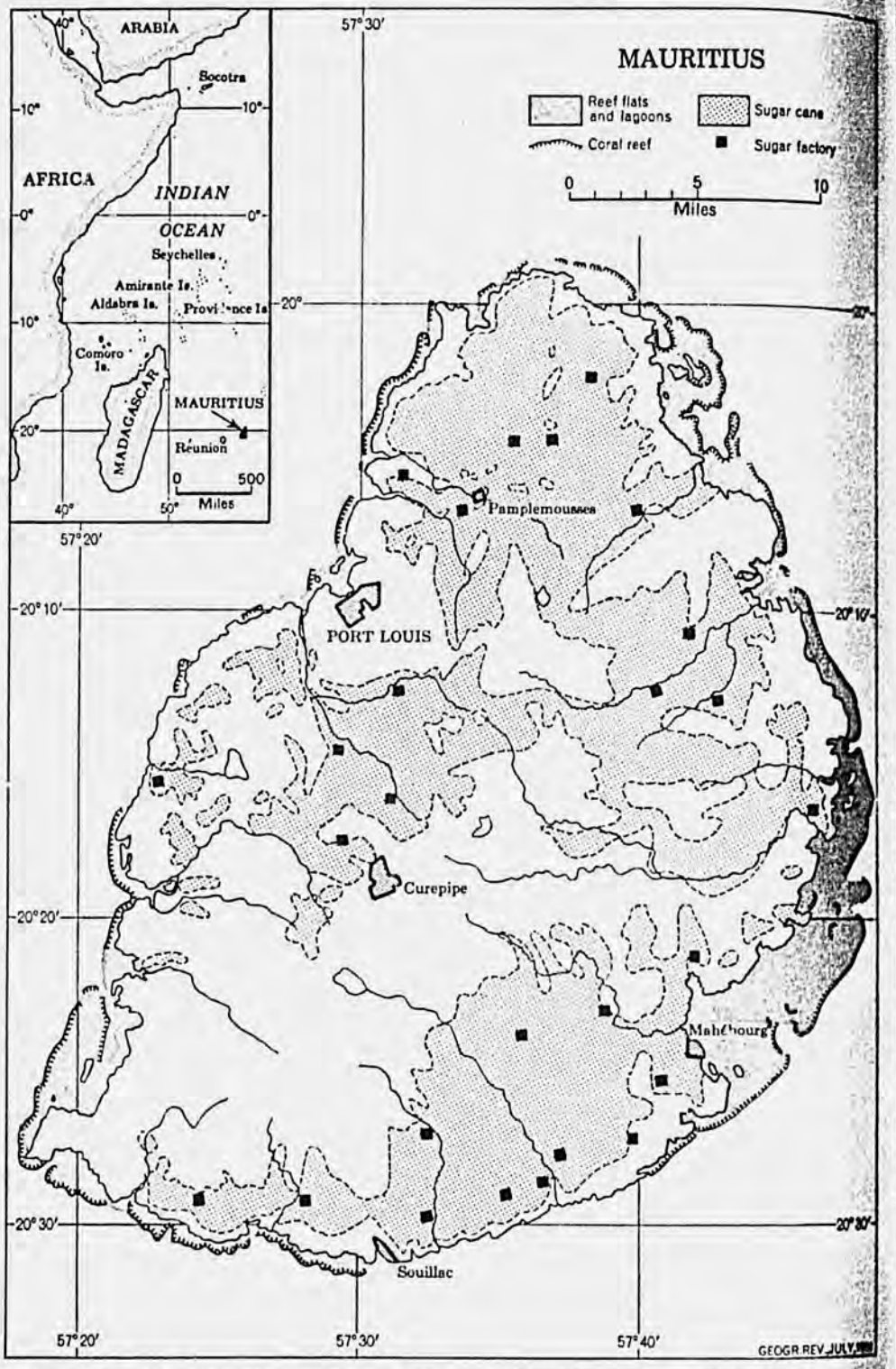

FIG. 1—Selected physical and cultural features of Mauritius. Adapted from the map of Mauritius, Series Y6[illegible], Edition [illegible] GSGS [illegible] published by D. Survey War Office and Air Ministry, 1957.

of the coast is fringed with coral reefs (Fig. 1). Only three major breaks occur in this coral girdle—a ten-mile stretch on the south coast, and two, with a combined length of seven miles, in the west.

