



Sphaerodactyls endemic to South Eastern of Martinique and geological history of the Eastern Caribbean

Marcel Bourgade

► To cite this version:

Marcel Bourgade. Sphaerodactyls endemic to South Eastern of Martinique and geological history of the Eastern Caribbean: Demonstration of a 4th species *S. X sp.* presents on the peninsula of Sainte Anne, supposed center of dispersion of the common ancestor of *Sphaerodactylus microlepis*, *S. vincenti*, and *S. festus*.. Lulu Press, 2020, 978-0-244-16758-5. hal-02471523

HAL Id: hal-02471523

<https://hal.science/hal-02471523>

Submitted on 12 Feb 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Copyright

Sphaerodactyls endemic to South-Eastern of Martinique and geological history of the Eastern Caribbean

Demonstration of a 4th species *S. X* sp. presents on the peninsula of Sainte-Anne, supposed center of dispersion of the common ancestor of *Sphaerodactylus microlepis*, *S. vincenti*, and *S. festus*.



By Marcel BOURGADE

*ICEV Research Department: Caribbean Institute of Ecology and Living,
CD2S, 12 Rosalie Soleil street, 97227 SAINTE-ANNE, MARTINIQUE, CARIBBEAN.*

**Sphaerodactyls endemic to South-Eastern of Martinique and geological history of the Eastern Caribbean:
Demonstration of a 4th species *S. X* sp. presents on the peninsula of Sainte-Anne, supposed center of dispersion of the common ancestor of *Sphaerodactylus microlepis*, *S. vincenti*, and *S. festus*.**

by

Marcel BOURGADE

*ICEV Research Department: Caribbean Institute of Ecology and Living,
CD2S, 12 rue Rosalie Soleil, 97227 SAINTE-ANNE, MARTINIQUE, CARAÏBE.*

for CSRPN (Regional Scientific Council of Natural Heritage)

of Martinique after opinion of November 2013

mbourgade@hotmail.com – cd2s.caribe@gmail.com

Abstract

In 2013 during preliminary work for the ABC (Atlas of the Biodiversity Communal) of Sainte-Anne, a very particular phenotype of *Sphaerodactylus* was observed present around and on the limestone Dulls of the peninsula of the southeastern Martinique; similarly during the IBR (Rapid Biological Inventory), still in 2013 at the initiative of the city of Lamentin in partnership with Cuban scientists from BIOECO in Santiago de Cuba, a particular morphotype was spotted on the islands of the Bay of Génipa and Cohé of Lamentin. Working for the Atlas of amphibians and reptiles of Martinique initiated by the PNRM (Regional Natural Park of Martinique) for many years, Dr. Michel Breuil reported the intriguing presence of sphaerodactyls with scapular ocelli (such as sphaerodactyls north of Martinique), yet located in the South East on the Vauclin Mountain In 2013 Groba & Thorpe's work in molecular biology carried first important data allowing to identify the existence of two *Sphaerodactyl* species for Martinique going back to the date of their divergence -12 My, and without integrating the data concerning the species of sphaerodactyls present in St. Lucia. It was not until 2015 that we became aware of additional data with the published work of Hedges *et al.*, allowing to integrate in our analysis sphaerodactyls present in Saint Lucia, and generally throughout the Caribbean to establish their phylogeny. These molecular biological data from Hedges are essential to establish our initial findings regarding our sphaerodactyl phenotypic data observed in 2013 at the St. Anne Peninsula and the IBR on Genipa, Ducos and Lamentin Bay. They allow us to test our hypothesis of demonstration of a third line in Martinique of sphaerodactyls represented by our *S. X* sp. in southeastern Martinique, distinct from the two lineages that generated *S. vincenti* in the southwest, and *S. festus* in northern Martinique.

Geological history and geoscience are crucial to understanding the overall evolution of biodiversity. The herpetofauna of the islands of the Eastern

Caribbean and especially small amphibians and squamates living in ecological niches on soils requiring litter, are then among the first occupants of emerged land surfaces. And so the geological evolution - tectonic and volcanic - of Martinique and the Caribbean archipelago is determining for the process of dispersions and thus of speciations of this herpetofauna originating from the zone of the current basin of the Orinoco. With advances in genetics, research in molecular systematics makes species of this micro herpetofauna in particular indicators allowing revelation and accuracy of dating phenomena and geological events. Phylogeny of a herpetofauna, and especially of Sphaerodactyls, which proves to be indicative of a geological history of the Eastern Caribbean where Martinique stands out as exceptional and central on the scale of this Grenadian basin where it is located; playing a main role of refuge island from - 38 My, then dispersal center from - 31 My, and - 12 My for Sphaerodactyls. A proto-Martinique island refuge in this almost unique Grenadian basin (with proto-Barbados) maintained not submerged from - 25 My, which was quite naturally dispersal center, first of all towards a proto-Saint Lucia in the geological phase of re-emergence around -31 My.

The research in herpetology and especially the first results of work in molecular systematics of 2013, then of 2015 relating to this Martinique herpetofauna jostle the geosciences and force a revision of the historical scenario of the formation and the geological evolution of the Caribbean's tectonics Oriental with land masses (forming an isthmus since the Eocene, well over - 45 My), then almost all submerged to -25 My. This isthmus at the top of a cordillera, located on the southeastern edge of the so-called lithospheric film The Caribbean Plate, at the junction of the three lithospheric films, Caribbean, North America and South America, has formed a bridge between the Orinoco basin and the Bank of Puerto Rico, and the islands of the proto-Greater Antilles. The history of biological endemism in the surface of emerged lands does not begin there, therefore, only in the Miocene at "- 24 My" as it is generally admitted.

Key words : Sphaerodactylus, biodiversity, biological connectivity, herpetology, genetics, molecular biology, phylogeny, geology, tectonics, lithospheric plates or films, Eastern Caribbean, Grenadian basin, proto-Martinique, isthmus, cordillera, bridge, Orinoco basin.

Introduction

The islands constituting proto Martinique 25 - 24 My ago are not "oceanic islands" that would have "emerged from the sea". They are rather residual islands of an isthmus that has emerged for well over 40 My resulting from the tectonic movement of the so-called Caribbean plate lithospheric film surmounting those of North and South America (subduction). Martinique being in a most extreme position to the east on this Caribbean plate, with Barbados

further east, at the point of intersection of the three plates: South American, North American and Caribbean; zone of impact and therefore of collusion between these three plates. Appendix 4, show details of the tectonic context of the so-called Caribbean plate lithospheric film (resulting from a fragmentation in three of the Farallon plate, itself being fragment of the Pacific plate), such as an appendage in front of the plates Cocos and Nazca, having opened a breach during its collision with the American lithospheric film, which it fractured in two films North America and South America, precisely in a geographical position located at almost same latitude as Martinique, facing Cape Ferré of the peninsula of Sainte-Anne (South-Eastern of Martinique). (Mercier de Lépinay, 2010)

Here we evoke a complex convergence story, in subduction relative to major events in the Eastern Caribbean region that correspond to the collision of the Caribbean, against America, separating and fracturing this America in two: South America and America North. Between - 100 My and 10 My there were series of deformations before, during and after the continental accretion process, allowing us to understand how the volcanic arc has grown tectonically on the American continental margin. It is the entire geodynamic history of this region from 100 My to the present day that incorporates phenomena of displacements and movements of thrust layers, migrations of sedimentary masses allowing the progressive uplift of two first isthmus (on the East of the so-called Caribbean plate, well before that of western Panama) creating the first inter-Americas bridge. (Stephan, 1990) - (This author inspired us for our achievements of figures of Appendix 2 and 3 constituting essays of representations of details focused on the geographical positions of the Aves and the Eastern Caribbean).

Thus Tiburon and Barracuda wrinkles are submarine reliefs located in the western Atlantic Ocean, where the oceanic lithosphere of the North and South American skins is subducted under the Caribbean wrap, forming arc of the Eastern Caribbean and the prism of accretion of Barbados. The underwater reliefs of these wrinkles are important markers that bear witness to the geodynamic history of this Eastern Caribbean, including major sedimentary flows from the Cretaceous to the present day. (Pichot, 2012)

The continuous tectonic phenomenon of thrust sheet movement that occurs on lithospheric films (so-called plates) is essential to understand the formations of the small cordilleras of the Aves and the Eastern Caribbean that have emerged a time in inter-American isthmus, and which then disaggregated precisely because of this dynamic of continuous displacement of thrust sheets which is accompanied by phenomena of total erosion of these layers in the straits; then where these sheets could not maintain and agglomerate and could not overcome submarine volcanic formations (thus containing significant magmatic chambers below the lithospheric film), where precisely the islands currently exist of the Caribbean arc. Testimonies of this phenomenon of horizontal movement of thrust sheets overcoming and agglomerating on volcanic formations are visible

in Martinique and many of the present islands of the Caribbean. (Mauvois, 2015)

These so-called horizontal tectonic phenomena take place in the formation and evolution of all the cordillera, and have been described for those continental lithospheric plates of the Americas colliding with the Pacific lithosphere film, from Tierra del Fuego to those of North America, passing through those of Mexico (Stille, 1936)

Thus the island of Désirade reemerged in the late Miocene, testifies to the fact that surfaces of the Pacific were carried; Ile de la Désirade, which is likely to have emerged during much of its thrust, and found itself submerged, as well as most of the isthmus that was formed between the Greater Antilles and Trinidad, there are - 24 My with the retreat of the Caribbean tectonic plate repelled by the American plates, themselves under pressure from the African plate. This decline of the Caribbean plate generating submersion of this quasi-first eastern Caribbean isthmus also marking the beginning of the formation of the westernmost isthmus west of the Caribbean plate, that of Panama.

Isthmus of Panama whose dating of the complete closure would be much older than thought, dating from -10 My instead of - 4 to 3 My. (Sepulcher *et al.*, 2014)

The formation of this eastern Caribbean isthmus (more or less completely emerged, in any case constituting an archipelago with very small straits), there are more than 40 My allowed a first terrestrial biological connectivity, such a bridge between almost the two continents American and is the origin of an ancient endemism of the present islands of the Eastern Caribbean. Thus, there has been a dispersion of plant and animal species, without marine geographical barriers, by land from South America (Orinoco basin), but also to a much lesser extent from the islands of West Indies, to the Eastern Caribbean (Grenadian basin). (Appendix 1 and 3fig.1). This data or approach to the geological history of the Caribbean, history of islands related to the existence of volcanoes certainly, but naturally also and above all history of tectonics, sediment thrusting, makes consistent the reading of data from systematic research results; molecular and phylogenetic reptiles and amphibians, and therefore for many species of the plant kingdom.

The existence of the eastern Caribbean isthmus from -100 My to -35 My, comes to clarify data of molecular research concerning species of reptiles and amphibians of the oldest present, originally refugees on proto Martinique. The remaining islands of proto Martinique, Caravelle and Sainte-Anne, became centers of dispersal of species that survived the significant extinction of biodiversity that had dispersed from the South and North American continents to the Caribbean isthmus since well over 40 My; isthmus all the more formed during glacial periods when the sea level is estimated at -130 meters from the current level (Appendix 3, Fig. 3). (Stephan *et al.*, 1990)

The beginning of formation of the Aves and Caribbean bridges, allowing terrestrial biological connection between continents, and thus very ancient dispersion in this Caribbean geographical position of terrestrial flora and fauna species, would result from the conjunction of tectonic geological phenomena (migrations of thrust sheets), and the consequences of the impact of the asteroid occurred 66 My at Chicxulub on the tip of the Yucatan Peninsula (Gulf of Mexico). (Smith *et al.*, 1994)

This impact event of an asteroid has caused major ecological changes that have lowered sea levels. (Gradstein *et al.*, 2005)

The evolution, the dispersions and speciations of Sphaerodactyls of Martinique, which constitute essentially our study materials, are therefore intrinsic to this geological history of the Eastern Caribbean.

Our method consists in combining recent data from molecular biology concerning Sphaerodactyls endemic to the Eastern Caribbean, with those of geology and more precisely those of paleogeodynamics.

And to compare the phylogenetic tree of these Sphaerodactyls with those of other genera of the Martinique herpetofauna, whose ancestors are supposed to have found proto-Martinique before - 30 My.

