

STONE IN HAITI



HAITI

0 10 20 30 40 50 km

Legend

- △ Marble
- Bedded Limestone
- Basalt



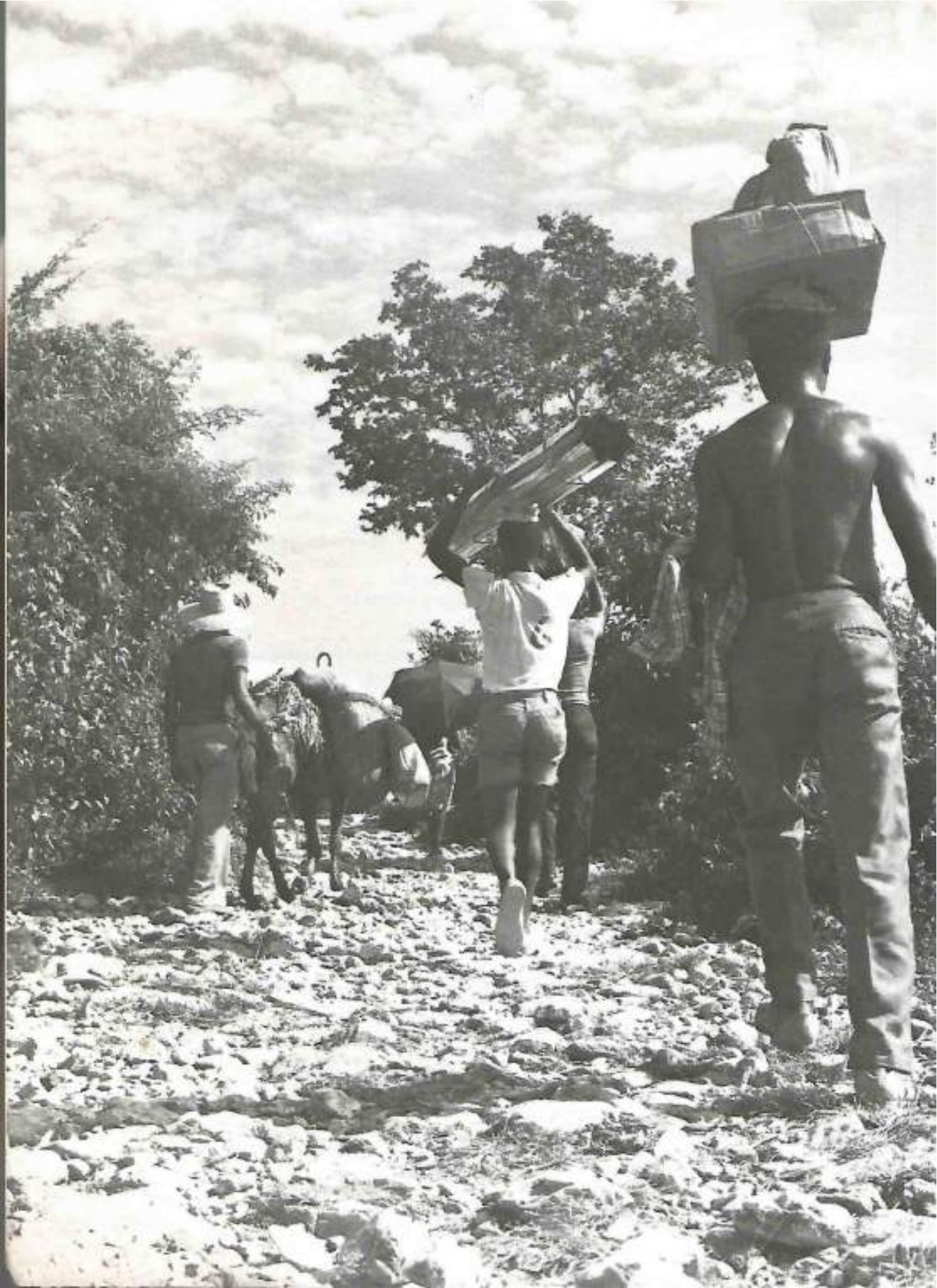


STONE IN HAITI

Prepared for the
Government of Haiti
by the
United Nations
Industrial Development Organization
acting as executing agency
for the
United Nations
Development Programme



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
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*Stone-paved road in the
Marcelline area*

PREFACE

As in many other countries, stone is the largest visible mineral resource in Haiti where major rock types include limestone, basalt, marl and a range of igneous rocks. Its potential contribution to the national economy is considerable since stone production, and especially stone utilization, is labour intensive and energy saving. Low-cost housing and exports are additional factors to be considered in stone development.

In Haiti, because of its geographical proximity to the large consumer centres—the Antilles, Mexico, the south-east of the United States of America, Venezuela etc., all countries that import sizeable quantities of stone, mainly from Europe—marble and possibly other stone materials have the potential to become a major export.

The Government of Haiti, recognizing the potential of its stone resources, requested the technical co-operation of the United Nations Industrial Development Organization (UNIDO) in their development, which is the responsibil-

Typical rural house - Artibonite valley



ity of the former National Institute of Mineral Resources (INAREM), now the Secrétariat d'État des mines et des ressources énergétiques (DMRE) in Port-au-Prince. UNIDO provided a consultant in stone technology, Asher Shadmon, who prepared this report, to study the use of stone resources in the construction industry in Haiti.

In the last few years, a new concept called integrated stone technology planning has been introduced that covers stone development from planning to marketing. The pattern is the same for developed and developing countries, but it is easier to put it into effect in the developing countries, which are free from tradition, legislative restrictions or shortcomings in planning. It is because of the planning that the concept should be considered early in any national master plan that covers, among other things, industrial or socio-economic aspects. Inclusion in planning ensures, for example, that the only economic stone prospect for a certain area is not lost by building an urban development on it.

The pattern for stone development is along the following lines: inventory of existing and potential stone resources; inclusion of the inventory in planning to ensure conservation and proper utilization of resources; prevention of improper uses of land; regard for environmental and energy-saving factors; introduction of appropriate technologies and improvement of current practices; establishment of central testing and documentation facilities; training of national personnel; introduction of stone products into local low-cost housing schemes and road paving projects; upgrading of stone for industrial and export purposes; initiation of new products based on stone as a raw material as, for example, for materials using fillers and manufacturing of rockwool for insulation; intensification of the use of lime mortars etc.; and establishment of small, cottage-type and artisan production units and industries.

Stone development aspects include low investment requirements; labour intensity that can be freely adjusted to meet requirements; small energy inputs; the possibility of setting up small, artisan production units; high added value for exports and environmental advantages; and high quality and durability whether the stone is used as a low-cost or prestige material.

Part of wall of rural stone house





Removal of loosened blocks with quarry levers

HISTORICAL NOTES

Early travellers describing Haiti stressed the rocky grandeur of the island. J. Brown¹ referred to the Plaisance mountain range as "Mountains with all their rocks and precipices, seen piled upon others equally abrupt and precipitous, or split from summit to base with chasms which seem immeasurable". He also reported: "There is a very good sort of marble found in some places, and in the southern mountains there are quantities of pozzolana earth . . ."

Stone in Haiti, as elsewhere, must have been one of the first materials to be used by man since its early working—for use as tools, in religious art and in construction—was independent of metal tools.

In the distant past, stone tools were used and well-shaped stones have been found in several river beds. Types recorded include petaloid celts (sculptured and plain), monolithic celts, dentoid and grooved axes, plain and sculptured pestles and three-pointed stones, petroglyphs (eared sculptured and plain axes), figurines or "dirks", heads and masks, nodules and balls and elaborate amulets. Sculptured collars and elbow stones have been found in, among other places, Laporte-Pilate, Cap Haitien, Gonaives and Les Cayes, but there is no certainty of their provenance.

Two principal periods of the stone age have been identified in Haiti: the Palaeolithic (Ciboney) and Neolithic (Arawak); the former is based on diggings in Valembrun and Hatte Latan in the Port-au-Prince bay and the latter on diggings in the regions of Frères, Cabaret, Léogane and Grand Goave. The artefacts found are made mainly of flints and igneous rocks and are considered Upper Palaeolithic. Stones associated with the pre-Columbian period are found in the river at La Voute de l'Inde near Dondon and the Pierre à l'Inde near Limbé.

Although the significance of stone in local folklore has not been fully recorded, names have been given to stones, for example, Pierre L'Orage for flintstone discovered after a storm, and Linglinsou, which is named after a spirit.

¹History of St. Domingo (1837), vol. 1.

Stones had their use in the Arawak ball game either to delineate the playing ground or to protect it, usually by walling.

Traditions in stone construction vary from locality to locality. Stone was used freely during the colonial period although much of it has been hidden by protective plastering. Plastering became more widespread when reconstruction and preservation were carried out during the post-colonial period.

King Christophe built his palaces at the time of his nation's independence, 175 years ago, and was a pioneer in using Haitian stone. Since that time, few people have exploited the potential of Haitian stone, but now marble and building stone from Haiti are being developed in a new enterprise.

In Port-au-Prince and areas where stone is freely available, for instance, between Fond des Nègres and Miragoane, most dwellings are made of stone as opposed to the mud and wattle constructions widespread in other parts of Haiti. The latter are usually made of wooden frames lashed together with fibre thongs, with

wicker walls sometimes covered with plaster or adobe.

Squaring of stone is little in evidence except in larger structures such as churches, communal buildings and other public facilities. Moreover, the squaring is mainly confined to corners.

In contrast to the structures visible above street level, stone has been used almost universally for foundations.

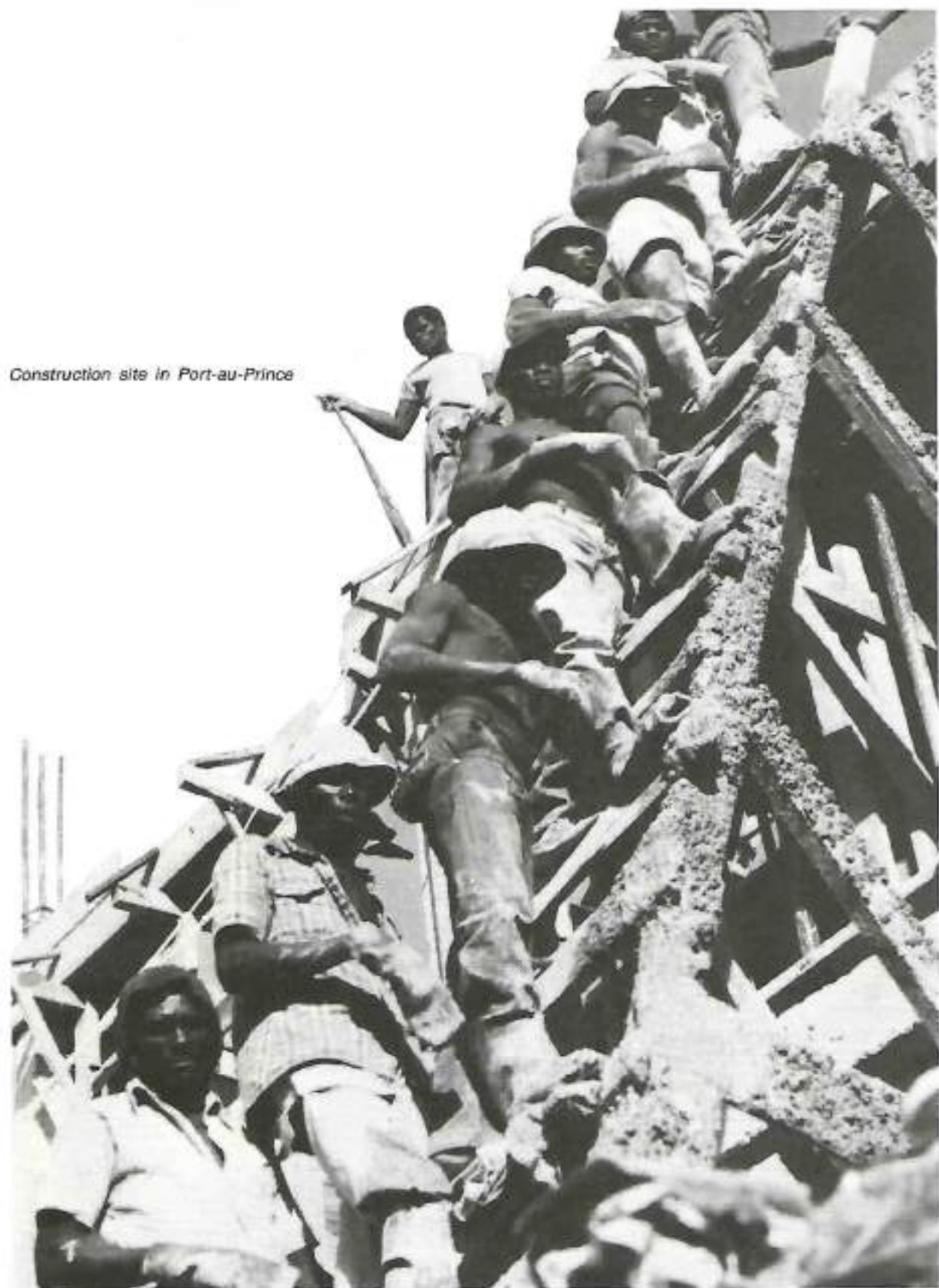
Eocene limestone from La Ferrière mountain and from Bonnet-à-l'Évêque has been used in the Citadelle—the "stone giant armed with canons"—mainly roughly shaped and laid as coursed rubble. Bricks were used liberally where the stone did not fit well, as in arches and corners, and for facing the openings.

The same limestone probably furnished the lime obtained from several kilns including those at Sans Souci and on the route to Ramiers. This limestone caps a high ridge, Bonnet-à-l'Évêque, which extends northward to the edge of the north plain west of Milot and is composed of porphyry and metamorphic detrital rock.

Team personnel



Construction site in Port-au-Prince



CONSTRUCTION METHODS

Wooden or fibre buildings are widespread in the rural areas. There are many objections to the use of wooden buildings in the tropics including the acceleration of deforestation, deterioration through rotting and damage by termites and other insects.

Stone has been utilized more extensively in foundations than in walling. Many aqueducts built during and since the colonial period consist of rubble masonry. Where stone has been used in walling, the masonry is often of an inferior type consisting of field stones or river-bed gravels of irregular size and shape, embedded in mud or laid in a thick, poor lime mortar. Lime in mortar has to be completely burned and perfectly slaked, and the sand should contain a minimum of impurities. Strong and good quality bonding materials are especially important in earthquake zones as buildings with poor mortars are the first to fall.

The field stones, river gravels and boulders include, in some of the more populated areas, soft Quaternary coralliferous limestone, which is frequently used because of the ease with which it is quarried and shaped. The same applies to the use of large coral heads from living reefs, especially at Port-au-Prince and Cap-Haïtien. These weather to a monotonous drab or grey. The chalk from the hardened upper crust of the Quaternary conglomerate appears to have a short life, especially when laid in thick lime mortar of doubtful specifications, and failures of structures in which it has been used are common.

There is a typical quarry of soft coralliferous limestone about a kilometre north of Môle St. Nicolas near the road to Jean-Rabel, well located for transportation by water. The limestone is fairly hard, and the thickness of the beds is 20–50 cm. The stone has lasted well in the extensive fortifications around the harbour, and the forts require little repair.



