GEOGRAPHICAL, CLIMATIC AND GEOLOGICAL CHARACTERISTICS OF THE BAHÍA HONDA REGION (VERAGUAS, PANAMA)

Alicia Ibáñez

The Bahía Honda region, which includes the private reserve studied here, is situated on the Pacific coast of the province of Veraguas, in the south of the Soná peninsula, on the Gulf of Chiriqui (Fig. 1, Fig. 2). The reserve is located between 7º 40' and 7º 55' North and 81º 25' and 81º 35' West and occupies an area of around 6,000 hectares (15,000 acres). It contains the island of Canales de Tierra (ca. 200 hectares) and other large stretches of land on the adjoining mainland which its owners continue to extend and interconnect (Fig. 3). Most of the population of the area live in the villages of Pixvae (District of Las Palmas, jurisdiction of Pixvae) and in Bahía Honda and Salmonete (District of Soná, jurisdiction of Bahía Honda), although there are many inhabitants of scattered farmsteads. This population, made up of approximately 2,000-3,000 people, practices a subsistence economy, based on artisan fishing, livestock farming and slash and burn agriculture. This is an isolated region with very difficult overland access, since there are no paved roads further south of the old Pan-American highway from Santiago to Soná and Puerto Vidal (except the road to Santa Catalina, in the SE of the Soná peninsula), and access to the area is thus mainly by sea.

Our area of study lies entirely south of the Lovaina-San Rafael geological fault or Soná fault, undoubtedly the most outstanding physiographic feature of the region. This fault, which runs NW-SE, is delimited by the Rivers Lovaina and

Caté to the north and by a mountain range whose highest point is Cerro Filo de la Cordillera, at 703 m. There are other notable hills, such as Cerro Batista (629 m), Cerro Común (662 m), Cerro Palma Real (462 m) and the San Lorenzo cordillera (327 m).

In general, the terrain is rugged and irregular, with steep slopes, especially on the sides of the cordillera and along the coast. This undulating relief occupies the entire territory except for the alluvial plains of the larger rivers in the region, such as the Salmonete, Luís, Conagua, Managua, Mona, Pixvae and Río Seco. These short rivers all rise from the spurs of the Cordillera to the south of the fault, and their flow varies considerably from day to day, depending on the rainfall. At the mouth of some of these rivers (such as the Pixvae, Managua and Salmonete) there are large mangrove swamps. There is also a large mangrove swamp at the mouth of the River Limón and smaller ones in the area around El Edén and at the mouth of individual streams or rivulets.

Climate

Panama stands in a humid tropical region and on the Pacific side the climate is characterised by two clearly differentiated seasons, a dry season (January to April), with little precipitation, and a rainy season (May to December), with heavy rainfall. This very seasonal climate is determined by the interaction between the trade winds -which blow round the year throughout Central America from NE to SW- and a large low-pressure air mass, known as the Intertropical Convergence Zone (ITCZ). During the dry season from January to April, the ITCZ lies to the south of Central America, allowing the trade winds to cross the isthmus of Panama and unload moisture on the Atlantic side of the central mountainous cordillera, making precipitation much lighter or practically non-existent on the Pacific side (Jackson & D'Croz, 1997) (Fig. 4, Fig. 5). This is a time of strong N-NE winds throughout the country. This area of convergence moves northward from May to December each year, to lie over Central America, interrupting the trade winds. When the two great wind systems meet, they produce torrential rain, as a result of convection currents. The Pacific coast of southern Costa Rica and SW Panama is also greatly influenced by the SW-NE wind, which because of the proximity of the mountains, unloads its moisture in the form of precipitation on these coasts. Rainfall is higher here than elsewhere on the Pacific coast of Central America, and in many cases equals or exceeds levels for the Caribbean.

According to McKay (2000), throughout the western Pacific side of Panama, including the peninsula of Soná and Coiba island, the western half of the Azuero peninsula, and continuing to the east through the central part of the Country, the District of Kuna Yala and much of Darién, there is a "sub-equatorial climate with a dry season", which is considerably wetter than that of the regions around the Gulf of Panama, which have a "tropical climate with a prolonged dry season", in which precipitation during the rainy season is considerably lower.