Materials and methods

Morphological data and analyses

Squamata - Family of Gekkonidae - Sphaerodactylus

Ti Mabouya (martinican name of dwarf gecko) ,

<i>S. microlepis</i> , Reinhardt & Lütken, 1862	Saint-Lucia
<i>S. festus</i> , Barbour, 1915	Martinique, Dominique (1)
<i>S. vincenti</i> , Boulenger, 1891	Martinique, St. Vincent, Grenadines, St-Lucia (2)
<i>S. X sp.</i> (2013)	Martinique (peninsula of Sainte-Anne) (5) (6) (7) (8)
<i>S. Y sp.</i> Breuil, (2013)	Martinique (Mountain of Vauclin) (3) (12) (13) (14)
<i>S. molei</i> , Boettger, 1894	Trinidad
<i>S. macrolepis</i> , Günther, 1859	Puerto-Rico (islands of the Bank of Puerto-Rico)
<i>S. nicholsi</i> , Grant, 1931	Puerto-Rico
<i>S. townsendi</i> , Grant, 1931	Puerto-Rico
<i>S. gaigeae</i> , Grant, 1932	Puerto-Rico
<i>S. beattyi</i> , Grant, 1937	Saint-Croix

Ti Mabouya originating from the Orinoco basin, dwarf geckos, squamate of the genus Sphaerodactylus, have dispersed on the Caribbean and Aves isthmus formed since much more - 40 My; and the ancestors of *S. microlepis*, *S. X sp.*, *S. vincenti*, and *S. festus* survived on proto-Martinique to a certain extinction of

other Sphaerodactyls, related to the submersion of this Caribbean isthmus which ran from -40 My to -25 My, and thus lying Genetically isolated animals have diverged since that time from their close relatives both from the South, *Sphaerodactylus moléi* (Trinidad and South America), and from the North, particularly *Sphaerodactylus macrolepis*, *S. nicholsi*, *S. townsendi*, *S. gaigeae*, *S. beattyi* (island of Puerto Rico) and generally from the islands of the proto-Greater Antilles to -37.8 My (Hedges *et al.*, 2015).

First dispersions and speciations of Sphaerodactyls on proto Martinique began - 31 My, in a southerly direction, towards proto Santa Lucia generating *S. microlepis*, then towards - 29 My (Hedges *et al.*, 2015), in intra proto Martinique is dispersed from the Saint-Anne hut to South West (Ducos, Génipa) and North (Caravelle peninsula), generating *S.vincenti*; and from - 12 My (Surget-Groba & Thorpe, 2013) following the formation phase of the emerging relief mountain range having as climax the Vauclin mountain, new divergence generating the *S. festus*. And the particular Ti Mabouya (3) (named "*S. Y sp.*" for our study purposes) that we observed on the mountain of Vauclin (in southeastern Martinique) following their discovery by Dr. Michel Breuil, mark well, this genetic proximity of *S. festus* with Sphaerodactyls from the south is Martinicans considered until then as *S. vincenti*. (**Fig. K**)

The sphaerodactyls also of particular phenotypes (4) observed during the IBR (Rapid Biological Inventory) with Dr. Ansel Fong G. on the islets of Genipa Bay and Cohé du Lamentin, testify to the process of a first speciation between first sphaerodactyls from southeastern Martinique to settle in the center-west and southwest to generate *S. vincenti*. (named "*S. Z sp. (or ssp.)*" for our study purposes).

From southwestern Martinique there will be dispersion towards -1,7 My of propagules towards Saint Vincent, the Grenadines, and Saint Lucia. Later from northwest Martinique there will be dispersion of *S. festus* towards Dominica. (Surget-Groba & Thorpe, 2013).

In the north of Dominica, sphaerodactyl propagules from the Puerto Rico bank will disperse once these islands emerge.

Before - 37 My, with the formation of the Aves bridge parallel to that of the Caribbean further east, the Grenadian basin was a super lagoon, whose coastal areas were fully bio connected with the continental basin of the Orinoco North of South America. (Appendix 2)

After -37 My the Cordillera of Aves will be totally submerged, certainly leading to an extinction of species that had speculated there.

The period of geological time between -37 My and -25 My, corresponds to that where tectonic phenomena are produced, related to the counter-pressure towards the west of the American plates on the Caribbean plate. (Ron Blakey, 2012) Thus there will be collapse, erosion of the Caribbean isthmus and formation of

straits to circulate the sea, with currents coming from the Pacific Ocean; and in parallel early formation west of the Caribbean Plate of the Isthmus of Panama.(Barat, 2013)

From - 25 My to -10 My, up to - 8 My we witness, with the formation of the Isthmus of Panama, the gradual closing of the straits that until then gave access to the waters and marine currents of the Pacific. (Sacco, 2015).

This separation between water masses of the Pacific and Atlantic oceans will fundamentally modify circulation and marine currents; the Gulf Stream will be configured in the dynamics of these profound upheavals naturally impacting evolutions of fauna and flora.

Thus, from -12 My, while intensifies volcanic activity, but especially that aggregates sheets thrusting these volcanoes, which will allow emergence of other parts of the proto Martinique, such as the Vauclin Mountain, but also important emergence of proto Saint Lucia, genera will disperse from this proto Martinique refuge; but also St. Lucia (Maria Island, Gros îlet) in the first place from this period will receive new genres from the South American continent. At this time of great upheavals related to the separation of waters between the Pacific Ocean and the Atlantic Ocean, kinds of reptiles and amphibians disperse from the deltas of the Orinoco but also of the Amazon. By plant raft snakes, failed on the only islands of the Eastern Caribbean emerged at that time, namely the proto Barbados, the proto Saint Lucia and proto-Martinique (Sainte-Anne, Vauclin, Caravelle).

Thus the proto Barbados hosted a species of snake, the proto Martinique of the same, and Saint Lucia better placed compared to the new senses of marine currents from the Amazonian coast hosted a greater number of kinds of snakes including Boas and Bothrops , which in a second time from St. Lucia dispersed to proto-Martinique. (Wüster *et al.*, 2002)

Molecular data and analyses

This is done after analyzes and interpretations of the molecular biology data produced in large part by the enormous genetic work carried out by the Honorable S. Blair Hedges and his collaborators in 2015, and those published in 2013 by Yann Surget-Groba and Roger S. Thorpe, establishing phylogenies of Sphaerodactyl species from all over the Caribbean. After -65 My, commonly accepted date of the impact of an asteroid on the geographical area of Yucatan, having generated planetary extinction of a large part of the fauna of which the big dinosaurs, we noted that it emerges, two great periods as to the dating of the divergences between these species of the micro herpetofauna survivors endemic

of the Eastern Caribbean, and their relatives of the Greater Antilles and South America (Orinoco basin). A period ranging from -55 My to -30 My, and the other from -25 My to -9 My.

For our analysis of molecular biology data, 9 *Sphaerodactyl* species identified as endemic to the Caribbean, including 5 originating from the island bank of Puerto Rico (whose ancestors are presumed to have been isolated after the disappearance of the isthmus Aves and Caribbean), and another from Trinidad (since there is no recorded presence of sphaerodactyls in Grenada), and the last three presumed native to Martinique and Saint Lucia; known species that we confront biological data of the observed specimens of our presumed new species *S.X* sp. endemic of the peninsula of Sainte-Anne (South East Martinique).

The interpretation of the phylogenies of the targeted species whose respective ancestors are presumed to have found refuge on the north side on the islands of the Bank of Puerto Rico, and further south-east on the proto-Martinique after the disappearance of the Caribbean isthmus, reveals a biological connection before - 37, 8 My. (Hedges *et al.*, 2015)

Systematic accounts

Sphaerodactylus X sp. nov.

Fig. α , Fig. β (1) and Fig. 6

Ti Mabouya of Martinique (South-Eastern, Peninsula of Ste- Anne)

Holotype. It is a specimen that observed and then released that could constitute our potential holotype to collect and record at the National Museum of Natural History of Paris (MNHN); adult male, observed on july 2013 on ground of the Val d'Or (limestone dull), Sainte-Anne, Martinique (Fig. α , Fig. β (1) and Fig. 6), 38 m (14°26'10.14"N 60°52'33.92"W), by Marcel Bourgade. Field tag number 03.

Paratypes. Specimens observed in 2013: *Sphaerodactylus X* sp. (22 specimens) from same locality ; from territory of Sainte-Anne municipality. *S. X* sp. is present on the Caribbean coast of the peninsula of Sainte-Anne. It is generally distributed over the oldest geological formation of Martinique known as Fond Mosquito (Limestone Dulls): Caritan, Bellevue, dull of North América and dull of South América, Val d'Or, Marguerite limestone dull, and Belfond dull, presumed cradle (since well over 24 My) of all the Ti Mabouya, geckos

dwarves, of the sub-eco-region of the Caribbean Eastern, from the Grenadines to Dominica. (see figure J (bis) location on aerial photo extracted from Google Earth below).

Diagnosis. The snouts of sphaerodactyls *S. X* sp. (Ste. Anne), and from *S. v. adamas* ssp. (Schwartz, 1964, on the Diamond Rock), and *S. v. psammius* (Schwartz, 1964, southeastern Martinique) are shorter and more rounded at the tip than the snouts of *Sphaerodactylus festus* (northern Martinique); but still slightly shorter than the muzzles of the *Sphaerodactylus vincenti* (south-west Martinique) (**Figure α & Figures A and B**) and this morphological criterion of the length and shape of the snout approximates the sphaerodactyls of the south-east Martinique of *Sphaerodactylus microlepis* in Saint Lucia (**Figures C and D**). This data is evoked and highlighted since 1885, in the work of descriptions of sphaerodactyls made by Boulenger and therefore visible on his very detailed sketches. We have also been able to make both phenotypic and morphological comparisons between *S. X* sp. and *S. microlepis* on the basis of data and photographs published by St. Lucia's National forest and bio-physical resource inventory project. (Daltry, 2009)

Description. Mean size adult *Sphaerodactylus* (SVL 32 mm) with morphotype related to the *S. vincenti* line (Boulenger, 1891); phenotype very close to *Sphaerodactylus microlepis* (Reinhardt & Lutken, 1862) [present in Saint Lucia; Smooth dorsal and ventral scales, a number of ventral scales from underarms to groin (26-32); dorsal, gular and pectoral scales carinated.

The “Ti Mabouya”, Martinican name of the dwarf geckos present in extreme south-east of Martinique, on the Caribbean coast of the peninsula of Sainte Anne (Figures in appendices 5, 6, 7, 8) geological formation the oldest emerged of Martinique known as Mosquitoes, are distinguished from *S. vincenti* sphaerodactyl recognized until now as the only species being present on the whole south of Martinique, by their particular dorsal patterns for the south of Martinique, with the presence or persistence in adults of dark brown ocelli often fused into a crossbar above the scapular girdle; these ocelli have crescent-shaped spots, or more or less variable oval forms, sometimes two oval spots light brown to yellow, more or less surrounded by dark brown; a size where females reach 32 mm body length (SVL: muzzle end to cleft palate) for a maximum total length of 62 mm; a number of ventral scales from armpit to groin (26-32) and dorsal scales from armpit to groin (29-40); scales dorsal,

gular and pectoral carinated, while the ventral are weakly smooth, rounded posterior edge; the throat and chin, which have a very generally gray-white pattern, sometimes immaculate with pale yellow spots on the throat; individuals with white-gray chins, and pale yellow throats, and even chins and throats entirely pale yellow, with in some of them on the flanks of the neck drawings of vague, oblique, dark brown bands. All juveniles observed have a throat and white-gray chin. A reticulated head, mottled with dark brown on a sometimes yellow background, sometimes bluish gray or a yellow brown head, slightly speckled with brownish beige spots; with for individuals (rather adults ♀) a clear outline of a Y in gray. A number of supra labial scales up to the center of the eye of 3-4.

A light brown trunk striped or striped with 6 to 7 dark brown transverse bands, and these bands persistent in some, and for others on their flanks fading to give brown spots on the back and the ribs; this blurring of the bands giving multiform tasks or drawings on adult patterns. The dominant dorsal coloration observed on these living *Ti mabouyas* is brown, more or less dark. The dorsal drawings are formed on the axes of the transverse bands in dark brown, gray, beige more or less wide and more or less parallel down on the flanks, or forming small ocelli adorned with white in the center. Adult individuals with less faded patterns (holding scapular ocelli and stripes or rays on their backs) usually retain their gray-white throats and chins.

On the dorsal at the base of the caudal fin, most individuals have a Y- or V-shaped mark, light brown surrounded by dark brown, whose base, more or less short or absent, is turned towards the tail. Dorsal staining of the tail of *S. X* sp. is like that of the back and flanks with transverse lines more or less marked (yellow orange in juveniles). No obvious sexual dichromatism.

Important notes on criterion of the numbers of inter-nasal scales

Procedure for counting inter-nasal scales : it is a question of counting the scales on the upper jaw at the end of the muzzle of the different specimens of *sphaerodactyls* (scales called first row); then count those in the second row between the two nostrils.

S. X sp. is resolutely distinguished from *S. vincenti* by the number of scales called inter-nasal. Indeed, there is a ratio of **1 - 5** for the inter-nasal scales of *S. X* sp., while for *S. vincenti* as the *S. festus* there is a ratio of **1 - 3** in number

of inter-nasal scales. This characteristic fact and criterion brings *S. X* sp. undoubtedly *S. microlepis*. (**Figures β (1,2,3,4) & C and D**)

Fig. β (1): On this close-up of the head of the holotype of *S. X* sp. we can count the number of inter-nasal scales which is one (1) for the first row in muzzle end, and 5 for the second row between the two nostrils. Let a result of 1-5.

Fig. β (2): On this close-up of the head of one of the specimen for paratype (see Fig. 5 below) of *S. X* sp. we can count the number of inter-nasal scales which is one (1) for the first row in muzzle end, and 5 for the second row between the two nostrils. Or also a result of 1-5.

Fig. β (3): On this close-up of the head of the holotype of *S. Y* sp. (see Fig. 3 below) we can count the number of inter-nasal scales which is one(1) for the first row in muzzle end, and 5 for the second row between the two nostrils. Let a result of 1-5.