The seaward margin of the reef is in general less than half a mile from the coast, though off the southeast coast near Mahébourg and in certain other sections the distance is as much as three miles. Some parts of the reef front can be reached on foot over extensive reef flats; others, only by using boats to cross lagoons of varying width (Figs. 2 and 3). A great variety of corals, including numerous species of *Porites*, *Acropora*, *Fungia*, and *Pocillopora*, are found in the shallow lagoons, on the reef flats, and, most abundantly, on the front of the reef. Many of these corals possess physical and chemical properties that give them value as a source of lime.

A need for rather large quantities of lime is also present. Mauritius, with more than 600,000 people, has a population density of about 900 to a square mile. Since Napoleonic days the population has been almost entirely dependent on the sugar industry. About 40 per cent of the 720 square miles is planted to sugar cane (Fig. 1), which accounts for more than 98 per cent of the exports.[4] Twenty-four sugar factories now produce more than 600,000 tons of sugar each year and, in the process, use some 5000 tons of lime as the principal chemical agent in clarifying the cane juice. Virtually the same amount of lime is used by the building trades, and small quantities are used also in the tanning industry and as a soil conditioner.[5]

Technology of the Industry

Reef coral, which is nearly pure calcium carbonate, can be converted into lime, or calcium oxide, by the addition of heat. Ideally, thermal dissociation of calcium carbonate takes place at 897° C., but in practice a slightly higher temperature is commonly used.[6] The heat is obtained by burning the raw material in kilns (Figs. 4 and 5). All limekilns in Mauritius are vertical structures, ranging in height from ten to fifty feet and in diameter from six to fifteen feet. Basalt blocks, numerous on this volcanic island,

[4] H. C. Brookfield: Problems of Monoculture and Diversification in a Sugar Island: Mauritius, *Econ. Geogr.*, Vol. 35, 1959, pp. 25–40; reference on p. 25.

[5] The *Yearbook of Statistics No. 12, for 1957* (Central Statistical Office, Port Louis, Mauritius) reports (p. 78) that the total output of lime in Mauritius in 1957 was 10,200 metric tons. Of this amount, 5700 tons was of first-grade quality, which is used mainly by the sugar industry. According to "The Economic and Social Structure of Mauritius" by J. E. Meade and others (London, 1961), the 1958 production total was 9600 metric tons (p. 145).

[6] S. Staub and E. Limfat: The Improvement of the Lime Industry in Mauritius, *Rev. Agricole de l'Île Maurice*, Vol. 33, 1954, pp. 226–231; reference on p. 226.

FIG. 2—Reef flat, with lagoon in background, at low tide near Mahébourg. The Indian coral fisherman is exhibiting a pile of "platin" he has pried from the reef.

FIG. 3—A typical Mauritian pirogue loaded with platin, taken from the section of the reef shown in Figure 2.

