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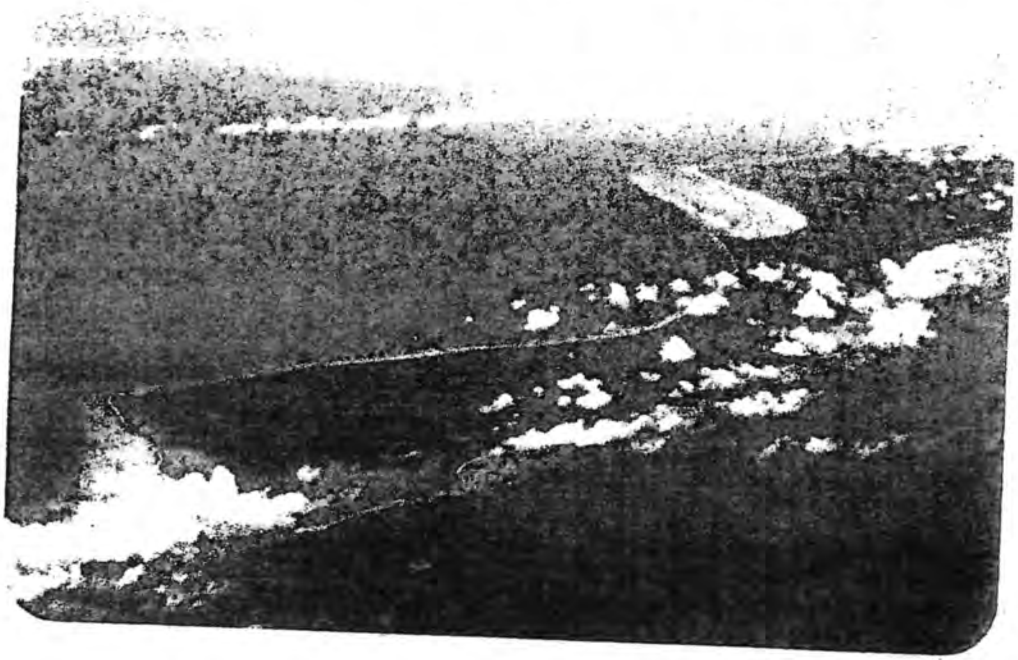
PRELIMINARY LIMESTONE MINING DIAGNOSIS



La Habana, November, 2014

GAMMA

ROCK MINING IN MAYAGUANA ISLAND, THE BAHAMAS: PRELIMINARY LIMESTONE MINING DIAGNOSIS

L.F. Molerio-León
E.J. Balado Piedra
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INVERSIONES GAMMA, S.A.

EXECUTIVE SUMMARY

As stated in the agreement between the Bahamas Agricultural and Industrial Corporation (BAIC) and INVERSIONES GAMMA, S.A. (Cuba) the Government of the Commonwealth of The Bahamas recognizes that the creation of a sustainable rock mining (limestone) industry for domestic and export use will greatly boost the economy of The Bahamas and create employment opportunities for Bahamians.

Therefore, the Bahamas Agricultural and Industrial Corporation (BAIC) has commissioned the group on September 11th 2014 to carry out a research project on the sustainability of the rock mining (limestone) on the island of Mayaguana and to formally make a presentation of its finding to the Hon. Executive Chairman of BAIC in order to provide guidance to the Hon. Prime Minister of the Commonwealth of The Bahamas.

From November 11th to November 23rd a group of specialists from INVERSIONES GAMMA, S.A. visited the Bahamas and spent four days doing field work in Mayaguana Island. The original work plan considering a field work session of two weeks in Mayaguana was rearranged after our team arrived to Nassau and according with those limitations in time and effort, the original scope of the work was reduced.

The agreed goals of the project were:

1. Identification of perspective zones for rock (limestone) mining in selected islands of Bahamas, particularly in Mayaguana .
2. Identification of the main factors controlling:
   a. Limestone occurrence, extension and physical properties for sustainable/responsible exploration & mining.
   b. Environmental issues of limestone prospection & exploitation.

These goals were intended to be accomplished by a geological reconnaissance according to International Good Practices, particularly following the United Nations recommendations but based only in field documentation and observation, satellite imagery interpretation, geomorphologic and structural geology interpretation of topographic maps and petrological/sedimentological interpretation of rock samples.

The Geological knowledge can only be obtained by geological exploration. UNFC has divided geological exploration into four successive stages of geological assessment in order of increasing details:

- Minimum distance of observation points is recommended for the each of the four stages depending on the tectonic setting and type of mineralization
- Classification of activities in each step of geological exploration depend upon the basis of works, and the resultant status of resource evaluation

These stages are:

- Reconnaissance Stage (G-4)
- Prospecting Stage (G-3)
- General Exploration Stage (G-2)
- Detailed Exploration Stage (G-1)

Limestone is among Bahamas most essential resources. Our understanding of that resource as an industrial mineral is poor given its importance to Bahamas economy.

Research on limestone should be focused on mapping deposits and a proper assessment of its resources, as well as understanding their roles as construction materials, aquifers and petroleum reservoirs. However, different data are needed to characterize limestone suitable for construction and other industries.
Carbonate rocks need to meet chemical purity requirements that vary by intended use. Some uses require that the limestone also has certain favorable engineering properties.

Standards and requirements for limestone use are rising, and a greater understanding of limestone characteristics, variability, and engineering properties is needed. It is important, though, to catalog such rocks as possible future resources.

The Bahaman Archipelago consists of two carbonate banks which were formed by a chain of carbonate platforms. The archipelago is an arcuate system of carbonate platforms, commonly capped with low islands, to have been built on oceanic crust located to the east and south of the continental margin North America.

The Bahamas have long been the focus of geologic work on modern carbonates and show a particular interest to geologists as it provides a modern analog for the dynamics of

ancient carbonate depositional platforms, many of which are major petroleum reservoirs.

The current landscape of the Bahamas is largely constructional and is greatly influenced by glacioeustatic sea-level fluctuations. Carbonate deposition occurs on the flat bank tops during glacioeustatic sea-level highstands when shallow lagoons dominate. During sea-level low stands, sea level drops below the bank margins. Carbonate sedimentation ceases and subaerial karst processes dominate on the exposed bank tops. Low stands are recorded in the sedimentary record by the development of terra rossa paleosols. These fossil soil horizons are the result of the concentration of insoluble materials, such as atmospheric dust, due to pedogenic processes.

The oldest stratigraphic unit exposed on the island is the Owl's Hole Formation, a bioclastic eolianite. Owl's Hole is overlain by a terra rossa paleosol separating it from the overlying MIS 5e Grotto Beach Formation, which includes a lower transgressive oosparite and peloidal grainstone unit, the French Bay Member, and an upper eolianite and distinct framestone unit (fossil reef), the Cockburn Town Member. A paleosol layer overlies the Grotto Beach Formation, and marks the end of Pleistocene deposition on the island. Holocene depositional units include the early Holocene North Point Member and overlying Hanna Bay Member, both of which belong to the Rice Bay Formation. Lower Holocene lithologies are dominated by bioclastic eolianite and calcarenite facies, while the overlying Hanna Bay Member is largely comprised of intertidal facies and eolian deposits in equilibrium with the modern sea level. Beachrock found within the Hanna Bay in San Salvador Island reveal evidence of rapid cementation.

Mayaguana, as most of the Bahamian Archipelago is a very low altitude island mostly at sea level. Ponds and wetlands dominate in the inland but it is common to find it in the shallow friable coast. Some of the coastal features are spits and hooks linked with the wave refraction phenomena. When the waves are refracted around the tip of the spit the attendant longshore currents become weaker and hence the material is deposited. Coastal ponds are associated with the development of offshore bars. Reef barriers practically surround the island contributing to the development of shallow bays.

Most of our geological exploration was developed at the southwestern sector of Abrahams Bay, so the main references on the geology and geomorphology will be exemplified in that area.

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With respect to the limestone mining in Mayaguana Island we are at the G-4 Reconnaissance Stage (Reconnaissance Resource) of the Western part of the island.

At the G-4 level of effort the explored area was divided into five blocks of different shape and thickness thus giving different potential volumes of carbonatites. This potential was estimated, depending on the inferred/tested lithological composition and the shape of the landscape involved. A confidence level of 85% was accounted because of the limited time in the field work and the restrictions of documentation (time, accessibility, denudation and complexity of the geological conditions.

Because of the environmental issues involved, particularly in what concerns to the protection of the groundwater level, roughly at the same level of the sea, a confidence interval of 1 m above sea level was considered as the lower limit of exploitation of the limestones. The upper limit was defined on average altitude or, in some cases, by the highest altitude of the block. Those were the boundaries used for the computation of the Reconnaissance Reserves.

According to our computations the **Reconnaissance Resources of the explored sector are estimated in 35 595 311 m^3 at the 85% confidence level.**

At this level of knowledge it is deeply recommended to continue to the following stage; v.gr. Prospecting (G-3 Stage) Inferred Resource.

Nassau, Bahamas & La Habana, Cuba

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INTRODUCTION

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These goals were intended to be accomplished by a geological reconnaissance according to International Good Practices, particularly following the United Nations recommendations but based only in field documentation and observation, satellite imagery interpretation, geomorphologic and structural geology interpretation of topographic maps and petrological/sedimentological interpretation of rock samples.

Having an understanding of the geology of the area leads to a better understanding of why the islands are shaped the way they are. The geology leads to an explanation of the placement of the islands along the carbonate banks, along with an explanation of both the tilt and the composition

[1] Onac, B.P., Sumrall, J., Mylroie, J.E. & Kearns, J. 2008, **Cave minerals of San Salvador Island, Bahamas.** The University of South Florida Karst Studies Series, 1, 68 p.

of the rocks. Also, with a greater understanding of the islands, models that focus on salinity levels and sedimentation patterns can be built and analyzed. Overall, knowing the geology of the area allows scientists to understand what has happened in the evolution of the islands and predict the future of the islands. A better understanding of how the islands are created also lend to a better understanding of the coral reefs because scientists know how the islands where made and can observe the roles that the coral reefs played in this evolution.

As a result, INVERSIONES GAMMA will produce a Report describing the **general geological characteristics, potential, use, exploitation means and environmental issues of rock mining in selected islands and the ToR's for the development of rock mining in selected places of the Bahamas** but now reduced to the small western sector of Mayaguana explored during the reduced field session. This document is destined to satisfy the general informative requirements of the agreement.

The BAIC technical experts finally designed included Mrs. Judith Thompson, Assistant General Manager, BAIC and Mr. Ralph Brennan a designated surveyor.

Twenty rock samples were collected during the field sessions and close to 10 cuts and outcrops were documented in the field. A few observations on groundwater hydrology in ponds and a blue hole were performed in the field. A detailed analysis of the topographic map and interpretation of Google images in real and false color were done In Bahamas and in Cuba. Also a very detailed revision of the available (published) literature on Bahamas geology, geomorphology and karst hydrology took place in Bahamas and Cuba. It was also advantageous the previous experience of Mr Molerio in geological and karst explorations in Bahamas some years ago.

The INVERSIONES GAMMA, SA. team included L.F. Molerio-León, Head of the Project, E.J. Balado Piedra, Assisstant Geologist and J.M. Marrero Basulto, Coordinator of the Bahamas Projects. Mr. Balado and Mr. Marrero carried out the field sessions in Mayaguana. Reconnaissance Reserves were computed by Mrs. Ana M. Sardiñas and Mr. Molerio who was in charge of the data processing and writing of the report. The conclusions and recommendations are shared by the INVERSIONES GAMMA team.

The authors wish to acknowledge the cooperation of BAIC team particularly that received from Mrs Judith Thompson and Mr Ralph Brennan in Bahamas. Special thanks to Mr Soberon Ambassador of the Republic of Cuba to the Commonwealth of Bahamas and his staff, as well as the Director, Havanatur office in Bahamas.

OVERVIEW OF THE GEOLOGY AND MINING OF LIMESTONE

"Limestone" means any rock formed mostly of calcium carbonate ($CaCO_3$), but to geologists, limestone is only one of several types of "carbonate rocks." These rocks are composed of more than 50% carbonate minerals, generally the minerals calcite (pure $CaCO_3$) or dolomite (calcium-magnesium carbonate, $CaMg[CO_3]_2$) or both[2]. Because of its high calcium content, limestone is usually light in color, although many variations exist. Commercially, the term limestone includes dolomite, dolomitic limestone, oolitic limestone, and travertine (Dolley 2007)[3], a porous calcitic rock that is commonly formed near hot springs (Figs. 1-3).

Fig. 1. Calcite

Fig. 2. Dolomite

Fig. 3. Aragonite

Most carbonate rocks were deposited from seawater. These sedimentary carbonate rocks are common on every continent and have formed through most of geologic history; they are still forming today in the tropics as coral reefs and at the bottoms of shallow seas. Marine limestone forms because seawater has high concentrations of two key dissolved chemicals—calcium (Ca^{++})

[2] USGS. 2012. **Limestone—A Crucial and Versatile Industrial Mineral Commodity.** Fact Sheet 2008–3089 Revised August 2012

[3] Dolley, T.P. 2007. **Stone, Dimension. USGS 2006 Minerals Yearbook.** Vol. 1, Metals & Minerals. <http://minerals.usgs.gov/minerals/pubs/myb.html>.

and bicarbonate ($HCO3^-$) ions. In the near-surface layer of most oceans, corals, clams, and other sea-dwelling creatures use these two chemicals to make protective shells by combining them to form calcite or "aragonite," which is the same chemical composition as calcite but has a different crystal form.

Some limestones have been changed by the introduction of magnesium in ground water. Magnesium in ground water may convert some or all of the calcite in the limestone to dolomite. Also, some rocks formed near the shores of ancient seas in arid climates were mostly dolomite at the time they were deposited.

Limestone comes in many different varieties. Chalk is a very fine grained, porous marine limestone composed almost entirely of microscopic fossils. Travertine is a freshwater sedimentary limestone that has very thin, crenulated layers and is commonly formed at springs. Marble is a carbonate rock, usually a marine limestone that has been squeezed and deformed like plastic by great heat and pressure deep beneath the Earth's surface. This process is called "metamorphism." There are also rare "igneous" carbonate rocks that have crystallized from molten magma in the same way that lavas or granites have. These are called "carbonatites" and this rock type is mined at a few places in the world as industrial limestone.