Fig. β (4): On this close-up of the head of a spécimen of *S. festus* from locality of Caravelle (see Fig. 1 and J below) we can count the number of inter-nasal scales which is one (1) for the first row in muzzle end, and 3 for the second row between the two nostrils. Let a result of 1-3. Same result of 1-3 as for sphaerodactyls identified as *S. vincenti*. (Barbour, 1921)

Comments. All these dorsal staining characteristics are found in both *Sphaerodactylus X* sp. ♂ and *Sphaerodactylus X* sp. ♀ make the patterns of these Ti Mabouya of Sainte-Anne very particular because of their varieties in the same niche; distinguished among all subspecies of sphaerodactyls in southern Martinique, and more widely in all of Martinique and the Ecoregion of Dominica to the Grenadines. (**Figs, G and H**)

This "phenotypic variety", or variety of types of Ti Mabouya *S. X* sp. adults ♂ and ♀, both ocellated on scapular girdle (fused or not) and "without ocelli" (asquebecomes), zebra or striped with or without transverse bands well marked on the back ... from the Caribbean coast of the Peninsula Sainte-Anne (singularly "Dull Limestone" and Belfond dull), could well translate and reveal a genetic diversity that is found not only within the same population of a dull, within a line of the same station, but also between these lines and populations of different mountains. (**Fig. I**)

Ti Mabouya *S. X* sp. remained in their cradle of the peninsula of Sainte-Anne since more than 24 My, on dreary, whose so-called "dull limestone", were not totally isolated geographically during their evolution; and have therefore known

contacts with dispersed populations from the Vauclin in a dynamic of parapatric speciation, and once established proto southeast of Martinique land contact between the island of Sainte- Anne and Vauclin between - 8 to - 4My with glacial periods involving the retreat of the sea, and therefore islands with larger surface areas than today (coastal linear corresponding to the 100 m probe line on current chart). Then much later, according to an important indication of Professor Allard Saint Albin (2015) which tells us that "with the recent geological history of the peninsula of Sainte-Anne which has been partially covered (during the last interglacial?) by a marine transgression. Given the probable level of water compared to the current of the order of more than 10 m, the region was to be dotted with many islets among which are the volcanic massifs of the region and the various limestone massifs. This landscape of rias was probably at the origin of geographical isolations of sub-populations of Ti Mabouyas. "; *S. X* sp. have thus "recently" experienced a phase of allopatric speciation to increase their reproductive isolation on the Limestone Dulls of Sainte-Anne (South and North America, Caritan, Bellevue, Val d'Or ...), and the Dull of Belfond in particular (west coast or Caribbean of the peninsula of Sainte-Anne) and then, after a retreat of the marine transgression, find themselves to this day more or less in contact with the adjacent niche (east and north coast of the peninsula of Ste-Anne) Ti Mabouya called *psammius*. These sayings *S. v. psammius* ssp. identified and described by Schwartz since 1964-1965 in south-eastern of Martinique, would be, according to our interpretation, the result of hybridizations generated by successive contacts and crossings between descendants of Ti Mabouyas lineages from the south-west peninsula of Martinique (Trois-Ilets, Diamant, Anses d'Arlet) dispersed to the southeast, Vauclin and Peninsula of Ste-Anne.

***Sphaerodactylus Y* sp.**

Figs. 3, 12 and . β (3)

Ti Mabouya of Martinique (Mountain of Vauclin)

Holotype. . It is a specimen that observed and then released that could constitute our potential holotype to collect and record at the National Museum of Natural History of Paris (MNHN); adult male, observed on september 2013 and august 2014 on ground of Fond Zami, locality on south east flank of the Vauclin

mountain, Vauclin, Martinique (Fig. 3, fig. . **β** (3)), 67 m (14°32'59.07"N 60°52'27.39"W), by Marcel Bourgade. Field tag number 02.

Paratypes. Specimens observed in 2013 and 2014 : *Sphaerodactylus Y* sp. (09) specimens) from same locality station, from Vauclin, Martinique, 67 m (14°32'59.07"N 60°52'27.39"W), by Marcel Bourgade. (Figs. 12, 13, 14)

Diagnosis. The snouts of spherodactyls *S. Y* sp. (Vauclin Mountain), like our *S. X* sp., the *S. v. adamas* ssp. (Schwartz, 1964, on the Diamond Rock), and *S. v. psammius* (Schwartz, 1964, southeastern Martinique) are shorter and more rounded at the tip than the snouts of *Sphaerodactylus festus* (northern Martinique) and the snouts of *S. vincenti* from the southwestern Martinique, and this morphological criterion of the length and shape of the snout approximates the others spherodactyls of south-east Martinique, although having a typical pattern coloring like *S. festus* on the north of Martinique. See **Figures β (1,2,3,4)**.

Description. We reserve here a true description of *S. Y* sp. ; it may be the subject of another publication relating solely to this presumed new species for science.

Comments. we observed that the throat and the chin are gray-white for a number of specimens of *S. X* sp. (Sainte-Anne), as for *S. adamas* (Diamond Rock), and *S. microlepis* (Saint Lucia); not observed for all *Sphaerodactyl* specimens reported by Dr. Michel Breuil, observed on the Vauclin Mountain (south-east of Martinique) *S. Y* sp. showing all throat and yellow chin with well-marked ocelli on shoulders clearly having coloring type like *S. festus* but listed today as *S. vincenti*. (**Fig. E**)

We have also compared these particular spherodactyls of the Mountain of Vauclin (which we named for need of our study *S. Y* sp.) with spherodactyls observed on a station of Petit Macabou still in Vauclin with about fifteen kilometers of the mountain, on the shoreline, and have noted that many adults have light ocelli in their scapular belts and correspond to the description made by Schwartz in 1965 for *S. vincenti psammius* (mostly present in the south-east of Martinique) with so-called vermiculoid patterns. (**Fig. F**)

With the *S. Y* sp. if we admit, as the extreme south-east of Martinique, the space between the Mountain of Vauclin and the peninsula of Ste-Anne, we can observe that all the phenotypes of *Sphaerodactylus* from Dominica to the Grenadines (types *S. microlepis*, *S. festus*, *S. vincenti*) are represented; according

to both staining characteristics and morphological criteria (number of inter-nasal scales with all existing combinations, ...).

This suggests that this region of South-East Martinique would be the cradle or center of dispersion, correlations and comparison that we dare from the results of geneticist work on African human population and migration. (Tishkoff *et al.*, 2010, 2012).

***Sphaerodactylus Z* sp. (or ssp.)**

Fig. 4

Ti Mabouya of Martinique (Islands of the Bay of Lamentin -Génipa)

Holotype. It is a specimen that collected during the IBR and record at the Museum of Santiago de Cuba, adult male, observed on june 2013 and august 2014 on ground of small island Ilet Cabrit, Lamentin, Martinique (Fig. 4), 11 m (14°36'12"N 61°01'09"W), by Dr. Ansel Fong G. and Marcel Bourgade.

Paratypes. Observed in june 2013 : *Sphaerodactylus Z* sp.(or ssp.) (05 specimens). Specimens of *S. Z* sp. (or ssp.) were observed on Gros Ilet in Genipa Bay on the territory of the municipality of Trois-Ilets, and also on the Doré and Cabrit islets in the middle of mangrove on the Lamentin territory, by Dr. Ansel Fong G. and Marcel Bourgade.

Diagnosis and description. We reserve here a true diagnosis and description for *S. Z* sp. ; it may be the subject of another publication relating solely to this presumed new species for science.

Comments. Specimens of *S. Z* sp. (or ssp.) have been inventoried for the first time on these islets from Martinique ; and present a phenotype different from *Sphaerodactylus vincenti* yet in geographical proximity on the peninsula southwest of Martinique such as those of Vatable (see Fig. 2 below) on the territory of The Trois-Ilets. The islands of Lamentin Bay, not considered as such, and not investigated and inventoried for example by Robert W. Henderson and Michel Breuil ; not in publication of Powell and Henderson, 2012.

Table : Comparative Table of Spherodactyls of Southern Martinique and Saint Lucia:

S. vincenti psammius (southeastern Martinique), *S. v. adamas* (Diamond Rock)

S. X sp. (Peninsula of St. Anne), *S. Y sp.* (Vauclin Mountain), *S. microlepis* (Saint Lucia)

	<i>S. X sp.</i>	<i>S. v. adamas</i> 1	<i>S. v. psammius</i> 1	<i>S. Y sp.</i>	<i>S. microlepis</i> 1
Maximum SVL for adults					
Male ♂	33	28	28	30,5	34
Female ♀	32	27	27	30	31
Supra labials scales	3-4	2-4	2-3	3-4	3-4
Dorsal scales 2	29-40	29-39	33-47	-	29-39
Ventral scales 2	26-32	26-32	28-33	-	26-32
Transverse bands	YES (3-4) Youngs and adults	YES (3-4) Youngs and +/- adults	NO	yes (3-4) Youngs and +/- adults	YES (3-4) Youngs and adults
Back pattern coloring	brown	brown	gray yellow	brown gray yellow	brown
Throat and chin coloring	Gray- white or pale yellow	Gray- white	yellow	yellow	Gray- white or pale yellow
Inter nasal scales	1-5	-	1-3	1-5	1-5
Ocelli on scapular belt	Yes for youngs and sometimes for adults	Yes for youngs	no	YES merged and or separated on the nape	YES Merged often on the nape
Head pattern coloring	Brown/ gray/ yellow marbled	Brown/ gray/ yellow marbled	Yellow	Brown/ yellow orange marbled	Brown/ gray/ yellow marbled

1 . Data completed by biometric work and descriptions of Boulenger (1885) and Schwartz (1965)

2. Number of ventral and dorsal scales counted from armpit to groin.

Data based on :

N = 22 specimens observed by the author of presumed *S. X sp.*

(Sainte-Anne – western coast 2013-2014)

N = 10 specimens observed by the author of *S. Y sp.*

(Fond Zamy, southeast flank of the Vauclin mountain - August 2014)

N = 16 specimens observed by the author identified as *S. v. psammius*

(on Peninsula of Sainte-Anne, territories of the municipalities of Marin, Vauclin and Sainte-Anne, 2013 -2014)

(Table elaborate in 2014 by M. BOURGADE)

Discussion

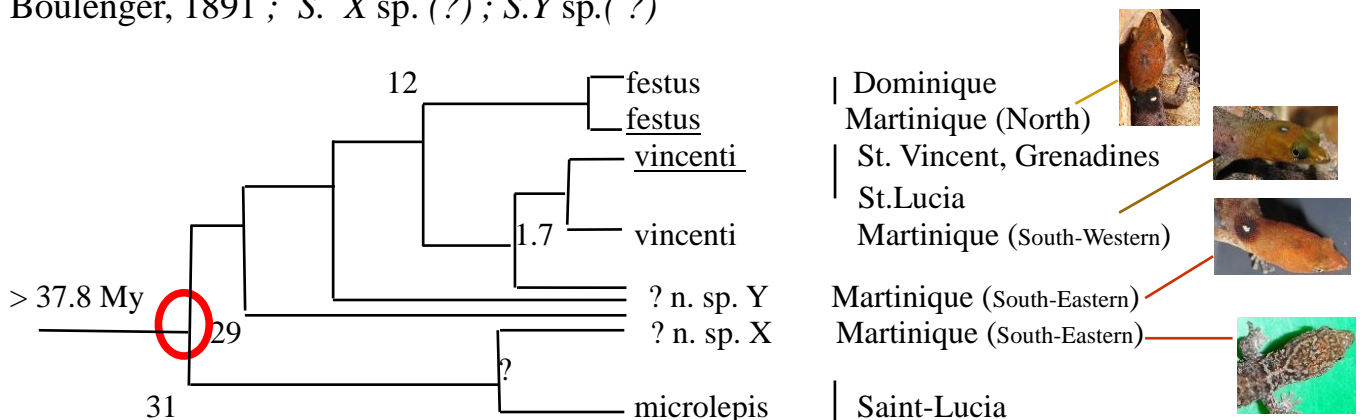
Molecular evidence for species differences


We reconstructed the phylogenetic tree of *Sphaerodactyls* of the Eastern Caribbean taking into account *S. X* sp., based on molecular data from Groba & Thorpe's work, published in 2013 (having collected biological samples of *S. X* sp.); and those more global and specifying molecular clock of Hedges et al. published in 2015, including collections of *S. microlepis* (in Saint Lucia), *S. festus* (north of Martinique and Dominica), and *S. vincenti* (including collection of *S. X* sp.). A phylogenetic tree constructed by looking for an indication (red circle) of the geographical position from which the ancestor common to all *Sphaerodactyls* of the Eastern Caribbean was dispersed; and this by combining geological history data from 45 My to the present day.

Ti Mabouya, Dwarf gecko, *Sphaerodactylus*

Small reptiles present in the Grenadian basin, endemic to the Eastern Caribbean (from Dominica to the Grenadines).

S. microlepis, Reinhardt & Lütken, 1862 ; *S. festus*, Barbour, 1915 ; *S. vincenti*, Boulenger, 1891 ; *S. X* sp. (?) ; *S. Y* sp. (?)