Because of its position on the Pacific side of Panama, the Bahía Honda region keeps to this typical pattern, with a dry season lasting for at least 3 months of the year. According to Köppen's classification, the climate of this area is Am, with precipitation in the dry season of under 60 mm (2.5 inches) a month, but a high overall rainfall which means that vegetation growth is not restricted at any time (Poorter & Bongers, 1993). However, we do not have climatic data for this region. There are various meteorological stations nearby; the nearest is on the island of Coiba, 22.5 km to the south. Using the (albeit incomplete) meteorological data for the period from 1971 to 1992 taken on the island of Coiba, we can assume an average annual precipitation for Bahía Honda of around 3,500 mm (12 ft.) (Brenes *& al.*, 1993) (Fig. 6). This data is included only as a guideline and is probable slightly different in the region under study.

Similarly, we can take the average temperatures of Coiba island as a reference for the Bahía Honda area. An average yearly temperature of 26ºC was recorded between 1972 and 1981 on Coiba island with a thermal amplitude between the averages for each month of only 1.4 ºC. Average maximum temperatures varied from 30.8ºC in January to 28.6ºC in October. Average minimum temperatures ranged from 20.3ºC in January to 22.0 ºC in August and September (Brenes *& al.*, 1993). The bio-temperature calculated using the Holdridge system, was 25.1ºC (Cardiel *& al.*, 1997).

It should be noted that climate conditions can vary on a very local scale. Due to the presence of the cordillera, which delimits the Bahía Honda region to the north, clouds are concentrated in the south and moisture is unloaded in the form of precipitation on this side. This is also reflected in the vegetation, which in the island of Canales de Tierra is drier than on the adjoining mainland. Judging by the vegetation found in the uplands (at the source of Río Seco), with an increased number of Bryophyta -an indicator of wetter conditions- we may assume that the areas closest to the cordillera are much more humid and experience more rain.

Although the temperature varies very little over the year, precipitation can vary considerably from one year to the next. Apart from the normal annual fluctuations, other variations are to a great extent due to the phenomena of "El Niño" -or ENSO (El Niño-Southern Oscillation)- and "La Niña", which affects Panama very intensely every 3 to 7 years (San Martín *& al.*, 1997). These phenomena, which result in a change in the relationship between the position and strength of the sea currents and the air masses in the tropical Pacific, cause alterations in patterns of precipitation, sea temperature, upwelling, biological productivity, etc. with important overall consequences on the climate in tropical and temperate areas alike (Jackson & D'Croz, 1997). In general when there is a strong "Niño" in the Pacific, conditions in Panama are drier than normal. 1982 and 1997-1998 were years with a heavy drought associated with a strong "Niño". Similarly, when there is a strong "Niña" in the Pacific, Panama experiences greater rainfall than normal, as was the case in 1999.

Geological history

The Panama isthmus was formed by the collision and separation of five plates from the earth crust, a process that lasted 15 million years and culminated with the complete closing off of the area between 3.1 and 2.8 million years ago (Coates & Obando, 1996; Coates, 1997). This is an area of subduction (between Costa Rica and Ecuador) where the ocean crust is submerging and melting beneath the Caribbean and South American continental plates. It was as a result of these phenomena of subduction of the then Farallon Plate (which later split into the Cocos and Nazca Plates) beneath the Caribbean Plate that a primitive chain of volcanic islands was formed between the North American and the South American Plates about 40 million years ago. Fresh volcanic episodes, together with the formation of numerous sedimentation bases on either side of the volcanic arc resulted in the stretch of sea between the two continents being gradually closed, with just 2 or 3 marine corridors remaining at one point, until finally a continuous barrier was formed.

The Bahía Honda region is largely volcanic. However its exact origin has not yet been fully established, although we do know that it is very old. Recently there has been talk of "exotic terrains" in this area—in other words, oceanic volcanoes transferred from very distant latitudes and incrusted in their present location. Like part of Coiba island and areas of the mainland such as the Azuero highlands and of the Osa and Nicoya peninsulas in Costa Rica, in Bahía Honda there is evidence of these "oceanic islands", which very probably arose out of the Galapagos hotspot during the Cretaceous period and scattered across the Cocos Plate. When the Cocos moved towards the Caribbean Plate, they were brought to the area of subduction near the Panamanian coast where, instead of sinking, they adhered to it.