Sedimentary limestone deposits can be extensive, covering hundreds of square miles, and can be relatively uniform in thickness and quality. Therefore, limestone quarries can be large and long lived, mining limestone layers that can be hundreds of feet thick over areas of several square miles. Many quarries produce multiple products, and crushed rocks that are not pure enough for certain uses may still be suitable as road aggregate. Marble quarries can also be very large. However, these rocks that were once regularly bedded have been metamorphosed into irregularly shaped bodies that are more difficult and costly to mine.

Limestone has many industrial uses and can be used as mined or processed into a wide variety of products. It is the raw material for a large variety of construction, agricultural, environmental, and industrial materials.

Limestone is used in construction almost everywhere. In 2007, crushed limestone was 68% of all crushed rock produced in the United States. Also, limestone is the key ingredient in making Portland cement.

Some white limestone is simply crushed and sieved for use in landscaping and roofing. Powdered limestone is used to remove impurities from molten metals like steel. It can also remove toxic compounds from the exhaust of coal-burning power plants. Limestone is used as a filler in a variety of products, including paper, plastic, and paint. The purest limestone is even used in foods and medicines such as breakfast cereals and calcium pills. Limestone is also the raw material for making lime (CaO) that is used to treat soils, purify water, and smelt copper. Lime has many additional uses in the chemical industries.

Dolomites are commonly less suitable than other industrial limestones for most applications. Most dolomite that is mined is simply crushed and sieved for use as aggregate in concrete or asphalt.

Limestone is most often mined from a quarry. However, underground limestone mines are found at places in the central and eastern United States, especially in and near cities. Underground mining of limestone has some advantages over surface quarrying and will probably increase in the future. Typical public concerns about limestone mining include dust, noise, blasting vibration, and truck and other traffic associated with quarry operations.

Some limestones are also aquifers, that is, they are rock units that can yield water to wells. Where limestone is an aquifer, there can be concerns that contaminants from the quarrying operations could escape into the ground water. In many areas of the world where limestone is found, it gradually dissolves in rainwater at the surface or in the near-surface ground water. In humid climates, great volumes of limestone dissolve and are carried away in the water. This creates caves, and sinkholes may develop where cave ceilings collapse. In cavernous limestone aquifers, contaminants in ground water move much faster than in other types of rocks, so quarries in such areas are special concerns

Limestone is among Bahamas most essential resources. Our understanding of that resource as an industrial mineral is poor given its importance to Bahamas economy. Research on limestone should be focused on mapping deposits and a proper assessment of its resources, as well as understanding their roles as aquifers and petroleum reservoirs. However, different data are needed to characterize limestone suitable for construction and other industries. Carbonate rocks need to meet chemical purity requirements that vary by intended use. Some uses require that the limestone also has certain favorable engineering properties. Standards and requirements for limestone use are rising, and a greater understanding of limestone characteristics, variability, and engineering properties is needed. It is important, though, to catalog such rocks as possible future resources.

UNITED NATIONS INTERNATIONAL FRAMEWORK CLASSIFICATION FOR RESERVES/RESOURCES[4]

As stated (see references), The United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) is a universally acceptable and internationally applicable scheme for the classification and reporting of fossil energy and mineral reserves and resources and is currently the only classification in the world to do so. As with extractive activities, UNFC-2009reflects conditions in the economic and social domain, including markets and government framework conditions, technological and industrial maturity and the ever present uncertainties. It provides a single framework on which to build international energy and mineral studies, analyze government resource management policies, and plan industrial processes and allocate capital efficiently.

UNFC-2009 is a generic principle-based system using a numerical and language independent coding scheme in which quantities are classified on the basis of the three fundamental criteria of:

- economic and social viability (E),
- field project status and feasibility (F), and
- geological knowledge (G),

Combinations of these criteria create a three-dimensional system. UNFC-2009, which can either be applied directly or used as a harmonizing tool, is the successor to the UNFC of 2004. The revision process has resulted in a simplified and user-friendly version of the Classification with generic high-level definitions. These are designed to ensure alignment with other widely used systems in the extractive industries – such as the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) Template and the Society of Petroleum Engineers (SPE)/World Petroleum Council (WPC)/American Association of Petroleum Geologists (AAPG)/Society of Petroleum Evaluation Engineers (SPEE) Petroleum Resource Management System (SPE-PRMS) – and to facilitate mapping with other classification systems.

The definitions of the UNFC-2009 categories and sub-categories have been simplified and the most commonly used classes are defined using plain language, providing harmonized generic terminology at a level suitable for global communications. The use of commonly-used words that are widely misunderstood by non-experts and which do not have a unique meaning is avoided; most importantly, the word "reserves" is not used other than in a general sense - "reserves" is a concept with different meanings and usage, even within the extractive industries, where the term is carefully defined and applied by technical experts.

Today's globalized world has resulted in an increasing number of multi-resource companies operating in many different countries and jurisdictions. In addition, the development of new types of resources, such as the mining of bitumen to produce synthetic crude oil, demonstrates that the historic boundaries between the minerals and petroleum sectors, which are reflected in different resource classification systems, public reporting requirements and accounting rules, is no longer sustainable. By covering all extractive activities, UNFC-2009 captures the common principles and

[4] ECONOMIC COMMISSION FOR EUROPE. 2010. **United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009.** ECE ENERGY SERIES No.39, UNITED NATIONS, New York and Geneva, 20:
Rendu JM and N Miskelly. 2014. **Mineral Resources and Mineral Reserves. Progress On International Definitions And Reporting Standards**

provides a tool for consistent reporting for these activities, regardless of the commodity. UNFC-2009 is a strong code, offering simplicity without sacrificing completeness or flexibility. It paves the way for improved global communications which will aid stability and security of supplies, governed by fewer and more widely understood rules and guidelines. The efficiencies to be gained through the use of UNFC-2009 are substantial.

UNFC-2009 applies to fossil energy and mineral reserves and resources located on or below the Earth's surface. It has been designed to meet, to the extent possible, the needs of applications pertaining to energy and mineral studies, resources management functions, corporate business processes and financial reporting standards.

UNFC-2009 is a generic principle-based system in which quantities are classified on the basis of the three fundamental criteria of economic and social viability (E), field project status and feasibility (F), and geological knowledge (G), using a numerical coding system. Combinations of these criteria create a three-dimensional system.

UNFC Categories

The first set of categories (the E axis) designates the degree of favorability of social and economic conditions in establishing the commercial viability of the project, including consideration of market prices and relevant legal, regulatory, environmental and contractual conditions. The second set (the F axis) designates the maturity of studies and commitments necessary to implement mining plans or development projects. These extend from early exploration efforts before a deposit or accumulation has been confirmed to exist through to project that is extracting and selling a commodity, and reflect standard value chain management principles. The third set of categories (the G axis) designates the level of confidence in the geological knowledge and potential recoverability of the quantities.

The categories and sub-categories are the building blocks of the system, and are combined in the form of "classes". UNFC-2009 can be visualized in three dimensions, as shown in Fig. 4, or represented in a practical two-dimensional abbreviated version as shown in Table 1. Tables 2-4 summarizes the specifications of each Category.

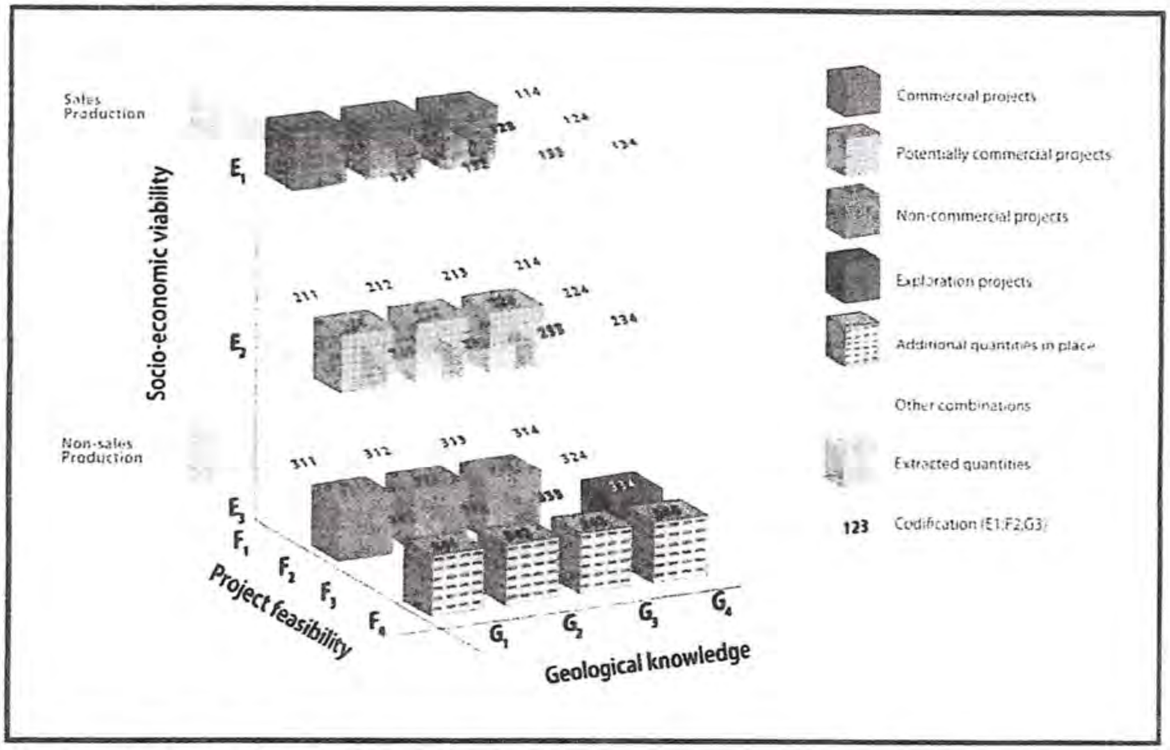

Fig. 4. UNFC-2009 categories and examples of cases

Table 1. UNFC primary categories

[illegible]		[illegible]		
	[illegible]	E	F	G[b]
Future recovery by commercial development projects or mining operations	Commercial Projects[c]	1	1	1, 2, 3
Potential future recovery by contingent development projects or mining operations	Potentially Commercial Projects[d]	2[a]	2	1, 2, 3
	Non-Commercial Projects[e]	3	2	1, 2, 3
Additional quantities in place associated with known deposits[g]		3	4	1, 2, 3
Potential future recovery by successful exploration activities	Exploration Projects	3	3	4
Additional quantities in place associated with potential deposits[g]		3	4	4

Table 2. Economic and social viability.

[illegible]	[illegible]	[illegible]
E1	Extraction and sale has been confirmed to be economically viable.[E]	Extraction and sale is economic on the basis of current market conditions and realistic assumptions of future market conditions. All necessary approvals/contracts have been confirmed or there are reasonable expectations that all such approvals/contracts will be obtained within a reasonable timeframe. Economic viability is not affected by short-term adverse market conditions provided that longer-term forecasts remain positive.
E2	Extraction and sale is expected to become economically viable in the foreseeable future.[E]	Extraction and sale has not yet been confirmed to be economic but, on the basis of realistic assumptions of future market conditions, there are reasonable prospects for economic extraction and sale in the foreseeable future.
E3	Extraction and sale is not expected to become economically viable in the foreseeable future or evaluation is at too early a stage to determine economic viability.[E]	On the basis of realistic assumptions of future market conditions, it is currently considered that there are not reasonable prospects for economic extraction and sale in the foreseeable future; or, economic viability of extraction cannot yet be determined due to insufficient information (e.g. during the exploration phase).Also included are quantities that are forecast to be extracted, but which will not be available for sale.

Table. 3. Feasibility of production

Category	Definition	Supporting Explanation
F1	Feasibility of extraction by a defined development project or mining operation has been confirmed.	Extraction is currently taking place; or, implementation of the development project or mining operation is underway; or, sufficiently detailed studies have been completed to demonstrate the feasibility of extraction by implementing a defined development project or mining operation.
F2	Feasibility of extraction by a defined development project or mining operation is subject to further evaluation.	Preliminary studies demonstrate the existence of a deposit in such form, quality and quantity that the feasibility of extraction by a defined (at least in broad terms) development project or mining operation can be evaluated. Further data acquisition and/or studies may be required to confirm the feasibility of extraction.
F3	Feasibility of extraction by a defined development project or mining operation cannot be evaluated due to limited technical data.	Very preliminary studies (e.g. during the exploration phase), which may be based on a defined (at least in conceptual terms) development project or mining operation, indicate the need for further data acquisition in order to confirm the existence of a deposit in such form, quality and quantity that the feasibility of extraction can be evaluated.
F4	No development project or mining operation has been identified.	In situ (in-place) quantities that will not be extracted by any currently defined development project or mining operation.

Table 4. Geological knowledge

G1	Quantities associated with a known deposit that can be estimated with a high level of confidence.	For in situ (in-place) quantities, and for recoverable estimates of fossil energy and mineral resources that are extracted as solids, quantities are typically categorised discretely, where each discrete estimate reflects the level of geological knowledge and confidence associated with a specific part of the deposit. The estimates are categorised as G1, G2 and/or G3 as appropriate. For recoverable estimates of fossil energy and mineral resources that are extracted as fluids, their mobile nature generally precludes assigning recoverable quantities to discrete parts of an accumulation. Recoverable quantities should be evaluated on the basis of the impact of the development scheme on the accumulation as a whole and are usually categorised on the basis of three scenarios or outcomes that are equivalent to G1, G1+G2 and G1+G2+G3.
G2	Quantities associated with a known deposit that can be estimated with a moderate level of confidence.	
G3	Quantities associated with a known deposit that can be estimated with a low level of confidence.	
G4	Estimated quantities associated with a potential deposit, based primarily on indirect evidence.	Quantities that are estimated during the exploration phase are subject to a substantial range of uncertainty as well as a major risk that no development project or mining operation may subsequently be implemented to extract the estimated quantities. Where a single estimate is provided, it should be the expected outcome but, where possible, a full range of uncertainty in the size of the potential deposit should be documented (e.g. in the form of a probability distribution). In addition, it is recommended that the chance (probability) that the potential deposit will become a deposit of any commercial significance is also documented.