Frame ready to be filled with stone

Doorway at Fort Jacques



STRATIGRAPHIC TABLE OF STONE RESOURCES IN HAITI

<i>Age</i>	<i>Locality</i>	<i>Lithology</i>
Quaternary to recent	Môle St. Nicolas	Coralliferous limestone
	Saut d'Eau	Basalt
Pliocene	Rivière Gauche	Sandstone
Oligocene	Bassin Zim	Labradorite
	Fond Duroc	Slabby sandstone
	Maneville	Basalt
Upper-Eocene	Port Margot	Crystalline limestone
	Terre Neuve	Crystalline limestone
	La Pierre	Crystalline limestone (some brecciated)
	Périsse	Crystalline limestone
	Dessalines	Crystalline limestone, Basalt
	Puilboreau	Crystalline limestone
Lower-Eocene	Jacmel	Crystalline limestone
	Pilate	Crystalline limestone
	Trouin	Crystalline limestone
	Ennery	Slabby limestone
Fermathe	Fermathe	Slabby limestone
	Duchity	Crystalline limestone
	Cavaillon	Slabby limestone
Upper Cretaceous	Camp-Perrin	Crystalline limestone
	Perches	Serpentinite
	Grand Bassin	Quartz-Diorite Andesite
Lower Cretaceous	Massif de la Selle	Basalt
	Chaber	Gabbro
Pre-Jurassic		Mica schist
Paleozoic	Tortue Island	Calcareous schists



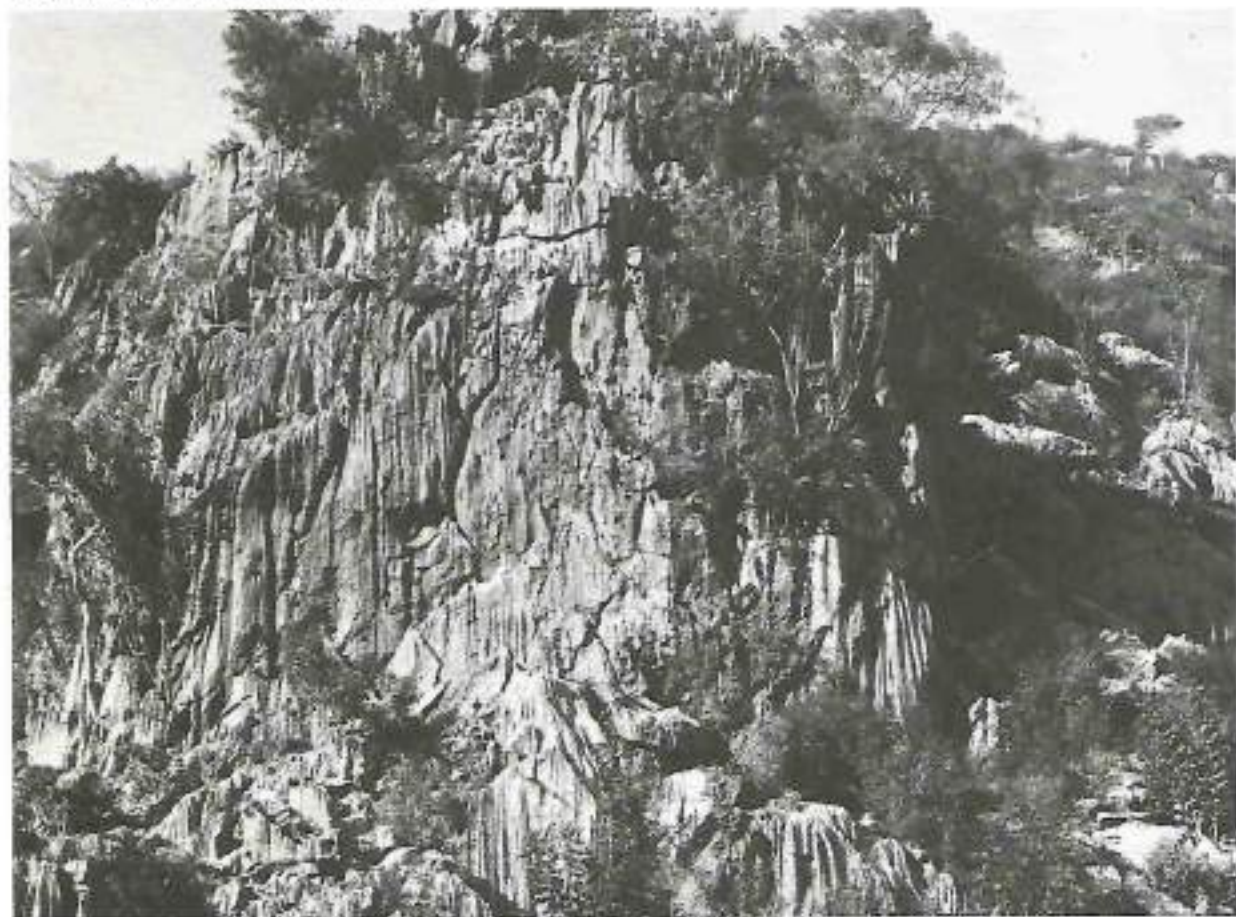
Stratified limestone at Novion



AVAILABLE STONE RESOURCES

Stone resources in Haiti are shown in the stratigraphic table, and the major stone varieties are discussed below. Marble and building stone are dealt with in this report in greater detail than the more obvious aggregates, gravels, fills and industrial derivatives such as cement, blocks and tiles.

Crystalline limestone deposit at Perisse





Boulders (darkest are basalts). In the background is the presidential palace in Port-au-Prince

MARBLE

Marble is a crystalline rock composed predominantly of one or more of the following minerals: calcite, dolomite and serpentine. For practical purposes, marble may be defined as essentially a calcareous rock, which includes sedimentary limestone, capable of taking a polish. Metamorphic origin, as required by strict geological definition, is not essential.

Marble is found at many localities in Haiti (annex I), but none has been exploited on a commercial scale. Sample blocks taken at numerous localities show great possibilities for marble extraction. The variety of colours and qualities is large for the comparatively small area of the country.

Ornamental marble can be used in slabs, as chips in terrazzo and ornamental concrete mixtures, and in statues.

BASALT

Basalt, besides its ornamental uses, as with marble, has potential industrial uses in petrology and in the manufacturing of insulation materials, for example, rockwool.

Many outcrops of basalt have been reported, the most widespread being in the south-western peninsula where they form a considerable portion of the outcrops in the Massif de la Hotte, and extend well into the Massif de la Selle. The trend of the outcrops is east-west. The extreme western boundary of the basalts is between Tiburon and Anse d'Hainault. The thickness of the basalts is estimated to exceed 1,000 m. There are indications from the volcanic eruptions that the basalts originate from submarine eruptions, probably during Upper Cretaceous times (Maestrichtian).

In the Massif de la Selle, the basalts from deep V-shaped valleys form 20 per cent of the outcrops and their base has not been observed; dating includes Lower Cretaceous deposits. No basalts have been reported from Cul-de-Sac where outcrops are very small, although conglomerates indicate the subsurface presence of basalt. The basalt outcrops in the Central Region (Chaîne des Matheux) are few and are of the Cretaceous, Oligocene (nephelite basalts) and Miocene ages. The basalt outcrops in the Trou-Déca are small. There are some Eocene basalts in the Montagnes Noires, none is reported in the Plateau Central but in the Massif du Nord there are deposits a few hundred metres thick, of Cretaceous age. Middle Eocene basalts appear in the north-eastern peninsula.

STONE

Rock whose geological identity is irrelevant for practical purposes may be termed stone, for example, in legislation and licensing or for use in aggregates where uniform lithologies are not critical as they are in dimension stones. Except for a large part of the Plateau Central, the Cul-de-Sac, the Artibonite plains and the Plaine du Nord, stone deposits cover most of Haiti.

Slabby deposits, simpler to exploit than massive beds, and convertible into usable construction units, are confined to a few outcrops, although there is good reason to believe that they occur below other exposures. Stone varieties not specifically described under main headings include andesites, aplites, diabases, dacites, pegmatites, peridotites, porphyries, schists and tuffs. Reference to some of these is made under granite.

At present, the largest consumption in Haiti of stone is, except for cement making, for road construction purposes. Compared with other countries, the mileage of good quality roads is very small. Early attention to this will open the country for further development. For this, the identification and inventory of conveniently situated stone materials are important, and a survey is at present in progress. Gravel from stream beds and older

gravel beds, e.g. in the Cul-de-Sac plain, are much used sources of materials. Their use causes erosion and other environmental problems, but controls can remedy this situation. Hillside quarries enable better control to be kept over quality and specification requirements.

Paving of roads with stone is almost unknown in Haiti except for some parts of Port-au-Prince, Port-de-Paix and at Cap Haitien where the cherty limestone was used with good results. A short stretch of stone paving at the entrance to Ennery has withstood wear and tear better than those portions of the road with different surfacing.

LIMESTONE

Limestone in Haiti is generally of a sedimentary nature, although some outcrops were originally described to have metamorphic features, as for instance in the "Lower Cretaceous" outcrops around Petit Goâve, Aquin and Camp Perrin; these are now considered Upper Cretaceous. An important group is the Macaya formation containing calcareous rocks, well bedded, often slightly clayey, finely detritic silicified and in some places containing siliceous veins in various colours including brown, yellow, green and purple. The thickness of the formation is

Slabby limestone at Ennery



estimated to exceed 2,000 m and covers an area of 20 by 13 km in the Massif de la Hotte where the type section is situated and forms the Macaya Massif in addition to the Morne Sinai outcrop, which is approximately 24 by 3 km.

In the Massif de la Selle, only negligible occurrences of limestone of Cretaceous age have been noted. In the Trois Rivières formation, in the Massif du Nord, grey massive crystalline limestone containing rudists and large Foraminifera is found, which is generally strongly affected tectonically. This is probably of the Upper Cretaceous age, with the upper part probably Campanian-Maestrichtian. In the north-western peninsula, an outcrop of more than 100 m thick occurs at Morne Miguinda (in the Terre-Neuve Massif) of rocks similar to those found in the Trois Rivières area.

Palaeocene and Eocene limestones in the Massif de la Hotte include white chalky varieties with chert and grey coralline in massive deposits, often crystalline with large Foraminifera. These reach a thickness of several thousand metres. They are largely represented in the Massif de la Selle and derive from the Marigot formation from a locality in the Massif. The massive limestone in the Ile de la Gonave is mainly of Upper Eocene age and of a crystalline nature. In the Chaîne des Matheux, crystalline limestones can be

Limestone wall of undressed field stones



seen on the Port-au-Prince to Mirebalais route, south of Terre Rouge and on the Plateau of Goyavier. They extend into the Trou d'Eau mountains. In the Montagnes Noires, they form the largest outcrops, mainly dark grey or red brown, massive and brecciated.

There are also important limestone deposits in the Montagnes de Terre-Neuve.

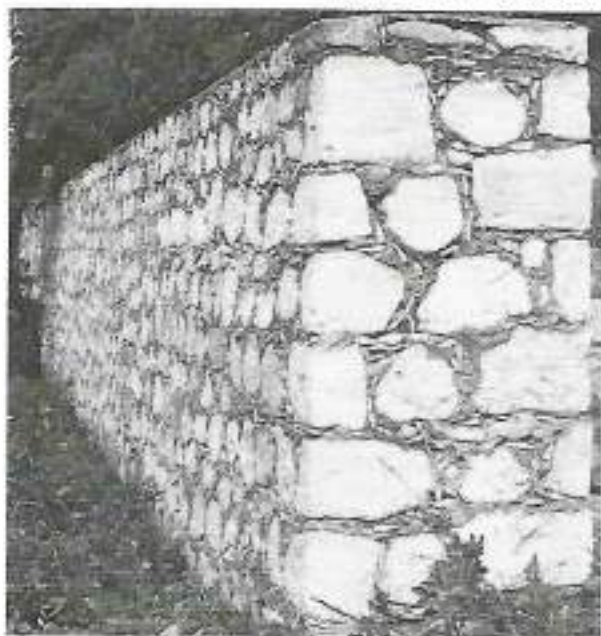
GRANITE

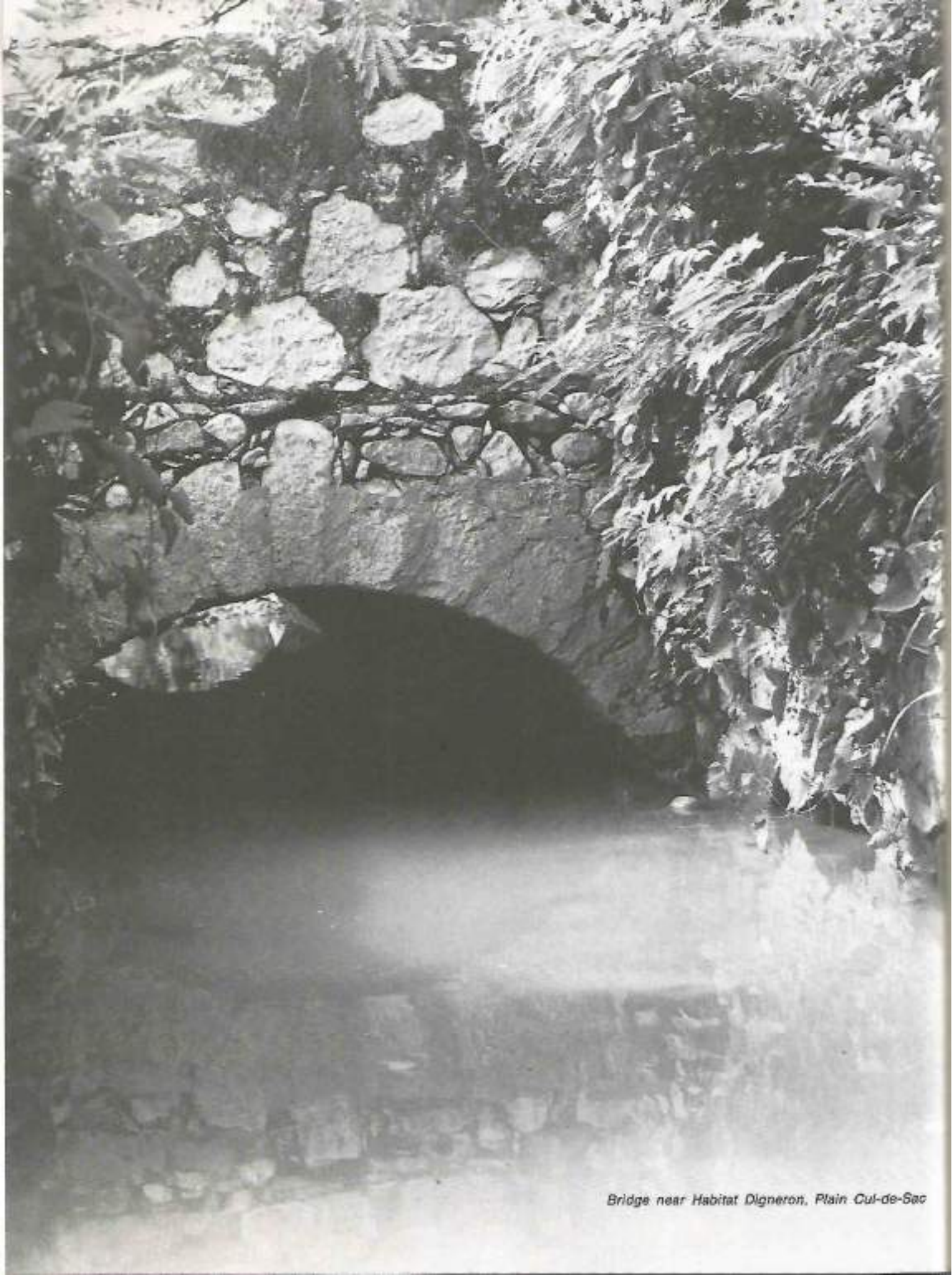
The Massif du Nord from Grand Rivière eastward to the Dominican border is characterized by large bodies of massive quartz diorite, probably of the Middle to Late Cretaceous to Eocene age with intrusions of minor stocks during the Miocene age, mainly along the central arch of the Montagnes de Terre-Neuve and including granodiorites and porphyries.

The quartz diorite is hard and tough and typically contains plagioclase, quartz and hornblende with magnetite and biotite as accessory minerals (approximately 3 per cent) and a larger percentage (approximately 10 per cent) of secondary minerals such as kaolin, chlorite and limonite.

The granites have been used sporadically in road construction and are presently under investigation for dimension use.

Limestone wall with roughly squared field stones





Bridge near Habitat Digneron, Plain Cul-de-Sac

SAND

Although actually a derivative of stone (sandstone etc.) sand is important as an abrasive and cutting medium in the slabbing of stone. For this siliceous sands are required. These are composed mainly of quartz and have been reported in large quantities only on the North Plain and along the streams in the adjacent part of the Massif du Nord that is underlain by igneous rock and derived mainly from the weathering of quartz diorite. The Grande Rivière is another prospect for sand. Most of the sands investigated are rather fine although a coarser sand was noted near Le Trou.

At present, sand is used only in lime mortar and in concrete. Some of the sand could be used in glass-making for ornamental purposes; industrial deposits are not known in Haiti.