The Bahía Honda region formed part of the original archipelago of volcanic islands that separated North and South America, together with the aforementioned areas of the mainland, at least by the mid-Miocene (16-15 million years ago) (Coates & Obando, 1996). (Fig. 7-9)

Geomorphology and Geology

As we have already stated, one of the most prominent characteristics of the geomorphology of this area is the Lovaina-San Rafael fault, which dissects the Soná peninsula from NW to SE (Fig. 10). This fault is a continuation of the one in the Azuero peninsula, although with a smaller southward displacement, and in turn runs parallel to the two most important faults on Coiba island. In the cases of Soná and Coiba, the faults separate a raised southern area -with older terrains towards the contact point- from a northern area -with more recent terrains- (Metti & Recchi, 1976) and are the result of the collision between the eastern part of the old Central American arc and the South American plate, during the mid-Miocene, 16 million years ago (Coates & Obando, 1996) .

The only studies published to date on the geology of the area are those by Metti *& al.* (1972) and Metti & Recchi (1976). We summarise below the different geological formations in the area to the south of the Lovaina-San Rafael fault by origin and age (Fig. 10).

Most of the territory to the south of the fault is formed by volcanic rocks, basalts and diabases, from the Majé group of the Tertiary S Soná Formation (TO-MAso) (Fig. 10). This is also the type of parent rock found in the island of Canales de Tierra. Other volcanic rocks, also from the Tertiary, in the Pajarón range (to the north of Rosario), are the diabases of the Majé group of the Tribique Formation (TEO-TRI).

As for the sedimentary rocks, there is a very old (Secondary) area of sedimentation of limestones and tuffs (K-CHAo), which occupies the small peninsula to the north of Playa Limón (Punta Roble), and which belongs to the Changuinola group, Ocú Formation. Other more recent sedimentary rocks (Tertiary), formed by shales and sandstones (TEO-TO), appear in the continental territories to the west of Canales de Tierra Island as far as the area of the islet of Mona, to the north as far as the area of Pixvae and in small isolated enclaves to the south of the fault, in the area of the Común highlands. Tuffs and tuffaceous sandstones from the Macaracas group and Macaracas Formation (TO-MAC), are found on Managua island in Bahía Honda and in the east of the Soná peninsula. There is a final more recent sedimentary phase (Quaternary) (QR-Ala) in the areas of sedimentation of the large rivers, now occupied by mangrove swamps and flatlands in the area around Salmonete and Pixvae. These are alluvial deposits, consolidated sediments, sandstones, corals, mangrove swamps, conglomerates, carbonaceous shales and delta type deposits corresponding to the Aguadulce group, Las Lajas Formation (Metti & Recchi, 1976).

One very old type of metamorphic rock (Secondary) is found from the Rosario area to the fault. These are green (chloritic-Actinolitic) schists (K-LO) from the Secondary Lovaina Formation and this is the only place in Panama where they have been found. Finally, to the north of this last formation we find quartz diorites, norites and glabrous, Plutonian rocks from the Tertiary belonging to the Tabasará group and the Valle Riquito Formation (TEO-RIQ).

TOPONYMS

In order to offer a better description of the sampling sites, we have drawn up an alphabetical list of place names taken from maps of the area and/or used by the field assistants, inhabitants of the region and people who know the area well. We have included names that are not shown on the maps, but which are commonly used in the area. These are marked with an asterisk (*). We have based this list on the National Topographical Map, scale 1:50,000, sheet numbers 3839 II and 3939 II. For each toponym we give a UTM coordinate, representing a precision of one square kilometre.