 **Proto South East Martinique (-45 to -35 My): refuge then dispersal center**

The divergence between *S. vincenti* and *S. festus* is attested as of -12 My and demonstrated by the work of Groba & Thorpe, 2013; but this divergence, which seems clearer, would have begun not with speciation on the Caravelle, but with the geological formation of the Vauclin mountain in the south-east; evidenced by the spoofer of morphotype close to *S. festus* reported by Dr. Breuil on this mountain of Vauclin. The speciation that generated the *S. festus* was well made from *sphaerodactyls* from southeastern Martinique, as we presume that generated *S. vincenti* still from southeastern *Sphaerodactyls*, which dispersed to the southwest of Martinique. According to the almost same pattern of dispersion as

the Anoles pug, which suggests the presence of land and refuge in place and current position of Genipa Ducos, pre-existing to the geological formation of the dull Pavillon and other reliefs of the southern peninsula. Where is. (Thorpe & Stenson, 2003 and Thorpe *et al.*, 2002, 2010)

An index of this dispersal and this step for the speciation that generated *S. vincenti* could be revealed by *Sphaerodactyls* that are isolated on the Islets of Gé nipa Bay and Cohé du Lamentin not counted before 2013 and not yet studied. The *Sphaerodactyls* found on the Diamond Rock have a morphotype very close to *S. X* sp. of the Sainte-Anne Peninsula (extreme south-east).

S. X sp. from south-east Martinique would be the representatives of the lineage remaining in the cradle, and the *S. vincenti* the lineage which has dispersed towards the south-west of Martinique, without any real and clear geographical barrier separating them; but the beginning of this subtle divergence between *Sphaerodactyls* of the south-east and south-west would be older than that which generated the *S. festus*, and would date from the divergence that generated *S. microlepis* between -31 to -25 My.

S. X sp. is then present in the cradle and geological refuge of the peninsula of Sainte-Anne having sheltered the ancestors of *Sphaerodactylus* sp. and *Anolis* sp. endemic to the eastern Caribbean (south of Dominica); The present *S. X* sp. in Martinique corresponds to the remark and deduction of Barbour presuming the fact not verified by himself of the presence of "*S. microlepis*" in Martinique. (Barbour, 1921) ; also the highlighting of *S. X* sp. corresponds to King's suggestion, indicating Martinique and Saint Lucia as habitat for *S. microlepis*; thinking at the time that sphaerodactyls present and identified first in Saint Vincent originated from this island. (King, 1962)

The *S. microlepis* in Saint Lucia for sphaerodactyls would be homologous in first speciation of species originating from the proto Martinique, in the *Anolis*, *A. luciae* in Saint -Lucia having diverged since - 25,37 My. (Hedges *et al.* 2015)

It is not excluded in our opinion, to explain this presence of *S. X* sp. , differing from *S. vincenti* on the peninsula of Sainte-Anne, a very old return of propagules from the islands of proto-Saint Lucia (Maria and Gros Ilet); a subspecies of *S. microlepis* (9) has been identified *S. m. thomasi* (10) (on ilet Maria). (Schwartz, 1965)

COMPARISON WITH PHYLOGENIC TREES OF OTHER GENRES OF HERPETOFAUNE EVOKS IN OUR ANALYSIS:

Identically, we have reconstructed the phylogenetic trees of *Anolis* (*Dactyloa*) of the Eastern Caribbean based on molecular data from the work of Thorpe *et al.*, Published in 2010, and the work of Hedges, 2015.

And for the Stenostomes (*Tetracheilostoma*) present in Martinique, Saint Lucia and Barbados, based on recent work and molecular data, from Hedges *et al.*,

2014 and 2015. Phylogenetic trees constructed for these two genera still seeking indication (red circle) of the geographical position from which the common ancestors of these two endemic genera of the Eastern Caribbean were dispersed; and this always by combining geological history data from 45 My to the present day.

We have therefore developed and reconstructed our phylogenetic trees targeted to species present or having been present in Martinique, based on the literature and scientific publications referred to below.

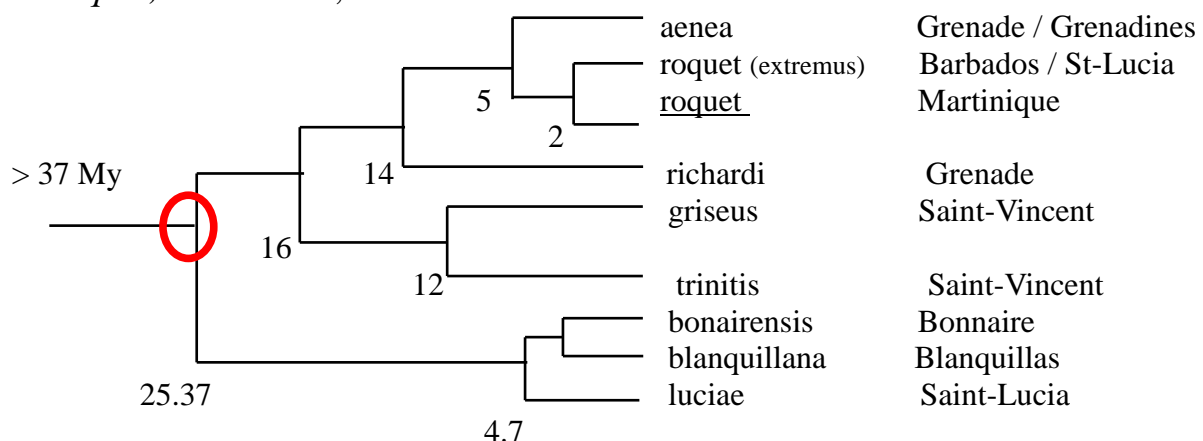
General work on all Caribbean reptiles and amphibians, Barbour 1920s, Schwartz 1960s, Powell *et al.* from the 1980s, from Hedges *et al.* from the 1990s to today, from Breuil (2000s), as well as those of Thorpe *et al.* (2000s).

Biological work of Powell *et al.*, 1986 for the *Anolis*. Work of Kaiser *et al.*, 1993, and of Hedges *et al.*, 2007, for the frogs.

Zanndoli (martinican name), *Anolis* (*Dactyloa*)

Small endemic lizards of the Eastern Caribbean

A. roquet, Bonnaterre, 1789



○ Proto South East Martinique (-45 to -35 My): refuge then dispersal center

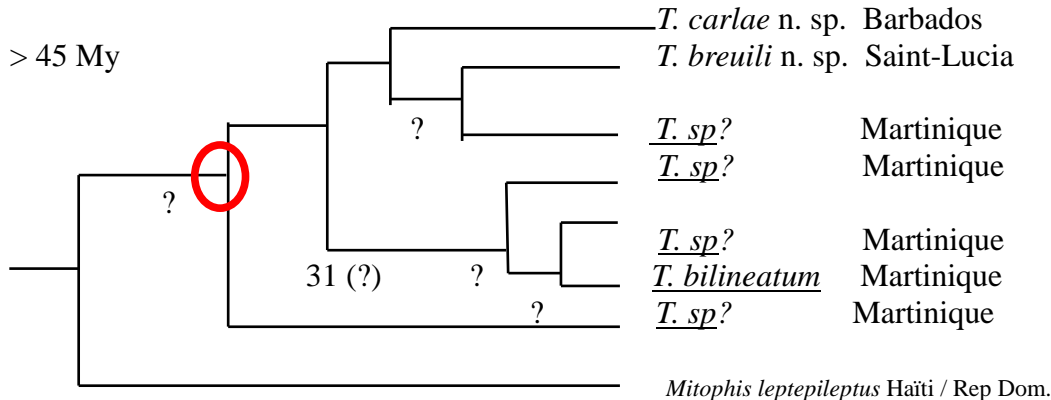
Hedges' molecular clock data from 2015 allows for an upward revision of the timing of puffing Anole dispersal episodes reported by Thorpe *et al.* in 2010. These episodes remain the same but would have taken place earlier, at least for the first two.

The puffy *Anolis* dispersal schematics from the publication of Thorpe *et al.*, 2010 demonstrate that the Ducos area, Génipa, is clearly identified as a very old refuge during a first stage of dispersal of precursors between the south-east and southwest of Martinique; also valid for the first dispersions of sphaerodactyls from southeastern Martinique, from Sainte-Anne to Ducos, but also from Sainte-Anne to proto Saint Lucia. This remark is valid for study of *S.v. Z ssp.* observed in 2013 on islets in Genipa Bay during work for the IBR (Rapid Biological Inventory), at the initiative of the city of Lamentin.

Ti Sèpan Tè (martinican name), Blind snake Typhlops, *Tetracheilostoma*

Small stenostome snakes endemic to the Eastern Caribbean

T. bilineatum, (Schlegel, 1839), *T. sp* > 3 (?)



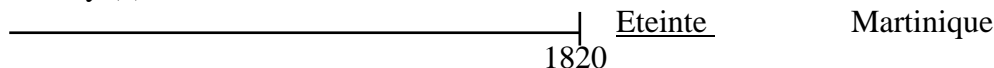
Proto South East Martinique (-45 to -35 My): refuge then dispersal center

Skink of Martinique

Small skink formerly strictly endemic of Martinique, extinguished species.

Capitellum metallicum, Plée 1820

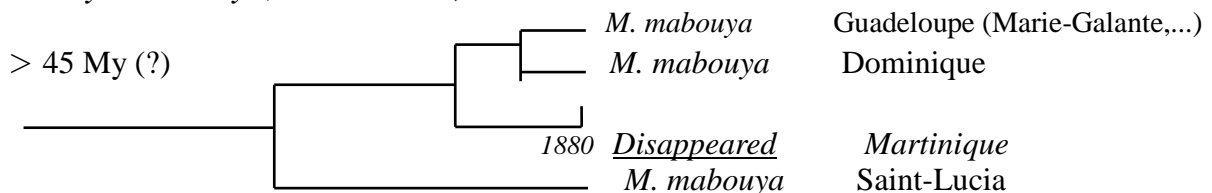
> 45 My (?)



Great Skink of Martinique

Of the genus Scincidae, an endemic species that has disappeared in Martinique.

Mabuya mabouya, Bonnaterre, 1789



Léza (martinican name), Holotropis of the Herminier

Only representative of the genus *Leiocephalus*, from the Eastern Caribbean, and strictly endemic formerly to Martinique, which would have diverged from other American genera, since probably more than 100 My (Hedges *et al.*, 2015)

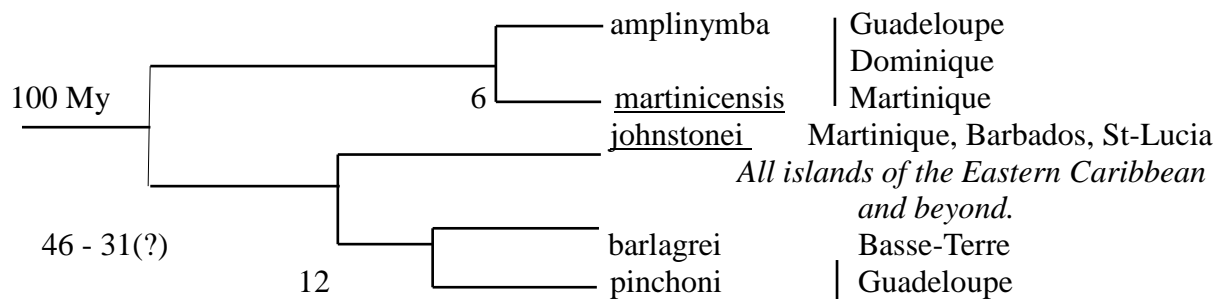
Leiocephalus herminieri, Duméril & Bibron (1837 Bois Lézard Gros-Morne)



Ti Gounouy (martinican name), hylodes, Euletherodactylus

Small amphibians in the Grenadian basin, endemic to the Eastern Caribbean since - 100 My (Hedges *et al.*, 2008)

E. johnstonei Barbour, 1914 , *E. martinicensis* (Tschudi, 1838)



These molecular biology data from Hedges *et al.* published since 2008 and then even more recent ones of 2015, demonstrating very close genetic proximity between *E. martinicensis* and *E. johnstonei*, definitively invalidate the hypotheses of Michel Breuil "declaring" wrongly in 2002 in a publication the hylode *E. johnstonei* as a species "introduced in the Lesser Antilles" and even "Invasive" (Breuil, 2002), even though this author acknowledges an origin that would be Barbadian species compared to other Caribbean islands, while suggesting that it would have been introduced there as well, and that it would come from undeniable natural environment of speciation: the Eastern Caribbean.

The past existence in Martinique of Mabouya, Skink of *Martinique Capitellum metallicum*, Plane 1820 (extinguished species), Gran Mabouya, Great Skink of Martinique *Mabuya mabouya*, Bonnaterre, 1789, (disappeared from Martinique) and Lizard, Holotropide of the Herminier, genus *Leiocephalus*, *Leiocephalus herminieri*, Duméril & Bibron (1837), genetically isolated species of their American congeners who died in Martinique whose genera did not have equivalents in Saint Lucia, confirm this certainty of a proto Saint Lucia not emerged before -20 My > -12 My.