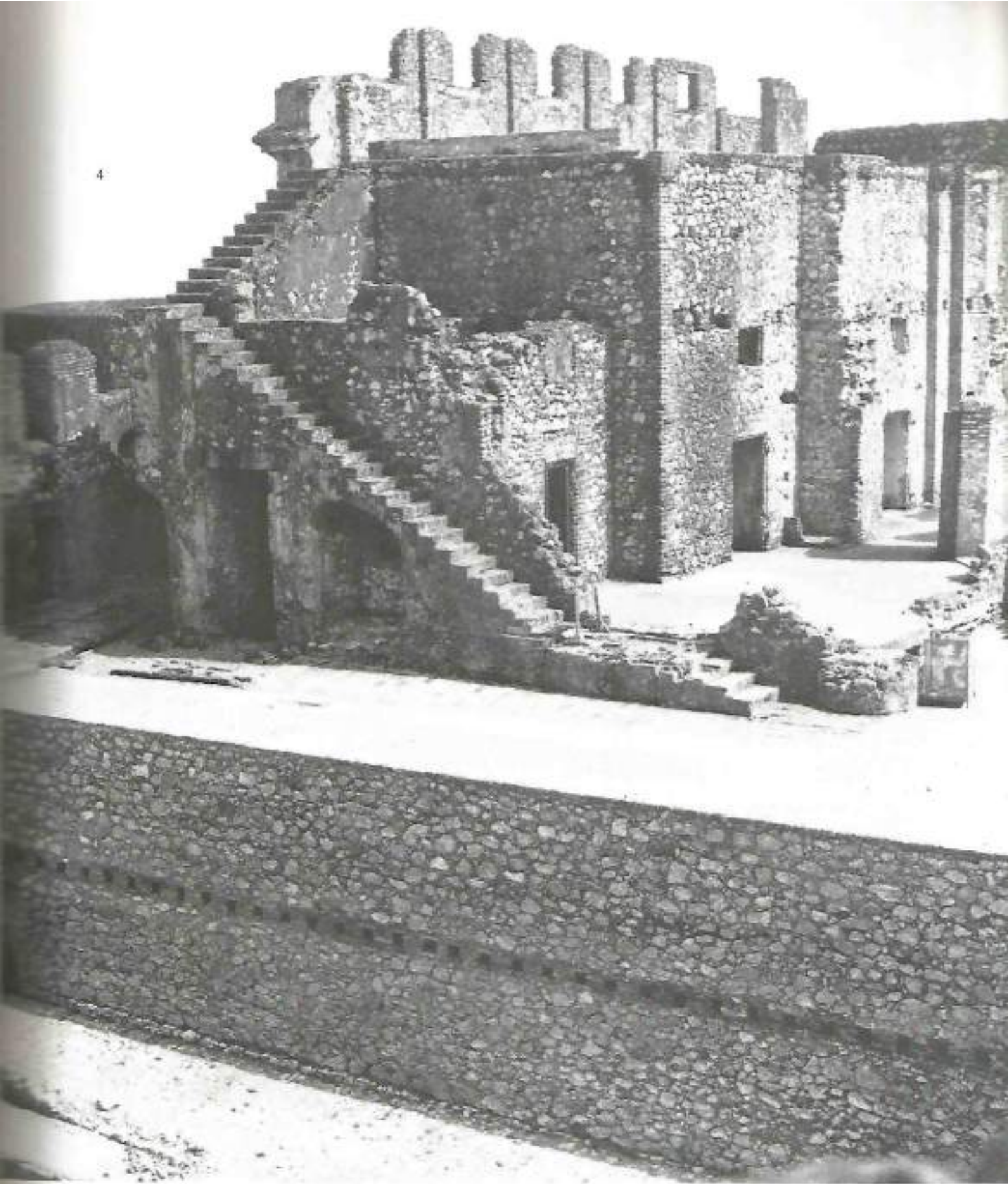
Boulders and sand in river bed near Cayes-Jacmel

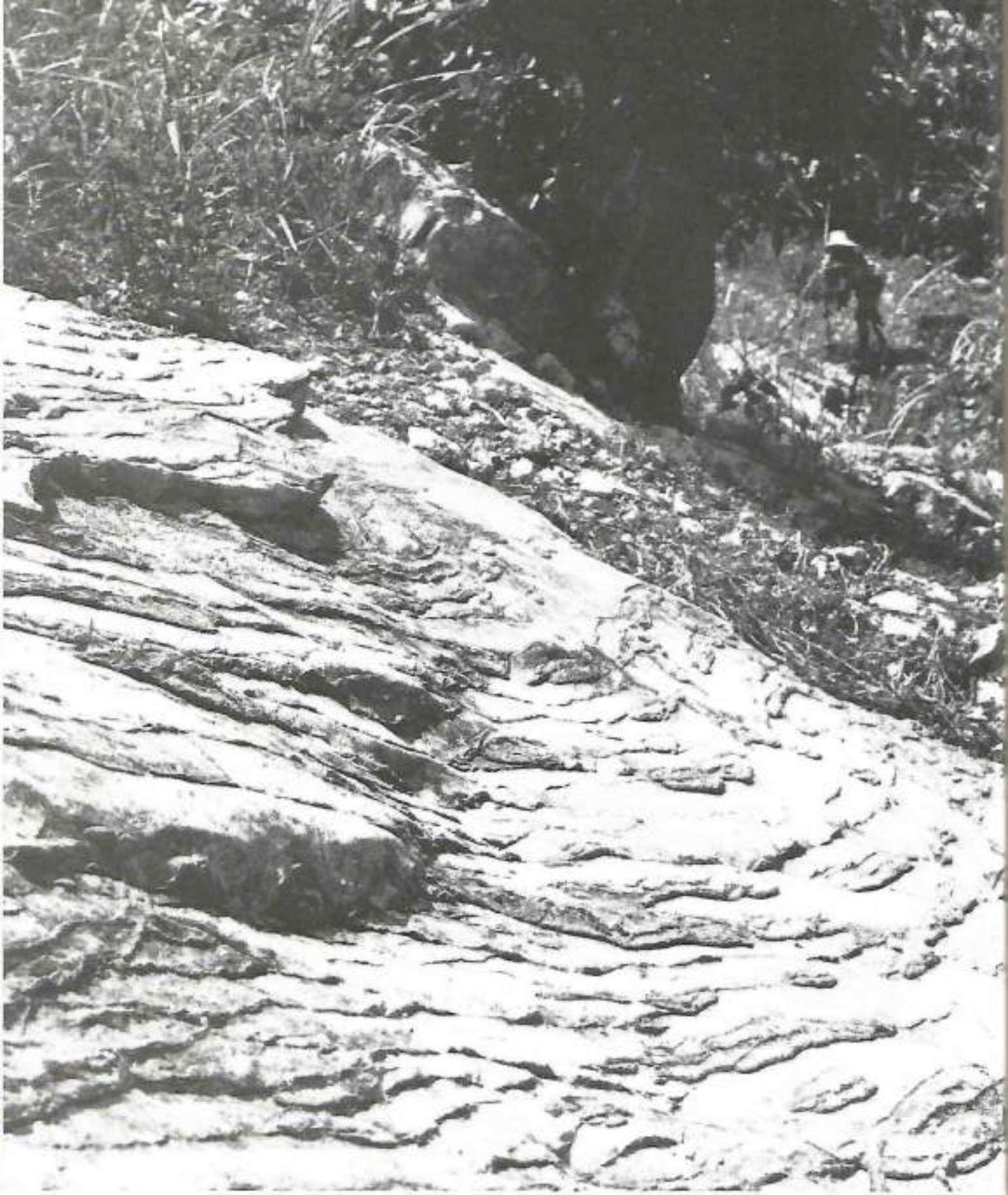




- 1 *The Citadelle at Cap-Haïtien*
- 2 *Colonial construction method with stone and brick*
- 3 *Corner at Fort Jacques showing construction of walls*
- 4 *Governor's quarters, overlooking the central court of the Citadelle*





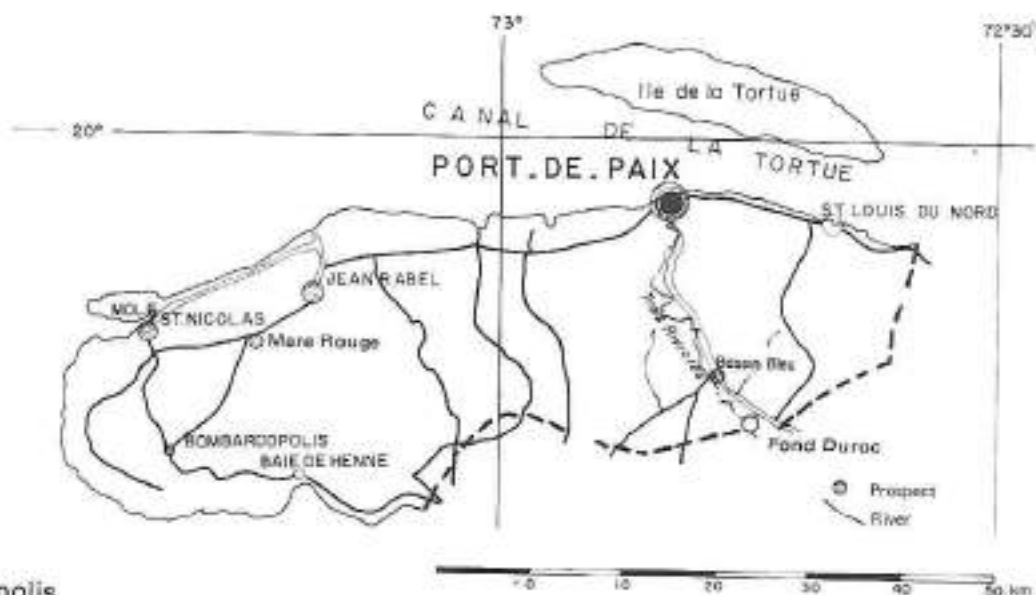


Limestone strata at Novion

DISTRIBUTION OF DEPOSITS

Stone resources of the main development areas are being investigated for integrated development in the physical planning (urban, rural etc.) of Haiti and are given below, listed under administrative divisions: marble varieties (Port Margot, Plaisance, Morne La Pierre, Gramont, Périssé, Trouin, Jacmel, Camp Perrin, Duchity); limestone (Ennery, Fermathe, Trouin); granite varieties (Bayhon, St. Suzanne, Grand Bassin, Acul Samedi); basalts (Massif de la Selle, Chaîne des Matheux, Trou-Deca, Montagnes Noires); gravels and river-bed deposits (Rivière Momanche, Rouillone, Liogane, Rivière Grise, Cul-de-Sac, Rivière de Montrouis, Rivière de Limbé, Grande Rivière de Jacmel, Rivière de Grand-Goâve, Ravine du Sud Cayes) and are generally described regionally.

DEPARTEMENT DU NORD-OUEST



Marble

Bombardopolis

Location: Mare Rouge some 15 km north of Bombardopolis.

Geology: Breccia (dissolution holes, caves) Quaternary.

DEPARTEMENT DU NORD



Some of the marbles and basalts present have been investigated. An important marble outcrop occurs along the Port Margot to Borgne route covering a large area. The rock is very fine grained to bioclastic, predominantly beige. Other marble outcrops are in the Pilate/Plaisance/Gros Morne area.

Basalts are found at Camp Coq not far from Limbé towards Plaisance, and also at Duplessy.

Marble

Port Margot

Location: From Port Margot, 3 km along the route to Borgne, covering Morne Limbé north-northwest of Port Margot.

Geology: Fine-grained beige to hard grey crystalline bioclastic limestone of the Eocene age with variable texture and many shell fragments. The dip is towards the north-east.

Cap Haïtien



Novion

Location: Approximately 8 km from Port Margot towards Borgne.

Geology: Limestone of the Eocene age with distinct stratification, bedding 30–40 cm. Contains silica modules of 3–20 cm diameter.

Puilboreau

Location: On the highest crest of Morne Puilboreau at 7.5 km from Ennery towards Plaisance.

Geology: Beige crystalline massive Eocene limestone covers the top part of Morne Puilboreau. Some parts are strongly affected by tectonics. A major fault on the southern flank of the Morne trends in a northwest-southeast direction; approximately 11 km² are exploitable.

Bedded limestone

Puilboreau

Location: Southern flank.

Geology: Clayey limestone, slabby, with beds 20–30 cm thick, strongly influenced by tectonics.

Basalt

Duplessis

Location: Approximately 5 km south of Port Margot towards Limbé.

Geology: Some 10 m thick, fairly altered, occurring in sheets of 20–30 cm, presumably of Cretaceous age.

Camp Coq

Location: Approximately 5 km from Limbé towards Plaisance.

Geology: Cretaceous.

DEPARTEMENT DU NORD-EST

Building stone is found at St. Suzanne, Grand Bassin, Vallières, and at Grosse Roche some 8 km east of Bahun.

It consists mainly of granodiorite, gabbro, rhyolite and basalts of the Cretaceous age.

Marble

Bourjois

Location: Some 2 km north-east of Cerca Carvajal, Bassin Coco and 2 km north of Cerca-La Source.

Geology: Crystalline limestone of the Upper Cretaceous age.

Bedded limestone

Mombin Crochu

Location: Mombin Crochu.

Geology: Slate schist.



DEPARTEMENT DE L'ARTIBONITE

This area has marble deposits at Terre-Neuve, La Pierre, Pailboreau, Perisse, Des-salines and, because of its relative proximity to one of Haiti's major highways linking Cap Haitien with Port-au-Prince, has received earlier attention than other areas that are essentially no less rich in marble resources.

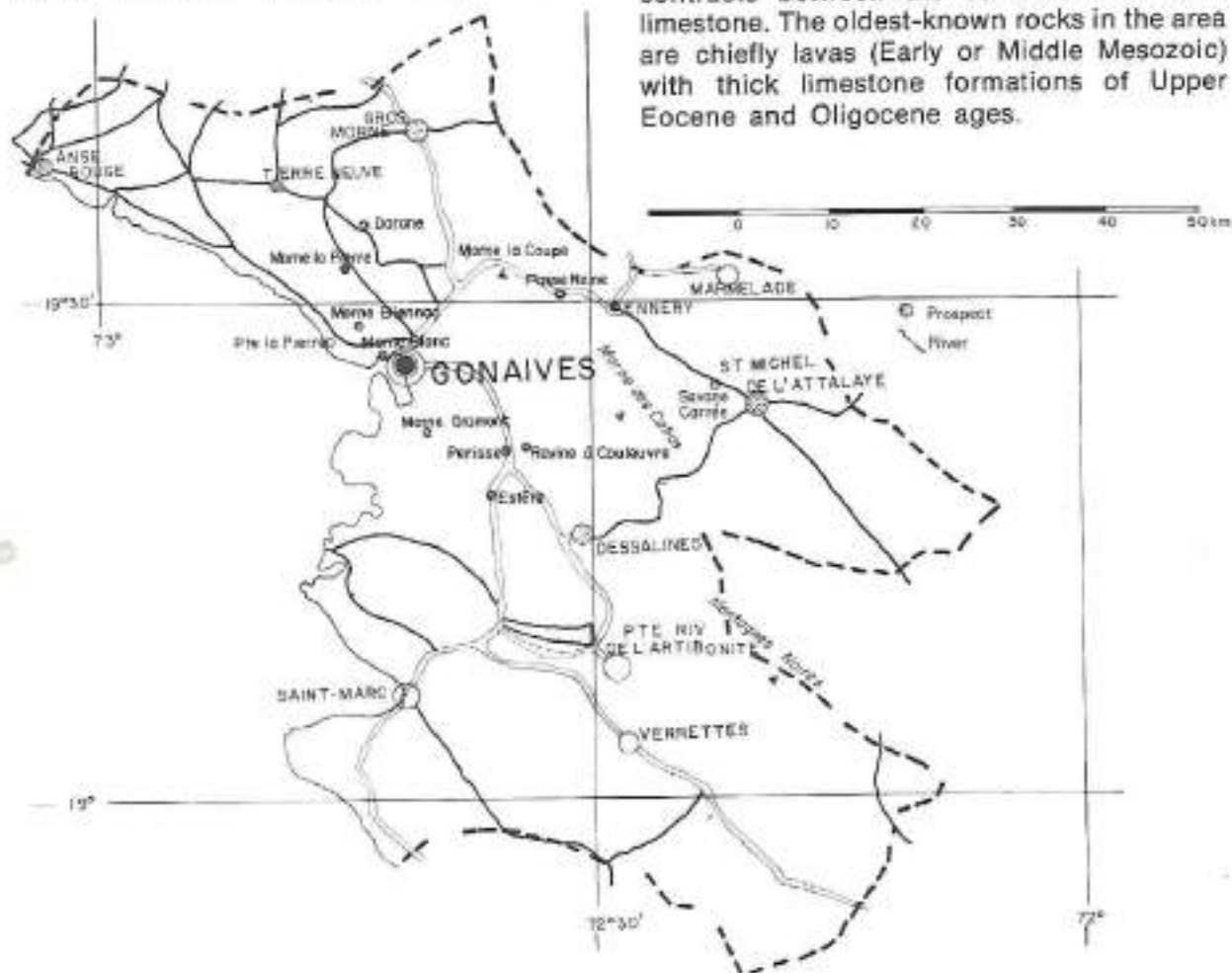
Basalts are found in the Terre-Neuve river, but the provenance is not clear. Also north of Perisse, there is a volcanic complex containing andesite, basalt and gabbro, reportedly sometimes covered by volcanic ashes.

The various stone varieties in the region include limestone at Bienac and suitable building stone at Morne Blanc. At Ennery, a slabby limestone forms an imposing cutting along the Port-au-Prince to Cap Haitien highway, and around Savane Carrée the slabby limestone covers a large area. It

reappears as a cover on the chalk of Morne Pailboreau. However, the area north of the Ennery region shows signs of strong tectonic influences. West of Morne Gramont a small dark limestone outcrop occurs. In the Mont Cahos area of the Montagnes Noires, various limestones occur. The Montagnes de Terre-Neuve, which extend north-west from Gonaives for a distance of about 30 km, have great potential for various stone materials. They comprise several distinct ranges which are oriented in a north-westerly direction with crests at an average altitude of 700 m above sea-level; some of the peaks are higher than 1,000 m.

Canyon-like deep valleys expose the limestone, which also occurs as cliffs on the escarpments and as dipslopes. This facilitates the selection of quarry sites, especially since the mountain crests are rounded and fairly smooth in contrast to the steep, rough slopes.

Cliffs are particularly common along contracts between the volcanic rocks and limestone. The oldest-known rocks in the area are chiefly lavas (Early or Middle Mesozoic) with thick limestone formations of Upper Eocene and Oligocene ages.



The Upper Eocene formation covers most of the Montagnes de Terre-Neuve as a thick cap unconformably on a basement of basaltic and andesite rocks. The upper part of the formation, some hundreds of metres in thickness, of bedded fossiliferous limestone, is of interest. It is less exposed than the lower part, which consists of a variety of rock types mainly in the interior part of the mountain mass. To the east, in the main part of the Trois Rivières Gorge, high-grade limestone of a massive type crops out.

Thin-bedded limestone with detrital material is exposed on the south slope of Morne Bienac and on the north slope of Morne Soleil. The latter contains also some beds with less detrital material and at least one bed of semi-crystalline foraminiferous limestone has been reported.