TOPONYMS ON CANALES DE TIERRA ISLAND

*El Acuario (The aquarium)	17NMU 3655
*Casa JP (House JP)	17NMU 3656
*El Cedro (Beach)	17NMU 3556
*Ceiba "de la bandera" (Ceiba “with the flag”)	17NMU 3556
*El Chombo (Beach)	17NMU 3556
*Estación del tren (Train Station)	17NMU 3656
*El Guabo (Service Marina)	17NMU 3657
*Laboratorio (Lab)	17NMU 3656
*Laboratorio (Beach)	17NMU 3656
*Los Luchos (Beach)	17NMU 3656
*Naranjo Amargo (Beach)	17NMU 3655
*Parcela 1 (Plot 1)	17NMU 3657
*El Quinco (islet))	17NMU 3556

TOPONYMS IN THE BAHÍA HONDA REGION

*Cabecera de río Seco	17NMU 4663
Caoba (Beach)	17NMU 4152
Cativito	17NMU 5151
*El Edén (Forest)	17NMU 3858
*El Edén (Lab)	17NMU 3958
Jeringón	17NMU 4452
Jeringuita	17NMU 4252
*Lerencito (Beach)	17NMU 4058
Lerín (Islet)	17NMU 4057
Limón (Waterfall)	17NMU 3759
Limón (Beach)	17NMU 3658
Limón (Sangrillal or Magic Forest)	17NMU 3758
Luís (River)	17NMU 4259
Managua (Island)	17NMU 4256
Manglarito (Waterfall)	17NMU 3760
Manglarito (Beach)	17NMU 3660

*Parcela 2 (Plot 2)	17NMU 3858
*Playa Blanca	17NMU 4053
Playa de Juana	17NMU 4851
*Playa del Sol	17NMU 4158
Pixvae	17NMU 3665
Punta Gorda (Ridge)	17NMU 3562
*Salmonete	17NMU 4459
*El Suto	17NMU 4551

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Fig. 1. Map of Panama and location of the area under study: The Bahía Honda region in Veraguas Province

Fig. 2. Satellite image of Soná peninsula in 1990, obtained by composition of the bands TM3, TM4 and TM5 of Landsat