Geological knowledge

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Where geological studies have been carried out and an estimate of the quantity of mineralization is possible (volume, tonnes, grade/quality etc.) then classification takes place on the geological axis on the basis of the level of detail of the studies and the degree of confidence in the geological model

Reconnaissance Stage (G-4)

This means that the systematic process of identifying areas of enhanced mineral potential on a regional scale is based primarily on results of regional geological studies. The objective is to identify mineralized areas worthy of further investigation towards deposit identification. Estimates of quantities (during exploration phase) should only be made if sufficient data available and estimated quantities associated with a potential deposit, based primarily on indirect evidence.

Prospecting Stage (G-3)

Prospecting is the systematic process of searching for a mineral deposit by narrowing down areas of promising enhanced mineral potential. The objective is to identify a deposit which will be the target for further exploration. Therefore, in this case, quantities estimated for the deposits are with a low level of confidence and the estimates of quantities are inferred, based on interpretation of geological, geophysical and geochemical results

General Exploration Stage (G-2)

General Exploration involves the initial delineation of an identified deposit. The objective is to establish the main geological features of a deposit, giving a reasonable indication of continuity and providing an initial estimate of size, shape, structure and grade.

In this stage, the degree of accuracy should be sufficient for deciding whether Pre-feasibility study and Detailed Exploration are warranted. Quantities estimated for the deposits are with a moderate (medium) level of confidence and the estimates of quantities are indicated, based on interpretation of geological, geophysical and geochemical results

Detailed Exploration Stage (G-1)

Detailed Exploration involves:

- The detailed three-dimensional delineation of a known deposit
- Size, shape, structure, grade, and other characteristics of the deposit are established with a high degree of accuracy
- A decision whether to conduct a Feasibility Study can be made from the information provided by Detailed Exploration
- Quantities estimated for the deposits are with a high level of confidence
- Estimates of quantities are measured, based on interpretation of geological, geophysical and geochemical results

Four stages of Geological Assessment Provide Four Resource Categories reflecting increasing degree of geological knowledge and confidence which are:

- Reconnaissance (G-4 Stage) Reconnaissance Resource
- Prospecting (G-3 Stage) Inferred Resource
- General Exploration (G-2 Stage) Indicated Resource
- Detailed Exploration (G-1 Stage) Measured Resource

After Field project status and feasibility (F), Economic and social viability (E) studies Mineral Reserves are classified as:

- Proved Mineral Reserves: code 111
- Probable Mineral Reserves: codes 121 + 122
- Feasibility Mineral Resources: code 211

GENERAL GEOLOGY OF BAHAMAS

The Bahaman Archipelago consists of two carbonate banks[5] which were formed by a chain of carbonate platforms[6]. The archipelago is an arcuate system of carbonate platforms, commonly capped with low islands, to have been built on oceanic crust located to the east and south of the continental margin North America. *"The Bahamas is comprised of a variety of limestone such as coral, which has not been transported, but were formed where they are now...known geologically as shallow water carbonates"*[7].

Of the 700 islands and cays of the Bahamas only a few have received any detailed scientific attention. A basic view of the surficial geology of some Bahamian islands has emerged since de early 80´s from studies in New Providence[8], San Salvador[9] and also in Lee Stocking Island[10] and the Caicos Islands[11]. Curran and White (1995) contain a collection of papers relevant to those preliminary studies.

The northwest-southeast (Fig. 5) trending archipelago extends 1,400 km from the stable Florida peninsula to the tectonically active Caribbean Plate boundary near Hispaniola (Carew and Mylroie, 1995). The Turks and Caicos Islands make up the southeastern extent of the same archipelago, but are a separate political entity. The Bahamian portion of the archipelago is 300,000 km^2 in area, 11,400 km^2 of which is subaerial land (Meyerhoff and Hatten, 1974)[12].

[5] Multer, H. Gray. 1977. **Field Guide to Some Carbonate Rock Environments: Florida Keys and Western Bahamas.** Dubuque: Kendall/Hunt Publishing Company, 1977.

[6] Curran, H. A. and B. White, ed. 1995.. **Terrestrial and Shallow Marine Geology of the Bahamas and Bermuda.** Northampton: Geological Society of America,

[7] Sealey, N 2006. **Bahamian Landscapes. An Introduction to the Geology and Physical Geography of the Bahamas.** 3rd Edition. MacMillan Caribbean, Thailand, 174:

[8] Garrett, P. and S.J. Gould.1984. **Geology of New Providence Island, Bahamas.** Bull. Geol. Soc. Amer. 95:209-220

[9] Carew, J.L., and Mylroie, J.E., 1985. **The Pleistocene and Holocene Straigraphy of San Salvador Island, Bahamas, with reference to marine and terrestrial lithofacies at French Bay.** In: Curran, H.A. [Ed] Geological society of America Field Guide, :11-61. **Pleistocene and Holocene Carbonate Environments on San Salvador Island, Bahamas,** GSA Annual Meeting, 1985, Orlando, Fl.
Hearty, P.J. and P. Kindler. 1993. **New perspectives on Bahamian geology: San Salvador Island, Bahamas.** Jour. Coastal Res. 9, 577-594

[10] Kindler, P. 1995. **New data on Holocene stratigraphy of Lee Stocking Island (Bahamas) and its relation with sea-level history.** In/ Curran, H. Allen and Brian White, ed. **Terrestrial and Shallow Marine Geology of the Bahamas and Bermuda.** Northampton: Geological Society of America, 1995.

[11] Wanless, H.R. and J.J. Dravis. 1989. **Carbonate Environments and Sequences of Caicos Plattform Field Trip Guidebook T374.** 28th Interbnatl. Geol. Congr. Amer.- Geophys. Union, 75:
Hearty, P.J. 1997. **Boulder deposits from large waves during the Last Interglaciation on North Eleuthera Island, Bahamas.** Quaternary Res. 48, 326-338

[12] Meyerhoff, A. A., and Hatten, C. W., 1974, **Bahamas salient of North America: Tectonic framework, stratigraphy, and petroleum potential:** American Association of Petroleum Geologists Bulletin, v. 58, p. 1201-1239.

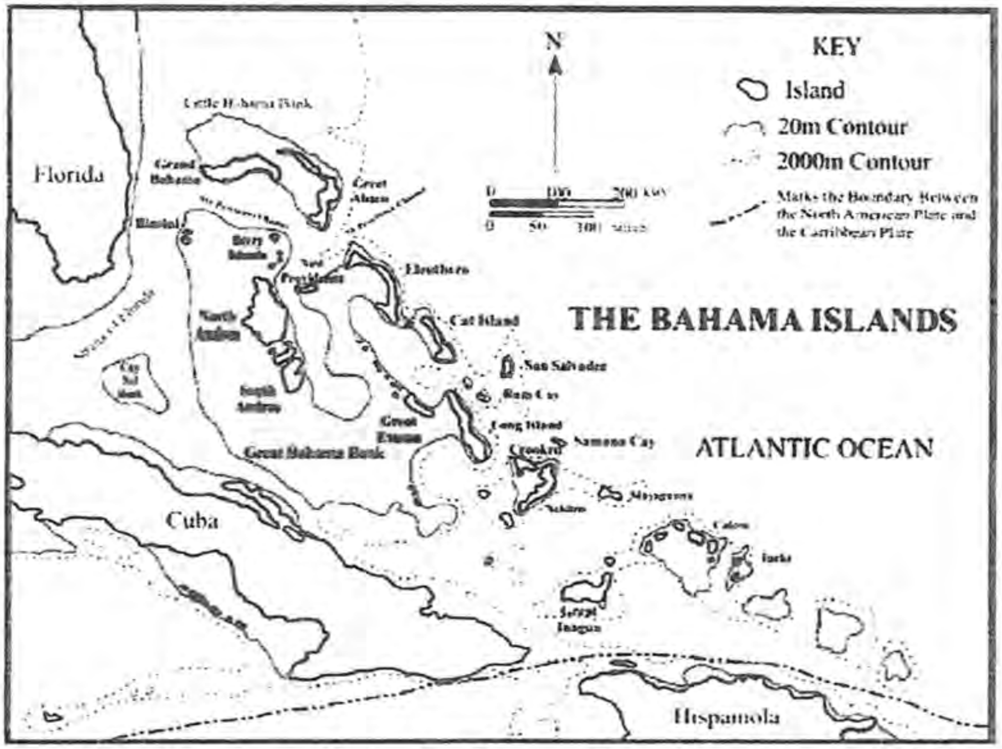

Fig. 5. Map of the Bahamian Archipelago and surrounding environment. Modified from Carew and Mylroie, 2001

The Bahamas have long been the focus of geologic work on modern carbonates (Illing, 1954; Multer, 1977; Tucker and Wright, 1990; Carew and Mylroie, 1997 and references therein)[13]. The Bahamas Platform has particular interest to geologists as it provides a modern analog for the dynamics of ancient carbonate depositional platforms, many of which are major petroleum reservoirs. The Bahamas Platform is composed of a series of thick, shallow-water, carbonate banks along the subsiding margin of North America (Mullins and Lynts, 1977, see previous footnote). The current landscape of the Bahamas is largely constructional and is greatly influenced by glacioeustatic sea-level fluctuations (Carew and Mylroie, 1997)[14]. Carbonate deposition occurs on the flat bank tops during glacioeustatic sea-level highstands when shallow lagoons dominate. During sea-level low stands, sea level drops below the bank margins. Carbonate sedimentation

[13] Illing, L.V., 1954. **Bahamian calcareous sands.** Bulletin of the American Association of Petroleum Geologists, v. 38, p. 1–95.
Multer, H.G., 1977. **Field guide to some carbonate rock environments, Florida Keys and Western Bahamas.** Dubuque, Kendall/Hunt, 417 p.
Tucker, M.E., and Wright, P.W., 1990. **Carbonate sedimentology**, Oxford, Blackwell Scientific Publications, 482 p.
Carew, J.L., and Mylroie, J.E., 1997. **Geology of the Bahamas**, in Vacher, H.L., and Quinn, T.M., eds., **Geology and Hydrogeology of Carbonate Islands**, Developments in Sedimentology 54, Amsterdam, Elsevier, p. 91–139.
Mullins, H.T., and Lynts, G.W., 1977. **Origin of the Northwestern Bahama Platform: Review and interpretation:** Geological Society of America Bulletin, v. 88, p. 1447–1461.

[14] Carew, J.L., and Mylroie, J.E., 1997. **Geology of the Bahamas**, in Vacher, H.L., and Quinn, T.M., eds., **Geology and Hydrogeology of Carbonate Islands**, Developments in Sedimentology 54, Amsterdam, Elsevier, p. 91–139.

ceases and subaerial karst processes dominate on the exposed bank tops. Low stands are recorded in the sedimentary record by the development of terra rossa paleosols. These fossil soil horizons are the result of the concentration of insoluble materials, such as atmospheric dust, due to pedogenic processes.

The Bahamas was originally formed by the rifting of Pangea, the super-continent, which resulted in the opening of North Atlantic basin. The rifting of Pangea was accompanied by volcanic activity due to the nature of the colliding North American and Caribbean plates. The collisions, commonly subduction zones where one plate is pulled under the other, formed the lower layer, which is commonly referred to as the basement rocks upon which the Bahamian islands now reside. Evidence of the volcanic activity is found in the tilted fault blocks of Jurassic volcaniclastics which are commonly found in the Florida Straits area[15]. In the southern region of the Bahamas, the basement rocks are oceanic crust, showing that the area was not a transitional region during the opening of the North Atlantic basin[16].

The Bahamas are referred to as carbonate islands, which is due to the formation of carbonate banks. This megabank formed in the Late Jurassic and is evidence of an absence of deep water at the time of formation due to the type of rock formed. Carbonates are more likely to form in shallower waters, thus the formation of two major carbonate banks in the Bahamas shows that there was an absence of deep water[17]. There is also evidence of faulting which is shown in the tilting of the Bahaman Banks. This tilting is due to the subduction of the North American plate under the Caribbean plate, in the vicinity of Cuba. The angle of tilting, which is left-lateral wrench faulting is in the direction of the subduction, supporting Cuban vicinity as the location of subduction. This faulting occurred because as the North American plate subducted under the Caribbean plate, not all the rock layers moved as one continuous unit. The Bahaman islands remained in the same location, thus the rocks had to fault, or break, in order for the North American plate to continue subduction and the islands to remain in their current location.

Subsurface Stratigraphy

Subsurface stratigraphy is the study of underlying rock layers, especially the distribution, deposition, and age of sedimentary rocks. Studying the subsurface stratigraphy gives an idea of what types of environments that the Bahamas evolved in over time. These underlying rock layers are studied through various methods including seismic refraction, seismic reflection, magnetics, and shallow and deep drilling.

The oldest stratigraphic unit exposed on the island is the Owl's Hole Formation (Fig. 6), a pre-MIS 5e bioclastic eolianite. Owl's Hole is overlain by a terra rossa paleosol separating it from the overlying MIS 5e Grotto Beach Formation, which includes a lower transgressive oosparite and peloidal grainstone unit, the French Bay Member, and an upper eolianite and distinct framestone unit (fossil reef), the Cockburn Town Member. A paleosol layer overlies the Grotto Beach Formation, and marks the end of Pleistocene deposition on the island. Holocene depositional units include the early Holocene North Point Member and overlying Hanna Bay Member, both of which

[15] Vacher, H.L., and T.M. Quinn, eds. .1997.**Geology and Hydrogeology of Carbonate Islands**. New York: Elsevier,

[16] Lytle, M. 2006. **Geology of the Bahamas Final Paper**. Tropical Field Courses -Western Program-Miami University

[17] Marshak, S. and Gautam M. **Basic Methods of Structural Geology**. Englewood Cliffs: Prentice - Hall 1982.

belong to the Rice Bay Formation. Lower Holocene lithologies are dominated by bioclastic eolianite and calcarenite facies, while the overlying Hanna Bay Member is largely comprised of intertidal facies and eolian deposits in equilibrium with the modern sea level. Beachrock found within the Hanna Bay in San Salvador Island reveal evidence of rapid cementation, exemplified by entrained cannonballs, bottle caps, and glass incorporated within the rock[18] (Mylroie and Carew, 2008).