Marble

Darang

Location: Situated along a trail passable to vehicles, 7 km south of Terre-Neuve and north of the Sedren copper mine.

Geology: Crystalline limestone of Eocene age, well bedded (between 40 and 200 cm) and covering an area of 16 km². Some parts are strongly affected by tectonics, the quarry site is a flat sinkhole underlain by less soluble limestone and surrounded by high cliffs of pure thick-bedded limestone. With a dip of about 10° north-east, which is more soluble.

La Pierre

Location: 7.5 km from Gonaives towards Anse Rouge.

Geology: White limestone some of which rather brecciated and described as an intraformational breccia of the Eocene age.

Morne Gramont

Location: West of Johanisse.

Geology: Middle Eocene. Dark massive limestone pitted and

roughened by solution. The mountain appears to form a tilted block that dips north-eastwards.

Perisse

Location: 12 km south of towards, and 5.5 km from, l'Estère.

Geology: A massive crystalline limestone of grey, beige and black of Eocene age.

Ravine à Coulevre

Location: 1.5 km south-east of Perisse.

Geology: Grey crystalline bioclastic limestone of Eocene age.

Dessalines

Location: Approximately 4 km east of Perisse.

Geology: Grey crystalline limestone of the Eocene age.

Morne la Coupe

Location: Approximately 8 km northwards from Gonaives near Ennery.

Geology: Massive crystalline limestone of the Eocene age.

Bedded limestone

Ennery

Location: (a) Southern face of Morne Pullboreau;
(b) 2 km east of Ennery towards St. Michel de l'Atalaye;
(c) Along the route from Passe Reine to Ennery.

Geology: Stratified limestone of the Eocene age.

Morne Blanc

Location: On the northern shore of Gonaives Harbour towards Anse Rouge, 4 km from Gonaives.

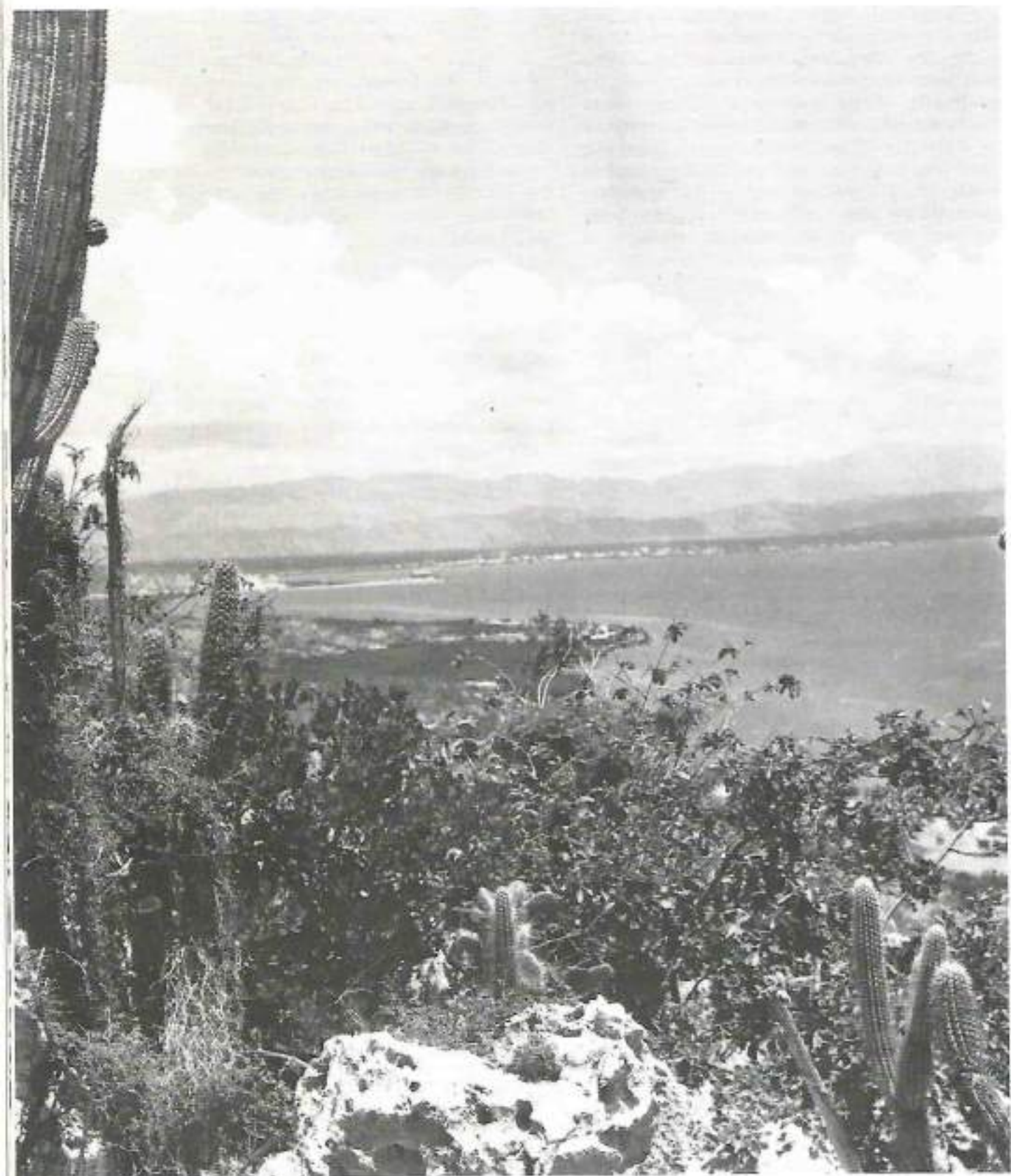
Geology: Stratified clastic type of white limestone of the Oligo-Miocene age. Tilted 15° to 20° in different directions, generally south-eastwards.

Basalt

Terre-Neuve

Location: Around Terre-Neuve.

Geology: Complex of basalts-andesites.



Morne La Pierre with the town of Gonaves in the background

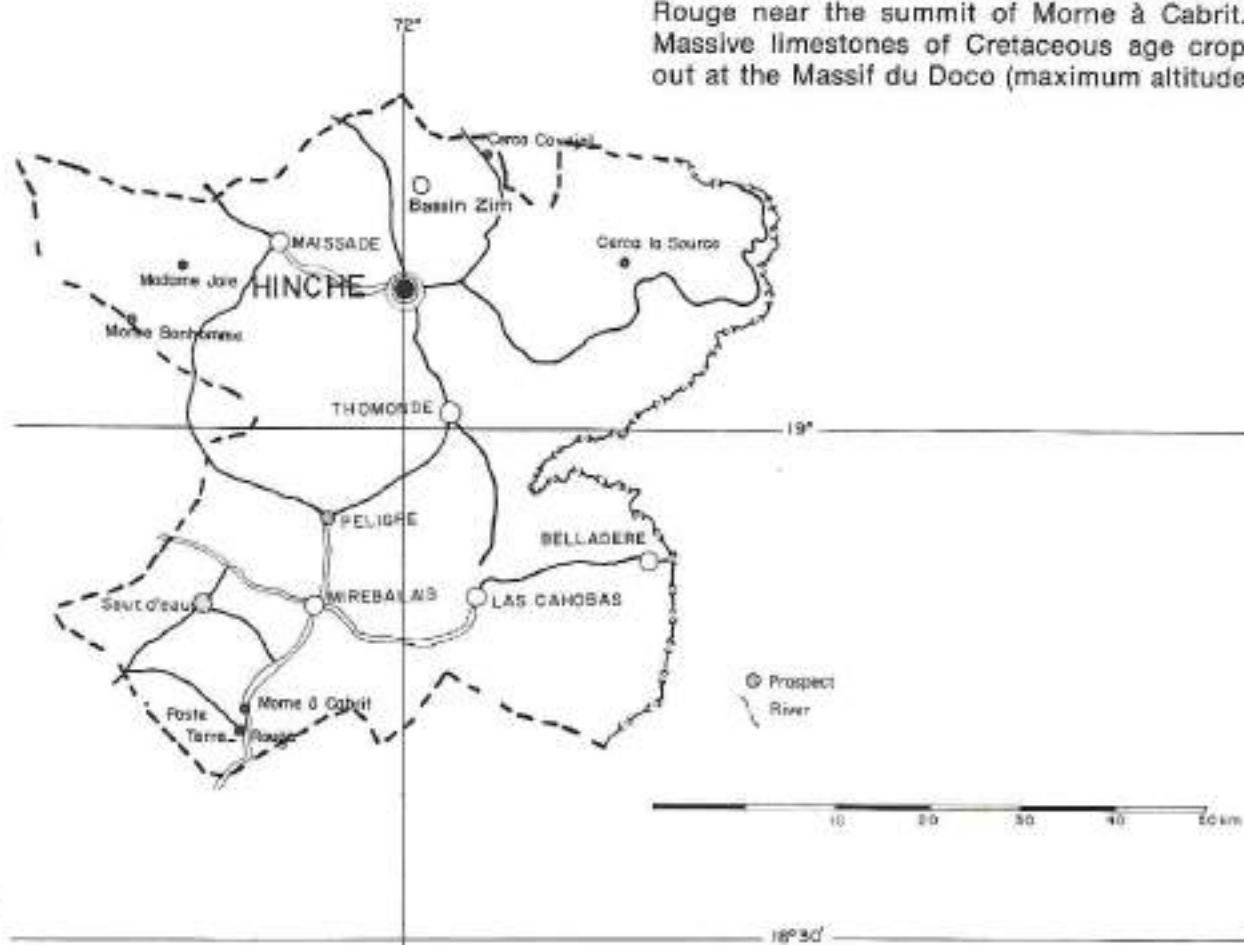
DEPARTEMENT DU CENTRE

Large parts of this Département are on the Central Plain, historically known as the Plaine de Goave, or Guaba, which is the largest interior plain in Haiti and a prolongation of the San Juan Valley in the Dominican Republic.

Three igneous eruptions have been reported from this region resulting in basaltic lavas and tuffs, including the nephelite basalts of the Quaternary age found south-west of Saut d'Eau. Some of the basalts are massive.

The colour is not sufficiently uniform for ornamental purposes.

The Central Plain has large deposits of Miocene rocks, some of which contain beds of lignite. Several beds of coralliferous limestone 5 m thick as, for example, those at the foot of Morne Madame Jolie, have economic potential, and further investigations are required. The coralliferous limestone often crops out in prominent ledges. Beige, Upper Eocene crystalline limestone is found at Poste Terre Rouge near the summit of Morne à Cabrit. Massive limestones of Cretaceous age crop out at the Massif du Doco (maximum altitude



1,788 m at Morne Bonhomme); similar outcrops are found at Domond near the village of Pelligre.

Marble

Trouin

Location: Approximately 4 km from Trouin towards Carrefour Fauché.

Geology: Crystalline limestone of the Lower Eocene age. Also a breccia (intraformational) of the Oligo-Miocene age.

Bedded limestone

Morne Hôpital

Location: Immediately south of Port-au-Prince.

Geology: Massive- to thick-bedded, generally dense, fine-grained limestone of the Upper Eocene with some layers 10 to 15 cm thick. A few beds are soft and chalky. Some chert has been observed. The dip is rather steep, northwards with complex folding as can be observed in the first deep ravine east of Petion-Ville near Source Millet where the folds are overturned to the north.

Fermathe

Location: Approximately 800 m from the Fermathe Police Post in the direction of Fort Jacques.

Geology: Lower Eocene of beige and grey, tectonically affected. Outcrops cover about 4 km².

Basalt

Kenscoff

Location: Approximately 30 km from Port-au-Prince, and at Ob-leon and Furcy.

Geology: Cretaceous.

Trouin

Location: Approximately 2 km east of Trouin.

Geology: Cretaceous.

Thomazeau

Location: On the road to Cornillon, 2-3 km east of Thomazeau at the foot of the mountain.

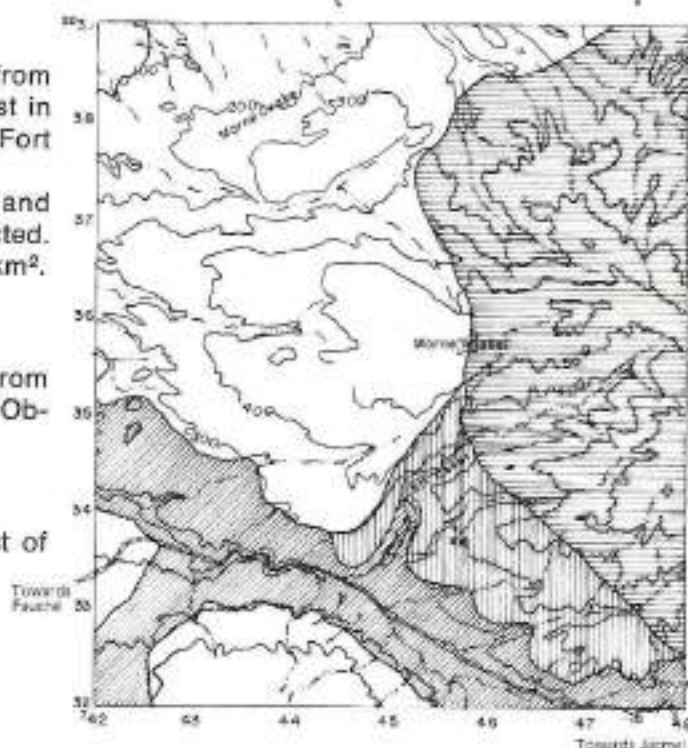
Geology: Nephelite basalts of the Tertiary age horizontally bedded, up to 1 m thick, fresh outcrops.

Leogane

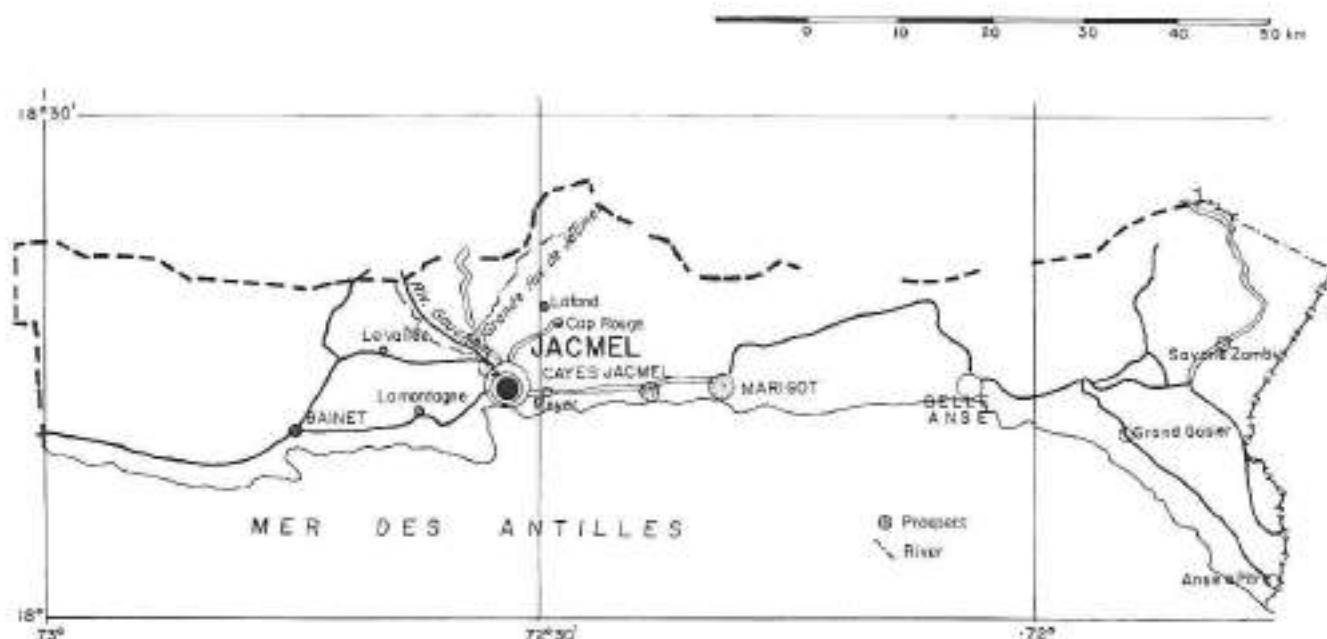
Location: In Rivière Rouyonne, 7 km upstream from Deslandes.

Geology: Olivine basalts, rather fresh, generally dipping steeply north.

TROUIN (Lithology)



DEPARTEMENT DU SUD-EST



Marble

Jacmel

Location: Carrefour-Raymond; 9.5 km from Jacmel towards the Cayes-Jacmel route and 4 km north of that route.

Geology: Lower Eocene-Palaeocene massive pink crystalline limestone. Occurs as cliff-forming massive beds with a mean thickness of 200 m, south of the Cap Rouge laterite plateau. Also a breccia (possibly intraformational) of the Lower Eocene age.

Location: On the road to Bainet, la Montagne.

Geology: Pink to red crystalline limestone Eocene beds up to some metres, partially in

dip slope to north. Outcrop rather strongly oxidized.

Location: Road to La Vallée.

Geology: Red and pink crystalline limestone (Eocene) and solution breccias, strongly affected by karst; cut by travertine veins of up to 0.5 m.