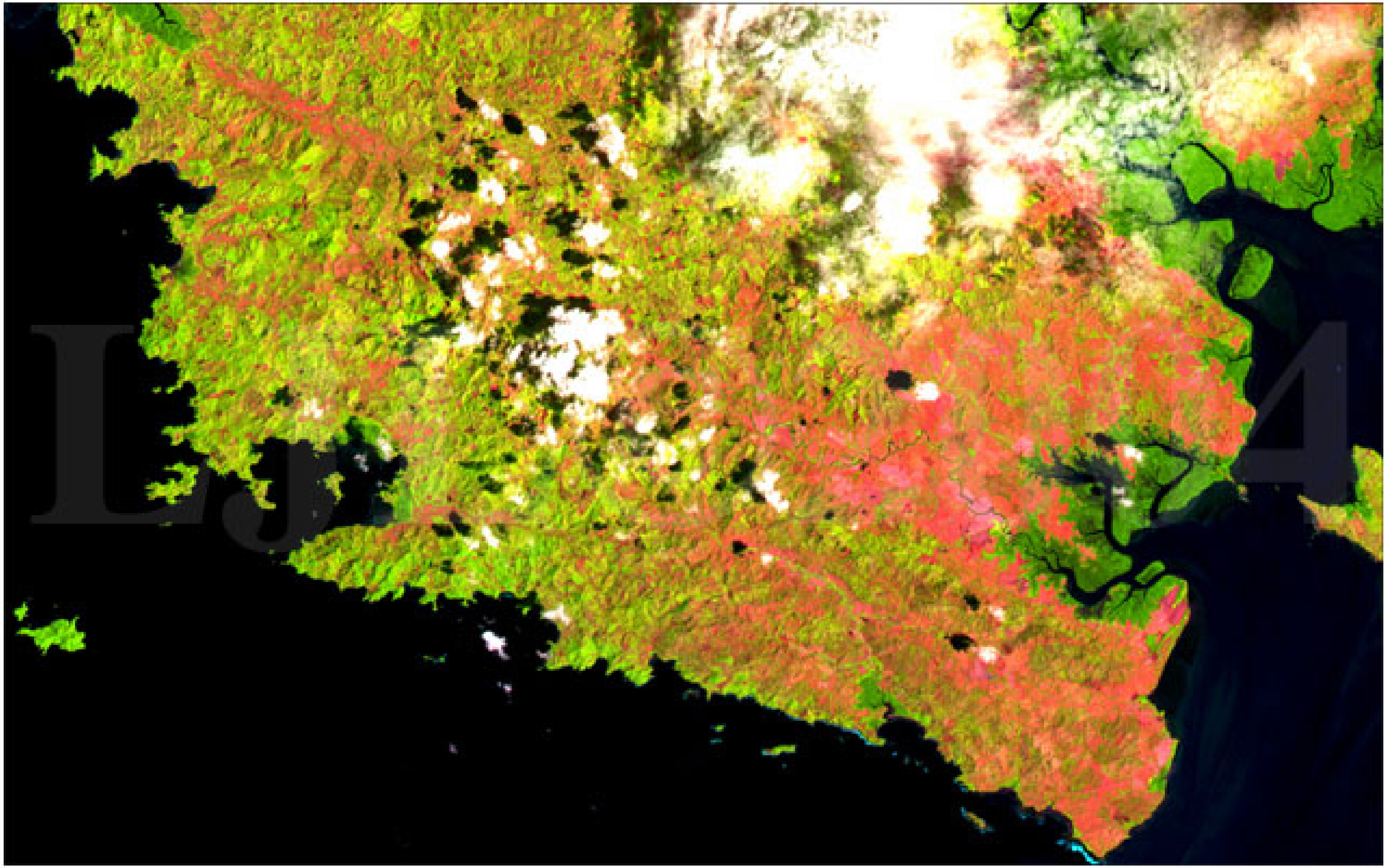

Fig. 3. Map of the Bahía Honda region and study areas

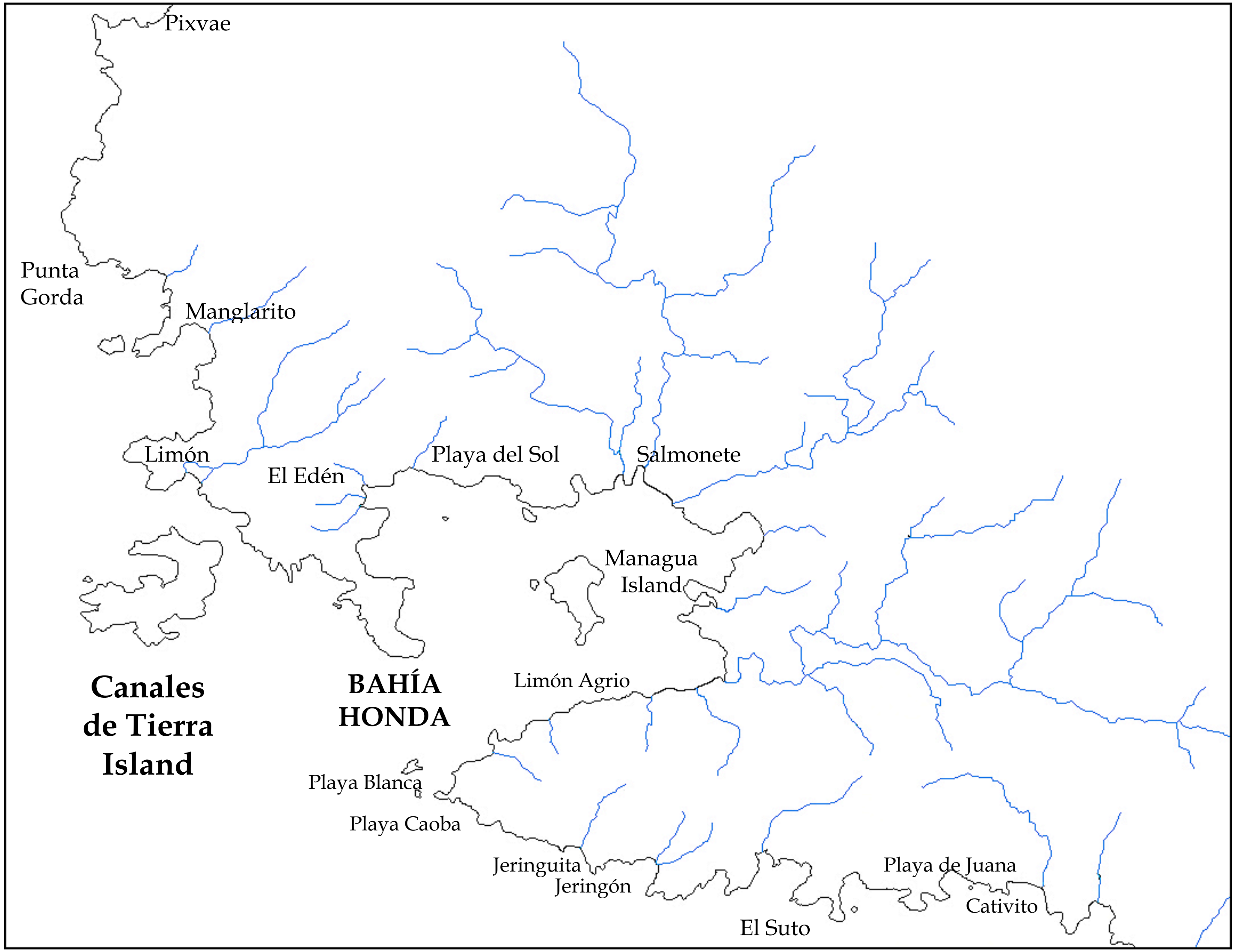

Fig. 4. Meteorological pattern that distinguishes the dry season in Central America. From about January to April the Intertropical Convergence Zone migrates to the south. The northeast trade winds then blow steadily across the Central American isthmus, bringing stable, drier, and less humid conditions (from Jackson & D'Croz, 1997)