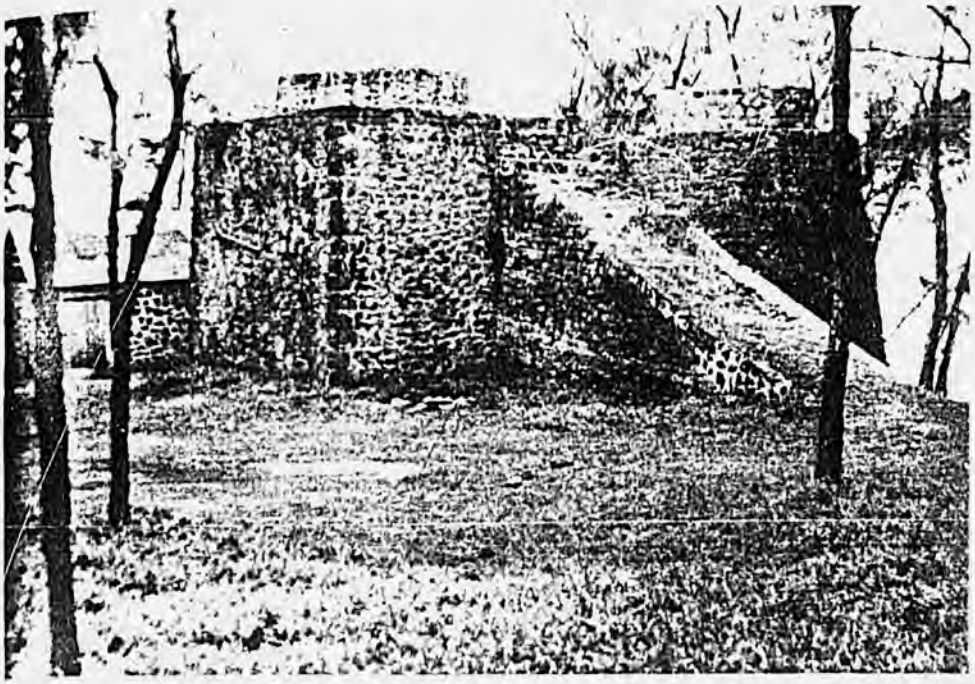

FIG. 4—Limekilns at Pte. Corail de la Prairie. The setting is representative in that most kilns are located adjacent to a lagoon and are surrounded by *Casuarina* and *Stenotaphrum*.

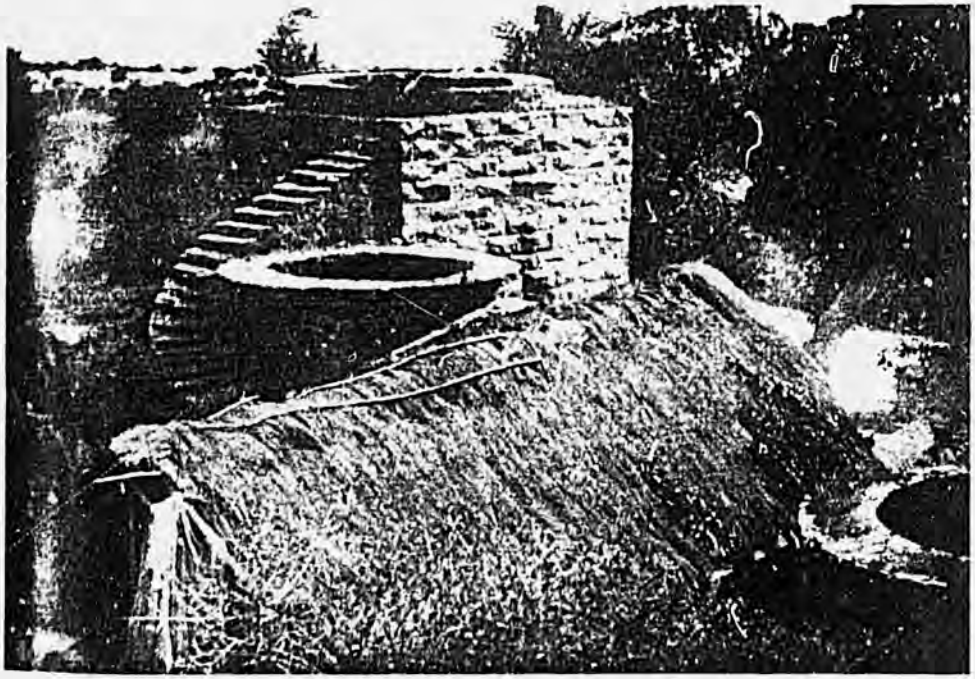

FIG. 5—Kiln assemblage near Port Louis, including a thatch-roofed work and storage shed.

are usually used in kiln construction, and even in place of refractory bricks by many kiln owners.

Although the kiln is the heart of the industry, one other structure is always present—a multipurpose building in which the burnt coral is slaked, graded, sacked, and stored. Most of these buildings are stone huts with thatched roofs (Fig. 5), and many are in disrepair. Additional equipment is relatively simple; it consists of a few axes, shovels, hoes, baskets, screens, sprinkling cans, and sacks.

Most of the coral is obtained directly from the reef, though any that washes into the lagoon or up on the beach is also collected. The coral that grows in the lagoons is in general too soft for economical lime production. Because of the heavy surf along the south and east coasts, coral carried shoreward from the reef edge is commoner there than along the west coast. Most of the coral fishermen pry the coral from the reef with iron bars at low tide (Fig. 2). Only rarely is it taken from water more than three feet deep, though along the west coast some coral fishermen use long-handled pincers to loosen and lift coral from water as much as fifteen feet deep at the edge of the reef.[7] Coral is carried from the reef in pirogues (Fig. 3) or on rafts either to the kilns or to the beach, where it is placed in piles. The coral piled on the beach is usually taken to the kilns by oxcart or donkey cart (Fig. 6), but trucks are also used. Some kiln owners have reduced transportation costs by the construction of docking facilities near the kiln. Regular coral fishermen average two or three trips to the reef a week; the number depends on such factors as weather, kiln capabilities, and sailing distance.