Location: In Rivière Gauche, road to Trouin 10 km north-west of Jacmel.

Geology: Big blocks of red, pink and white limestone with large fossils.

Marigot

Location: On the road, 2 km west of the Cayes-Jacmel route.

Geology: Blocks of pink, crystalline limestone in a road cutting.

Bedded limestone

Coq Chante

Location: Approximately 18 km from Jacmel towards Leogane.

Geology: Stratified limestone of the Eocene age.

Jet d'eau

Location: Approximately 4 km towards the north from the Cayes to Jacmel route.

Geology: Stratified limestone of the Oligocene age.

La Fond

Location: Approximately 12 km north of Jacmel.

Geology: Stratified limestone of the Eocene age.

Basalt

Jacmel

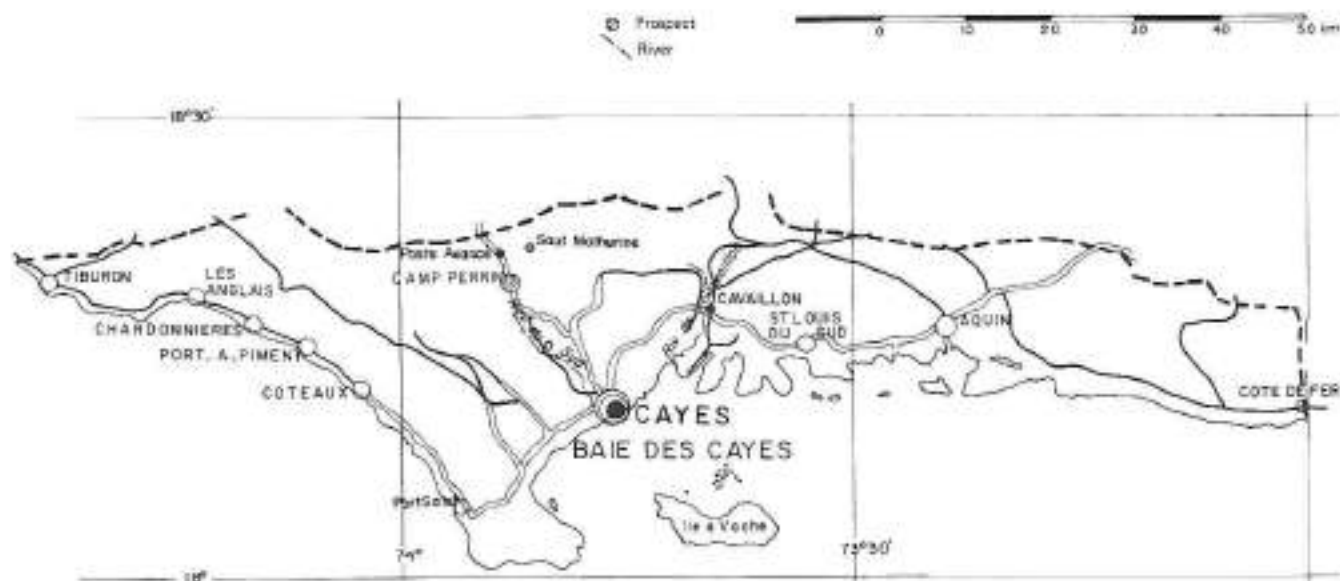
Location: Stretches south of the marble outcrop down to the coast line.

Geology: Eroded polygonally on the surface; however, the boulders are black and indurated.

Stone foundations at Jet d'eau in the Jacmel area



DEPARTEMENT DU SUD



There are large outcrops of marble in the Camp-Perrin/Duchity area, of colours not found in other parts of the country. Access to the outcrops is difficult and hampers the development of the region.

Marble

Barradères

Location: 7 km from Barradères, on the road to Cavillon.

Geology: White crystalline limestone (Cretaceous) heavily veined, opalescent with grey to brownish-black veins; takes a very good polish.

Camp-Perrin

Location: Marcelline 5 km north of Camp-Perrin on the road to Saut Mathurine.

Geology: Cream limestone, heavily veined (grey, brown, green, opalescent) with red spots, and contains in some places silica blebs; takes a good polish.

Poste Avancé

Location: Rivière Cavillon 9 km from Camp-Perrin.

Geology: Large blocks of brown, chocolate and pink-brown limestone (Cretaceous), heavily veined (grey and black), reaching several cubic metres each. Also some white and green veined limestone.

Location: 8 km from Camp-Perrin towards Duchity.

Geology: Massive crystalline veined limestone of varied colours; Cretaceous age.

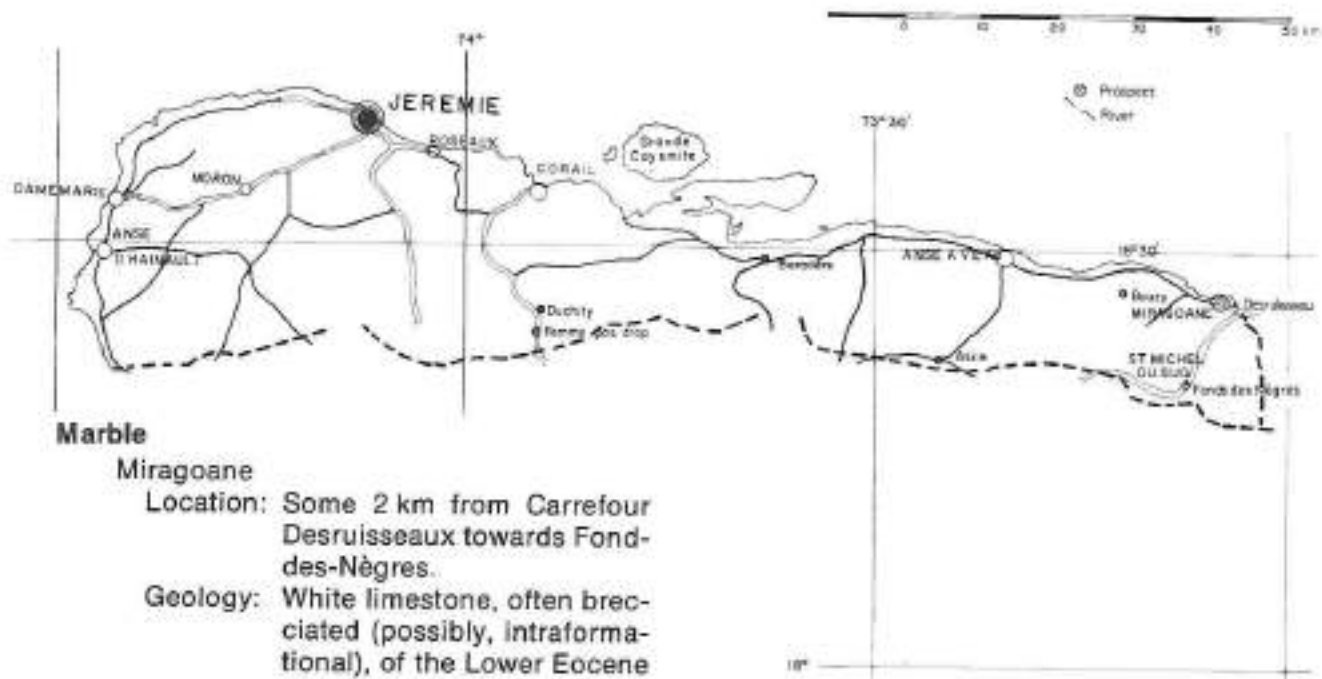
Basalt

Fond des Nègres

Location: North of Bousy (road to L'Asile).

Geology: Gently dipping layers of olivine basalts up to several metres thick. Alternating with zeolitic basalts.

DEPARTEMENT DE LA GRANDE ANSE



Marble

Miragoane

Location: Some 2 km from Carrefour Desruisseaux towards Fonds-Nègres.

Geology: White limestone, often brecciated (possibly, intraformational), of the Lower Eocene age.

Duchity

Location: 3 km from Duchity towards Camp-Perrin.

Geology: Crystalline veined limestone of the Upper Cretaceous age.

Location: Ravine Citron; 3 km south-east of Duchity.

Geology: Cream limestone, heavily veined (grey, brown green, opalescent) with red spots, which corresponds in some places to silica blebs; takes a good polish.

Location: Nan Canary 2 km south-west of Duchity.

Geology: Cream to brownish-pink veined limestone, tectonically brecciated with reddish-brown veins.

Location: Femme Pas Drap 2 km south of Duchity.

Geology: Conglomerate of grey, green, brown and black sandstone shale and limestone pebbles with calcareous cement, in beds some metres thick, whole detrital sequence over 10 m.

- 1 OBAN BRECCIA
- 2 JACMEL ROSE FONCÉ
- 3 DARANG BEIGE
- 4 FAUCHÉ CRÈME
- 5 Stone chimney of colonial times at a sugar plantation in the Cul de Sac Plain
- 6 LA RAMPE MARRON FONCÉ
- 7 LA RAMPE MARRON CLAIR
- 8 LA RAMPE PANACHÉ
- 9 LA PIERRE BRECCIA





APPROPRIATE TECHNOLOGIES

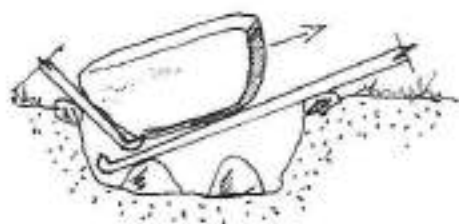
Since the energy crisis started, the utilization of stone is being reconsidered and the use of high energy-consuming components, such as iron and steel, in the making of concrete questioned.

Technological advances in the extraction and processing of stone have enabled it to be used in ways that would have been economically unsound not so long ago. Epoxy, prestressing techniques and innovations in the processing of stone at the quarry have all contributed to the increased use of stone.

In extraction, besides the advances in heavy-duty equipment, sawing techniques and recently developed splitting techniques by mechanically hand-operated machines, save much of the power used by engine-driven or other energy-consuming devices and have also given an impetus to new training techniques.

Stone splitting is making possible low-cost housing in hilly areas, not unlike the way ramming made possible mass production of adobe units where earth or clayey materials are available. However, proper training is required in the techniques for utilizing stone to the best advantage. Construction methods have to be matched to those techniques.

For developing countries to plan the development of stone resources, guidance must be received on patterns of supply and demand and utilization policies as well as technological know-how. Gradually the appropriate pattern of stone development is emerging and now a programme can produce quick results in economic housing construction without sacrifice to long-term integrated stone development planning.

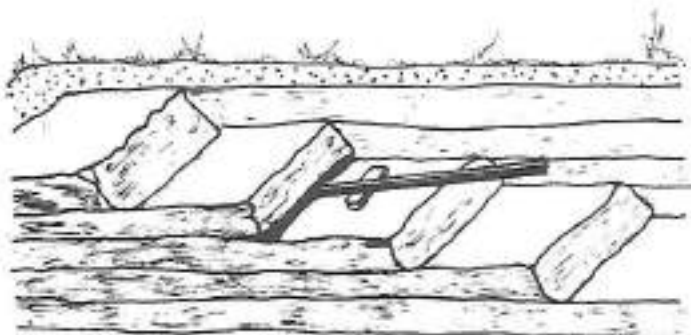


Four stages in the digging up of large field stones

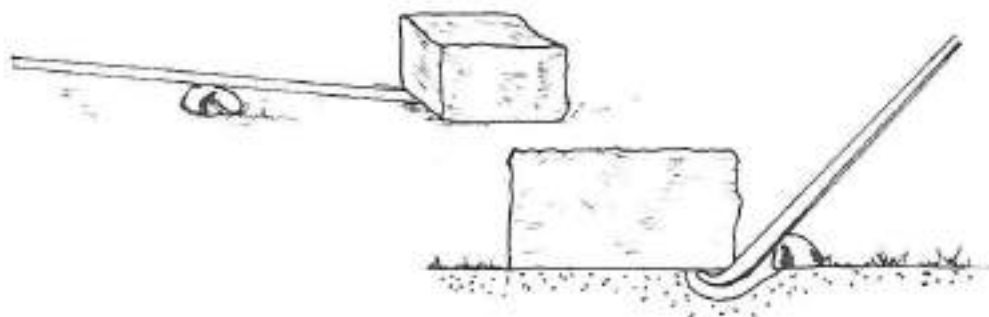


Drilling at the Mome La Pierre marble deposit

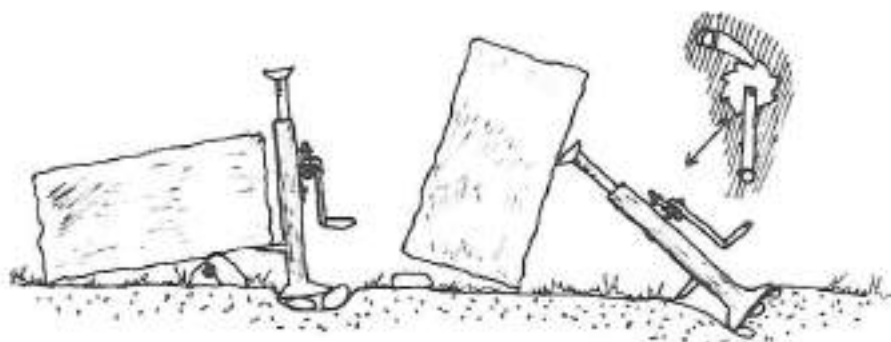
Removal, by lever and pivot, of slabs from layered deposit



Moving of blocks by straight or shaped levers



Use of mechanical jacks for lifting and pushing blocks

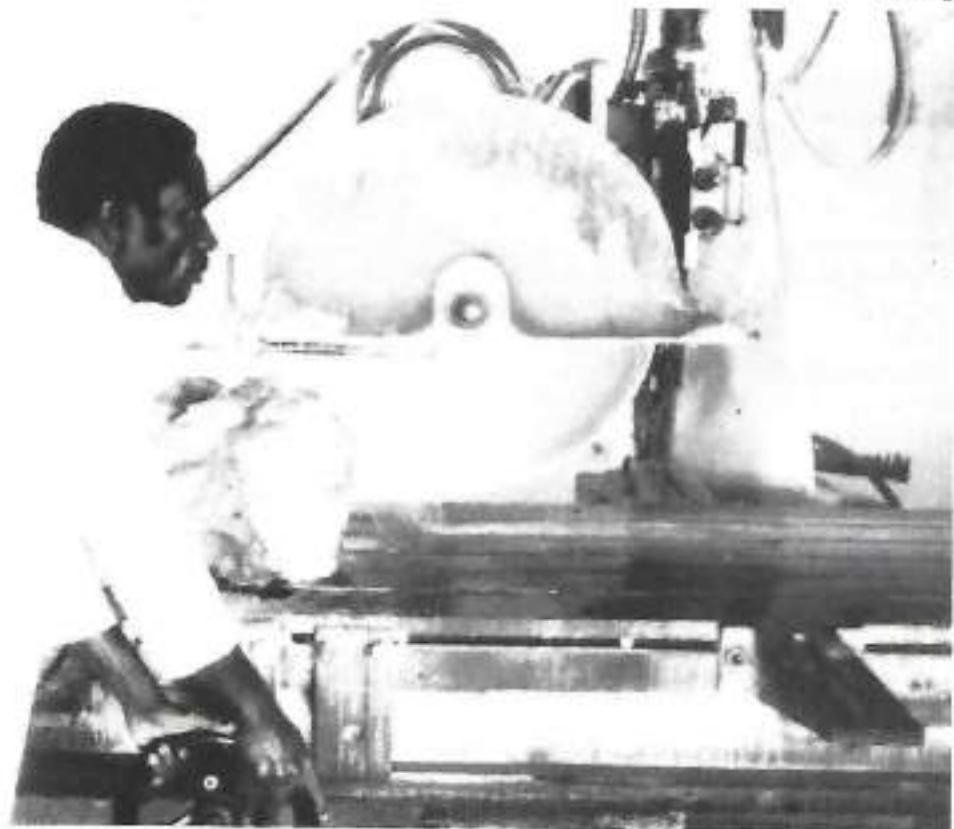




Pilot processing plant in Port-au-Prince

Polishing

Sawing



BUILDING STONE PRODUCTION

To utilize to the full the stone available, a basic knowledge of production methods is required. Rock is the raw material used to make building stone, including loose rock, field stone; wadi and river boulders, and can be obtained from *in situ* rock at a quarry site or building foundation.

Production of building stone is based on: (a) hand-cut rock; and (b) machine-cut rock. Hand-cut rock is obtained by the use of a jackhammer or other mechanical means and then subdivided into convenient units with hammers, chisels and wedges. Diamond blades, wiresaws etc. are used for cutting. Often the machine-cut types can be supplied from the quarry to the building site to be used without further processing in construction.

FINISH OF STONEMWORK

Stonework can be finished by: (a) mechanical dressing; (b) hand dressing; and (c) mechanical and hand dressing combined.

To obtain stone dimensions suitable for use in buildings, whether as individual units or part of prefabricated panels, some units are subdivided by machines (saws, splitters etc.), others are hand-cut from foundation rocks, field stones or quarry material. Even when the physical properties from *in situ* quarry material and material from other sources are equal, continuity of supply, uniform ornamentation, colour, and other factors, which all together make up the quality of stone, have to be taken into consideration (annexes II and III).