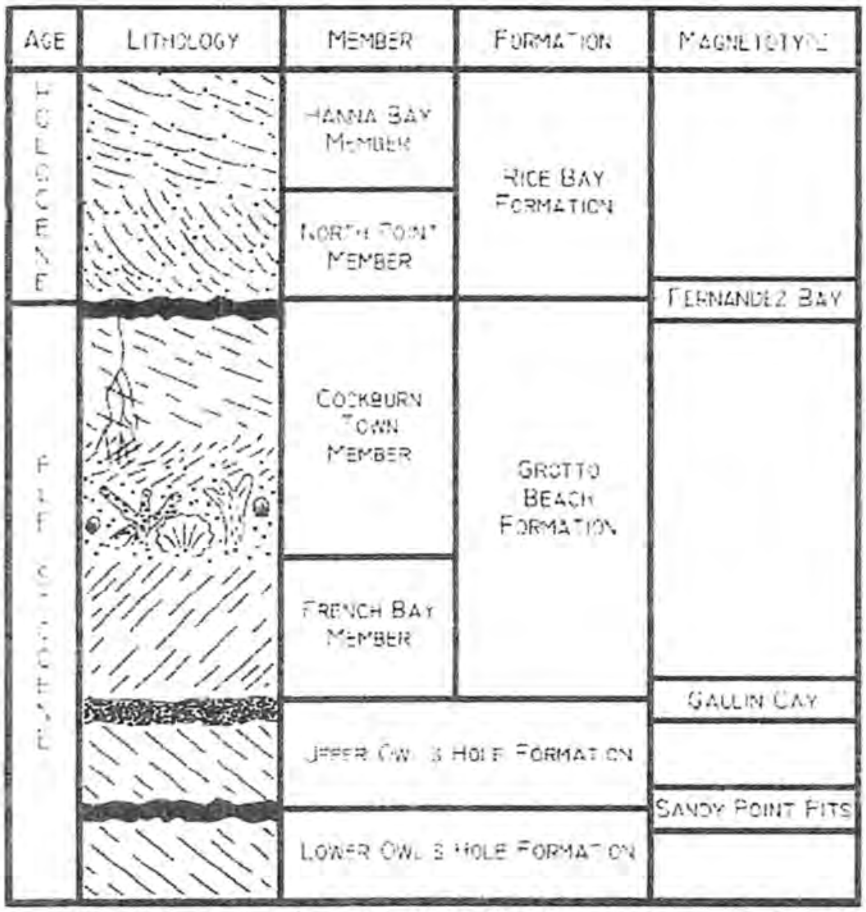

Fig. 6. Stratigraphic column for San Salvador Island, and by extension, the Bahamian Archipelago. The Owl's Hole Formation subdivisions shown are not recognizable in the field on San Salvador Island, and are partitioned based on paleomagnetic evidence from laboratory analysis. Otherwise, all subdivisions can be determined by field observation. From Panuska et al., 1999[19].

[18] Horwitz M.H & T. M. Roberts. 2010. **Geomorphic zoning and eogenetic karst on limestones within the supratidal environment: San Salvador, Bahamas.** Studia Universitatis Babeş-Bolyai, Geologia, 2010, 55 (1), 17 – 27

Mylroie, J.E., Carew, J.L. 2008, **Field guide to the geology and karst geomorphology of San Salvador Island** (Mylroie, J.E., Carew, J.L., Eds.). Bahamian Field Station, San Salvador, 88 p.

[19] Panuska, B. C., Boardman, M. R., Carew, J. L., Mylroie, J. E., Sealey, N. E., and Voegeli, V., 2002, **Eleuthera Island Field Trip Guide, 11th Symposium on the Geology of the Bahamas and Other Carbonate Regions.** Gerace Research Center, San Salvador Island, Bahamas, 20 p.

Using deep drilling it was determined that the Upper Jurassic carbonates are approximately 5 km down. Above these carbonates are Lower Cretaceous dolostone, limestone, and evaporites, which are sedimentary deposits that result from the evaporation of seawater. On the margins of the banks there is a known transition from Pliocene skeletal and reefal facies to Quaternary oolites and eolianites[20]. This is believed to have occurred with the onset of the glaciation of the northern hemisphere. Another important observation is the Pleistocene-Holocene sediments are not uniform showing that the deposition situation was not constant throughout the entire Bahaman Archipelago, but through the exposed coral reefs and flank margin caves the entire archipelago behaved similarly for the past 300 000 years.

There are five types of Holocene sediments (Fig. 7): peloidal, oolitic, coralgal, grapestone and aggregate, and mud, found in the Bahamas are indications of shallow waters at the time of deposition. These sediments were deposited onto of a regional unconformity that is the karsted top of the cemented Pleistocene deposits that developed during the subaerial exposure of the last glacial low standee approximately 120 000 years ago[21]. In these deposits, early reef development has been found. The reefs developed in the early Holocene when sea level was well below the platform top and eventually were covered by peloidal sands from the platform[22].

Fig. 7. Peloidal sands of recent deposition.

[20] Vacher, H.L., and T.M. Quinn, eds. **Geology and Hydrogeology of Carbonate Islands.** New York: Elsevier, 1997.

[21] Ginsburg, Robert N., ed. 2001.**Subsurface Geology of a Prograding Carbonate Platform Margin, Great Bahama Bank: Results of the Bahamas Drilling Project.** Tulsa: Society for Sedimentary Geology, 2001.

[22] Whitaker, F.F., Smart, P.L. 2007. **Geochemistry of meteoric diagenesis in carbonate islands of the northern Bahamas:2. Geochemical modeling and budgeting of diagenesis.** Hydrologic Processes, 21: 967-982.

White, B., Curran, H.A. 1988. **Mesoscale physical sedimentary structures and trace fossils in Holocene carbonate eolianites from San Salvador Island, Bahamas.** Sedimentary Geology, 55: 163-184.

Using the depositional nature of the Holocene sediments as a guide for the Pliocene – Pleistocene carbonate rocks, the islands were determined to have formed on the windward or ocean facing margins of the carbonate banks. Along the Pleistocene sea-facing bank margins, there is limestone evidence of coral reefs that defended the islands (Fig. 8). There is also evidence of varying water levels due to the Lucayan Formation. The Lucayan Formation is nonskeletal packstones and grainstones, and formed in a shallow water (less than 10m), semi restricted environment. The Lucayan Formation is not found on the Pleistocene reef side, showing that the water was deeper there during the Pliocene[23]. The interior of the bank has skeletal rich limestone that is pre-Lucayan which indicates water deeper than 10 m with open circulation.

Modern Depositional Systems

The evidence from the subsurface statigraphy shows that the water level fluctuated constantly over time and events around the world, like glaciation affected the Bahamas even though the islands were not directly a part of the glaciation. Using this knowledge, the modern day lithofacies, rock records of any sedimentary environment, are used as models for interpretation of ancient carbonates. As supported by the previously discussed Holocene sediments it was shown that the present is the key to the past which respect to geological terms and ideology. There is a wide variation in the accumulation, depositional style, and sediment type, all which is affected by the islands varying orientations to currents and winds.

An example of this is stromatolites which range from very large subtidal ones to small costal and subtidal ones to one found in hypersaline lakes, where salinity fluctuates in response to rainfall. Stromatolites generally occur where rapid currents or hypersaline prevents grazing by macrofauna or where there is rapid cementation (Fig. 9).

Fig. 8. Coastal environment in small carbonate islands

[23] Lidz, B., and P.R. Rose. 1977. **Diagnostic Foraminiferal Assemblage of Shallow Đ Water Modern Environments: South Florida and the Bahamas.** Miami: University of Miami, 1977.

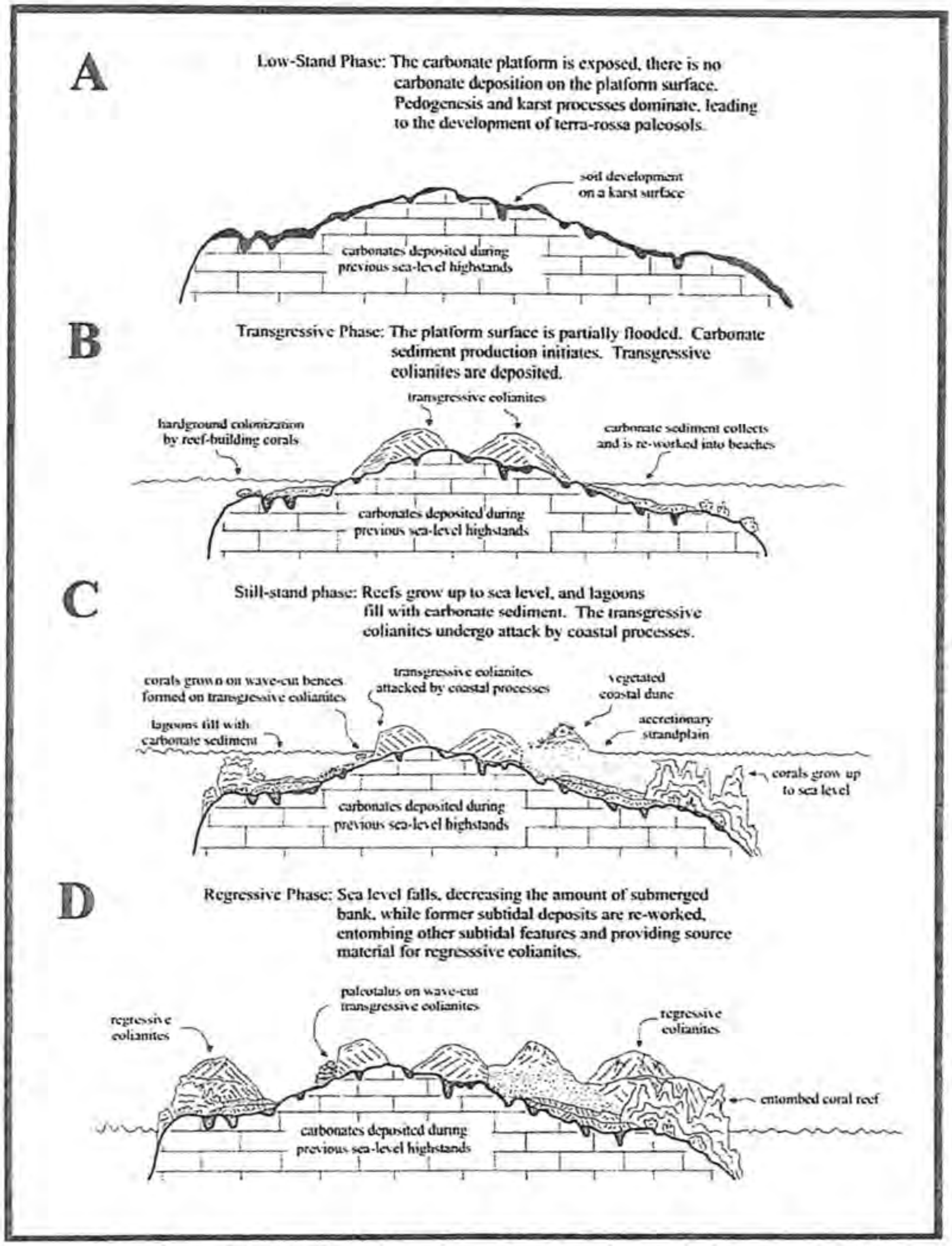

Fig. 9. Depositional model for San Salvador Island and the Bahamas overall. Carbonate deposition is restricted to transgressive, stillstand, and regressive phases of a glacioeustatic sea-level highstand. Surficial karst processes and pedogenesis dominate lowstands below about -20 m.

Geomorphology

Shaping of the landscapes

The landscapes of the islands can be attributed to the accumulation of carbonate sediments which are deposited by currents, waves, and winds. Along with accumulation, erosion is another major factor in the shaping of the landscape because all the rocks are subjected to erosion by currents, waves, and winds. On the islands there are two major landforms which dominate. There are eolianite ridges which rise 30 m above sea level and low lands which are composed of marine and terrestrial deposits. On the interior of the islands, the land is typically below sea level and thus contains marine to hypersaline lakes.

Karst processes

Since the islands consist mainly of limestone for the first 5 m, there is a large possibility for the formation of caves and blue-holes (Fig. 10). Limestone is a very porous material and thus is easily eroded by rainfall and runoff from the surface. The rate at which the surface water is carried underground causes there to be few freshwater rivers on the islands. The water weathers the limestone, forming a large variety of karst formations including caves, sink holes, and solution pits. Since the majority of the islands are limestone, there are many channels for carrying the water underground, providing the opportunity for the formation of karsts throughout the islands.

Another type of cave that can be formed is a flank margin cave, which is found the outer edges of the islands. The flank margin caves are formed by dissolution caused by the mixing of fresh and salt water. Dissolution caused by the combination of fresh and salt water is a relatively quick process, having dissolution rates as high as 1 m3/yr. Since these caves are created on the margins of the islands, the flank margin caves are indications of sea levels throughout history.

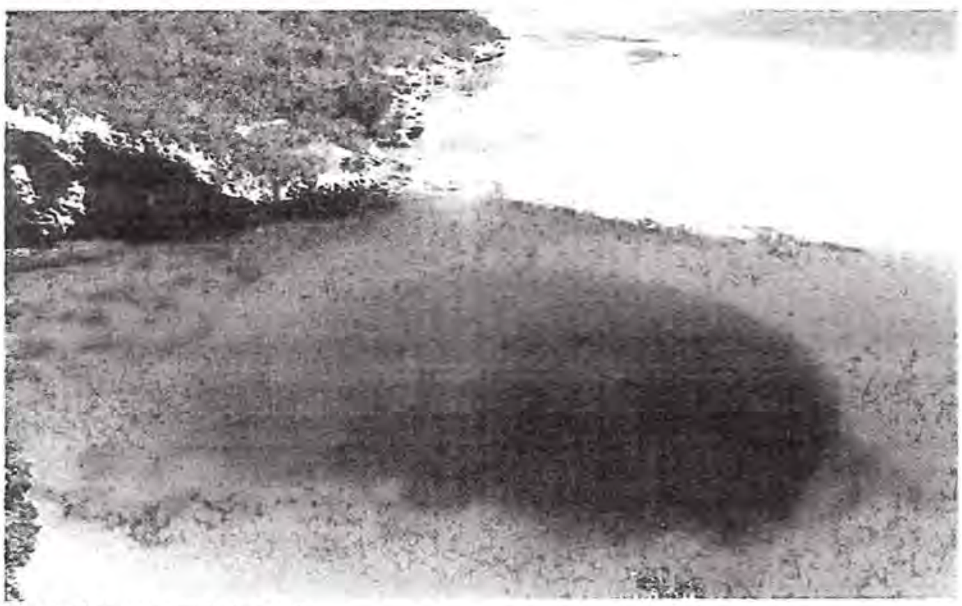

Fig. 10. Blue hole near to the coast.

