Some examples of karst development in Cuba.

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ABSTRACT

The Cuban land territory encompasses 110,992 km² of which 66% are karstified rocks plus 67,831 km² of the shallow water shelf karst. Under humid tropical conditions karst has developed a wide variety of systems, determined by a combination of factors as topography, lithology, hydrodynamics, water chemistry and others. Several types of karst that illustrate the variety of such features are presented as examples. A summary of the main caves and underground passages is given.

Key words: karst, Cuba, geomorphology, hydrogeology, caves.

INTRODUCTION

The territory of Cuba, which includes the island of Cuba, Isle of Youth and nearly 4,194 keys and small islands, measures 110,922 km² and is surrounded by 67,831 km² of shallow water shelf. Tropical karst is well developed in the country, as almost 66% of the land area is underlaid by karstified rocks, while almost the whole shelf is underlaid by karstified limestones. As a consequence, karst is a very important element in the Cuban surface and submarine landscape. Carbonate rocks range in age from Greenville (≈ 1000 Ma) to Recent. Local gypsum karst is also found.

The study of karst in Cuba has a long tradition, and during the last 35 years a great effort has been concentrated towards the speleological, geomorphological, geochemical, hydrogeological and engineering geological research in these terrains, since karst areas are the main source of fresh water and are a complicated basement for every kind of construction. Several books and papers have been published dealing with this subjects, most of then in two journals: Voluntad Hidráulica (published by the National Institute of Hydraulic Resources), and Serie Espeleológica y Carsológica (Published by the Cuban Academy of Sciences). An important bibliographic list related to the Cuban karst can be found in NÚÑEZ-JIMÉNEZ et al. (1988).
There are several kinds of classifications of the Cuban karst. The first were mostly geographical (NÚÑEZ-JIMÉNEZ, 1964), later on they were geological-geomorphological (NÚÑEZ-JIMÉNEZ et al., 1968, 1988), and one was developed for hydrogeological and geological engineering purposes (SKWALETSKI & ITURRALDE-VINENT, 1971).

The karst landscapes are strongly differentiated in the cuban territory, and some examples will provide an idea of the kind of the karstification developed (Figure 1). Table 1 summarizes some of the climatic-geomorphological characteristics of these territories.

**Los Órganos karstic mountain range**

Located in western Cuba, it is a northeast-southwest linear limestone range surrounded north and south by non-karstic elevations where rivers arise and run toward the limestone massif. The whole area drains southwestward to the Caribbean Sea via the Cuyagua-teje river.

The massif includes Late Jurassic, Cretaceous and Early Tertiary dense limestones, either massive or well stratified in the section. The rocks are wholly deformed with many faults and fractures and locally strongly folded, generally dipping to the north. Surface karst phenomena are well developed, from microforms (dog teeth, karren, channels) to megaforms (mogotes = tower karst, poljes, large sinkholes). Subsurface karst is the combination of two patterns, one vertical and the other horizontal. The vertical (vadose) karstic features are due to the infiltration of the local rain (1600-1800 mm/year), while the horizontal pattern in due to the combined effects of fluvial drainage and uplift of the mountains-sea level variations (Fig. 2).

Horizontal Karst are long and anastomosing fluvial caves tightly aligned along the fracture pattern and along the bedding planes where dipping is more than 40°. Caves are as long as 50 km, the largest in the country, with up to five levels. Rivers normally flow through the lower level, but during hurricanes and rain storms the second level is also active. The third and fourth levels are dry, with plenty of calcite secondary formations (Fig. 3), while the fourth and fifth levels show increasing graviclastic phenomena which can open very large subsurface rooms and create new vertical entrances. The vertical karstic features are deep dolines and caves which usually intersect the horizontal Karst.

**San Juan mountains Karst**

Located in the mountain region of Escambray, in Central Cuba, where the highest point reaches 1400 m (Figure 1). The rocks are Jurassic and Cretaceous marbles and calcareous schists, several hundred meters thick that rest, as an allochthonous sheet, on top of non-karstic metamorphic rocks. The marbles and schists are poreless, but a set of vertical fractures and faults dissect the massif.

The only water supply of the massif is from rainfall, that reaches >2000 mm/year, therefore the karstification is active throughout the whole thickness of the calcareous rocks (Fig. 4). The massif drains through several rivers and many local springs that run with a radial pattern. Caves are vertical and horizontal (aligned according to the fracture pattern of the massif), because the heavy rains and karstification create many underground rivers. In this region is found the highest cave systems in Cuba, at about 1.000 m above sea level.

This kind of mountain Karst is very common in Cuba, but at different scales. Frequently it is found as isolated hills with a limestone cap on top of non-karstified rocks. In these conditions the Karst massif is isolated and the only water input is rain. Therefore the whole limestone cap is strongly karstified and drainage takes place as many small springs active during the rainy season.