QUARRYING METHODS

The equipment required to quarry stone material includes sledge hammers, wedges, logging chains or ropes, a stone boat, jacks, winches, carts, ramps, barrows, levers and high-wheeled, box-shaped garden carts for pouring concrete.

Stones should be looked over for lines, streaks and patterns where splits could be

made. Splitting is possible by hitting hard with a big mason's hammer or sledge hammer along the grain with a pointed head, hammering out dents at intervals, and repeating this along the scored line till a crack opens. For final breaking wedges are used.

MECHANICAL AIDS FOR SPLITTING AND BREAKING STONE

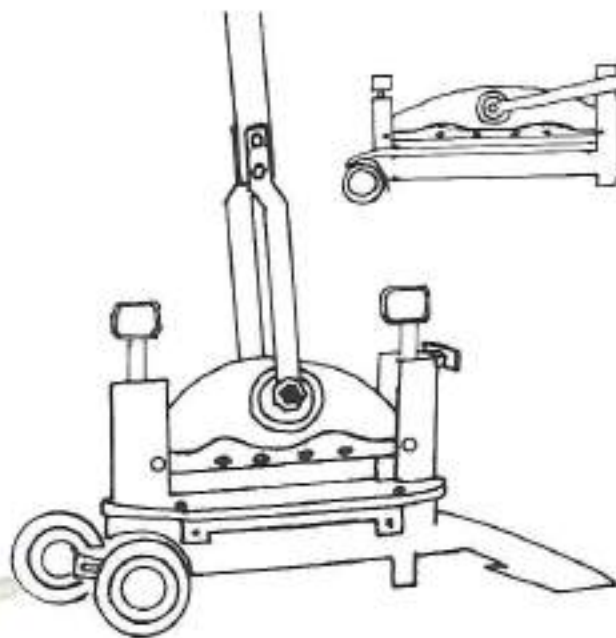
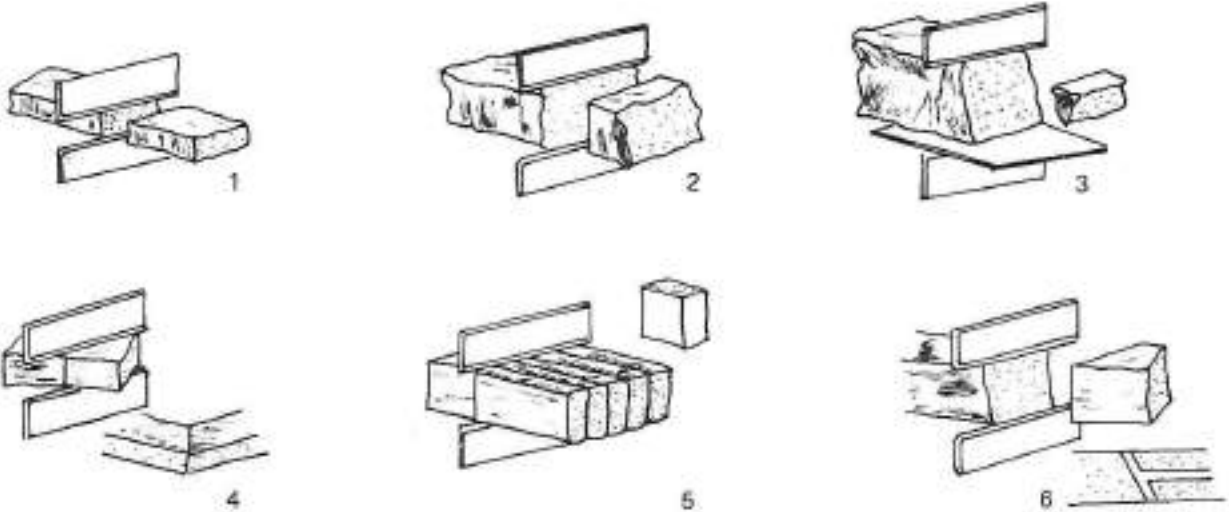
Stone is brittle at low pressures. A stress field of great concentration near the surface of stone will cause a spall or chipping because of the non-homogeneous nature of stone. Spalling is the basis of stone dressing as it requires comparatively little energy. Spalling causes instability and the energy released by loss of cohesion is used to enlarge the break.

Attrition and abrasion are part of stone cutting, e.g. sawing, and to a certain extent, grinding and polishing. Compared to spalling, abrasion uses much more energy and machinery design should be based on breaking rather than on abrasion.

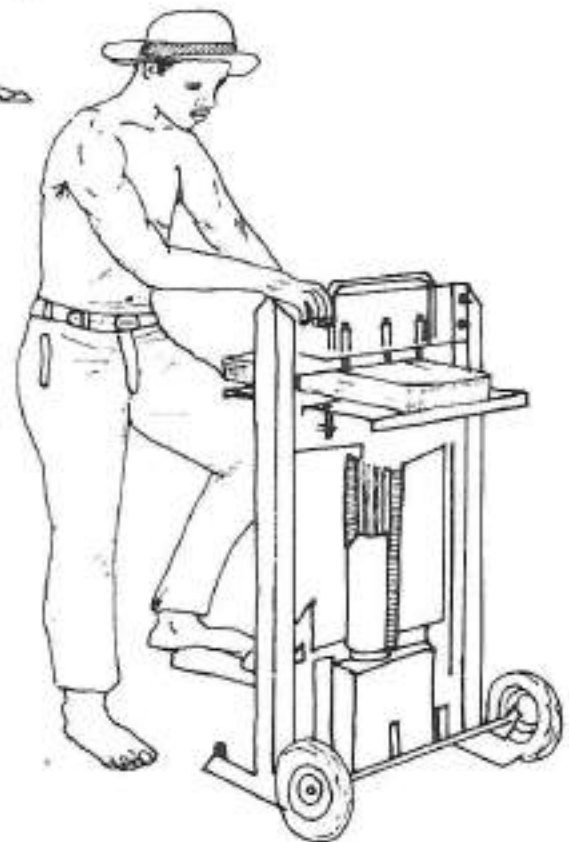
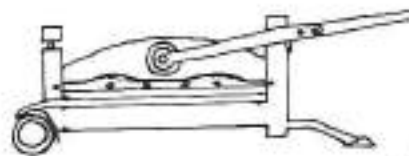
A number of splitting devices are now available for rock breaking rather than cutting. As the machines for primary and secondary breaking are fairly equal in construction principles, differing only in size, which depends on the thickness of the piece being worked, the splitters are classified for both processing stages as hydraulic, lever operated, cam, and flypress.



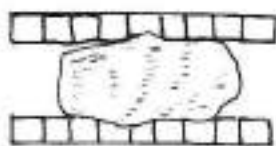
Various stone splits are obtained by using upper and lower knife edges (1 and 2); lower plate (3); angular splitting of edges (4); multiple splitting (5); joints (6)



Hand-operated portable lever-cam splitter



Foot-operated splitter



Equalizing chisel-edged blades



Drilling marble in La Pierre

All these splitters can be worked by hand, hand and foot, motor or other power source. Stationary, mobile and portable models are available. The tool may be a single fixed blade, upper and lower blades, equalizing blades, chisel edges or polygonal steel rods. Some models may have side cutters for squaring. Forces exerted by these machines may normally be up to 200 tons although the force required is much smaller. High force capacities diminish fatigue in the cutting edges whose main purpose is to transmit the forces and not to cut. In order that stone can be progressively reduced to sizes suitable for practical applications, preferably in modular units, a series of stone breaking or splitting appliances of various sizes is required.

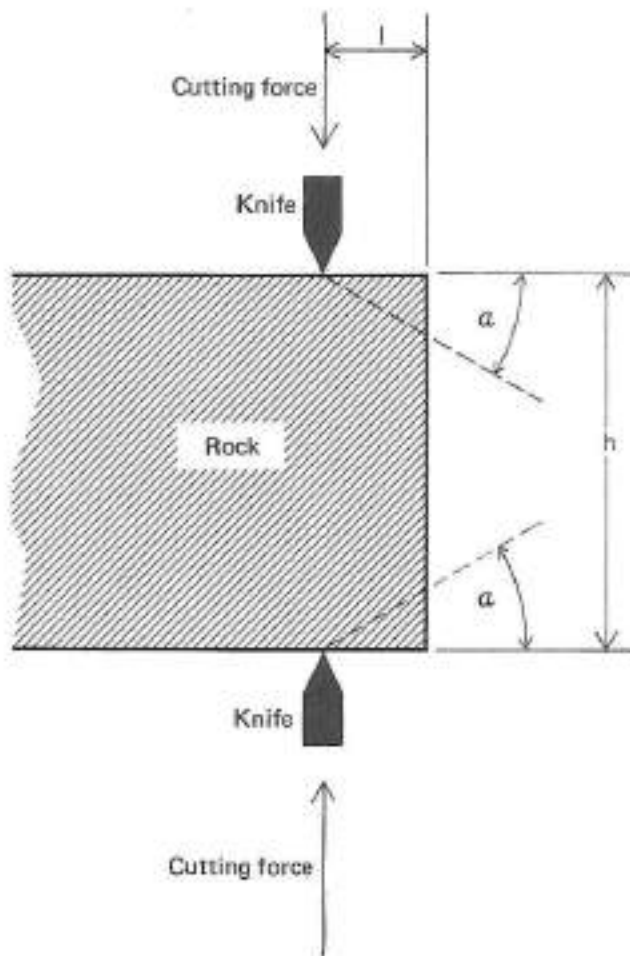
Early models of rock-splitters (guillotines) were principally laboratory rock-splitters. Attempts to mechanize slate-splitting resulted in a number of devices. In the last three decades, splitting implements have appeared on the market for specific purposes rather than as part of a flow-line concept. Refinements include separate teeth that can conform to irregular surfaces and transmit equalized pressures.

Another refinement is the induction of a stress field to have directional split and to obtain rock-faces of a conchoidal nature with exaggerated convexity. An experimental model of such a machine is at present operational with good results. This machine works on the "Brazilian test" principle, creating a concentrated load that diminishes rapidly with increased depth.

In stone splitting, a linear relationship exists between the pressure and the split surface, i.e. larger surfaces require higher pressures.

Torsional twisting to simulate a mason chiselling the stone is not essential as linearly aligned knives are adequate to provide the various dressing effects.

The split can be controlled as shown in the figure:



These results are experimental and differ according to the properties of the stone.

Rock or stone splitting by jacking power or hydraulically operated wedges is not new but has recently received more attention. A jack is a simple, versatile tool that facilitates pushing, lifting, shoring and prestressing. In addition most jacks are portable, which is important for quarrying, and take up little space, which is important when prospecting.

Screw-operated lifting jacks were the first to be used in the stone industry but were eventually replaced by hydraulic jacks. The latter gave irregular breaks when inserted in existing splits or crevices and their use was limited for breaking although they were useful for moving or lifting. The next development was the use of jacks with drilled holes.

When using hydraulic splitters, a hole has to be drilled in the material to be broken, the breaker inserted into the hole with an

Splitting near free face:

Condition	Result
$l/h < \frac{1}{2}$	Corners spill off, angle α increasing with l
$\frac{1}{2} < l/h < \frac{3}{4}$	Rockfaced surface
$l/h \geq \frac{3}{4}$	Straight break ($\alpha = 90^\circ$)

Additional forces:

The limits $\frac{1}{2}$ and $\frac{3}{4}$ change to other values.

equalizing shim ("feather") and the hydraulic pump operated. Oil pressure forces the break pistons outward against the wall of the hole, causing a shearing break at right angles to the point of thrust. The pistons are retracted by a control valve.

Hydraulic wedge splitters for stone have been developed fairly recently although "hydra-wedges" have been used for some time to fell trees. The wedge splitters apply the plug and feather technique with the power of a hydraulic cylinder. Various models work in drilled holes, in cracks or open joints, or in both.

The plug attached to the piston rod of the hydraulic ram is pulled into the feathers and loosely attached to the end of the cylinder. Various sizes are available for wedging 15-80 mm for drill holes of 21-56 mm. Some models are operated by compressed air, others by electric rotary hammers. Splitting forces are up to 350 tons.

Recently available self-propelled rock-splitters operated from heavy earth-moving equipment are in reality vehicle-mounted large chisel-edged breakers.

PAVING SETTS

Several methods have been devised to make paving setts by machinery as well as by manual methods. The fact that stones differ greatly in the ease with which they yield to the sett-maker's hammer makes mechanization difficult. Most of the rock used for sett-making, especially igneous, possesses one plane of easy cleavage, and another plane, at right angles to the first, in which cleavage is difficult. This is the so-called tough way or "hem". Often there is a third direction in which the splitting is only moderately good. Sedimentary rocks, such as limestone, provide good material for setts and their economic use depends often on their availability as natural slabs with fairly parallel bedding surfaces.

Most stone-splitting machines are restricted by (a) being unable to cleave the hem without first making a scratch in the desired direction to prevent splitting at a wrong angle and wasting material; (b) having drop hammers that give a dead blow instead of a feathering sharp blow, crushing the stone rather than cleaving it; (c) having drop hammers with rigid fastenings between the hammerhead and the guideboards so that they cannot accommodate themselves to the surface of the stone to be split, especially when it is in the least uneven or not quite horizontal; and (d) the fact that the heaviest blows are given to the smallest stones; as the lower the stone is the greater the height from which the head drops.

A sett-making machine without these drawbacks was constructed early this century in Sweden. The three cleaving directions of the stone are taken into account and the hammers fixed with springs in such a way that they can accommodate themselves to the surface of the stone on which they fall.

The machine, controlled by means of a foot-lever, raises the hammers (one for breaking and one for cleaving) to the full height, where they are retained by an automatic brake while the stone is placed in position. A spiral spring regulates the strength of the blow to the resistance of the stone. This spring is thrown out of action during the final

part of the fall of the hammers, the point of release being adjusted at will to any angle between 0° and 25° .

The machine is used in the following way:

(a) Both the hammers are elevated by means of the foot-levers. To split the hem first, a small pneumatic tool is used to make a "scratch" or small channel across the stone in the direction to be split;

(b) The stone is then turned upside down on a bed of well-stamped stone dust, placed in a frame about 20 cm high on a hard stone block and the breaking hammer, which has a rounded head and is operated by the right foot-lever, gives a few light blows just above the place where the scratch has been made on the other side of the stone. After these light blows, the foot-lever is kept down a little longer, the hammer rising higher thereby and when falling giving a heavy blow, and the stone breaks along the hem;

(c) The stone is then taken to the cleaving hammer and placed at right angles to its first position while balanced on the sharp edge of the block. The hammer is raised by the left foot-lever to a height corresponding to the thickness of the stone. With a single heavy blow of the sharp-edged cleaving hammer, the stone is split in one of its easy cleaving directions, that is, the "flat" or the "reed";

(d) The split stone is rolled over to the left by the operator and conducted by a belt conveyer in a direction at right angles to the machine. This conveyer is of hardened steel, about 40 cm wide, and passes over two pulleys at each end. The cleaved setts are removed by sett-makers, standing in a row on each side of the steel conveyer, and dressed. The waste is carried on the belt to a dumping car, and transported to the stone-crusher.

This machine is capable of making thousands of setts per day, the output depending on the nature of the stone and the skill of the operator. A motor of 4 horsepower (3 kW) is sufficient to drive the two hammers and the belt conveyer. It has a gear direct to the hammers, which serve at the same time as a counterbalance.

PAVEMENT LAYING

In order to lay pavement, the following steps should be taken. First, the foundation is prepared. If necessary, bad soil is removed and replaced by a bed of sand. If a thick bed is necessary, the sand should be brought in, in layers of approximately 30 cm, and then compacted. The compactor should go over the sand two or three times. Then, if necessary, a new layer should be laid and the process repeated. If it is not possible to compact, a thicker layer of sand will be necessary.

After the foundation is prepared, there are two ways to proceed:

(a) With skilled workers, who are able to spread the sand under each stone in such a way that the sand is levelled before the stones are laid;

(b) With unskilled workers, in which case the sand is levelled by the use of a length of board. Wooden rails at each side of the road improve results. The sand is scraped level and any holes filled in. The amount of uncompacted sand used for this is too small to affect the foundation.

Starting at one end, the stones are laid as closely as possible. The workers should move forward over the stones as they lay them in order not to destroy the levelled sand. Then the compactor should go over the pavement two or three times. By hammering the stones in this way, the gaps between them will be filled with sand from the bed which is better than spraying sand over the stones before the pavement is compacted.

In theory any compactor with sufficient centrifugal force can be used. In practice, however, a compactor used on stones requires a thick sole because of the heavy wear. A lot of extra centrifugal force is needed to provide the necessary vibrations if the sole mass is insufficient.

The type of compactor used depends upon the road surface. A roller (with one or two rolls) tends to follow the unevenness of the sand, or better, will sink the stones where the sand is not fully compacted.

Vibrating rollers are very good for tarmacadam etc., which is rather soft when not



Pavement reconstruction at the Citadelle

compacted and which tends to stick to the sole of a plate compactor if water is not sprayed before the machine. On warm asphalt, a plate would hardly move forward.

On stones, a plate will provide a much more even surface as the higher-lying stones get the total force of the machine, and in this way a level surface is provided. However, it often happens that small pieces of gravel are lying on the slabs when they are vibrated into the sand; the full load of the compactor on such a spot causes the slabs to break. Therefore, a special compactor, called a roller vibrator, has been developed. The rolls have a rubber coating that can absorb this gravel without damaging the slabs, and thus a level footpath with slabs can easily be laid.