Ti Sèpan-tè (martinican name), stenostome of the genus *Tetracheilostoma* before generating several species in the Eastern Caribbean, particularly in Martinique (3 to 4), then (?) Barbados (1) and Saint Lucia (1), a diverged about - 45 to -35 My from its closest relative, of the genus *Mitophis* (endemic to the large island of Hispaniola - Haiti / Rep. Dom.). (Hedges, 2009, Hedges *et al.*, & Vidal, 2014).

The Zannoli (martinican name), the Anolis of Martinique (*Dactyloa* or *A. roquet*) diverged from its closest relatives in South America some 37 My ago and after dispersion it generated a species of anole of Sainte-Anne. Lucie (*A. luciae*), but also the Anolis of the Grenadines (*A. richardi*), ... there are 12 Ma (Hedges *et al.*, 2015), before founding in Martinique several lines of which one which dispersed towards the Barbados there are 4 My (Thorpe *et al.*, 2010).

The hylode *E. johnstonei*, and the *Anolis* of Martinique are the two species of herpetofauna endemic to the Eastern Caribbean that have spread at great distances from their dispersal center. Until Jamaica for *E. Johnstonei*, and to the island of Bonaire on the coast of Venezuela for *Anolis* native of Martinique. Note that the known record in distance traversed propagules embedded on rafts of plants, is that of a Gekkonidae, ancestor of *Hemidactylus greeffi* who crossed the Atlantic Ocean from the island of Gulf of Guinea, to fail on the coast from the Brazilian Nordeste to *H. brasiliensis* (Carranza and Arnold, 2005).

If one adds to this inventory of herpetofauna species strictly endemic to the Proto Martinique, the data of the rare or even unique presence for the Eastern Caribbean of an endemic species of terrestrial mammal (non-flying), the Pillory Rat or Muskrat of Martinique *Megalomys desmarestii* (J. Fischer, 1829), who suffered greatly from the introduction of the rat (*Rattus rattus*) and the small Indian mongoose (*Herpestes edwardsi*), and who was observed living in Martinique until 1897 - 1902, which died out with the eruption of Mount Pelee (on the flanks of which there were last specimens). (Andrei Miljutin, 2010)

Species on proto Martinique who also would have dispersed to proto Saint Lucia to generate *Megalomys luciae* (Forsyth Major, 1901), also extinct since 1881, which one of the last specimens died in a zoo in London in 1852, one can then to be convinced of the past existence of a Caribbean land bridge between the Orinoco basin and the small islands of the Bank of Puerto Rico, and those of the proto-Greater Antilles, which disappeared and left only refuge for this land mammal the proto Martinique in proto Eastern Caribbean. Species close to this large Martinique Piloni rat of the same family Cricetidae, also extinct on islands east of Puerto Rico, have certainly borrowed the land bridges of the Aves and the Eastern Caribbean to disperse from of their center of origin of the Orinoco basin. And this, knowing that it is much more complicated for a terrestrial mammal than for reptiles and amphibians to migrate over very long distances at sea on a raft.

Once admitted this certainty, one can hold reasoning such as the following by example for hylodes emblematic of the Caribbean geological history basically determining dispersions and speciation of species; *E. johnstonei* and *E. martinicensis*, very close genetically whose ancestors were with certainty isolated either on Proto Martinique or Proto Barbados from -25 My, then secondarily on Proto Saint Lucia. Either divergence has occurred on proto Martinique between presumed hylode of the Caravelle and hylode of Sainte-Anne. Is he was presumed to be a proto-Barbados hylode and a proto-Martinique hylode. Or that the only species was on the only refuge of the proto Martinique (without differentiating itself and therefore without any real geographical barrier between Caravelle and Sainte-Anne) and later, when possible, dispersed to proto St. Lucia where would have been *E. johnstonei*.

This latter scenario joins Hedges' suggestion of a St. Lucian origin of the *E. johnstonei* hylode speciation (Hedges *et al.*, 2008).

This certainty of a proto-Martinique that has remained emerging since the Eocene from -45 My is further strengthened if we estimate the potential of new probable species that could be identified and with lineages specified by molecular biology (correlated with geological history), it's more than 3 species of stenostomes (Dewynter, pers. com.), + 4 new Martinique species (Vidal *et al.*, in prep.); which would not be the case for Saint Lucia.

Results

Statistical calculations concerning the comparative rate of endemic herpétofaune between Saint Lucia and Martinique still allow, despite anthropogenic pressures and destructions, a verification of these cross-referenced data of geology and molecular biology that place the Martinique as the main dispersal center for the connected organic East Caribbean.

Of a total of 7 species for 7 herpetofauna genera identified to be or have been strictly endemic to the Eastern Caribbean:

There is a strong probability that these species have found proto Martinique (Caravelle, Sainte-Anne): > -45 My, and proto Barbados : > -40 My as their first refuge and biotope of speciation. While the proto St. Lucia was completely submerged and could only have a safe-haven status to count for Ilets Maria <- 31 My, and Gros-Ilet <- 25 My.

The certainty that there was no refuge other than the proto Martinique, in the first place and proto Barbados second, in other words that the position of proto St. Lucia was completely submerged, becomes absolute when we consider the number of species among the 7, which are recognized as strictly endemic to the Martinique proto before -37 My, our estimate of 6/7 and therefore 85%.

The existence in southeastern Martinique of two *S. X* sp. and *S. Y* sp. lines with morphotypes approaching *S. microlepis* (Saint Lucia), different from *S. vincenti* and *S. festus*, testifies and confirms precisely that it is this geographical position which was center of dispersion; but still traced in intra-southeast, between the peninsula of St Anne and Mountain of Vauclin, divergences older than those of the lines having generated after *S. festus* in North of Martinique, and *S. vincenti* towards the southwest of Martinique.

The highlighting of *S. X* sp. still come to affirm the certainty of a proto-Martinique existing as the only refuge for a micro herpetofauna 45 My ago, and then as a dispersal center towards other islands of the Eastern Caribbean as the geological evolution of the eco-region.

FIGURE CAPTIONS

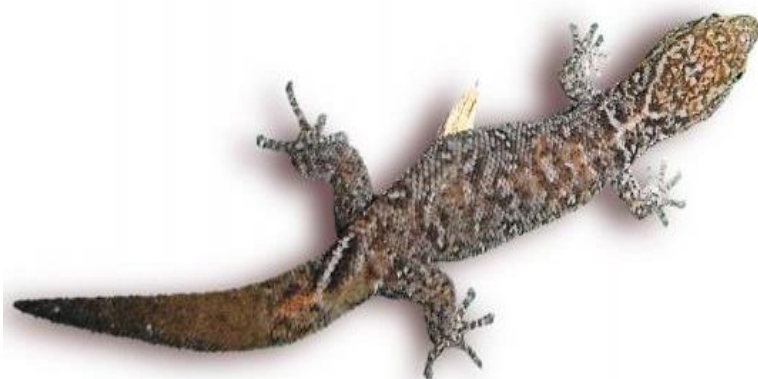


FIGURE α

Fig. β (1)



Fig. β (3)



Fig. β (2)



Fig. β (4)



Typical schematics for inter nasal scales:

(Illustrations by the author)

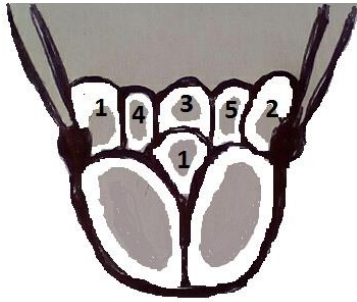


Fig. β (1) et Fig. β (2)

S. X sp.



Fig. β (3)

S. Y sp.



Fig. β (4)

S. festus and *S. vincenti*
(usually)

(1) *S. festus*



(2) *S. vincenti*



(3)



(4) *S. Z ssp. ?* having its tail like a caudal fin



(5)

(6)



(7)



(8)



(9)



(10)



(11)

-
- (1) *S. festus* (Caravelle – shot by M. BOURGADE)
 - (2) *S. vincenti* (Vatable Trois-Ilets – shot by A. FONG G.)
 - (2) *S.Y* sp. (Mountain of Vauclin – shot by M. BOURGADE)
 - (4) *S. Z* sp. (*ou* ssp.) (Ilet Morne Cabrit - shot by A. FONG G.)
 - (5) *S. X* sp. (from limestone dull South America STE-ANNE- shot by M. BOURGADE)
 - (6) *S. X* sp. (from limestone dull of Val d'Or STE-ANNE- shot by M. BOURGADE)
 - (7) *S.X* sp. (specimen from limestone dull of Val d'Or STE-ANNE- shot by M. BOURGADE)
 - (8) *S.X* sp. (Dull of Belfond specimen phenotype STE-ANNE – shot by M. BOURGADE)
 - (9) Egg shell of *S. X* sp. (Caritan limestone, shot by M. BOURGADE)

(10) Juvenile *S. X* sp. (Caritan limestone dull – shot by M. BOURGADE)

(11) Head of a type specimen of *S. X* sp. (limestone dulls of Sainte-Anne –
shot by M. BOURGADE)

(12)



S. Y sp. 02 ♀ SVL 30 mm



(13)

(14)

S. Y sp. 04 ♂ SVL : 30, 5 mm



(12) *S. Y* sp. Dorsal and ventral face of our holotype (Mountain of Vauclin – shot by M. BOURGADE)

(13) *S. Y* sp. Female specimen carrying an egg (Mountain of Vauclin – shot by M. BOURGADE)

(14) *S. Y* sp. (Mountain of Vauclin – shot by M. BOURGADE)

FIG.

A)

Central axis of the eye / Supra labials scales



S. X sp.

Number of supra labial scales up to the center of the eye

3 – 4

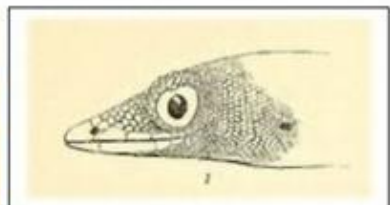
Central axis of the eye / Supra labials scales



S. vincenti

2 – 3

Adults ♂ heads



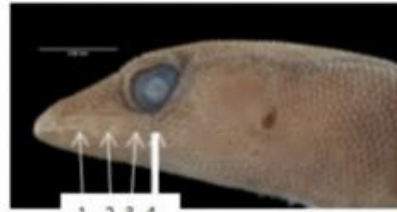
Sketch for morphological description of *S. vincenti* by Boulenger, Cat. Havards Brit. Museum, 1885

FIG.
B)



S. X sp.

Number of supra labial scales up to the center of the eye : 3 - 4



S. microlepis

Number of supra labial scales up to the center of the eye : 3 - 4

Photo: Holotype of Havard University Museum of Comparative Zoology

FIG.
C)



S. X sp. inter nasal scales: 1-5

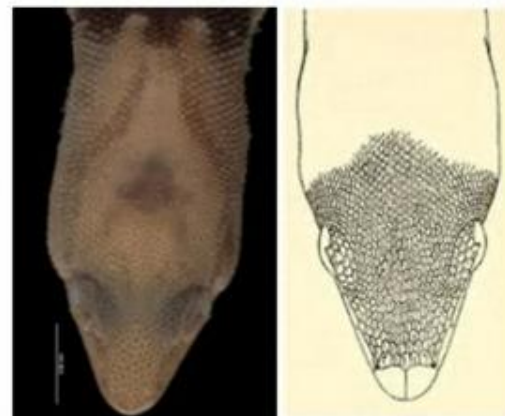


S. vincenti, inter nasal scales : 1-3
for *S. v. psammius* according to Schwartz

FIG.
D)



S. X sp. inter nasal scales: 1-5



S. microlepis inter nasal scales 1-5

Photo : Holotype of Havard University Museum of Comparative Zoology. And sketch for morphological description of *S. microlepis* by Boulenger, Cat. Havards Brit. Museum, 1885

FIG.

E)



Coloring
gray-white
throat
and chin
S. X sp.