Coral fishermen are generally selective to the extent demanded by the kiln owner. Although many operators burn any type of coral or shell, including the giant clam, most prefer either a heavy, platelike *Acropora*, locally called *platin*, which is taken in large slabs from the reef flat (Fig. 2), or a light, spherical *Porites*, known as *tête de mort*. Platin is denser than tête de mort and therefore provides more lime per unit volume and is more economical to process. On the other hand, tête de mort has fewer impurities and thus yields a higher-quality lime.[8] High quality is more important in cane-juice clarification than in construction.

Coral fishermen gather by hand about twenty-five thousand tons of coral a year, most of which comes from the reefs off Port Louis and Mahé-

[7] M. Paul Koenig: Les coraux et leur rôle économique dans l'industrie sucrière, *Trans. Royal Soc. of Arts and Sciences of Mauritius*, Ser. C, No. 11, Port Louis, Mauritius, 1943, pp. 7–14; reference on p. 12.

[8] S. Staub and F. Durocher-Yvon: The Manufacture of Lime for Use in the Sugar Industry and for Building Purposes, *Rev. Agricole de l'Ile Maurice*, Vol. 23, 1944, pp. 59–61; reference on p. 60.

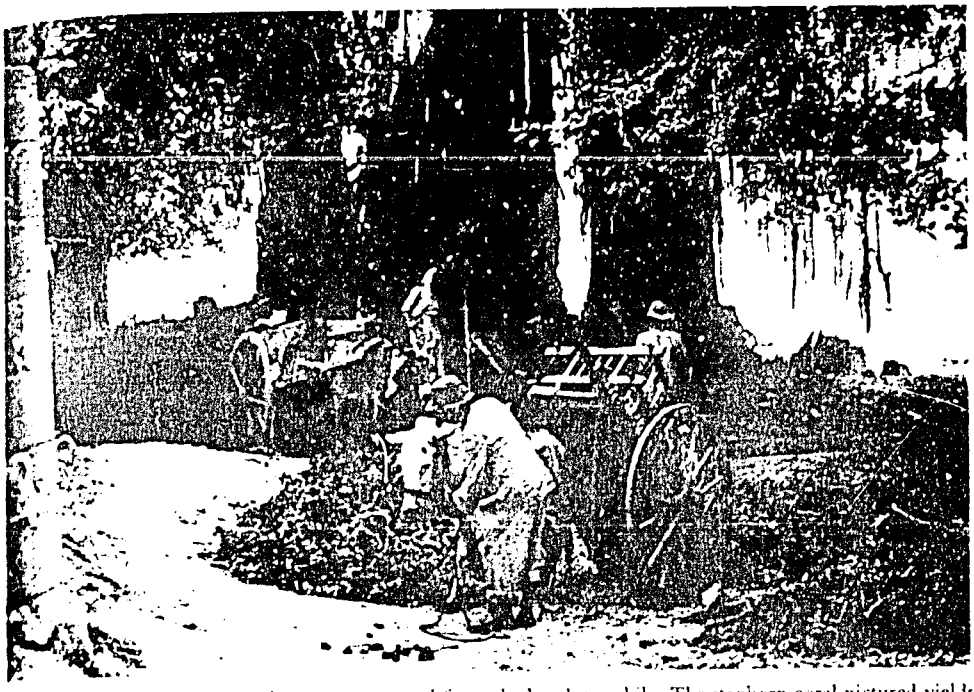

FIG. 6—Donkey carts used to transport coral from the beach to a kiln. The staghorn coral pictured yields another type of lime.