The roller vibrator comes either as a complete machine, for contractors who use it regularly, or with a separate roller frame that can be attached with four screws. When the frame is attached, the vibrations are damped because of the extra weight, which makes the machine suitable for slabs up to 60 x 60 cm. For debris used under a street, a heavier type without a roller frame is used.

ARCHITECTURAL USE OF STONE



The natural structure of stone combined with careful processing and application enables a skilled articulation possible with few other structural or ornamental construction materials. The same stone material can be costly or cheap depending on its uses and the quality of workmanship.

Different depths of courses, invisible butt joints and prominent horizontals give a strong horizontal shadow effect by regularly alternating slabs with recessed ashlar courses. Emphasis on horizontals and restrained treatment of vertical joints can be made to dominate parts of a construction. Various joint widths and raking depths enable an infinite variety of emphasis.

Matching stone dimensions to the proportions of the construction, for example, by using elongated stretchers or extending butt joints over more than one course, is important, especially in the sculpture block concept of a cluster of buildings. The structure and form of a building can be expressed by varying the use of the stone materials to combine function with ornament. Stone, by itself, with its natural varied colouring and irregular edges, enlivens large flat walls. Large expanses can be relieved by adding a few courses of stone in different shades.

Stone sills and lintels, while serving as integral constructive elements, can also decorate stone walls. Stone enables the building to blend with the landscape, particularly in mountainous areas where local rubble is used for walls, retaining walls and terracing. A severe composition in stone can appear as an autonomous element without relation to the environment. Care in selection enables the use of as-found material for well-fitted and matched geometrical shapes and straight edges. Unworked rough surfaces often achieve the greatest effect of light and shadow without any further finish. The use of large and small unhewn slabs in the same wall, laid according to their natural shapes, produces an interesting surface effect.

Setting back courses regularly, especially on piers, gives the illusion of inclined planes and adds depth.

ASHLAR

In modern practice squared stones are prepared by mechanical means to reduce hand-dressing to a minimum.

Machine-cut

Machine-cut ashlar is basically squared on five sides, with the back left rough if unexposed. The exposed face may be: sawn-cut (diamond saw); rubbed; rock- or pitch-faced; tooled; pointed; sandblasted; brush hammered; vermiculated or rusticated with various margins, usually of a different pattern than the central part (boss). All these textures can be obtained by hand-dressing, mechanical-dressing or a combination of the two. The cutting of the basic stone by machine ensures squared and clean arrises and saves time in the final dressing as the exposed face is regular and needs only a minimum of finishing operations.

Hand-cut

The same types of dressing can be used for hand-cut as for machine-cut ashlar. The ashlar is prepared either with hand tools, rock-splitters or mechanical hammers and chisels.

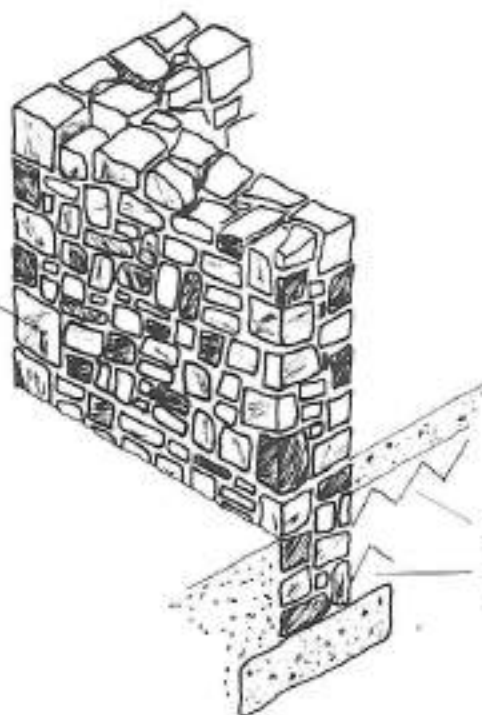
RUBBLE

Rubble is shaped irregularly and the stones roughly trimmed to fit with each other in the wall. When the stone comes from fairly parallel well-bedded layers, often the natural bed is used with no further treatment except for cleaning, especially when clayey skin would weaken the mortar bond. Rubble may come in many forms, for example, polygonal, coursed, field stone and random. It is often used in combination with ashlar, in which case, rubble may be used as backing or filling between quoins.



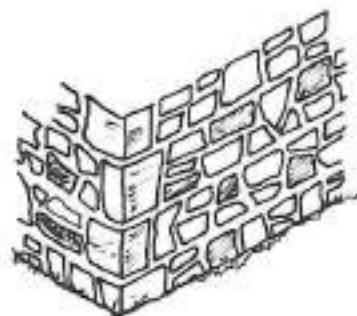
Stone church on the Gonaives-Cap Haïtien Highway near Pailboreau

Large, roughly squared stones selected for quoins



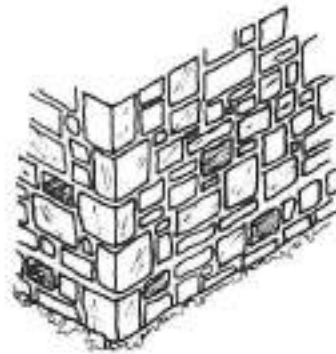
Random rubble - uncoursed

Random rubble — brought to the courses so as to course-in with quoin stones (25-40 cm in height)

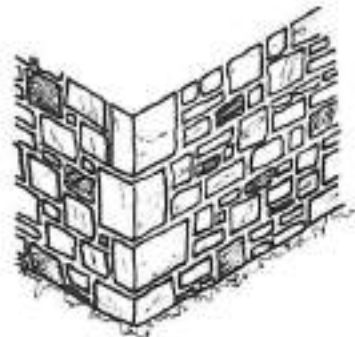


Concrete covers the hard core of broken stone

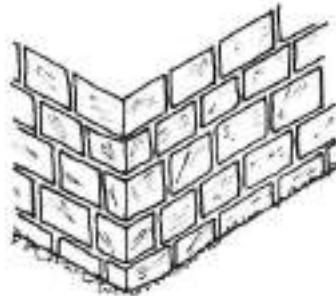
Squared rubble-uncoursed



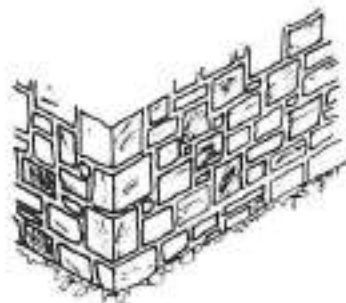
Squared rubble brought to courses



Squared rubble-coursed



Snecked rubble (squared)



TRIMMING

All regularly cut stone not in the form of ashlar can be classified as trimming. This includes lintels, sills, caps, mouldings, coping, columns and entablatures (cornices, friezes, architraves etc.), stone steps and arches.

FIELD STONE TECHNIQUES

Essential elements for construction include:

- Lay-out
- Footings
- Height-width relationship
- Tying-in
 - "Flats" for top stones
 - "Rectangulars" for ends and corners
 - "Longs" for tying-in

The difference between a stone wall and a pile of stones is in the laying of the stone. Besides pent-up energy, which enables it to be broken with minimum effort, another important property of stone is its high relative density, which together with its high rigidity, allows it to be laid up in strong, stable walls.

In order to build low-cost shelters or walls, stone must be available in the vicinity. If it has to be transported it should be noted that stone weighs only half as much when moved under water. Sources for stone material include ledges, road-cuttings, old quarries, mine-waste heaps, outcropping schists (which split easily), old buildings, field walls, river valleys, wadis and field stone from clearings. No special skill or equipment is required to collect it and although splitting is helpful, broken or whole stones can be used.

The terms splitting and breaking are often used interchangeably. However, although all splits are breaks, the former term usually denotes the use of the natural direction of the stone when breaking it.

It is always important to clear the surface of any patch of stone about to be removed. The right positioning of a crowbar or jack can sometimes bring tons of stone down a cliff.

A properly constructed dry-stone wall expands and contracts with changes in temperature, unlike a mortared wall which is rigid and absorbs stress with breaks and cracks.

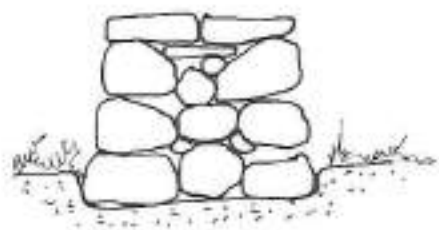
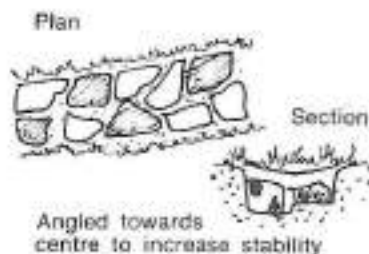
To build a wall the outline is laid out with cord looped to sticks or stakes. The footing (lowest courses) should rest on subsoil rather than directly on the ground. Stakes higher than the planned wall are hammered in to mark the four corners.



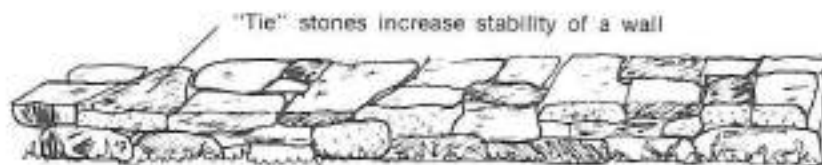
Well tied-in end



Weakly constructed end



Rounded boulders or rubble can be used if properly stacked and batter is continued below ground level

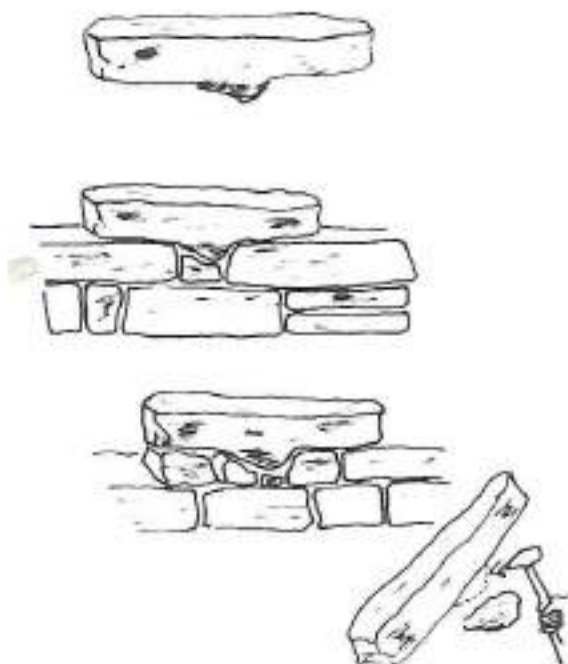


Cord is tied to the four stakes at wall-top height and stretched. Stakes are added with the string touching the inner-facing of each stake, and fastened to prevent curving by the wind. Usually the top of the wall is flat.

Whether to use small odd-shaped stones for the foundation and to save the biggest flat stones for the topping course is debatable as the foundation is critical and settlement may lead to cracks in the incumbent courses. Open spaces filled with smaller stones provide good drainage. A slight inward angle towards the centre causes the outer walls of the structure to lean in against themselves, increasing stability.

The thickest and heaviest rocks should be kept for the lower courses to avoid unnecessary lifting. When laying a wall the following should be noted:

- The best flat face of the narrow dimension of each stone should be facing out.
- Each stone should be bedded solidly on the stones below.
- A wobble should be chipped off of a stone rather than shimming the stone with small rocks and wedges.
- Small stones used in the outer faces may work loose in time.



Sectional view

Front view



Downward slant towards centre of wall increases stability



Retaining wall

- Joints between stones should not extend from course to course to form a "run". The wall will try to fold there as dynamic stresses concentrate at the weakest point.

- Every 2 to 3 m a long "tie" stone helps in tying one face to another.

- Rectangular stones of even thickness, the longer the better, should be saved for ends and corners, especially the outside edges.

- The higher the wall, the wider and deeper the footings should be.

- The top course should consist of good flats, as big as can be handled with ease.

- The top face of each stone should have a slight downward slant on which the next course can rest.

- Splinters and wedges should be added to stones so that they will not move.

- Wedges should be placed with the widest end in the core, the thin edge pointing out.

- A ditch on the upper slope of the wall and also a hole or culvert in the first above-ground course will control drainage.

- The bottom of vertical posts should be buried well below ground level.

- A lattice fence should consist of alternate squarish blocks and thin slabs with a support block where the slabs in the course above meet.

- Batter is required for retaining walls, especially for the backward slope, the angle increasing with the height required. A rubble filling between the wall and the earth bank will enable water to flow freely behind the wall and prevent build-up of pressure at any point.

- Gaps can be built at an angle to keep out cattle.

- Stiles should be planned beforehand with rises of about 20 cm and the same distance forward per step.

- Gate or door hangers should be fixed into the facing ends of the opening by drilling holes with hammer, chisel and dust scoop, preferably with the stone in a horizontal position before fixing.

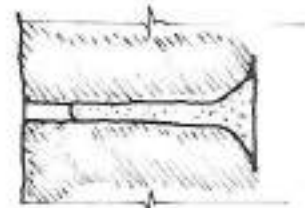
- Besides other binders, molten sulphur, strips of tamped-in lead with or without melting are used for fastening anchors, eyebolts etc.

- Stones should be dropped into place rather than put down so that they will find their own level.

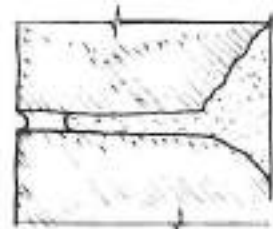
POINTING

All pointing should be sloped downwards and outwards to prevent water collecting in the joints.

Channels should be cut into large expanses of mortar to keep the water from getting between the stone and the mortar.

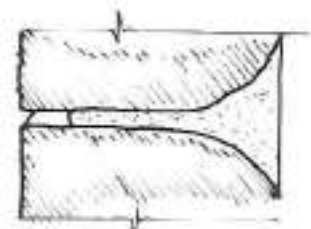
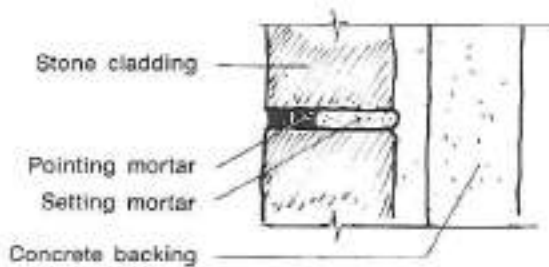


Flush joint



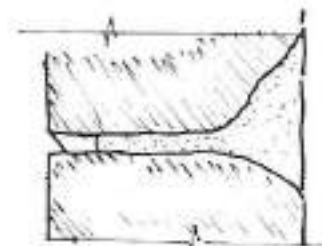
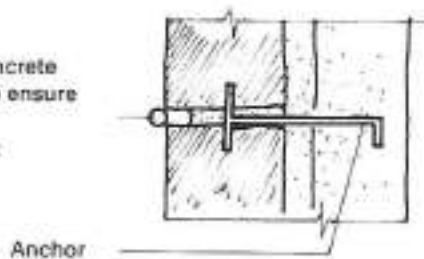
Concave, keyed or core joint

Two- to three-stage pointing



Struck joint

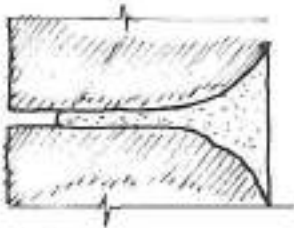
A tool with a concrete profile is used to ensure a hard and impervious joint



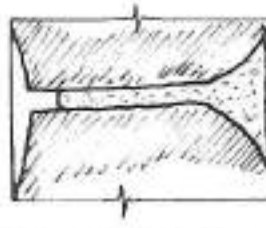
Weathered (struck) joint



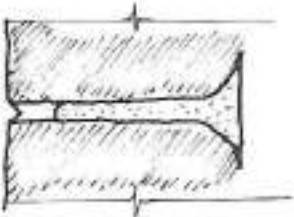
Square, sunk or rustic joint



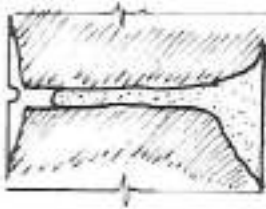
Raked joint



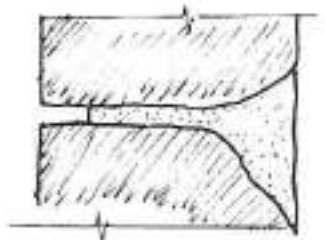
Feather-edge joint (irregular pointing)