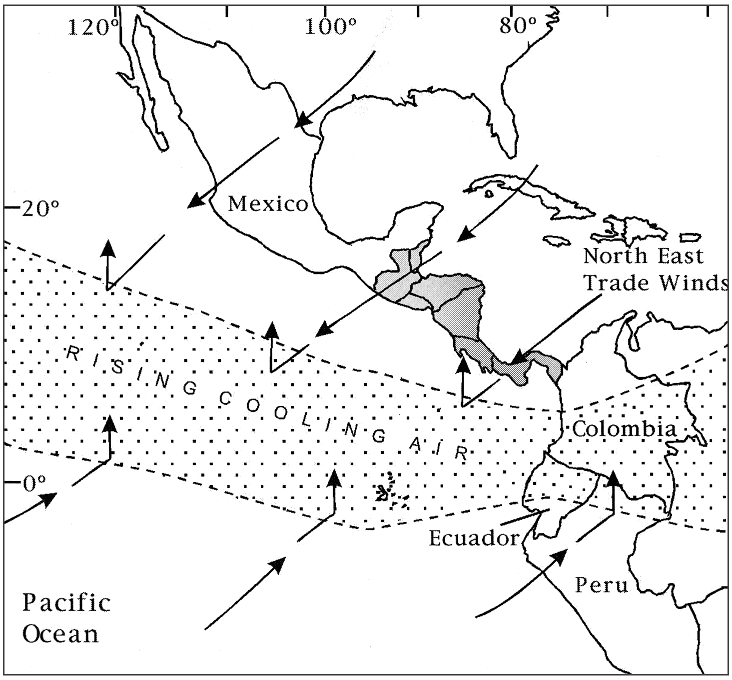

Fig. 5. Meteorological pattern that distinguishes the rainy season in Central America. From about May to December the Intertropical Convergence Zone lies over Central America as shown. In this zone, air from the northeast and southwest trade winds meet and rise. The result is the cooling of the air mass, condensation, and widespread rain (from Jackson & D'Croz, 1997)