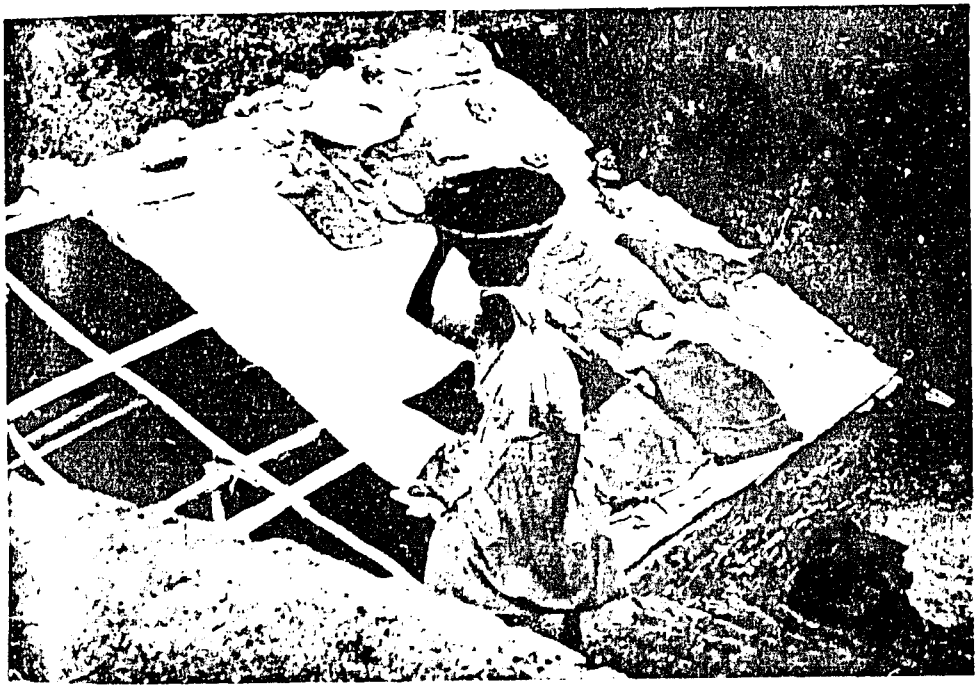

FIG. 7—Indian woman carrying a basket of coal to the top of a kiln for addition to the fuel layer being arranged by the kiln foreman.

bourg. Intensive mining at a few locations in these two sections has temporarily affected growth on the reef. Despite obvious local overexploitation, visual observation suggests that, under present demand, reef coral should be considered a renewable resource.

After the coral has been transported to the kiln, it is broken into more or less uniform cubes about three to four inches on a side. Size is important in ensuring the maximum amount of calcination and thus the greatest yield of high-quality lime per charge. If a stockpile of coral can be built up, it is allowed to stand for several months; during this time some of the impurities such as the sulphates, alkalies, and chlorides will be washed out by rain.[9]

When a new batch is to be prepared for burning, workers fill the kiln with alternate layers of coral and fuel. The bottom layers are placed in the kiln through openings around its base, but the rest of the filling must be from the top. Laborers, mostly women and children, carry fuel and coral up the steps or sloping ramp in baskets on top of their heads (Fig. 7). The contents are then dumped in the kiln under the direction of the foreman, who, during the charging, is at the top of the kiln. Charging by this procedure usually takes two to three days.

Coral and fuel layers vary in thickness from kiln to kiln and from batch to batch, depending on operational procedures and the type of fuel. Fuel, which accounts for more than half the cost of lime production,[10] is generally wood, though most operators also use some coal. All coal is imported, usually from South Africa. Since coal is the most expensive of the fuels used, many lime burners resort to coal ashes, which they are able to buy from the local railroad company. The type of fuel used in lime burning is important because it affects the quality of lime produced. Most Mauritian woods have a low calorific value and when used as fuel result in incomplete calcination. One of the best of the fuel woods is the filao (*Casuarina equisetifolia*), which, since its introduction from Australia, has become the commonest tree of coastal Mauritius (Fig. 5).

After the kiln is charged and most of the openings around the base have been blocked, the charge is fired. Calcination requires between five and twelve days; the length of time depends on such factors as wind strength and direction, type of coral and fuel used, size of charge, and control exercised by the operator. The calcined coral is moved from the kiln to the slaking shed, a procedure that requires another two days.

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[9] Staub and Durocher-Yvon, *op. cit.*, p. 59.

[10] Staub and Limfat, *op. cit.*, p. 230.