Island karst is a result of the unique environments and associated processes that affect carbonates in small island settings (Mylroie et al., 2004; Jenson et al., 2006)[24]. Island karst is different from typical karst landscapes that develop in continental settings, and from karst on islands, which

[24] Mylroie, J.E., Mylroie, J.R., and Jenson, J.W., 2004. **Modeling carbonate island karst**, in Lewis, R.D., and Panuska, B.C., eds., **Proceedings of the 11th Symposium on the Geology of the Bahamas and other Carbonate Regions: San Salvador Island, Bahamas,** Gerace Research Center, p. 135–144.
Jenson, J.W., Keel, T.M., Mylroie, J.R., Mylroie, J.E., Stafford, K.W., Taborosi, D., and Wexel, C., 2006. **Karst of the Mariana Islands: The interaction of tectonics, glacioeustasy and fresh-water/sea-water mixing in island carbonates**: Boulder, Geological Society of America Special Paper 404, p. 129–138.

forms in the interiors of large islands such as Puerto Rico, Cuba, and Jamaica (Vacher and Mylroie, 2002)[25]. Karst on islands is more similar to continental karst than carbonate island karst. The principles of island karst are summarized by the Carbonate Island Karst Model, or CIKM, described by Mylroie, et al. (2004) and Jenson et al. (2006)[26].

Modern Landscapes

Coastal effects, deposition, and erosion

Erosion caused by the sea water has had a major role in the shaping of the islands. The water has slowly eroded the eolianite ridges that are along the coastline. Numerous reentrants have been created, which are the eroded remnants of flank margin caves. There are also tidal channels and creeks that penetrate the shoreline, resulting in tidal delta deposits. In reference to the Bahamas a creek is a restricted marine embayment. Also, the deposition and erosion rates are relatively equal because while each occurs daily, there is not any significant change over the past 300 kilo-years.

In contrast to the beach environment where morphologic change is largely attributed to the combined effects of tide, current, and wave processes yielding changes on temporal scales of hours to days, along rocky carbonate coasts morphologic change is generally a slow and gradual process, dominated by the combined effects of mechanical, biologic and chemical weathering processes (De Waele et al., 2009)[27].

Coastal karst morphologies are often distinct, characterized by jagged, pinnacled and commonly delicately etched and fretted surface morphologies, referred to as phytokarst by Folk et al[28]. (1973). The mechanisms yielding these distinct karst morphologies appear to be in large part controlled by position relative to sea level and the land-marine interface (Moses, 2003; Taborosi et al., 2004; De Waele et al., 2009)[29]. On the island, Pleistocene and Holocene-age limestones are undergoing surficial meteoric diagenesis yielding eogenetic karst (Vacher and Mylroie, 2002)[30], providing an excellent setting to examine coastal karst development.

Carbonate dunes

Carbonate dunes are formed during the transgressive phase, where the rising sea level is causing subtidal sedimentation which is transported to beaches and turned into dunes. Carbonate dunes form close to their beach sources and consist of sand-sized fragments of mollusks, limestone, and

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[25] Vacher, H.L., and Mylroie, J.E., 2002, **Eogenetic karst from the perspective of an equivalent porous medium:** Carbonates and Evaporites, v. 17, no. 2, p. 182–196.

[26] Jenson, J.W., Keel, T.M., Mylroie, J.R., Mylroie, J.E., Stafford, K.W., Taborosi, D., and Wexel, C., 2006. **Karst of the Mariana Islands: The interaction of tectonics, glacioeustasy and fresh-water/sea-water mixing in island carbonates:** Boulder, Geological Society of America Special Paper 404, p. 129–138.

[27] De Waele, J., Mucedda, M. & Montanaro, L. 2009. **Morphology and origin of coastal karst landforms in Miocene and Quaternary carbonate rocks along the central-western coastal of Sardinia (Italy).** Geomorphology, 106 (1-2): 26-34.

[28] Folk, R.L., Roberts, H.H. & Moore, C.H. 1973. **Black phytokarst from Hell, Cayman Islands, British West Indies.** Geological Society of America Bulletin, 84: 2351-2360.

[29] Moses, C.A. 2003. **Observations on coastal biokarst,** Hells Gate, Lord Howe Island, Australia. Zeitschrift für Geomorphologie, 47 (1): 83-100.

Taborosi, D., Jenson, J.W. & Mylroie, J.E. 2004. **Karst features in island karst: Guam, Mariana Islands.** Zeitschrift für Geomorphologie, 48: 369-389.

[30] Vacher, H.L., and Mylroie, J.E., 2002, **Eogenetic karst from the perspective of an equivalent porous medium:** Carbonates and Evaporites, v. 17, no. 2, p. 182–196.

eolianites. Due to the dunes location close to the shore, they undergo rapid cementation due to sea spray and meteoric precipitation.

Rock exposures on most of the other islands in the archipelago, are dominated by variably lithified eolianite dunes with exposures of inter-tidal to subtidal deposits confined to lower elevations.

Stillstand Phase

The stillstand phase occurs when the sea level remains relatively stable allowing carbonate sedimentation to remain high and the coral reef growth catches up with the sea level. During the stillstand phase much of the marine record is deposited on the islands because there is less factors working against the deposition like high erosion rates. Due to the stillstand phase, lagoons fill and reefs grow high enough to become barriers to transportation. On the islands, beaches develop, heavily vegetated coastal dunes develop, and inter-dune depressions may contain lakes. Currently, majority of the Bahaman islands are in the stillstand phase, before the regressive phase occurs which is accompanied by high erosion rates.

MAYAGUANA ISLAND

Mayaguana, the eastern most Bahamian island, is 537 km (355 miles) southeast of New Providence and 706 km (468miles) southeast of Palm Beach, FL. The closest island is Acklins Island to the west. The area of the island is about 110 mi^2 (almost 285 km^2 and around 2% of the total area)[31].

According to the 2000 Census its estimated population (2000) was 262 inhabitants (0,08% of the total population), making a population density of 2.38 people per square mile (0,92/km^2). The largest city is Abrahams Bay. The studied area is shown in Fig. 11.

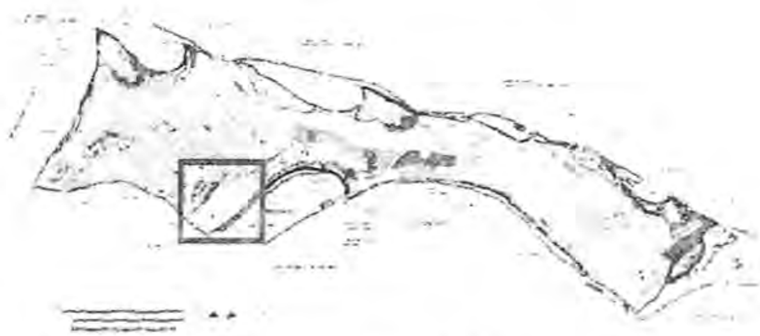


Fig. 11. Study area for the geological reconnaisasance in Mayaguana.

Geology and Geomorphology

Mayaguana, as most of the Bahamian Archipelago is a very low altitude island mostly at sea level. Ponds and wetlands dominate in the inland but it is common to find it in the shallow friable coast. Some of the coastal features are spits and hooks linked with the wave refraction phenomena. When the waves are refracted around the tip of the spit the attendant longshore currents become weaker and hence the material is deposited. Coastal ponds are associated with the development of offshore bars. Reef barriers practically surround the island contributing to the development of shallow bays. Most of our geological exploration was developed at the southwestern sector of Abrahams Bay, so the main references on the geology and geomorphology will be exemplified in that area (Figs. 12-15).

Several inland ponds are associated with karst depressions refilled with groundwaters or are typical blue holes.

Extensive sectors of the coast are eroded and the carbonatites outcrops. Only in small patches recent sediments are found but the carbonate rocks exhibit the typical karren features derived from local karstification. These eroded beaches are often linked with abandoned marine cliffs. These cliffs gradually increase its altitude from sea level towards inland reaching 40 m above sea level in Low Point Hill, for example. Those cliffs show a dominant SW-NE trend for almost 5 km from the Benchmark close to the Dock of Russells Bay to the airport runway. All the cliffs run parallel to the coast of Abrahams Bay and clearly indicate the ancient positions of the sea during the upper stands of glacioeustatic sea level.

[31] USACE. 2004. **Water Resources Assessment of The Bahamas**, United States Army Corps of Engineers, Virginia, 114:

The upstream section of these cliffs alternates with longitudinal depressions that seem post beach formations or erosive features eventually linked with rill wash and/or lateral erosion. In fact some ponds outcrops in these intra terrace longitudinal depressions. The contribution of wind erosion is not discounted in the origin of these longitudinal depressions or even in the morphology of the faces of the cliffs because the orientation of the airport airstrip follows this direction.

Fig. 12. Eroded coastal pond where small patches of recent sand is redeposited in small depressions.

Fig. 13. Coastal pond.

Fig. 14. Inland bluehole.

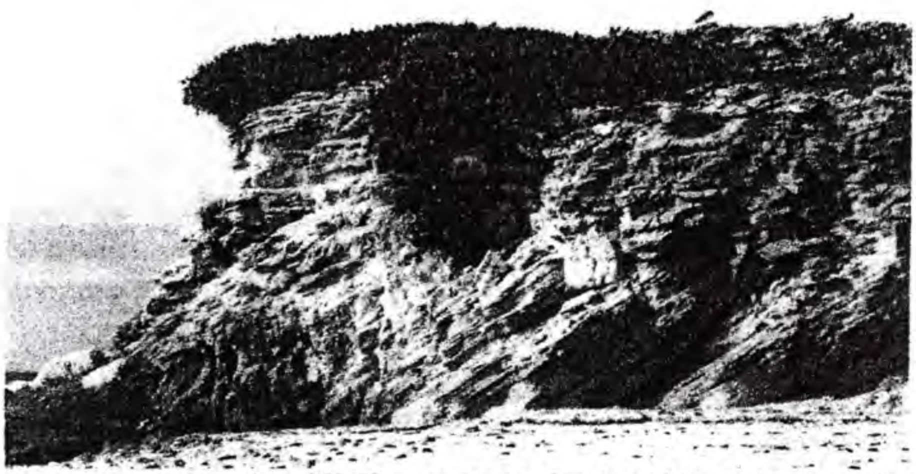


Fig. 15. Abandoned coastal marine cliff. The sequence of carbonatites is dominated at the center of the outcrop by cross-stratified calcarenites in contact with younger arenaceous beach deposits and overlain by horizontal eolianites. The vegetation is sustained on a small thickness stratum of indurated limestones.

In fact, tectonic control could be of some importance. Undoubtedly, as it is shown in Fig. 16 morfoalignments show a fracture control in the development of several morphological features, like ponds and depressions. This fracture network together with the almost pure carbonate composition of the carbonatites helped the fast development of the eogenetic local karst.

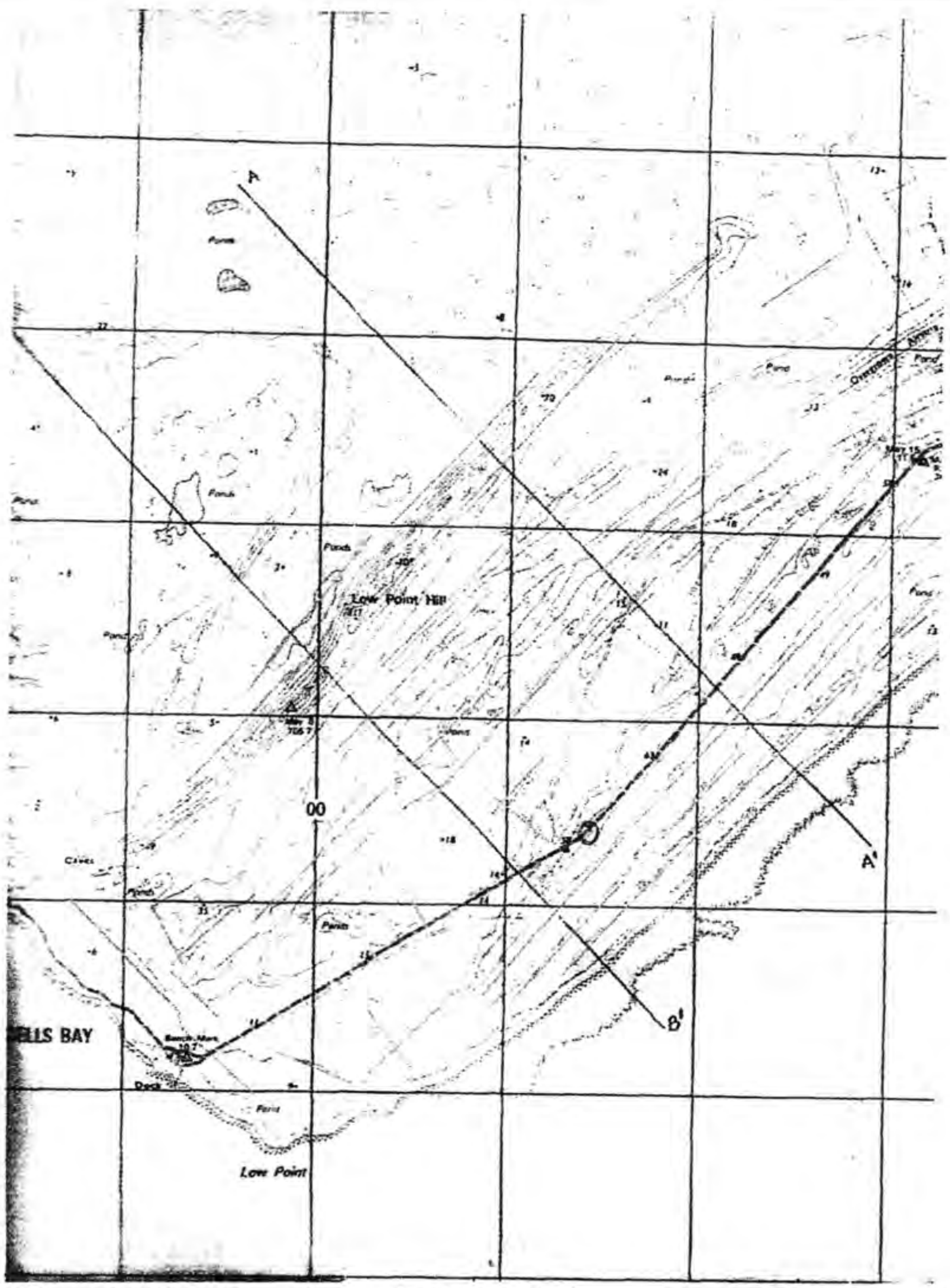


Fig. 16. Red straight lines shows the dominating morfoalignments most of them expressing the fracture pattern of tectonic origin controlling the morphology of the landscape.