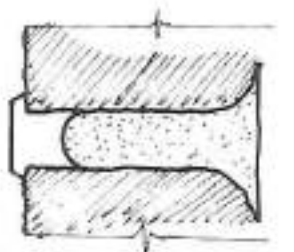
V-shaped joint



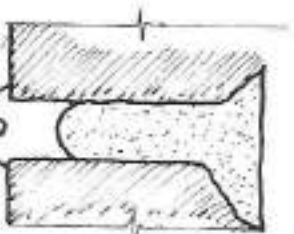
Indented feather-edge joint



Beaded joint

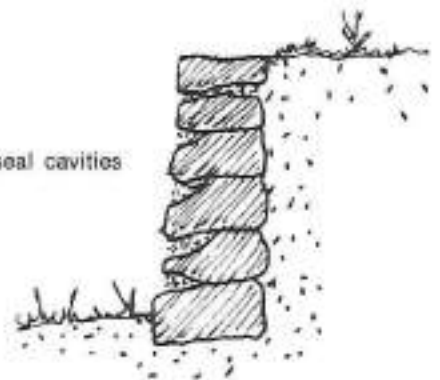


Raised joint



Indented, raised joint

Joints should seal cavities



Loose cement encourages deterioration



1



3



2



4



- 1 PERISSE NOIR
 2 PERISSE DORE
 3 CAMP-PERRIN GRIS VEINÉ
 4 CAMP-PERRIN GRIS
 5 CHANGIEUX BEIGE
 6 PORT-MARGOT DORE
 7 LA PIERRE VEINÉ
 8 MARCELLINE ROSÉ
 9 Entrance to the Citadelle behind the
 drawbridge
 10 MIRAGOANE BRECCIA
 11 LA RAMPE ROSÉ
 12 JACMEL PALE
 13 LA PIERRE FLAMBOYANT

5



6



7



10



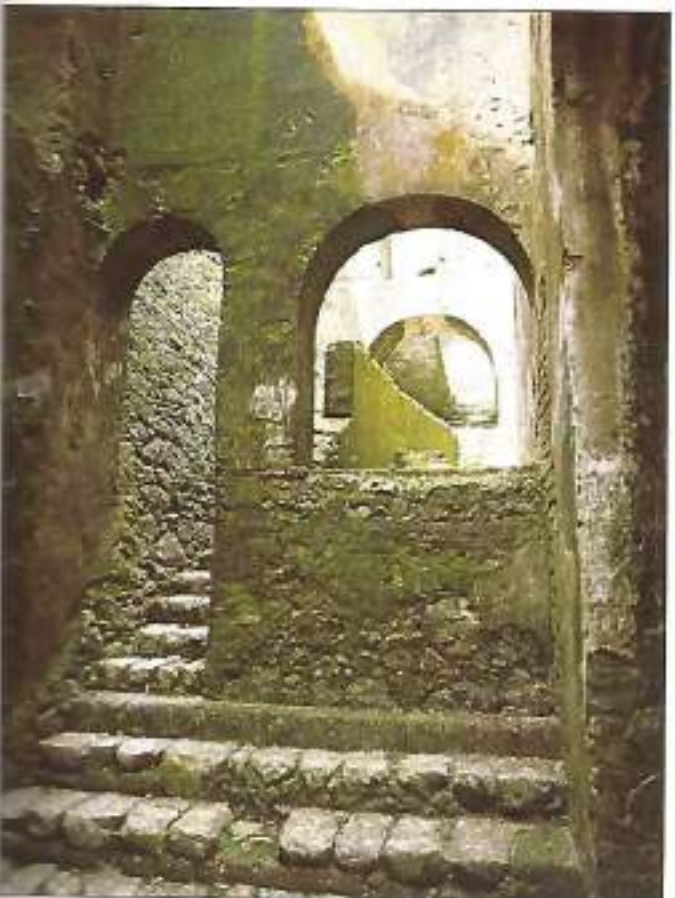
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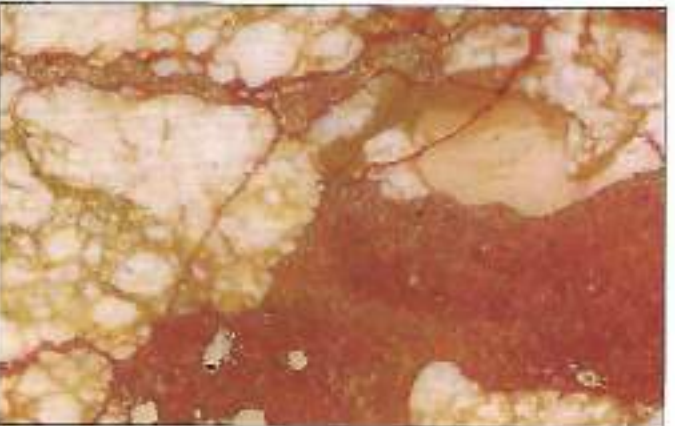
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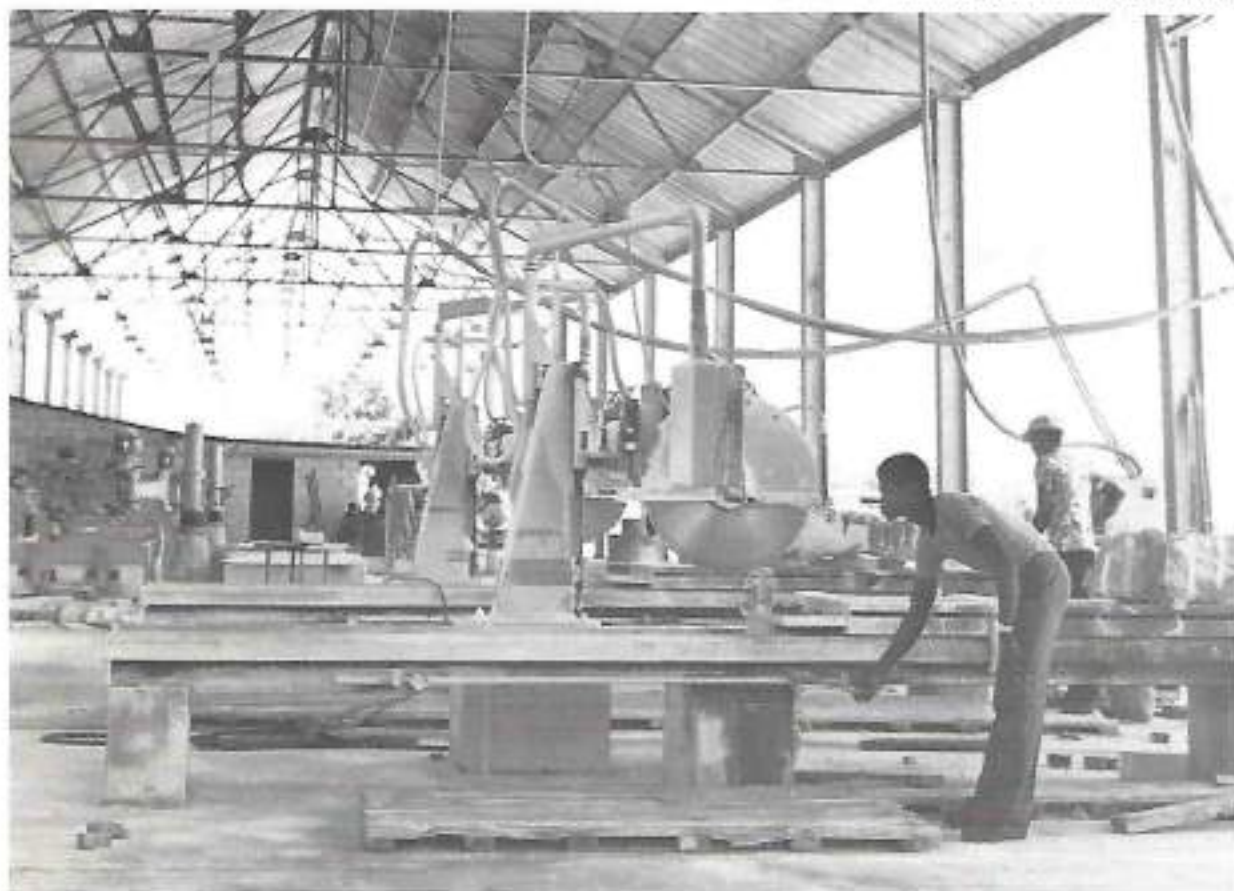
Annex I

VARIETIES OF HAITIAN MARBLE

Varieties of marble, classified according to colour and location, are:

Light		Medium		Dark	
White	{ La Pierre Miragoâne	Ivory } Cream }	Terre Neuve	Buff	La Coupe
Ivory	La Pierre	Beige }		Brown	Post Avancé
Cream	Miragoâne	Buff	{ Marchand La Coupe	Grey	Périssse
Beige	Novion	Brown	Post Avancé	Black	Périssse
Buff	Puilboreau	Pink	Jacmel		
Pink	Puilboreau	Grey	Périssse		
Grey	Périssse				

First industrial marble and processing plant in Port-au-Prince



Annex II
CHARACTERISTICS OF BUILDING STONE MATERIALS

<i>Characteristic</i>	<i>Limestone</i>	<i>Sandstone</i>	<i>Granite</i>	<i>Marble</i>	<i>Slate</i>	<i>Quartzite</i>
Use	Walling and cladding		Walling, cladding, plinths, surrounds and steps	Window surround, floors and stairs	Cladding sills, coping, steps and paving	Cladding, plinths, floors, paving and stairs
Composition	Largely calcium carbonate	Quartz in all mica and felspar grains in some. Bonded largely with silica or calcium carbonate	Mainly felspar, quartz and mica	Mainly calcium carbonate	Mainly silica, alumina and iron oxides	Mainly quartz
Method of production	Quarried, cut to size (masonry and sawing), finish as required, e.g. patterned, rock faced, fair picked, fine axed, rubbed, eggshell or polished					Finish—natural, riven
Specific weight (kgf/m ³)	1900–2700	1950–2550	2400–2900	2725–2900	2400–2900	About 2600
Compressive strength (MN/m ²)	9–59	21–105	90–146	About 60	75–200	About 100
Water absorption (per cent)	2.5–11	2–8.5	0.1–0.5	0.1–0.5	0.1	0.1–0.5
Effect of fire	All non-combustible					
Moisture expansion (per cent)	About 0.01	0.07	None		Negligible	
Effect of chemicals	Attacked by acids	Resistant to most acids except calcareous types which are attacked	Resistant to most acids	Attacked by acids	Mainly resistant to acids	Resistant to most acids
Resistance to effect of soluble salts	Poor to very good	Poor to good	Poor to good	Good	Good	Good
Thermal expansion co-efficient (°C ⁻¹)	4 × 10 ⁻⁶	12 × 10 ⁻⁶	11 × 10 ⁻⁶	4 × 10 ⁻⁶	11 × 10 ⁻⁶	11 × 10 ⁻⁶
Thermal conductivity (Wm°C ⁻¹)	1.5	1.5	3.0	2.5	1.9	3.0
Resistance to frost	Poor to very good	Poor to excellent	Good to excellent	Good to excellent	Good to excellent	Good to excellent
Durability		Dependent on	4.07.05, 4.05.02.	4.03.04, 4.13	4.04.08.	
Ease of working	Easy to hard	Hard	Hard	Fairly hard	Hard	Hard
Tendency to soil	Soil in urban atmosphere		Resistant	*Fairly resistant	Resistant	
Ease of cleaning	Fairly easy	Difficult	Difficult		Difficult	

Source: CIB (International Council for Building Research, Studies and Documentation) master list for materials.

Annex III

ORNAMENTATION TERMS FOR MARBLE AND STONE

alternate (stripes)	laminated	slender, slenderly
amygdaloidal	(resembling wood)	(streaked)
bands (alternate)	marked	slight
blotched	markings (threadlike)	spangled
bright	matrix	specks, speckled
broken	merging	splashed
close (veins)	mingled	spots (small fossil-like),
clouded, cloudy	minute (pattern)	spotted
comminuted	mixed	sprinkled
compact	mosaic	stainings, stained
conical (fossils)	mottled	streaks, streaked
contorted	mutual	(like wood)
crinkly	narrow	strewn
crowded	netted	striations
curly	(with white veins)	string-like
dappled	not clearly defined	stripes
dendritic	obliterated	subdued
dots	orbicular	thin
dull	packed	tinge
edged	patches, patchy	traverse
elongated	patterned	undulating
faint	pencilled	uniform
feathery	radiating	varicoloured
figuring	ragged (patch)	varied (shades)
filament	ramified (dendrites)	variegated-irregular
fine (lines)	relict	patches and veins of
flushed	reticulated	different colours
jagged	ribboned	and shades
		veined (amygdaloidally)

Some typical descriptions:

bardiglio—faint bluish-white ground pencilled clearly with straight dark blue-grey, "pencilled vein"
 calacata—white background with irregular, light and dark, sepia veining
 cipollino—whitish ground streaked with parallel straight or undulating bands of green, contorted

fiorito—veins interlacing or confluent
 pentellic—white background with slight cloudy, grey figuring
 texture—grain pattern relating to size, shape and mutual relations of component grains or crystals

Colour classification (basic)

white beige	blue	pink red	black grey	violet	yellow	green
Colours black, nearly, deep, dead, dull black, powdered, shining bluish cast bright cream brownish-grey brownish-pink buff of varied shades dull black faint fawn fiery red green floriate (moss) grey, ash grey, drab			grey, lead grey, mixed grey, slaty grey, smoky grey, warm pale red, mixed red yellowish rose, rich ruddy sepia slaty (grey) snowy unicoloured—of one colour, though not necessarily of one shade, without any positive markings			white, dull white, glassy white, watery white, wax yellow, plum
						Texture elastic equigranular granulitic interlocking (e.g. granite) mosaic porphyritic unequigranular

Cabotage transport



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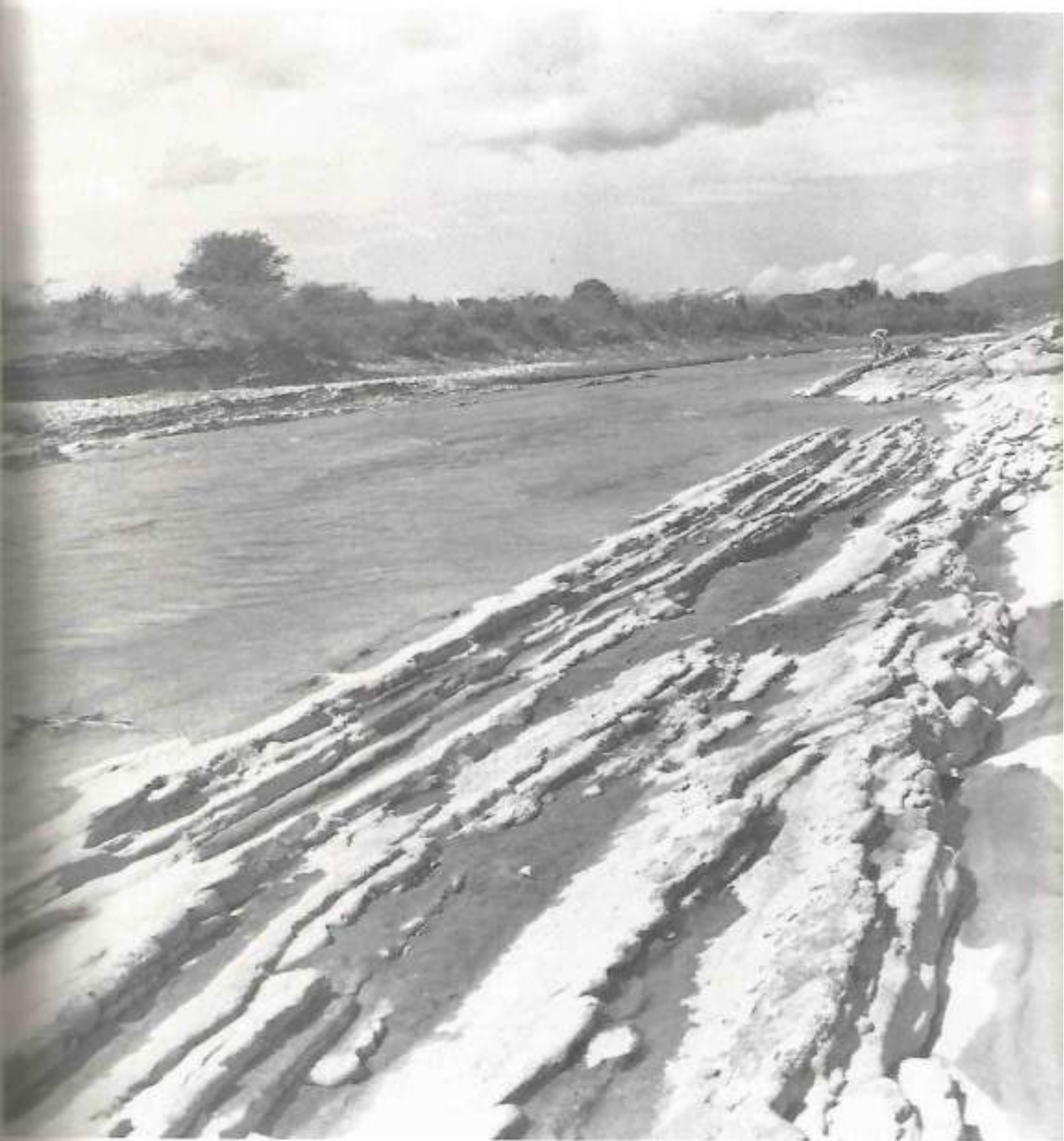
Stones transported at Plain de Cul-de-Sac



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Richard Hervé
John Isaac
Asher Shadmon

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Layered sandstones and other stone types of oligocene-miocene age at Les Trois Rivières, Fond Duroc