Yellow color
throat and
chin of
vast majority
of
S. vincenti
and *S. festus*

The same trend of gray-white coloring of the throats and chins of *S. microlepis* and *S. v. adamas*

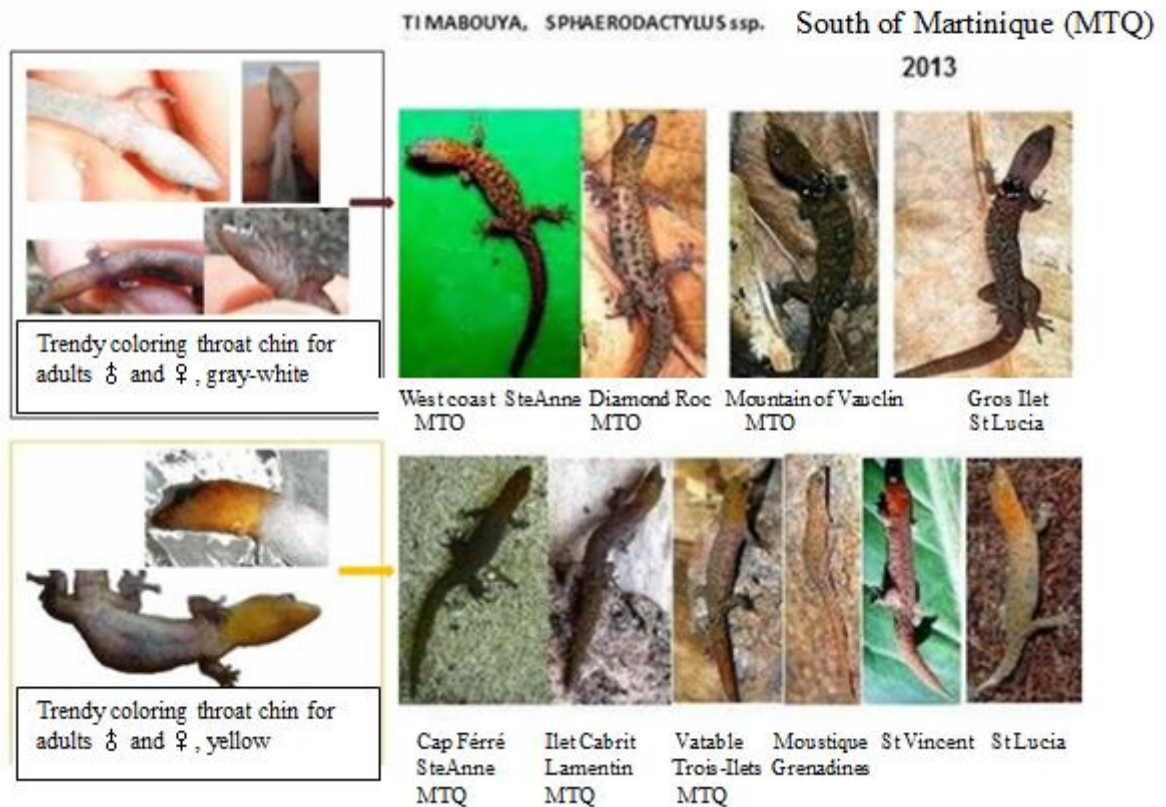
FIG.

F)



Sphaerodactylus vincenti psammius , Macabou Vauclin

FIG.
G)



S. microlepis in St.Lucia shot by J. DALTRY, *S. vincenti* in Trois Ilets and Vatable shot by A. FONG
S. ssp. on Diamond Rock and *S. sp.* on Mountain of Vauclin shot by M. BREUIL

FIG.

H)

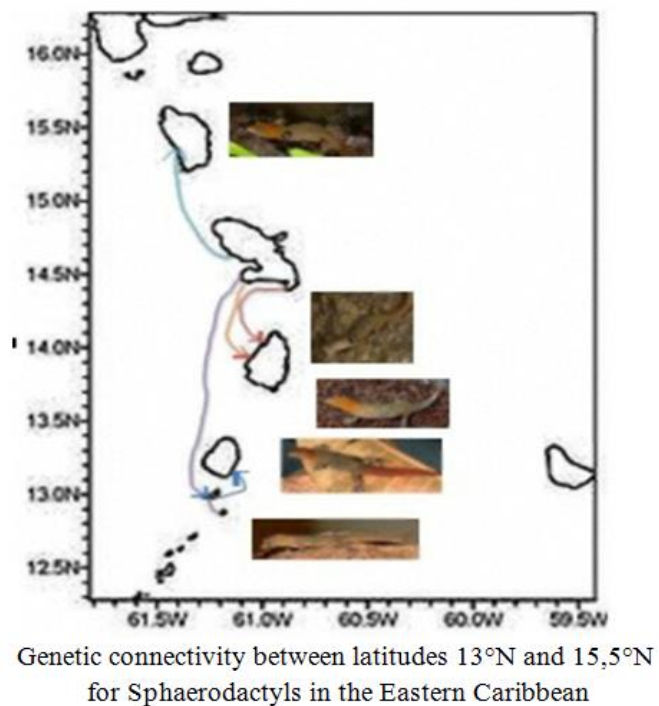


FIG I)



FIG.
J)



Location of observations of *S. X* sp. (Peninsula of Ste Anne) and *S. Y* sp. (Mountain of Vauclin) and *S. Z* sp. (Lamentin and Genipa Bay); and also *S. festus* (Caravelle) on the map.

FIG. J (bis)

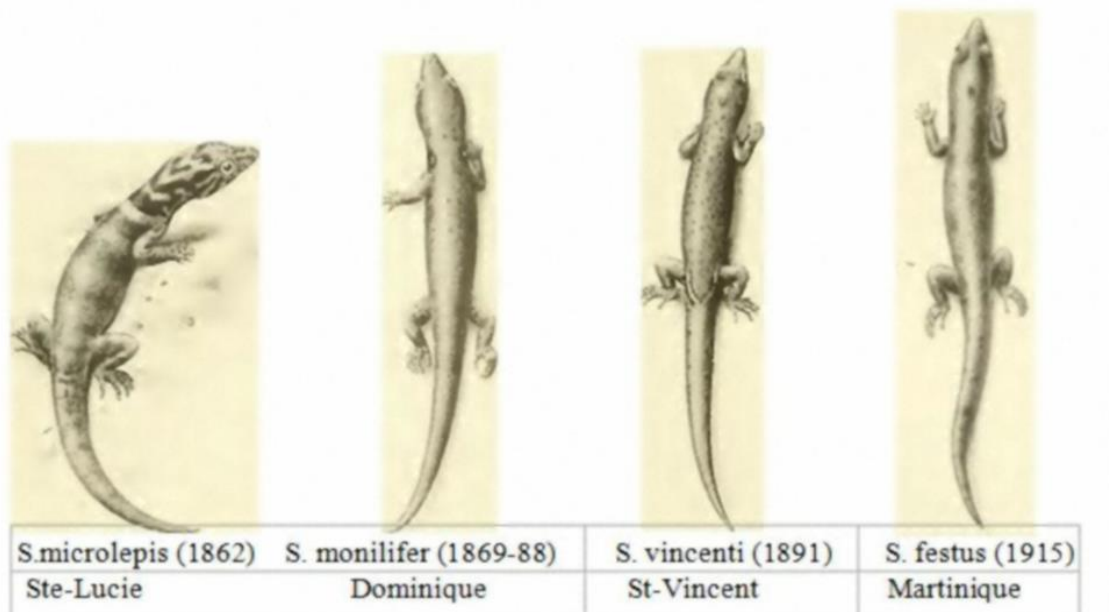


South part of the peninsula of Sainte-Anne Martinique

Figure K / Status of the data in images:

from 1862 to 1915, then 2013

History of sphaerodactyls taxa in the eastern Caribbean (Dominica to Grenadines)



Representations of Ti Mabouya extracted from “Memoirs of the Museum of Comparative Zoology at Harvard College. Vol. XLVII. No.3. Sphaerodactylus” ; Barbour, T. (1925)

2013 :



S. microlepis shot by J. DALTRY, *S. vincenti* shot by A. FONG

Acknowledgements

We thank Doris JOSEPH (general coordinator of the IRBST for Lamentin City), Ansèl FONG GRILLO, and David MACEIRA FILGEIRA (BIOECO, Santiago du Cuba), Ronald BRITHMER, Garcin MALSA, for commenting on the manuscript ; Michel DELBLOND, Pascal VATBLE, Christophe AUGUSTE for general biological information, Roger MAUVOIS, for its fundamental geological vision explaining the construction of the Cordillera of the Aves and the Caribbean, their formations then deformations as essentially phenomena of tectonics, of "horizontal" movements on the Caribbean lithosphere film known as thrust sheet migrations ; Charles ETILE (CD2S), for Caribbean geological information ; STEPHAN, J.F., Bernard MERCIER de LEPINAY for geological graphics and information and for his permission to use the figure "Appendix 4" ; Michel BREUIL, R. S. THORPE, Y. SURGET-GROBA, Nicolas VIDAL, Maël DEWYNTER, Stephen Blair HEDGES (Center for Biodiversity at Temple University) for basic biological information and molecular biological data information ; J. DALTRY for photographs of specimens of *S. microlepis* in St. Lucia, Gilles BOEUF, Ivan INEICH (Muséum national d'Histoire naturelle de Paris), Pascal SAFFACHE, Romain FERRY, Alex ALLARD SAINT-ALBIN, Jean-Raphael GROS-DESORMEAUX (CSRPN of Martinique), for scientific support.

This research was supported by the CD2S (Centre Caribéen du Développement Durable et Solidaire) with Caribbean institute ICEV (Institut de l'Ecologie et du Vivant).

REFERENCES

- Barbour, T. (1921). Memoirs of the Museum of Comparative Zoology at Harvard College. Vol. XLVIL. N°3. *Sphaerodactylus*. Cambridge, U. S. A. December. 12: 242-243 plate 3, 10 p. + 32: 267-268, 34 and 35: 270-272 plate 9, 25, 26 p.
- Stille, Wilhelm Hans (1936). "Die Entwicklung des amerikanischen Kordillerensystems in Zeit und Raum," in Sitzungsberichte der preussischen Akademie der Wissenschaften zu Berlin, Math.–Phys. Kl. .
- King, W. (1962). Systematics of Lesser Antillean lizards of the genus *Sphaerodactylus*. Bulletin of the Florida State Museum – Biological sciences University of Florida – USA. Vol. 7, N°1: 27-48.
- Schwartz, A. (1964). A review of *Sphaerodactylus vincenti* in the southern Windward Islands. Caribbean Journal of Science, 4, 391–409.
- Schwartz, A. (1965). A new subspecies of the gecko *Sphaerodactylus microlepis*.
- Martha, A., Marcum, Michael A., Alexander J., Muensch, H., Arnold, F. , Powell, R. (1986). Redux: New genera of anoles (Squamata: Dactyloidae) are unwarranted Steven Poe, Department of Biology and Museum of Southwestern Biology, University of New Mexico, Albuquerque, NM 87131 USA.
- Stephan, J.F. (1990). Paleogeodynamic maps of the Caribbean. Bulletin n°6 Soc. Geol. France, Paris.
- Kaiser, H. (1993). Systematics and biogeography of Eastern Caribbean frogs (Doctoral dissertation, McGill University).
- Kaiser, H., Green, D. M. , Schmid, M. (1994). Systematics and biogeography of Eastern Caribbean frogs (Leptodactylidae: Eleutherodactylus), with the description of a new species from Dominica. Redpath Museum and Department of Biology, McGill University, 859 Sherbrooke Street West, Montreal, QC H3A 2K6, Canada, and Institut für Humangenetik, Universität Würzburg, Biozentrum, Am Hubland, 97074 Würzburg, Germany.
- Hedges, S. B. (1996). The origin of West Indian amphibians and reptiles. Contributions to West Indian herpetology: a tribute to Albert Schwartz.

- Breuil, M. (2002) . Atlas des amphibiens et reptiles de la Martinique : illustration et cartographie provisoires (IVème partie) - Histoire géologique et différenciation géologique des populations de sphérodactyles de la Martinique (*Sphaerodactylus vincenti*) – Laboratoire des Reptiles et Amphibiens Muséum national d'Histoire naturelle – France

- Breuil, M. (2002). *Eleutherodactylus johnstonei* (Barbour, 1914) . Hylode de Johnstone. Histoire naturelle des amphibiens et reptiles terrestres de l'archipel guadeloupéen. Ed. Museum national d'histoire naturelle de Paris.

- Wüster, W., Thorpe, R. S., Salomão, M. D. G., Thomas, L., Puerto, G., Theakston, R. D. G., & Warrell, D. A. (2002). Origin and phylogenetic position of the Lesser Antillean species of *Bothrops* (Serpentes, Viperidae): biogeographical and medical implications. *Bulletin of the Natural History Museum: Zoology*, 68(02), 101-106.

- Thorpe, R. S., Stenson, A. G. (2003). Phylogeny, paraphyly and ecological adaptation of the colour and pattern in the *Anolis roquet* complex on Martinique. *Molecular Ecology*, 12(1), 117-132.

- Carranza, S., Arnold, E.N. (2003). Investigating the origin of transoceanic distributions: mtDNA shows *Mabuya* lizards (Reptilia, Scincidae) crossed the Atlantic twice. *Syst. Biodiv.* 1, 275– 282.

- Gradstein, F. M., Ogg, J. G., Smith, A. G., Eds. (2005). *A Geologic Timescale 2004*. Cambridge University Press.

- Hedges, S. B., Heinicke, M. P. (2007). Molecular phylogeny and biogeography of West Indian frogs of the genus *Leptodactylus* (Anura, Leptodactylidae). *Molecular phylogenetics and evolution*, 44(1), 308-314.

- Steinberg, D.S., Hite, J.L., Powell, R., Henderson R.W. (2008). Catalogue of American Amphibians and Reptiles. *Sphaerodactylus vincenti*.

- Johansson, H., Surget-Groba, Y., & Thorpe, R. S. (2008). . Microsatellite data show evidence for male-biased dispersal in the Caribbean lizard *Anolis roquet*. *Molecular ecology*, 17(20), 4425-4432.

- Thorpe, R. S., Surget-Groba, Y., Johansson, H. (2008). The relative importance of ecology and geographic isolation for speciation in anoles. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363(1506), 3071-3081.