General geology of Mayaguana is not quite different from the other islands except for the development of a consolidated massive limestone of no more than 5 m thickness that forms the crests of the marine terraces and fossil dunes in the southern and eastern parts of the island. These rocks form a hard crust that preserves part of the summits of the cliffs and it could be observed forming the upper strata in the outcrops and cuts in the quarries. These indurated limestones form the top of the hills.

Terrestrial waters

Surface Water

Mayaguana is a flat, low-lying island. The island is relatively dry with an average rainfall of around 76 cm per year. Mayaguana boasts a variety of surface water bodies, which may be classified as flooded-topographic lows, lagoons, marsh or wetlands, and caverns. A small area of wetlands occurs along the southern, central coast, near Abrahams Bay. Ponds and lagoons can be found along the northern coast of the island. In most cases, these surface water features are saline to hypersaline. Blue holes have not been discovered on the island. Large-scale chemical or biological contamination of the surface water has not been reported.

Ground Water

A freshwater lens was discovered on western Mayaguana Island. The lens occurs in the Lucayan limestone aquifer and reaches a maximum thickness of 10.5 m (34 ft). Moderate quantities of freshwater are available from this lens. Water levels are within one to two meters of the surface. Uncased boreholes should be used to abstract ground water from the limestone aquifer. Also, abstraction should be spread over many boreholes. Recommended pumping rates are between 0.6 to 1.5 L/s (10 to 25 gpm). Drawdown and water quality should be monitored for increased salinities in an effort to avoid saltwater intrusion from overpumping.

Holocene sand aquifers along the coasts of Mayaguana have not been exploited; however, their location near the sea suggests the ground water is likely brackish to saline. The water table is within a meter of the surface. These aquifers, which comprise 6% of the total area of the island, are unsuitable for large-scale ground water extraction.

East of Abrahams Bay, there is no freshwater source. The limestone bedrock in this area has many small sinkholes which prevent the formation of freshwater lenses. The island receives much less rainfall than the northern Bahamian islands and the little recharge it does receive quickly infiltrates through the sinkholes and mixes with the saline water. Areas that are not underlain by limestone or sand aquifers are also unsuitable for ground water development and comprise 84% of the total island area. Chemical or biological contamination of the aquifers has not been reported for Mayaguana Island.

RECONNAISSANCE RESOURCES

The Terms Reserve and Resource

A considerable semantic problem exists worldwide concerning the meanings of the terms reserve and resource. The issue is further complicated by the fact that in some languages one of the terms reserve or resource does not exist and in other languages one or both of the terms have a completely different meaning from that usually attached to them.

However, in the English speaking community dealing with geomatters, a growing trend is to apply the term reserve to economically extractable, appropriately assessed quantities and the term resource to quantities that are currently not economic but may possibly be so in future. Furthermore, there is a growing understanding that reserve is a part of resource, which to some extent contradicts the above meaning of resource as being currently not economic.

For this reason the term Total Resource has been introduced. Thus, Reserve plus Additional Resource comprise the Total Resource, or Total Resource minus Reserve gives the Remaining Resource (Fig. 17), depending on the viewpoint: The investor, banker, and industry tend to see an "additional resource" since the reserve is their prime interest; in contrast, the planners tend to see a "remaining resource" since their prime interest is the Total Resource.

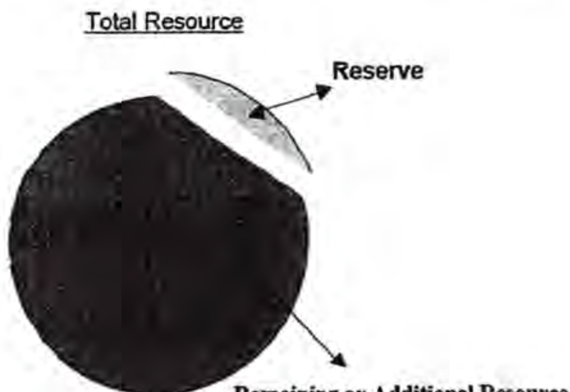


Fig. 17. The terms Reserve and Resource

Carbonatites Resources of the Study Area

The Reconnaissance Resources include all the carbonatites in the study area without any distinction in terms of:

- Specific petrophysical and geotechnical properties (like compressive strength, specific and unitary weight, density, angle og internal friction which not were studied).
- Granulometry.
- Lithological/mineralogical composition.
- Stratigraphic position ant tectonophysical relations among them.

Several outcrops were observed showing the huge variety of carbonatites in the study area. These carbonatites includes among others, the following:

a. In the top of the hills:
    - Indurated limestones, commonly in the top of the cliffs and probably at the bottom of

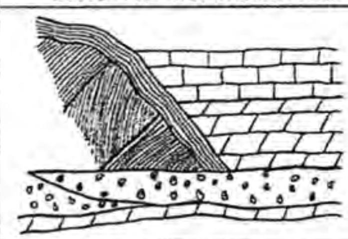
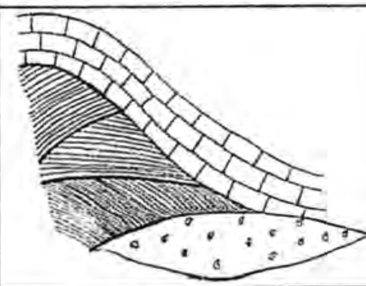
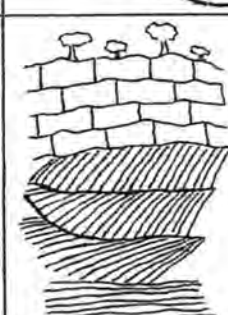
some of the intra cliff longitudinal depressions.

- Oolitic fossiliferous recrystallized and massive limestones. These oolites could also appear thin stratified with thin laminar gypsum crystals and black-colored probably due to sulfur oxidation.
- Calcarenites (generally speaking), comprising eolianites (mostly bioclastic) and calcareous sandstones primarily consolidated sands –probably fossil dune and/or fossiliferous eolianites.
- Poor consolidated oolites with detritic/organic material with abundant mollusks (genus *Cerion*) and fossil roots of trees including also fragments of other rocks (looking like a coastal breccia) and small stromatolites.

b. In the depressions between the hills:
   - Oolitic massive limestone recrystallized in horizontal bands with mollusks fossils
   - Calcareous breccia or coastal (beach rock) agglomerate; the rounded to subangular fragments belongs to darker rocks; matrix is recrystallized.

Important horizontal facial variations are observed. Stratification is also very variable which difficult the estimation of the real thickness of the rocks. While they often lye massively and horizontally, cross stratification is common, and also talus and slope deposits with important dipping angles are also recognized. Table 5 show some geological sections documented in the study area (Figs. 18-21).

Table 5. Typical geological sections documented in the study area (drawings are not at scale)

GENERAL DESCRIPTION AND LOCATION	LITHOLOGICAL SECTION
Abandoned quarry close to the airport	
Quarry close to the road to the abandoned Naval Base	
Same place but in the western face. The oolitic limestone show more thickness over the fossil dune	

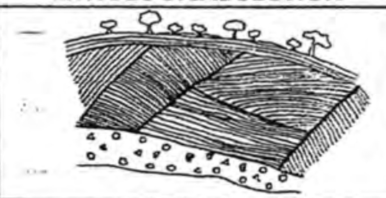
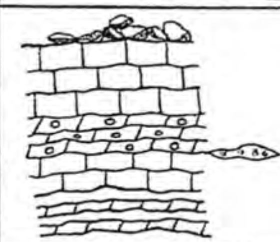
GENERAL DESCRIPTION AND LOCATION	LITHOLOGICAL SECTION
Quarry in Abrakhams Bay. Cross stratified calcarenites appear in the top of the outcrop.	
Cut close to the Gas Station. Strata with stromatolites are abundant here.	

Fig. 18. Massive micritic limestone with a thin continental weathering crust that contributes to indurate the sediments.

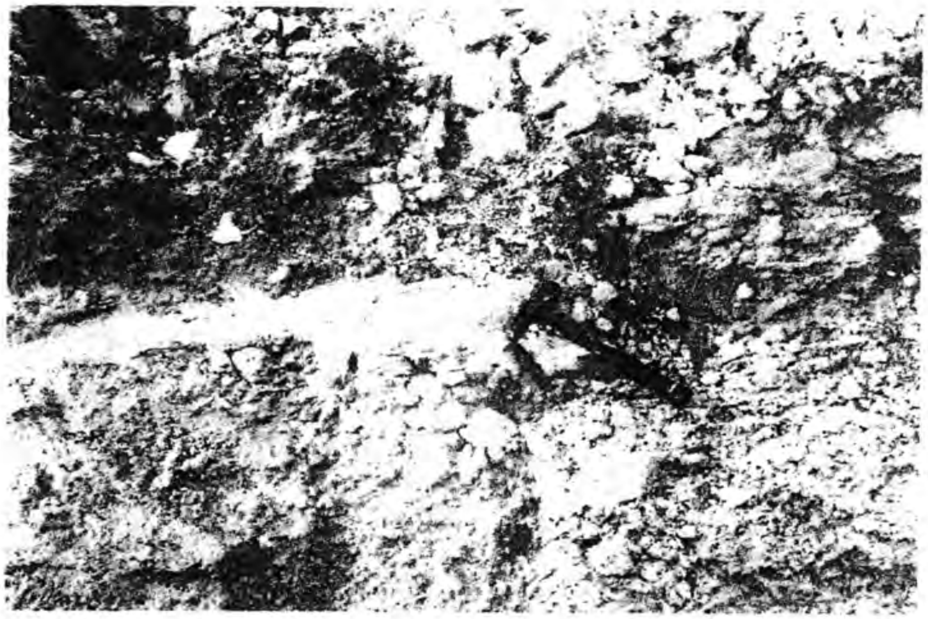


Fig. 19. Breccia or beach rock sediments (lower strata) covered by weathered arenaceous limestones.

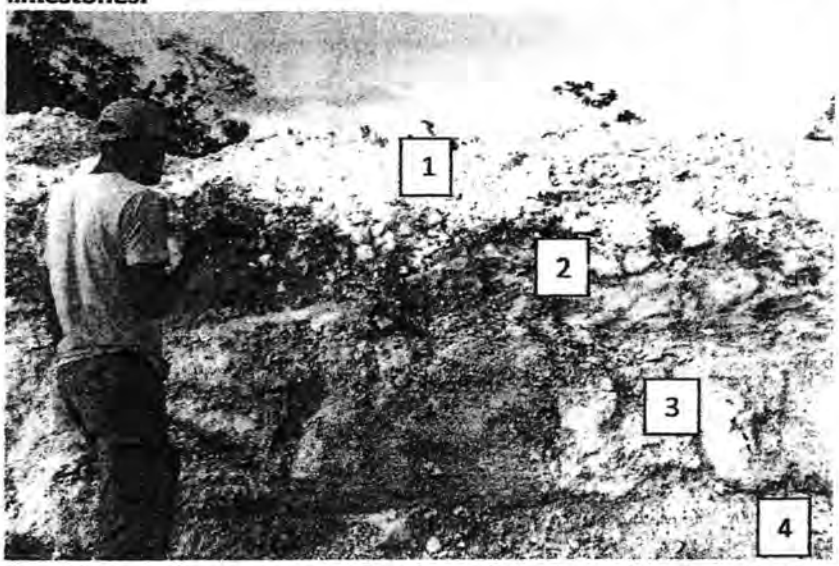


Fig. 20. Complex sequence of carbonatiites. From top to bottom: weathered oolitic limestones or breccia-like sediments; calcarenites; oolitic well and thin stratified; ooolitic limestones with beach sediments and mollusks.

Rigorously the suitable industrial end use of all the carbonatites could not be anticipated at this stage of research. Fig. 23 show the potential use of the carbonatites depending on their physical, chemical and mineralogical properties.

Table 6. Reconnaissance (potential) Resources of limestones (carbonatites) of the explored sector of Mayaguana Island at the G-4 Reconnaissance level.