In the batch method of lime production, a kiln is employed in non-burning activities for about half of the time it is in use. To increase production, some kiln owners now use a continuous-burning technique. A kiln for this type of production differs from the common kiln in that it has three openings around the base (the common kiln has only one large opening),

TABLE I—KILNS AND KILN LOCATIONS, 1959

	NORTHWEST	NORTHEAST	SOUTHEAST	SOUTHWEST	TOTAL
Number of kilns					
Operative	25	11	6	3	45
Inoperative	23	29	7	11	70
Total	48	40	13	14	115
Number of locations					
With operative kilns	14	7	2	2	25
With inoperative kilns	15	17	7	7	46
With both	5	4	1	1	11
Total	24	20	8	8	60

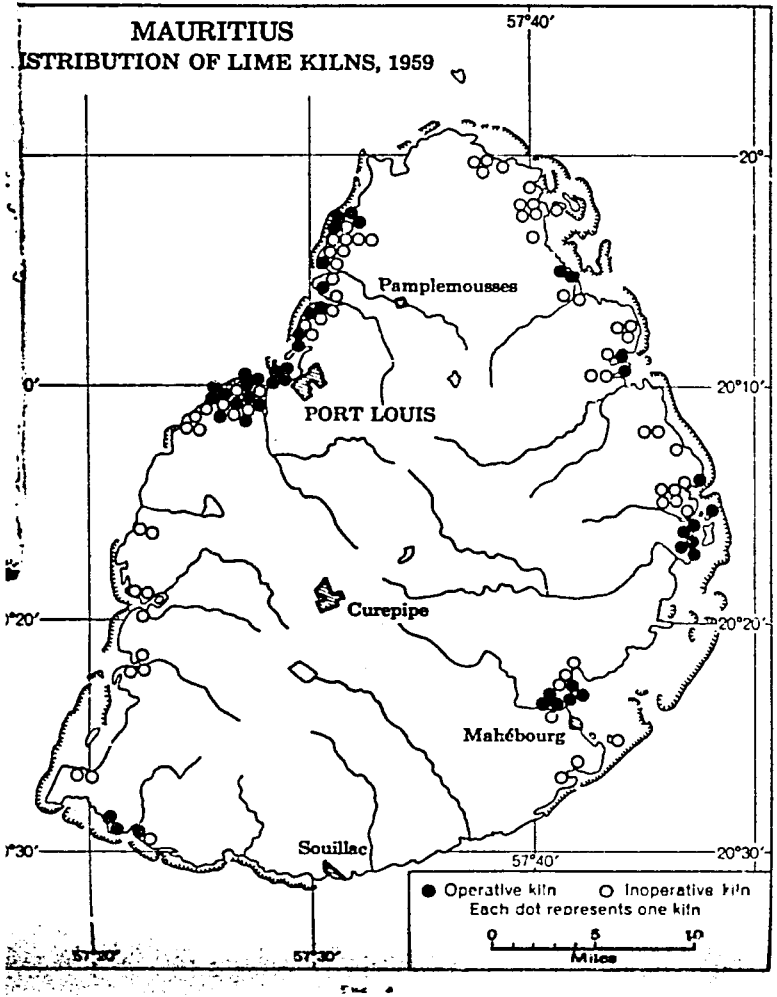
from which burnt coral is alternately and periodically taken while at the same time a compensating amount of fuel and coral is added to the top of the charge. This procedure, though it saves fuel and time, requires a continuous supply of coral, which most lime burners are unable to maintain.