**The southern Habana and Matanzas karstic plain**

This is another typical example of the Cuban karst. The plain is limited to the north by non-karstic hills of low elevation while to the south it is covered by shallow marine waters. The massif was built up by Miocene massive and thick bedded limestones with high primary porosity, slightly deformed, but with many open fractures and faults. These limestones pinch out northward, but can reach several hundred meters thick to the south (Fig. 1).

Water input into the massif comes from three sources: small rivers that enter the plain from the north and flow into caves, subsurface drainage from northern underground basins, and rainfall that reaches 1000-1600 mm/year. The massif drains towards the southern marine shelf, where local submarine fresh water springs and blue holes are found. An intrusive saline wedge is sometimes located below fresh waters, and represents another input of water into the massif.

The surface karst features are mostly microforms (dog teeth sometimes unusually large, small dolines and sinkholes). Subsurface karst is very complex due to the combination of several components as: fresh and brackish waters that acts upon the massif, changes of sea level, existence of two main water conducts, non-homogeneous porosity and fractures patterns. As a consequence, the limestones suffer an overall karstification that increases the porosity and transforms the rock in a low resistance clayish-calcareous material. During rotary perforation karstic rock recovered is as a structureless marly material.

Vertical caves are due to vadose infiltration, but they are usually shallow, because the water table is not far from the surface. Horizontal caves are of two kinds, fluvial and phreatics. Fluvial caves are linear and after a
few hundred meters dilute into the other types. Phreatic
caves are typical labyrinth, with several interconnected
levels, sometimes up to several kilometers long (Fig. 5).

Hydrogeological research shows that in this area,
down to 100 m deep, the limestones are strongly
karstified, and that karstification is active in the whole
thickness of the limestones massif, up to the marly
substrata. This means that underground waters move
steadily through the whole massif, but more actively in
the first 100 m.

Underground waters from this massif are intensively
used for human consumption and, as a consequence, a
salt wedge is at present arising from the southern marine
shelf. In order to stop it, exploitation has been reduced,
and a channel opened along the southern coast. This
channel, fed with fresh water, is designated to improve
infiltration of surface water on top of the saline wedge.

Another example of plain karst is found in the
southern Pinar del Río plain since it develops in
subsurface conditions. In this example the plain lies over
the Tertiary limestones and argillaceous rocks that crop
out locally along the northern edge of the plain.
Southward the section is covered by argillaceous
Quaternary sediments. As a consequence, surface waters
reach the karstic massif only along its northern area, and
underground drainage takes place toward the south into
the shallow marine shelf. Miocene limestones have
primary porosity and karstification is active along
fractures and pores, but not as strong as in the plain
south of La Habana and Matanzas. No caves are known
to open as surface features in the plain.

In this area underground water is under exploitation
without risk of contamination from human surface input,
because of the Quaternary argillaceous isolating bed, but
the amount does not cover the needs. To improve
exploitation the massif is recharged through a set of
specially designed wells fed by channels that carry river
waters from the mountains.

The shallow marine shelf Karst
This type of karst is known from drill holes and
submarine speleological research, but an uplifted
example is represented by many marine terraces found
along sea shores. Most of the shelf was built up by Late
Tertiary and Quaternary limestones, with high primary
porosity and many open fractures and faults. Submarine
fresh water springs are known in many localities, and
blue holes have been found in the northern and southern
shelf. The deepest, known as "Hoyo 15 de Enero",
reaches 290 m below sea level. Another example, “Ojo
del Megano”, opens at 70 m below sea level. But also
sub-horizontal and deep inclined caves have been
described. Drill holes in several keys and in shallow
marine waters have recovered strongly karstified
limestones, sometimes destroyed as a “marly stuff”.

Actual marine terraces with strongly developed dog
teeth are an example of the old shelf. Dry uplifted blue
holes and long horizontal or distinctly inclined dry caves
have been reported in several regions. A relevant
element in this landscape are the karstic lagoons and
small linear lakes, developed along fractures and faults
that parallel the shore line. This features sometimes are
connected with vertical and horizontal caves, where
“ancient” stalactites and stalagmites are presently found
submerged below sea level.

In this type of karstic regions fresh water is limited to
a horizon of several tens of centimeters above the
brackish waters, because marine water dominates the
underground basins. Surface drainage in these areas is
nearly absent, and underground waters move slowly
toward the sea. The main water imput is from rainfall.
This kind of karstified terrains are the only source of
fresh water in the keys and small islands, but also in
some littoral communities of Cuba and the Isle of Youth.

These examples of karst development in Cuba show
the wide range of conditions that prevail in tropical
islands, quite different in character and origin.