BLOCK		AREA (m^2)	POTENTIAL VOLUMEN (m^3)
Block 1		215625	6468750
	Block 1 variant a	90175.75	2705272.5
Average			**4587011.25**
Block 2		664724.1	**17748133.47**
Block 3		136036.56	**408109.68**
Block 4		3790.9	**14198816**
Block 5		1644805.68	**4934417.04**
TOTAL			**41876487.39**
TOTAL 85% Confidence Level			**35595014.28**

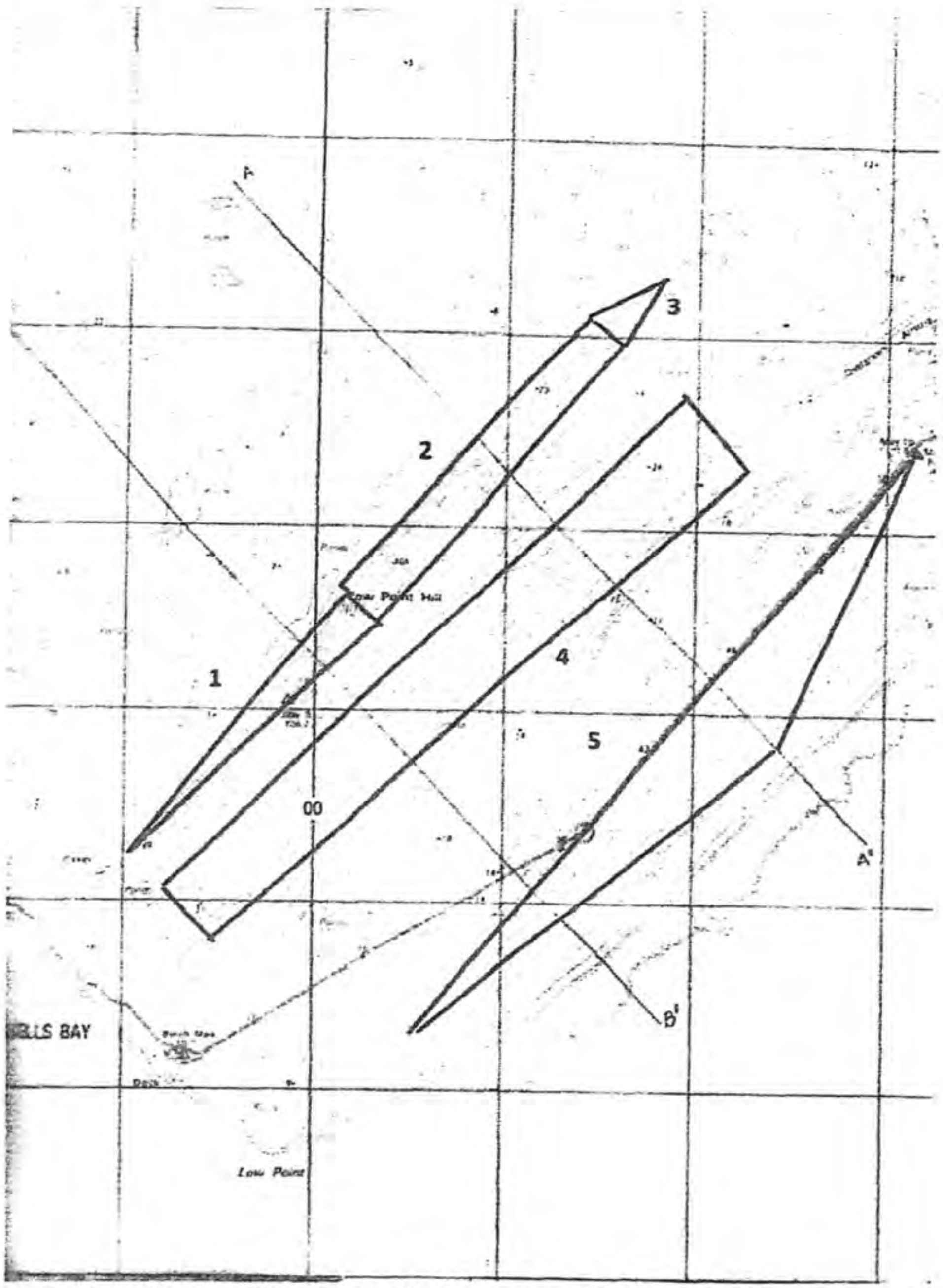


Fig. 22. Distribution of selected blocks for the assessment of the Reconnaissance Resources.

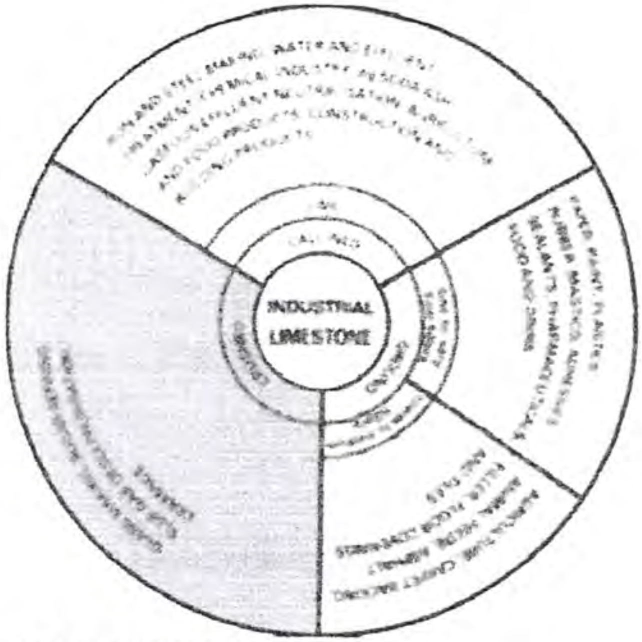


Fig. 23. The capabilities of the limestone industry.

CONSIDERATIONS ON LIMESTONE QUARRYING AND UNDERGROUND MINING OPERATIONS[32]

Quarrying

Extraction (more commonly referred to as quarrying) consists of removing blocks or pieces of stone from an identified and unearthed geologic deposit. Differences in the particular quarrying techniques used often stems from variations in the physical properties of the deposit itself—such as density, fracturing/bedding planes, and depth—financial considerations, and the site owner's preference. Nevertheless, the process is relatively simple: locate or create (minimal) breaks in the stone, remove the stone using heavy machinery, secure the stone on a vehicle for transport, and move the material to storage. A flow diagram of typical quarrying operations is shown in Fig. 24.

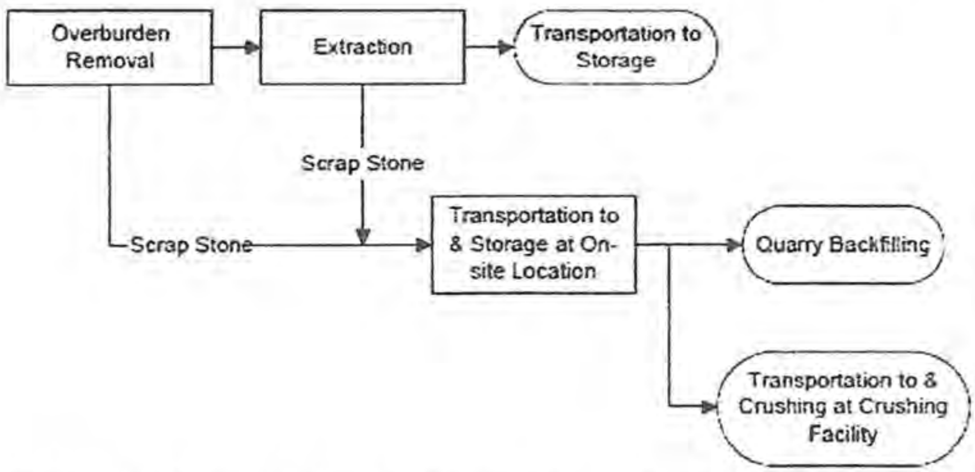


Fig. 24. Process flow diagram for limestone quarrying operations (After Univ. Tennessee, 2006).

As shown in Fig. 24, the first step in quarrying is to gain access to the limestone deposit. This is achieved by removing the layer of earth, vegetation, and rock unsuitable for product—collectively referred to as overburden—with heavy equipment that is sometimes coupled with small explosive charges. The overburden is then transferred to onsite storage for potential use in later reclamation of the site. After the face of the limestone is exposed, the stone is removed from the quarry in benches, usually 8 to 12 feet square extending 20 feet or more using a variety of techniques suitable to the geology and characteristics of the limestone deposit.

Quarrying operations typically include drilling holes along the perimeter of the bench followed by cutting the stone out of the deposit using saws equipped with diamond wire, or by splitting the stone using hydraulic splitters. If bedding planes are visible, forklifts can be used to pry up the blocks. Once the bench is cut or split loose from the deposit, heavy equipment is used to lift the limestone bench and transfer it to an inspection area for grading, temporary storage, occasional preprocessing into slabs, and eventual shipment from the site. Limestone of insufficient quality or size for current demand is stored on-site for future use, crushed for use in paving and construction applications, or stored for future site reclamation activities.

[32] University of Tennessee. 2006. **Limestone Quarrying and Processing:A Life-Cycle Inventory**. Center for Clean Products. Natural Stone Council, 25:

Limestone Processing Operations

Processing operations include much more variation than extraction. Nevertheless, the general procedures begin with initial cutting, followed by application of a finish, and conclude with second cutting or shaping step. Due to the array of stone products, the second and/or third steps may be eliminated, specifically when the product will have a "natural" appearance. Figure 25 depicts the fabrication process.

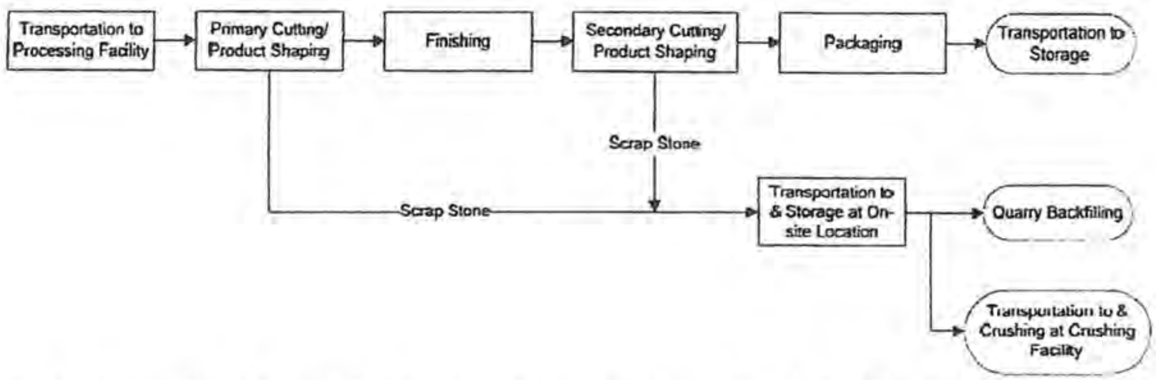


Fig. 25. Process flow diagram for limestone processing operations (After Univ. Tennessee, 2006).

Processing commences with transportation of the (raw) stone from the quarry to the processing facility, as depicted by Fig. 25. It should be noted that this step may consist of multiple transportation steps; prior to reaching the doors of the facility, the stone may be transferred to a number of vendors or distribution locations worldwide. Additionally, some limestone (blocks) may have been cut into slabs before reaching the main fabrication plant. These are most commonly sliced to a thickness of 3/4 in (2 cm), 1-1/4 in (3 cm), or more in lengths of approximately 10-12 ft and widths around 3-5 ft. The route that the stone takes through the plant therefore depends on its physical state upon arrival, as well as the product to be produced.

The first step of the process is a primary cutting or shaping of the material. This is typically accomplished for limestone using a circular blade saw, diamond wire saw, or a splitter. When operating a circular or diamond wire saw, a continuous stream of water over the saw is required in order to dissipate heat generated by the process; sufficiently-elevated temperature can cause major machine and material damage. Natural-faced products, such as veneer or flooring, may be completed with this step, while other products require a finishing application, secondary cutting, or both.

Limestone is often produced with a natural surface, but finishes can be applied. In such cases, often a polished or honed finishing is given to limestone products, but a variety of other finishes are also common. Polishing and honing are manually and/or mechanically accomplished through the use of polishing pads or bricks.

A secondary shaping step may be necessary if the product includes any features or custom size or shape. For this procedure, a circular blade saw is frequently implemented for limestone, but a variety of hand tools are also common. Cooling water is again necessary for large circular saws.

Once a product is completed, it is packaged and stored for shipment or direct sale. Limestone of insufficient quality or size for current demand is stocked on-site for future use, crushed for use in paving and construction applications, or stored for site reclamation activities.

Life Cycle Inventory (LCI) Boundaries

Limestone Quarry Operations

The LCI for quarry operations includes the inputs and outputs for each of the processes depicted in Fig. 24. Specifically, processes and operations represented in the inventory presented in this report include:

- Removal of overburden using heavy equipment
- Transfer of overburden to on-site storage
- Quarry operations required to remove stone from deposit including drilling, cutting, prying, and use of explosive charges.
- On-site transport of stone using heavy equipment.
- Transport of scrap stone to on-site storage
- Onsite generation of energy and compressed air
- Capture and treatment of wastewater
- Upstream production of energy and fuels

Limestone Processing Operations

The LCI for limestone processing operations includes the inputs and outputs for each of the processes depicted in Fig. 25. Specifically, processes and operations represented in this portion of the inventory include:

- Primary shaping of stone into large, less-refined pieces, such as tiles or flagstone
- Application of a surface finish or texture
- Secondary shaping, including hand detailing, of stone into specific products
- Packaging of finished limestone products or slabs for shipment
- On-site transport of stone using heavy equipment, such as forklifts
- Transport of scrap stone to on-site storage or reclamation
- Onsite generation of energy and compressed air
- Capture and treatment of wastewater and other waste materials such as dust
- Upstream production of energy and fuels

Since a fabrication facility often processes more than one stone type, each facility was categorized as a "limestone" facility if the majority of their production was indicated to be limestone. Under this condition, all respondents who are labeled "limestone" processors indicate that at least 97% of their production is limestone.

LCI Results

Data have been obtained for the quarrying and processing of 570,000 tons and 250,000 tons of limestone, respectively. The average gross energy required to produce one ton of limestone is 0.808 Million BTUs. Table 7 shows the breakdown of this gross energy per ton of limestone product produced. Table 8 displays the water required for the same production.

Note that the abbreviations found in Tables 7 and 8 imply the following:
- W = Withheld to avoid disclosure of company proprietary information
- N/A = Not applicable due to a lack of data
- NR = Not reported by any facility (i.e., all surveys left this survey question blank)

Table 7. Gross energy to produce one ton of limestone products (BTU/Ton, After Univ. Tennessee, 2006)

ENERGY TYPE	QUARRYING	PROCESSING	TOTAL
Electricity	2,03E+04	1,18E+05	1,38E+05
Natural Gas	1,5E-03	4,15E+05	4,15E+05
Propane	2,3E+02	3,22E+04	3,24E+04
Diesel	2,5E+05	4,77E+04	2,98E+05
Gasoline	7,31+03	2,43E+04	3,16E+04
Other Fuel	NR	NR	NR
TOTAL	**2,78E+05**	**6,37E+05**	**9,14E+05**

Table 8. Water consumption for limestone quarrying and processing at the quarry and processing sites only (gal/Ton, After Univ. Tennesee, 2006)

ENERGY TYPE	QUARRYING	PROCESSING	TOTAL
Groundwater	2,00E+01	2,43E+03	2,45E+03
Surface water	6,23E+02	7,23E+03	7,85E+03
Public water	7,10E-02	9,66E+03	9,66E+03
TOTAL	**6,43E+02**	**1,93E+04**	**2,00E+04**

Underground mining of limestone

Where geologic and market conditions permit, limestone for aggregate is extracted from underground mines[33].