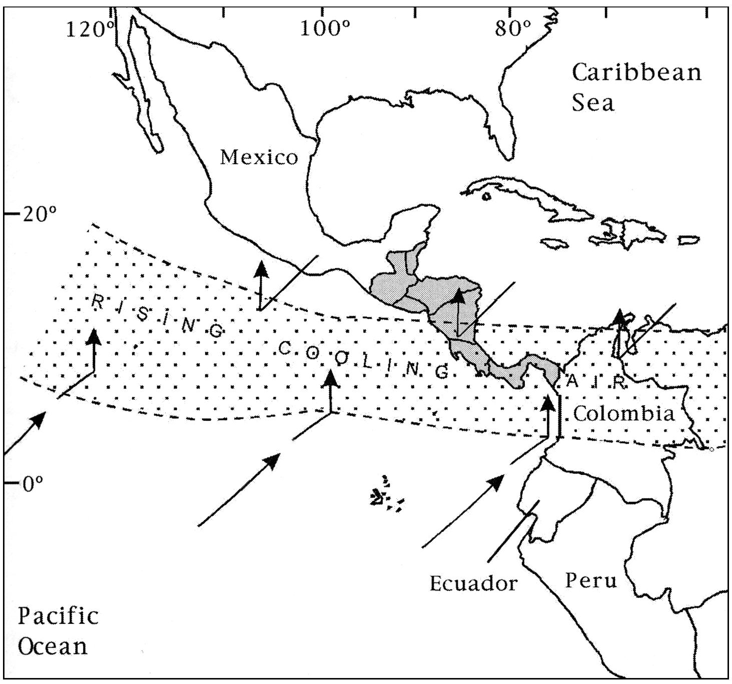

Fig. 6. Climatic diagram for Coiba Island

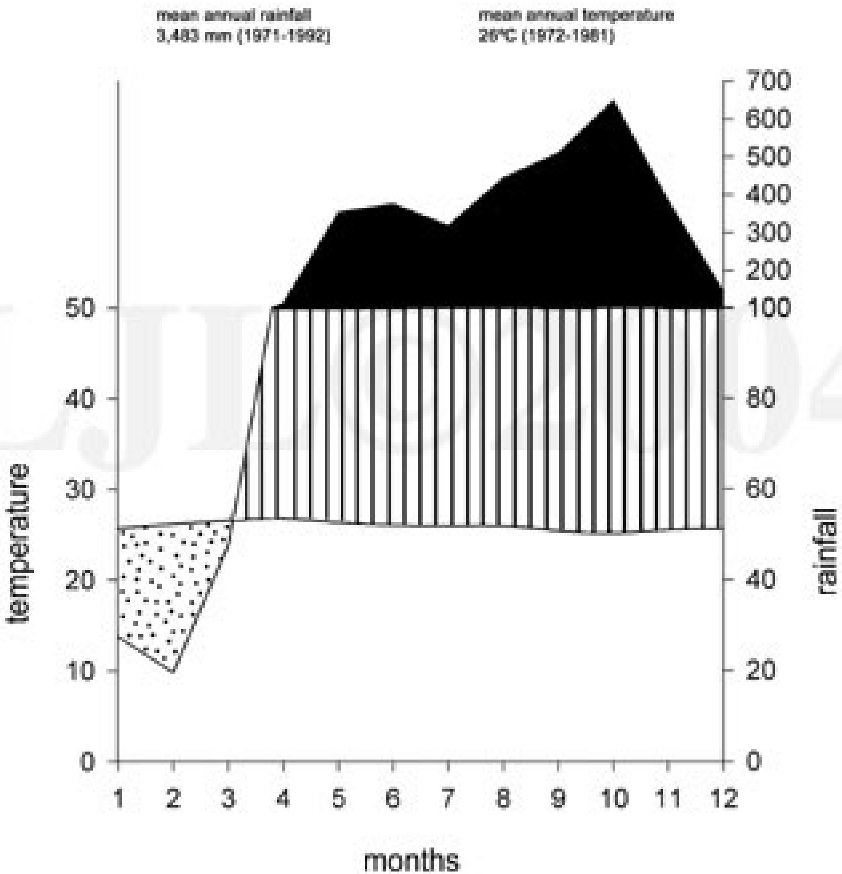

Fig. 7-9. Central American isthmus from Mid Miocene until its closure c. 3 Ma. (From Coates & Obando, 1996).
Emerged land shown in oblique lines