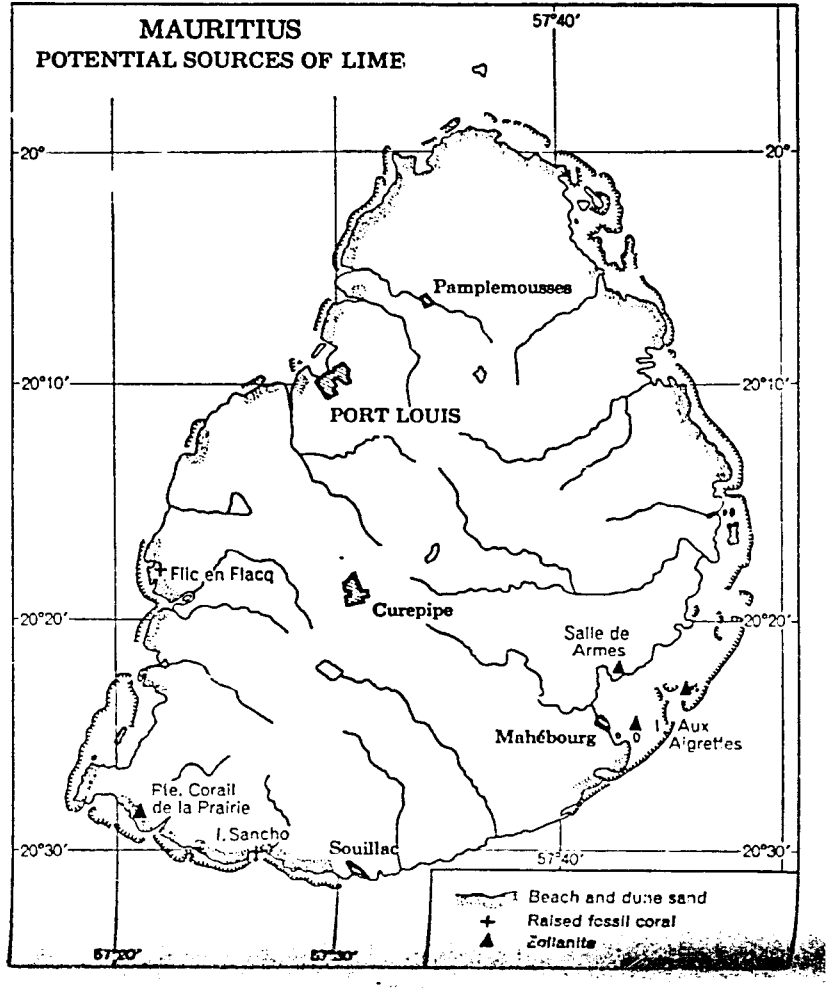
After the burnt coral has been taken from the kiln, it is slaked by being sprinkled with water. If the proper amount of water is added, the burnt coral disintegrates into a fine powder, which is hydrated lime. It is then graded by being passed through a series of screens of different mesh, after which it is sacked and stored. In Mauritius practically all operations are done by hand. Only one plant has a motor-driven hoist and an automatic screening and sacking machine.

LOCATION OF THE INDUSTRY

During the development of the lime industry in Mauritius, at least 115 kilns were built at sixty locations. All kilns are on the coast, most of them within a few feet of sea level, and all are on the parts of the coast fringed with coral. Thus the longest coral-free section has no kilns, though it fronts on one of the most intensive sugar-producing areas of the island. Most kilns were also constructed close to a town or to the sugar factory for which they produced lime.

The limekilns are grouped irregularly along four sections of the coast (Fig. 8). In 1959 the northwestern section, centered around Port Louis, had twenty-five producing kilns, more than half of the island's total (Table I). Of the 115 kilns or kiln remnants observed on the coast in 1959, only forty-


MAURITIUS
ISTRIBUTION OF LIME KILNS, 1959
57°40′
20°
20°10′
20°20′
20°30′
57°30′
Pamplemousses
PORT LOUIS
Curepipe
Mahébourg
Souillac
Operative kiln
Inoperative kiln
Each dot represents one kiln
0
5
10
Miles


MAURITIUS
POTENTIAL SOURCES OF LIME
57°40′
20°
20°10′
20°20′
20°30′
57°20′
57°30′
Pamplemousses
PORT LOUIS
Flic en Flacq
Curepipe
Salle de Armes
Mahébourg
Aux Aigrettes
Ile. Corail de la Prairie
I. Sancho
Souillac
Beach and dune sand
Raised fossil coral
Collanite

five were being used, and these were concentrated in twenty-five locations.

The gradual abandonment of limekilns over the past seventy-five years has paralleled a general abandonment and consolidation of the sugar factories. In earlier periods many of the sugar factories manufactured their own lime, but today only five factories continue to do so.[11] Improved transportation on the island has combined with other factors to concentrate kilns near the centers of largest population. Today, of the forty-five kilns still operating, thirty-seven are located within two miles of four of the largest coastal towns.

Future of the Industry

The gradual concentration of the coral-lime industry has been a long-time process, but in general it has not been accompanied by major changes in technique. In recent years a demand for a more uniform lime and the increased cost of coral recovery have fostered the search for a new source of lime. With the kilns and techniques currently employed by Mauritians, coral is the only usable source. However, other raw materials are available if the proper equipment can be developed. One of these sources is coral sand, which is found on the coral-fringed beaches except where mangroves or mud flats occur (Fig. 9). This sand is more than 90 per cent calcium carbonate.[12] In the mid-1940's an unsuccessful attempt was made to develop a kiln capable of utilizing coral sand.