Though more costly than quarrying, the underground mining of limestone can be both economical and necessary in some areas. Sometimes shallow rock units, which were once acceptable, may no longer meet newer engineering standards for construction aggregate. In other instances, it is not economical to strip both the overlying deposits and the poorer quality, shallow bedrock in order to quarry. An operator must decide whether to cease production and move to an alternate location, if one exists, or to shift operations underground. Numerous factors are weighed to determine the feasibility of such a production change particularly if is the needed quality rock present in sufficient thickness and at suitable depth; if the market conditions satisfactory to warrant the added expense of underground start-up and production and if it is environmentally sound to develop an underground mine.

A major element of the mining process is breaking up the rock[34]. This fragmentation is accomplished by detonating explosives set in blast holes[35]. The heading, or rock face to be blasted, is typically 40-feet wide by 20- to 25-feet high. A designed pattern of 40 to 50horizontal drill holes two inches wide by 12- to 14-feet deep, are bored into the rock face by large portable drills. This

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[33] McKay Robert M. and Michael J. Bounk. 1987. **Underground Limestone Mining**. Iowa Geology No. 12, Iowa Department of Natural Resources, 3:

[34] Molerio León, Leslie F. (1990): **CLEO. Presentación de un Algoritmo para el Cálculo de la Estabilidad de las Cavernas**. Congr. 50 Aniv.Soc.Espel. Cuba, La Habana: 89

Molerio León, Leslie F. 1993: **Problemas Ingenieriles en Áreas Cársicas: La Estabilidad de las Cavernas**. II Jornadas Venezolanas de Geología Ambiental, Maracaibo, Venezuela, 15:

[35] Molerio León, Leslie F.;M. Hernández Moret; O. Velázquez Sánchez; M. Guerra Oliva & M. Labrada Cortés 1990: **Estudio Experimental de Resistencia a Cargas Dinámicas en la Bóveda de una Caverna**. Congr. 50 Aniv.Soc.Espel. Cuba, La Habana: 88

Fig. 27. Open underground limestone mine.

Controlling groundwater is another important aspect of mining operations. Water is usually present at some depth below the surface; and once encountered by mining, open crevices, fractures, and solutional voids in the limestone may produce variable flows of groundwater. This inflow must be routed along drainage slopes and ditches to collection places where it can be discharged from the mine. Most operators eventually need to collect water in a sump, or low spot, within the mine and pump it out from that point. On rare occasions, a heading may intersect a fracture or void which releases hundreds of gallons of water per minute. If the problem cannot be remedied, a portion or the entire mine may be closed.

Proper ventilation also must be maintained in any underground mine. Exhaust fumes from machinery must be vented and fresh air introduced. Natural ventilation of level headings is adequate when mine workings are not extensive. Warm air, either from outside or within the mine, will flow along the ceiling while cool air will move along the floor. As the workings are extended, however, forced ventilation becomes necessary.

Fans move air from one or more exterior openings to the active part of the mine. As workings progress or become deeper, the producer may have to drill large-diameter vertical ventilation shafts from the surface to the mine level. Large volume ventilation fans are installed which move air down, usually in colder weather, and can be reversed to move air up during warmer humid weather.

Although operations of an underground limestone mine are more expensive and require some specialized techniques to overcome inherent difficulties, there are also significant advantages to underground stone extraction. Stripping unneeded overburden, a costly inconvenience in surface operations, is eliminated. The lands above the mine can be utilized for other purposes simultaneously with stone removal. Reclamation of disturbed land and its associated costs are reduced. Noise and dust pollution are generally contained within the mine. Working conditions, while dark and temperature in the Tropics is high but variable in summer and winter.

If geologic conditions are suitable and proper planning has been done, large portions of the mine workings may eventually be converted to usable underground space. This space can be utilized for warehouses, offices, industrial production, agricultural product storage, and even recreational facilities, such as tennis courts. Small portions of the mines could be converted into mine managers' office areas, and abandoned underground mines could be used as a storage facility.

Underground mining in urban areas can be an attractive future alternative when the stone producer must compete with other land uses and increasing land acquisition costs. Other uses that could be considered include civil defense or storm shelter, warehouse – storage facility or mushroom farming.

Impacts of mine dewatering

When an open pit intersects the water table, groundwater flows into the open pit. For mining to proceed, mining companies must pump and discharge this water to another location. Pumping and discharging mine water causes a unique set of environmental impacts that are well described

Impacts of mining projects on air quality

Airborne emissions occur during each stage of the mine cycle, but especially during exploration, development, construction, and operational activities. Mining operations mobilize large amounts of material, and waste piles containing small size particles are easily dispersed by the wind.

The largest sources of air pollution in mining operations are:

- Particulate matter transported by the wind as a result of excavations, blasting, transportation of materials, wind erosion (more frequent in open-pit mining), fugitive dust from tailings facilities, stockpiles, waste dumps, and haul roads.
- Exhaust emissions from mobile sources (cars, trucks, heavy equipment) raise these particulate levels; and
- Gas emissions from the combustion of fuels in stationary and mobile sources, explosions, and mineral processing.

Once pollutants enter the atmosphere, they undergo physical and chemical changes before reaching a receptor (Figure 1). These pollutants can cause serious effects to people's health and to the environment.

Large-scale mining has the potential to contribute significantly to air pollution, especially in the operation phase. All activities during ore extraction, processing, handling, and transport depend on equipment, generators, processes, and materials that generate hazardous air pollutants such as particulate matter, heavy metals and carbon monoxide, sulfur dioxide, and nitrogen oxides.

Mobile sources

Mobile sources of air pollutants include heavy vehicles used in excavation operations, cars that transport personnel at the mining site, and trucks that transport mining materials. The level of polluting emission from these sources depends on the fuel and conditions of the equipment. Even though individual emissions can be relatively small, collectively these emissions can be of real concern. In addition, mobile sources are a major source of particulate matter, carbon monoxide, and volatile organic compounds that contribute significantly to the formation of ground-level ozone.

Stationary sources

The main gaseous emissions are from combustion of fuels in power generation installations, and drying, roasting, and smelting operations.

Fugitive emissions

The U.S. Environmental Protection Agency defines 'fugitive emissions' as "those emissions which could not reasonably pass through a stack, chimney, vent or other functionally-equivalentopening." Common sources of fugitive emissions include: storage and handling of materials; mine processing; fugitive dust, blasting, construction activities, and roadways associated with mining activities; leach pads, and tailing piles and ponds; and waste rock piles. Sources and characteristics of fugitive emissions dust in mining operations vary in each case, as do their impacts. Impacts are difficult to predict and calculate but should be considered since they could be a significant source of hazardous air pollutants.

Noise and vibration

Noise pollution associated with mining may include noise from vehicle engines, loading and unloading of rock into steel dumpers, chutes, power generation, and other sources. Cumulative impacts of shoveling, ripping, drilling, blasting, transport, crushing, grinding, and stock-piling can significantly affect wildlife and nearby residents.

Vibrations are associated with many types of equipment used in mining operations, but blasting is considered the major source. Vibration has affected the stability of infrastructures, buildings, and homes of people living near large-scale open-pit mining operations.

Impacts of mining projects on wildlife

Wildlife is a broad term that refers to all plants and any animals (or other organisms) that are not domesticated. Mining affects the environment and associated biota through the removal of vegetation and topsoil, the displacement of fauna, the release of pollutants, and the generation of noise.

Habitat loss

Wildlife species live in communities that depend on each other. Survival of these species can depend on soil conditions, local climate, altitude, and other features of the local habitat. Mining causes direct and indirect damage to wildlife. The impacts stem primarily from disturbing, removing, and redistributing the land surface. Some impacts are short-term and confined to the mine site; others may have far-reaching, long-term effects.

The most direct effect on wildlife is destruction or displacement of species in areas of excavation and piling of mine wastes. Mobile wildlife species, like game animals, birds, and predators, leave these areas. More sedentary animals, like invertebrates, many reptiles, burrowing rodents, and small mammals, may be more severely affected.

If streams, lakes, ponds, or marshes are filled or drained, fish, aquatic invertebrates, and amphibians are severely impacted. Food supplies for predators are reduced by the disappearance of these land and water species. Many wildlife species are highly dependent on vegetation growing in natural drainages. This vegetation provides essential food, nesting sites, and cover for escape from predators. Any activity that destroys vegetation near ponds, reservoirs, marshes, and wetlands reduces the quality and quantity of habitat essential for waterfowl, shore birds, and many terrestrial species.

The habitat requirements of many animal species do not permit them to adjust to changes created by land disturbance. These changes reduce living space. The degree to which animals tolerate human competition for space varies. Some species tolerate very little disturbance. In instances where a particularly critical habitat is restricted, such as a lake, pond, or primary breeding area, species could be eliminated.

Surface mining can degrade aquatic habitats with impacts felt many miles from a mining site. For example, sediment contamination of rivers and streams is common with surface mining.

Habitat fragmentation

Habitat fragmentation occurs when large areas of land are broken up into smaller and smaller patches, making dispersal by native species from one patch to another difficult or impossible, and cutting off migratory routes. Isolation may lead to local decline of species, or genetic effects such as inbreeding. Species that require large patches of forest simply disappear.

Impacts of mining projects on soil quality

Mining can contaminate soils over a large area. Agricultural activities near a mining project may be particularly affected.

Impacts of mining projects on social values

The social impacts of large-scale mining projects are controversial and complex. Mineral development can create wealth, but it can also cause considerable disruption. Mining projects may create jobs, ads, schools, and increase the demands of goods and services in remote and impoverished areas, but the benefits and costs may be unevenly shared. If communities feel they are being unfairly treated or inadequately compensated, mining projects can lead to social tension and violent conflict.

Environmental Impact Assessments (EIA) can underestimate or even ignore the impacts of mining projects on local people. Communities feel particularly vulnerable when linkages with authorities and other sectors of the economy are weak, or when environmental impacts of mining (soil, ai, and water pollution) affect the subsistence and livelihood of local people. Power differentials can leave a sense of helplessness when communities confront the potential for change induced by large and powerful companies. The EIA process should enforce mechanisms that enable local communities to play effective roles in decision-making.

Mineral activities must ensure that the basic rights of the individual and communities affected are upheld and not infringed upon. These must include the right to control and use land; the right to clean water, a safe environment, and livelihood; the right to be free from intimidation and violence; and the right to be fairly compensated for loss.

CONCLUSIONS AND RECOMMENDATIONS

1. Limestone is among Bahamas most essential resources. Our understanding of that resource as an industrial mineral is poor given its importance to Bahamas economy.

2. Research on limestone should be focused on mapping deposits and a proper assessment of its resources, as well as understanding their roles as construction materials, aquifers and petroleum reservoirs. However, different data are needed to characterize limestone suitable for construction and other industries.

3. Carbonate rocks need to meet chemical purity requirements that vary by intended use. Some uses require that the limestone also has certain favorable engineering properties.

4. Standards and requirements for limestone use are rising, and a greater understanding of limestone characteristics, variability, and engineering properties is needed. It is important, though, to catalog such rocks as possible future resources.

5. The Bahaman Archipelago consists of two carbonate banks which were formed by a chain of carbonate platforms. The archipelago is an arcuate system of carbonate platforms, commonly capped with low islands, to have been built on oceanic crust located to the east and south of the continental margin North America.

6. The Bahamas have long been the focus of geologic work on modern carbonates and show a particular interest to geologists as it provides a modern analog for the dynamics of ancient carbonate depositional platforms, many of which are major petroleum reservoirs.

7. The oldest stratigraphic unit exposed on the island is the Owl's Hole Formation, a bioclastic eolianite. Owl's Hole is overlain by a terra rossa paleosol separating it from the overlying MIS 5e Grotto Beach Formation, which includes a lower transgressive oosparite and peloidal grainstone unit, the French Bay Member, and an upper eolianite and distinct framestone unit (fossil reef), the Cockburn Town Member. A paleosol layer overlies the Grotto Beach Formation, and marks the end of Pleistocene deposition on the island. Holocene depositional units include the early Holocene North Point Member and overlying Hanna Bay Member, both of which belong to the Rice Bay Formation. Lower Holocene lithologies are dominated by bioclastic eolianite and calcarenite facies, while the overlying Hanna Bay Member is largely comprised of intertidal facies and eolian deposits in equilibrium with the modern sea level. Beachrock found within the Hanna Bay in San Salvador Island reveal evidence of rapid cementation.

8. Mayaguana, as most of the Bahamian Archipelago is a very low altitude island mostly at sea level. Ponds and wetlands dominate in the inland but it is common to find it in the shallow friable coast. Some of the coastal features are spits and hooks linked with the wave refraction phenomena. When the waves are refracted around the tip of the spit the attendant longshore currents become weaker and hence the material is deposited. Coastal ponds are associated with the development of offshore bars. Reef barriers practically surround the island contributing to the development of shallow bays.

9. The Geological knowledge can only be obtained by geological exploration. United Nations

has divided geological exploration into four successive stages of geological assessment:

- Reconnaissance Stage (G-4)
- Prospecting Stage (G-3)
- General Exploration Stage (G-2)
- Detailed Exploration Stage (G-1)

10. With respect to the limestone mining in Mayaguana Island we are at the G-4 Reconnaissance Stage (Reconnaissance Resource) of the Western part of the island.

11. At the G-4 level of effort the explored area was divided into five blocks of different shape and thickness thus giving different potential volumes of carbonatites. This potential was estimated, depending on the inferred/tested lithological composition and the shape of the landscape involved. A confidence level of 85% was accounted because of the limited time in the field work and the restrictions of documentation (time, accessibility, denudation and complexity of the geological conditions.

12. Because of the environmental issues involved, particularly in what concerns to the protection of the groundwater level, roughly at the same level of the sea, a confidence interval of 1 m above sea level was considered as the lower limit of exploitation of the limestones. The upper limit was defined on average altitude or, in some cases, by the highest altitude of the block. Those were the boundaries used for the computation of the Reconnaissance Reserves.

13. According to our computations the **Reconnaissance Resources of the explored sector are estimated in 35 595 311 m^3 at the 85% confidence level.**

14. At this level of knowledge it is deeply recommended to continue to the following stage; v.gr. Prospecting (G-3 Stage) Inferred Resource.

Nassau, Bahamas & La Habana, Cuba

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