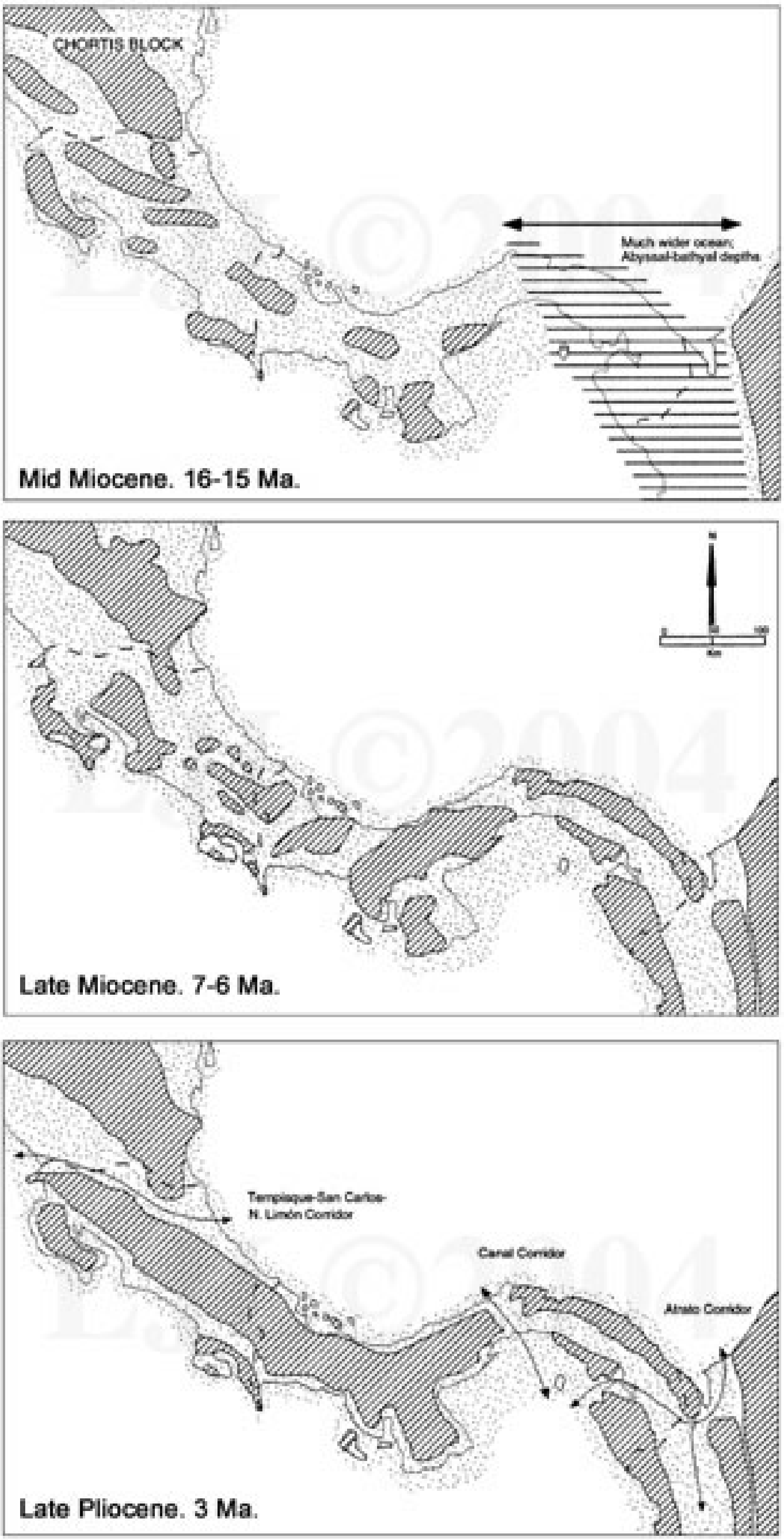

Fig. 10. Geological map of the Bahía Honda region (Metti & al., 1972)