Large Cave Systems
According to the Cuban Speleological Society
(NUÑEZ-JIMÉNEZ & GUTIÉRREZ, 1994) there are
nearly 10,500 known caves with more than 450 km of
passages, from which the following highlights are
extracted:

<table>
<thead>
<tr>
<th>Largest horizontal caves</th>
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<tbody>
<tr>
<td>Great Cave Santo Tomás</td>
<td>44,615</td>
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<tr>
<td>Majaguas-Cantera Cave System</td>
<td>33,500</td>
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<tr>
<td>Palmario-Pan de Azucar Cave</td>
<td>29,700</td>
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<td>Great Cave Fuentes</td>
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<td>Great Cave Los Perdidos</td>
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<td>Amistad-Caliente-Román Cave System</td>
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<td>Santa Catalina Cave</td>
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<td>Constantino Cave System</td>
<td>9,568</td>
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<td>Campanario Cave</td>
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<th>Largest vertical depths in caves</th>
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<tr>
<td>Cuba-Magyar Deep</td>
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<td>Jíbaro Cave</td>
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<td>Pipe Deep</td>
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<th>Largest inundated caves</th>
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<td>Tanque Azul Cave</td>
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<td>Cristalitos de Papaya Cave</td>
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<th>Largest inundated vertical passage in caves</th>
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<tr>
<td>XXXV Aniversario</td>
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<td>Iona</td>
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<td>Dagmar</td>
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<tr>
<td>Pipe Cave</td>
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<tr>
<th>Deepest sink hole</th>
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</table>
Hoyo 15 de Enero 290

**Deepest subsurface cave**

San Román I Well 5,392

**The highest cave**

La Campana Cave 1,110

**Largest subsurface room**

"Los Pajaros" in Majaguas-Cantera Cave System

H: 328 m, L: 131 m, W: 211 m

**References**


**Figuras (solicitarlas al Coordinador de la Comisión)**

Figure 1. Location map.

Figure 2. Majaguas-Cantera Cave System: Example of Los Órganos mountain tropical holokarst with up to five superimposed horizontal fluvial karstic levels and vertical dense vadose karstic development. The system is efficiently fed by fluvial and pluvial waters that are drained to the Cuyaguateje river. Horizontal caves are in line with the fracture system of the poreless limestones.

Figure 3. Speleothems developed in the interior of one middle level room in the Santo Tomás Cave System.

Figure 4. San Juan mountain karst in marbles and calcareous shists. The system is fed by rainfall and a drain pattern toward the surrounding lower lands and ultimately into the Caribbean Sea. Subhorizontal "fluvial" caves are due to the autochthonous drainage.

Figure 5. Tunel Cave. Example of karst development in the La Habana-Matanzas plain. Arrows indicate current and past levels of the water table. Vertical vadose activity is also evident. very active dissolution and rock desintegration takes place near the present day water table.

**PRIMERAS MEDICIONES DE LA CONCENTRACION DE RADON EN CUEVAS VENEZOLANAS**

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**RESUMEN**

La concentración de radón fue determinada utilizando dosímetros pasivos en la Cueva del Guacharo, Monagas; Alfredo Jahn, Miranda; cuevas de Quebrada Amarilla 2-3 y San Antonio 1, Guaramacal, Trujillo. Los resultados indican una gran variabilidad en las concentraciones, desde algunas décimas hasta un máximo de 80 KBq/m³, que representa niveles 400 veces mayores que el nivel de intervención recomendado de 0.2 KBq/m³. En la Cueva del Guácharo se colocaron siete detectores desde su boca hasta el fondo encontrando que la concentración aumenta hasta 12 K bq/m³. Estudios adicionales se están llevando a cabo para evaluar el posible peligro para la salud de los visitantes.

**Palabras claves**: Radón, radioactividad natural, Guaramacal, Birongo, Caribe, Cueva del Guácharo.

**ABSTRACT**

Radon concentrations where measured using passive dosimeters in Guacharo Cave, Alfredo Jahn Cave and in the caves Quebrada Amarilla 2-3 and San Antonio 1 in Trujillo. The results show a wide variability in the concentrations from a few hundreds of Bq/m³ to a maximum of 80 KBq/m³ which is 400 times higher than the recommended intervention level of 0.2 KBq/m³. In the Guacharo Cave where several detectors were placed, the concentration increases with distance from the entrance to a maximum of 12 KBq/m³. Further studies are being carried out to assess health hazards.

**Key words**: Radon, natural radioactivity, Guaramacal, Birongo, Carípe, Guácharo cave.

**INTRODUCCIÓN**

Numerosos trabajos muestran el riesgo de contraer cáncer pulmonar en los seres humanos, al estar expuestos a los productos de la desintegración del radón 220 y 222 emisores de radiación alfa, ya que estos se depositan en las vías respiratorias contribuyendo en promedio a un 52% de la dosis total de radiación ambiental a la cual está expuesta la población humana (ICRP, 1987). Así que dependiendo de la concentración de estos elementos en el aire, el riesgo de contraer cáncer pulmonar en algunos ambientes puede ser alto,