Along the southwest and west coasts raised fossil coral, some of which was observed by Darwin,[13] is found, though not in quantities sufficient to support a lime industry. A third available source is consolidated coral dune sand, or eolianite, which, though found in only a few localities, is plentiful, especially in the vicinity of Mahébourg and on the southwest coast (Fig. 9). Eolianite is compact and difficult to mine with primitive methods, and it does not burn easily or completely in a simple kiln. Within the past decade a modern kiln has been constructed at Mahébourg, and within the past few years the use of this source of lime has been successfully tested. In 1959 the use of dynamite in mining the eolianite at Salle de Armes was authorized, a measure that greatly reduced the cost of the raw material. As Salle de Armes is on the coast across a bay from the kiln at Mahébourg, transportation by barge will further reduce costs in the future.

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[11] Personal communication from Raymond Raffray, Mauritius.

[12] C. E. F. Williams: Report on the Mauritius Cement Project, *Mauritius Legislative Council Sessional Paper No. 7 of 1956*, Port Louis, 1956, p. 2.

[13] Charles R. Darwin: The Voyage of the Beagle (New York, 1955), p. 467.

Now that an improved technology is making feasible the use of a new, more economical source of raw material, lime producers who continue to burn coral in primitive kilns may not be able to compete. Most of the forty-five kilns in use in 1959 appear destined to join the more than seventy kilns already abandoned. Some may share the fate of those which have been destroyed by tropical cyclones and ocean waves, and disappear completely; others, like two of their predecessors, may be converted into beach cottages. Many, because they are conspicuous coastal landmarks, will still be included on sailing charts, as they have been since 1800 and before. In addition, most of the five hundred people or more engaged in coral fishing and lime burning will have to seek other means of livelihood. For many it will be a first change in occupation, since some of the kilns have been in the same family for more than a hundred years.

Thus the lime industry in Mauritius appears to be on the threshold of a revolution, a revolution that will result in the disappearance not only of an outmoded technique but also of a unique use of a seldom-exploited renewable resource—coral.

POPULATION OF THE QUECHUA REGION OF PERU

DONALD R. DYER

ONE of the most fascinating aspects of the geography of Peru is the diversity of population distribution according to elevation. Probably the world's highest habitation, such as the shepherd's hut at 17,100 feet seen by Isaiah Bowman in 1911,[1] is to be found in the southern Andes of Peru. Several villages that are presently capitals of districts lie above 15,000 feet, and many mining camps are also found at very high elevations.[2]

Although about 16 per cent of Peru's population live at elevations higher than 11,500 feet, the major concentration is in the altitudinal zone just below 11,500 feet. This zone is commonly called the "Quechua Region" by geographers in Peru; it has been defined altitudinally as lying between about 8200 and 11,500 feet (Fig. 1).

THE QUECHUA REGION

According to Javier Pulgar Vidal, noted Peruvian geographer, the Quechua region of Peru can be defined by a composite of features—elevation, relief, climate, vegetation, and man's work.[3] However, his definition of regions rests on the "indigenous geographical understanding" of the landscapes in which the original inhabitants lived. He states that the Indians, whose culture is derived from oral tradition and whose contacts have been almost entirely outside school and urban centers, know nothing of the Spanish-derived concepts of *costa*, *sierra*, and *montaña*—the three classical regions of Peru. Although their geographical terms do refer to different kinds of landscapes, the nomenclature of the Indians is more detailed in regional identification. This means, then, that they recognize a larger number of regions.

The result of Pulgar Vidal's study of native nomenclature is the identification of eight natural regions. However, there are more than eight geo-

[1] Isaiah Bowman: The Andes of Southern Peru [*Amer. Geogr. Soc. Special Publ. No. 2*], New York, 1916, p. 52.

[2] Donald R. Dyer: Population and Elevation in Peru, *Northwestern Univ. Studies in Geogr. No. 6*, Evanston, Ill., 1962.

[3] Javier Pulgar Vidal: Las ocho regiones naturales del Perú (Lima, 1949), pp. 83–103.

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