- Thorpe, R. S., Jones, A. G., Malhotra, A., Surget-Groba, Y. (2008). Adaptive radiation in Lesser Antillean lizards: molecular phylogenetics and species

recognition in the Lesser Antillean dwarf gecko complex, *Sphaerodactylus fantasticus*. School of Biological Sciences, College of Natural Sciences, Bangor University, Gwynedd LL57 2UW, UK

- Adalsteinsson, S. A., Branch, W. R., Trape, S., Vitt, L. J., & Hedges, S. B. (2009). Molecular phylogeny, classification, and biogeography of snakes of the Family Leptotyphlopidae (Reptilia, Squamata). *Zootaxa*, 2244, 1-50.
- Hedges, S.. B., Kumar (2009). *Discovering the timetree of life*, Oxford University Press, New York.
- Breuil, M. (2009). The terrestrial herpetofauna of Martinique: Past, present, future. *Applied Herpetology*, 6(2), 123-149.
- Daltry, J. C. (2009). The status and management of Saint-Lucia's forest reptiles and amphibians. National forest and bio-physical resource inventory project ; Caribbean – Saint-Lucia.
- Thorpe, R. S., Surget-Groba, Y., & Johansson, H. (2010). Genetic tests for ecological and allopatric speciation in anoles on an island archipelago. School of Biological Sciences, Bangor University, Bangor, United Kingdom ; *PLoS Genet*, 6, e1000929.
- Campbell, MC and Tishkoff S. (2010). The evolution of human genetic and phenotypic variation in Africa. *Current Biology* 20(4): R166-173. PMID: PMC2945812.
- Andrei, Miljutin (2010). Notes on the external morphology, ecology, and origin of *Megalomys desmarestii* (Sigmodontinae, Cricetidae, Rodentia), the extinct giant rat of Martinique Island, Lesser Antilles. *Estonian Journal of Ecology*, 59, 3, 216-229.
- Mercier de Lépinay, Bernard (2010). À propos du séisme d'Haïti du 12 janvier 2010, replacé dans le contexte tectonique des Caraïbes - CNRS - Géoazur, Univ. de Nice-Sophia Antipolis.
- Breuil, M. (2011). The terrestrial herpetofauna of Martinique: Past, present, future. *Conservation of Caribbean Island Herpetofaunas*, 2, 311-338.
- Hedges, S. B., & Díaz, L. M. (2011). The conservation status of amphibians in the West Indies. *Conservation of Caribbean Island Herpetofaunas*, 1, 31-47.
- Robert Powell and Robert W. Henderson (2012). Island lists of West Indian amphibians and reptiles . Editors : *Bulletin Florida Museum Natural History* vol. 51(2)). 86 – 159 p.

- Sepulchre, P., Arsouze, T. , Donnadieu, Y. , Dutay, J.-C., Jaramillo, C. , Le Bras, J. , Martin, E., Montes, C., Waite, A. J. (2014). Consequences of shoaling of the Central American Seaway determined from modelling Nd isotopes; *Paleoceanography*, DOI: 10.1002/2013 PA002501

- Sepulchre, Pierre (2014) Vers une nouvelle chronologie de la connexion des amériques; CNRS, Centre National de Recherche Scientifique, LSCE/IPSL article sur site web : <http://www.insu.cnrs.fr/node/4706>

- Nicholson, K.E., Crother, B.I., Guyer, C., Savage, J.M. (2012). It is time for a new classification of anoles (Squamata: Dactyloidae). *Zootaxa* 3477, 1-108.

- Ron Blakey, (2012). Vidéo Paleogeography Views of Earth's History provided, by Professor of géology, Northern Arizona University; www2.nau.edu/rb7. Vidéo présentant simulation de l'évolution des plaques tectoniques, et dérive des continents depuis 600 Ma et prévisions futures + 100 Ma. http://www.dailymotion.com/video/xp5k5f_les-continents-terrestres-700-millions-d-annees-de-mouvement_tech

- Hirbo, JB, A Ranciaro, and SA Tishkoff (2012). Population structure and migration in Africa: correlations between archeological, linguistic, and genetic data. In *Causes and Consequences of Migration* B. Campbell and MH Crawford (eds.) Cambridge University Press.

- Pichot, Thibaud (2012). Les rides de Barracuda et de Tiburon, à l'Est de la subduction des Petites Antilles : origine, évolution et conséquences géodynamiques.

- Barat, Flore (2013). Nature et structure de l'isthme inter-américain, Panama : implication sur la reconstruction et l'évolution géodynamique de la plaque Caraïbe.

- Breuil, M. (2013). Composition et endémisme de l'herpétofaune martiniquaise : histoire géologique et différenciation intra-insulaire du sphérodactyle. In *Biodiversité insulaire la flore, la faune et l'homme dans les Petites Antilles* Schoelcher, 8 – 10 novembre 2010 : 116-129.

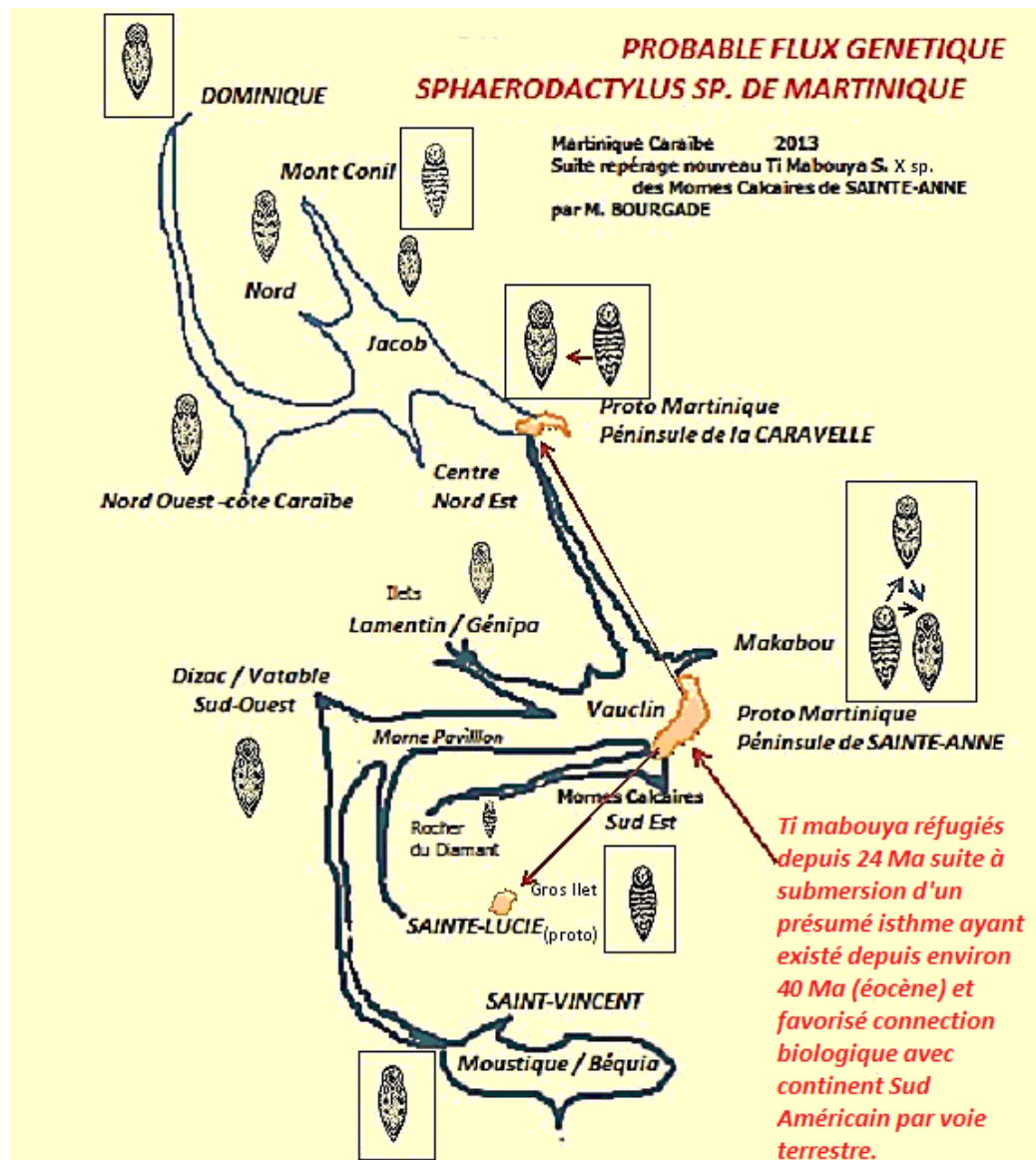
- Yann Surget-Groba and Roger S. Thorpe (2013). *Journal of Biogéography* n°40 – School of Biological sciences , College of Natural Sciences, Bangor University - UK - Supporting information A likelihood framework analysis of an island radiation: comparative phylogeography of the Lesser Antillean gecko *Sphaerodactylus vincenti* . 105-116 .

- Hedges, S. B., Marion, A. B., Lipp, K. M., Marin, J., & Vidal, N. (2014). A taxonomic framework for typhlopoid snakes from the Caribbean and other regions (Reptilia, Squamata). *Caribbean Herpetology*, 49, 1-61.

- Prates, I., Rodrigues, M. T., Melo-Sampaio, P. R., & Carnaval, A. C. (2015). Phylogenetic relationships of Amazonian anole lizards (Dactyloa): Taxonomic implications, new insights about phenotypic evolution and the timing of diversification. *Molecular phylogenetics and evolution*, 82, 258-268.
- Sacco, L. (2015). Isthme de Panama : une datation de sa fermeture secoue les géosciences. Article paru dans revue Futura-Sciences : <http://www.futura-sciences.com/magazines/terre/infos/actu/d/tectonique-plaques-isthme-panama-datation-fermeture-secoue-geosciences-57723/>
- Allard Saint-Albin, Alex (2015). Présentation PowerPoint sur le thème de la biodiversité martiniquaise fonction de l'évolution géologique - Atelier UNESCO, Martinique. Organisé par pôle scientifique du Parc Naturel Régional de la Martinique au mois d'octobre.
- Mauvois, Roger (2015). "Nouvelle hypothèse relative à la formation géologique de l'archipel Caraïbe" présentée lors de l'atelier UNESCO, Martinique; Organisé par le pôle scientifique du Parc Naturel Régional de la Martinique au mois d'octobre.
- Hedges, S.B., Marin J., Suleski M., Paymer M. & Kumar S. (2015). Tree of Life Reveals Clock-Like Speciation and Diversification. *Mol Biol Evol* 32: 835-845.

Appendix 1 .

Likely genetic flow of Sphaerodactyles since Martinique.(original in french)



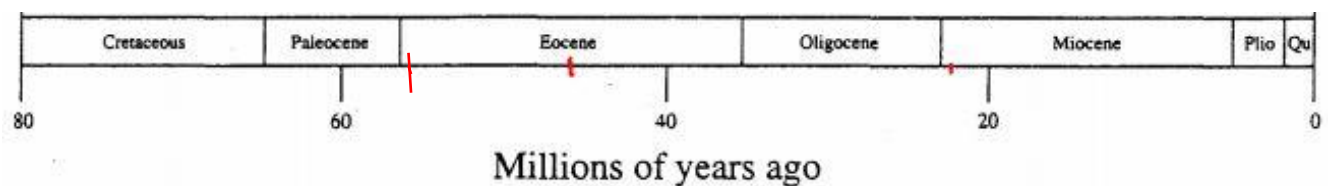
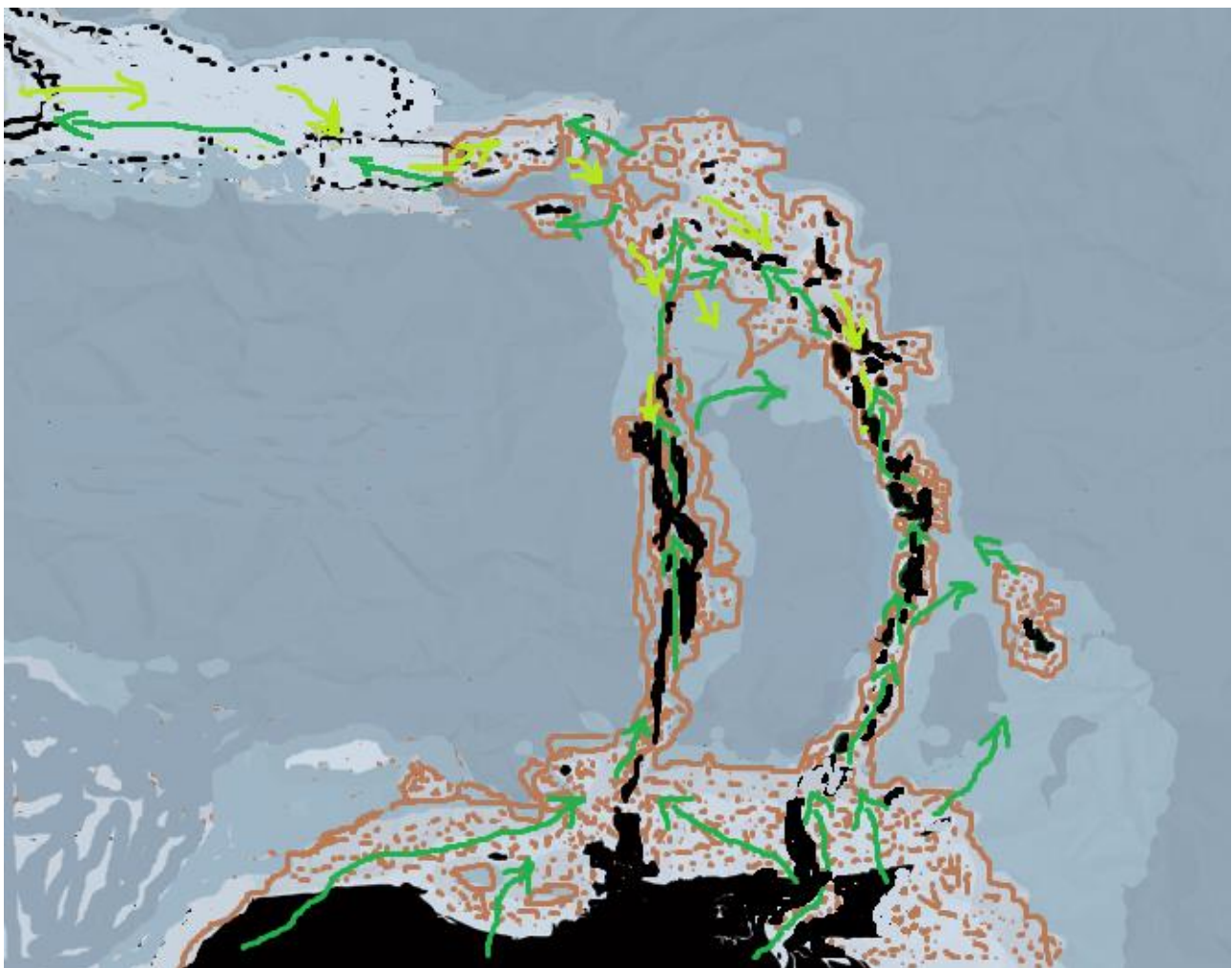
Copyright - © 2013 Marcel BOURGADE



Appendix 2 . > > > - 55 My (Early Eocene)

Geological formations related to fundamentally tectonic fold phenomena of the so-called Caribbean plate lithospheric film, creating a double bridging for the terrestrial dispersion of more South American species (and by rafts of plants to the islands of Puerto Rico and Proto-Cuba), and also less dispersal by rafts of plants originating from proto-Central America (proto Yucatan), present on small islands of proto-Greater Antilles (largely not yet emerged), on isthmus west of the Aves, and second isthmus east of the Caribbean; the Grenadian basin constituting a super lagoon almost closed.

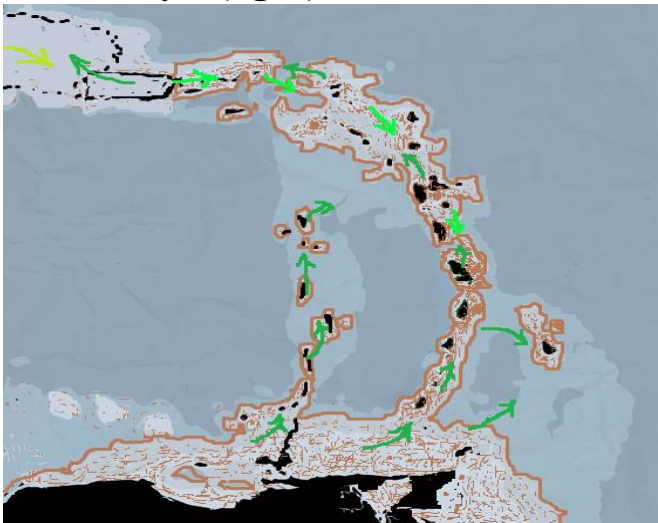
These bridges allowing inter-continental biological connection terrestrial would result from the conjunction of tectonic phenomena (migrations of thrust sheets), and consequences of the impact of the asteroid occurred 66 My to Chicxulub on the tip of the Yucatan peninsula (Gulf of Mexico). This asteroid impact event caused major ecological changes that lowered sea levels.



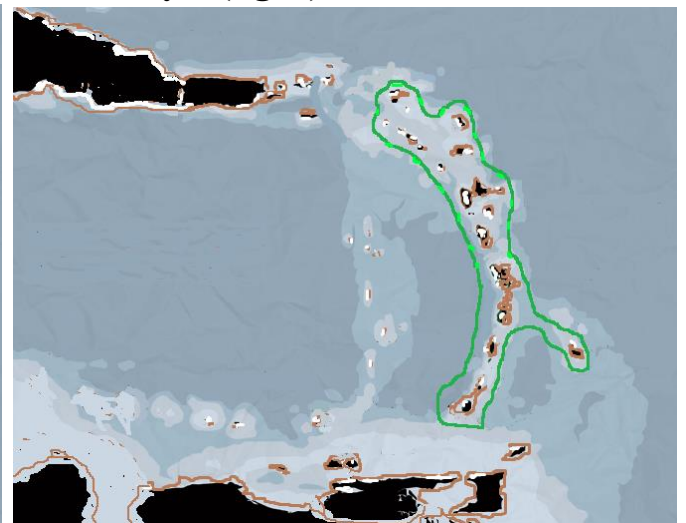
Copyright - © 2015 Marcel BOURGADE

Appendix 3 . Fig. 1: Isthmus of the Eastern Caribbean formed in peaks of cordillera, constituting a bridge favoring dispersion of faunistic and floristic species before - 45 My. (Middle Eocene). **Fig.2:** rupture of the isthmus, resulting in progressive isolation of refugee species on islands, until disappearance of these species from -37 My to -25 My (Eocene Superior). Disappearance, total submersion of the Aves bridge (evolution of tectonic fundamental phenomena). **Fig. 3:** genetic isolation of refugee species on proto Martinique and proto Barbados from - 25 My to - 12 My. (Miocene). **Fig. 4:** from - 12 My, bio-connectivity between proto-Saint Lucia, Martinique and Barbados, welcoming dispersal of species by plant raft from the deltas of the Orinoco but still the Amazon. Thus came the *Bothrops* snake, and the *Gymnophthalmus plei* squamate, which first failed on proto Saint Lucia.

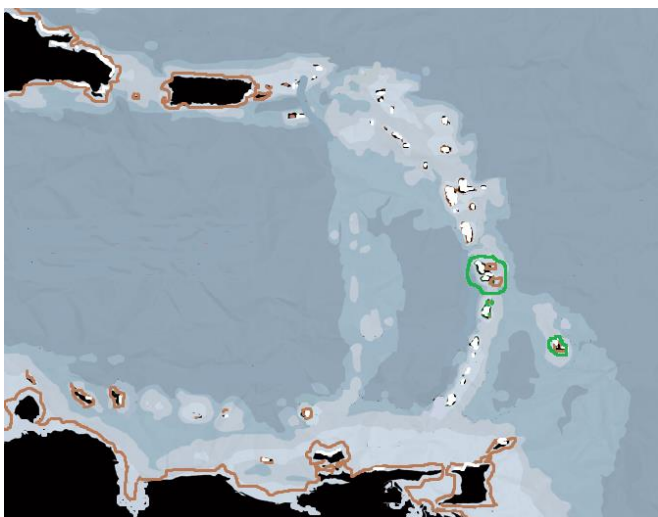
> - 45 My (fig. 1)



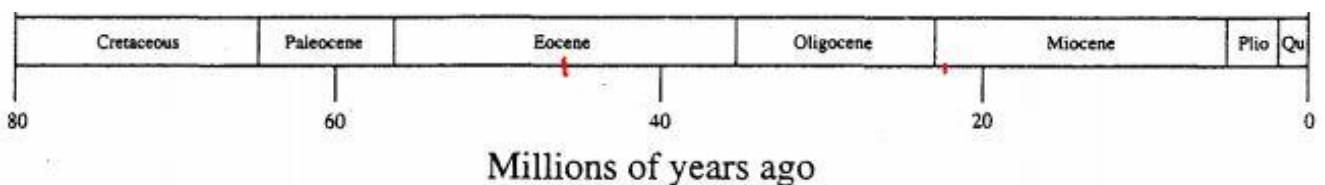
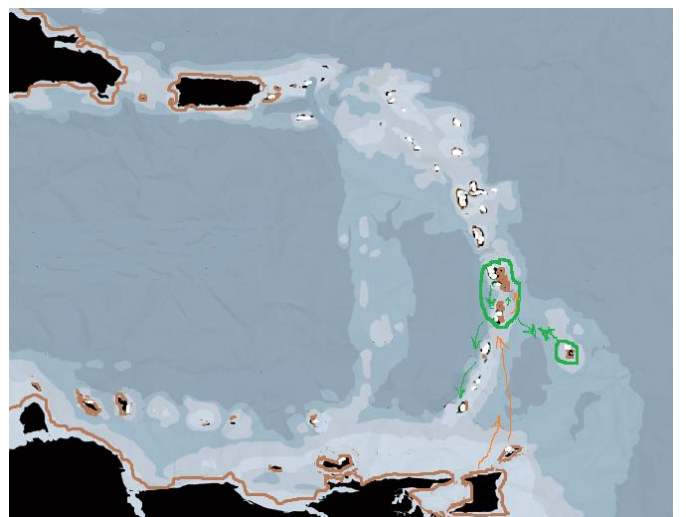
- 37 My (fig. 2)



- 25 My (fig. 3)

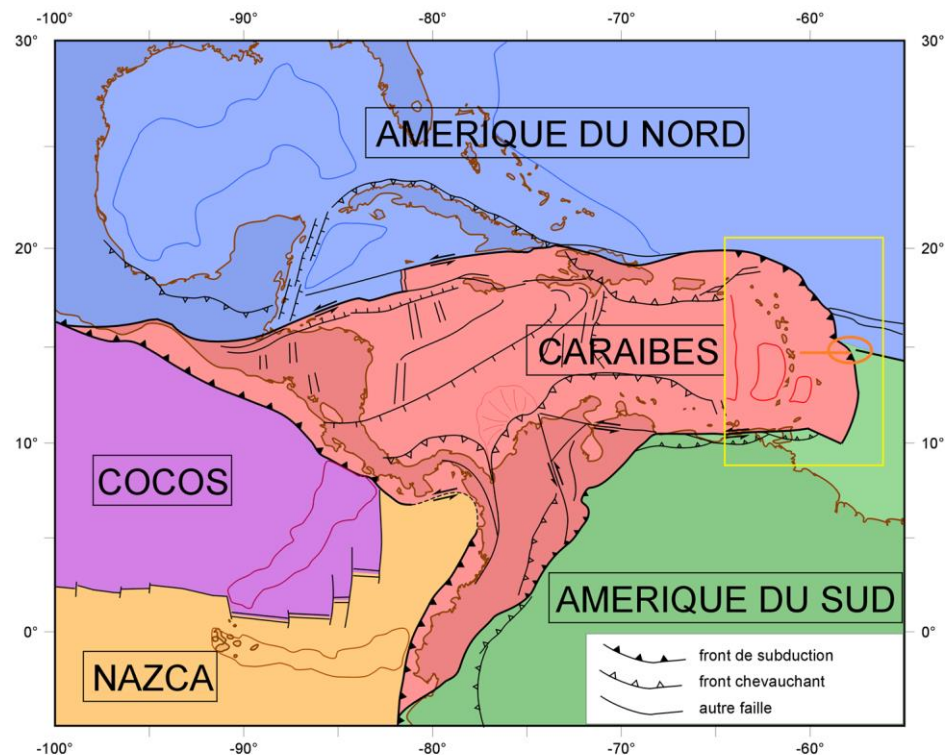


- 12 My (fig. 4)



These Appendix 2 and 3 that we present focus the vision of paleogeodynamic evolution on the geographical position of the Eastern Caribbean (Aves and Caribbean Arc) and are inspired by more global maps realized by STEPHAN JF *et al.* in 1990 (Paleogeodynamic maps of the Caribbean. Bulletin n° 6) , reflect a complex history of convergence, in subduction relative to major events of this region which correspond to the collision of the Caribbean, against America, separating and fracturing this America in two: South America and North America between - 100 My and 10 My. They document the deformations before, during and after the continental accretion process and allow us to better understand how a volcanic arc is tectonically growing on a continental margin. We can then reconstruct the geodynamic history of this region from 100 My to the present day. By integrating displacement phenomena and movements of thrust layers, migrations of sedimentary masses allowing the progressive raising of a first isthmus (east of the Caribbean film, well before that of western Panama) creating a first inter-Americas bridge.

Appendix 4. Details of the tectonic context of the so-called Caribbean plate lithospheric film (resulting from a fragmentation in three of the Farallon plate, itself being fragment of the Pacific plate), such as an appendage in front of the plates Cocos and Nazca, having opened a breach during its collision with the American lithospheric film, which it fractured in two films North America and South America, precisely in a geographical position located at almost same latitude as Martinique, facing Cape Ferré of the peninsula of Sainte-Anne (South East Martinique).



Right reserved- © 2010 Bernard Mercier de Lépinay
Published with his authorization

Extract of the general and global tectonic context of the so-called Caribbean plate lithospheric film among the 12 currently on the actual surface of the globe, on which the seas and continents are perpetually evolving. At their junction, there are faults and subduction zones.