GAARLANDIA LAND-BRIDGE VS LESSER AntiLLES DISPERSAL PATHWAYS – COUPLING SUBDUCTION DYNAMICS AND SPECIES EVOLUTION PROCESSES IN THE CARIBBEAN DOMAIN.

Pont terrestre 'GAARlandia' vs voies de dispersion à travers les Petites Antilles–Couplage entre dynamique de la subduction et processus d'évolution des espèces dans le domaine des Caraïbes.

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Project summary

The purpose of the GAARAnti project is to unravel couplings between deep Earth dynamics and evolutionary processes through an innovative and original multi-disciplinary study combining Earth and Life sciences. This innovative approach will reconcile biological and geological clocks and timeframes through the combined use of radiochronological methods, biostratigraphy and phylogenetic inferences, to constrain the Cenozoic paleo-biogeography of the Antillean arc. The GAARAnti project will generate novel collaborative works between geologists/marine geophysicists and biologists/paleontologists and new results by constraining the pattern, timing, and dynamics of biodiversity in Lesser Antilles at the Cenozoic scale. This will in turn allow untangling biotic and geological constraints that forced such history. In the frame of the ongoing debate about the Cenozoic origin of terrestrial organisms of the Greater Antilles, GAARAnti will focus on the role of subduction dynamics onto the evolution of emergent areas as a promoter or an antagonist of the dispersal of the terrestrial fauna. Although it is now widely admitted that most components of Antillean terrestrial communities originated from South and Central America, the mechanisms (dispersal *vs* vicariance) responsible for the observed evolution and its precise timing are still highly debated. Previous studies have mainly addressed this question through Earth sciences or Life sciences separately. We are confident and deeply believe that our innovative and original multi-disciplinary approach within the GAARAnti project will generate major advances in the knowledge of Cenozoic Antillean biodiversity dynamics.

The project is organized in five tightly interconnected scientific tasks and a supplementary management task including annual meetings (***Task 0***). ***Task 1***, based on fieldworks, will quantify past emergent areas through Cenozoic times, and estimate the timing and duration of land emersion periods (amplitude and rate of vertical motions) both being key constraints for paleo-geographic reconstructions. ***Task 2*** will estimate divergence times among living, recently extinct, and fossil mammals from the Lesser Antilles. We will then clarify the pattern and timing of mammalian dispersals into the Caribbean and propose paleo-biogeographic models. ***Task 3*** will refine the knowledge of the poorly known structure of both the Aves Ridge and the Lesser Antilles back-arc domains, i.e., the most probable dispersal pathways. This task is connected to the GARANTI marine cruise project, taking place in May-June 2017 and aiming at acquiring a large dataset of Wide Angle Seismic (WAS) and Multi-Channel Seismic (MCS) lines and dredged/cored samples. Onshore-offshore correlations will be realized to establish paleogeographic reconstructions at the scale of the Eastern Caribbean. In ***Task 4***, we will perform 2D/3D numerical and analog models of subduction in order to simulate surface response (topographic variations) to deep processes and to propose a global framework for the geodynamic evolution of the Lesser Antilles arc during the Cenozoic. ***Task 5*** is a

central and federative task in the project aiming at (1) establishing palinspastic reconstructions, (2) testing the influence of abiotic (temperature, eustasy, continental domain surfaces) vs biotic variables (species diversity, clade diversity, clade-specific shifts) based on birth-death models and (3) develop new mixed models to test the link between abiotic and biotic variables (to be assembled during the project) and the macroevolutionary dynamics of studied groups in the Antilles.

Beyond the novel expected scientific outcomes, the GAARAnti project will promote the preservation of both the geological and paleontological patrimony of the Antilles by disseminating results through local institutions of scientific popularization that are associated to the projects and through collaborations with local primary and high schools and Guadeloupe ESPE.

Summary table of persons involved in the project:

Partner	*Name*	*First name*	*Current position*	*Involvement (person. month)**	*Role & responsibilities in the project (4 lines max)*	*Task*
Partner 1 - GM	**Münch**	**Philippe**	**PU UM**	**18**	**Coordinator, Co-PI Task 5,** Geo-Thermo-chronology	**0, 1, 3, 5**
	Arcay	Diane	CR2 CNRS	12	**Co-PI Task 4**, subduction modeling	**0, 3, 4**
	Arnaud	Nicolas	DR1 CNRS	3	Geo- Thermo-chronology	**1**
	Bonno	Michael	IE1 CNRS	6	Geo- Thermo-chronology	**1**
	Bosch	Delphine	DR1 CNRS	3	Geochemistry	**1**
	Cadio	Cécilia	MdC UM	6	Gravimetry, seismology analysis	**3, 4**
	Cornée	Jean-Jacques	DR2 CNRS	24	**Co-PI Task 1**, Sedimentology, paleo-geography	**0, 1, 3, 5**
	Garel	Fanny	MdC UM	10	subduction modeling	**4**
	Heuret	Arnaud	MdC UG	12	Tectonics, Geodynamics	**3, 4**
	Lallemand	Serge	DR1 CNRS	12	**Co-PI Task 3**, subduction processes, geodynamics, seismic interpretation	**0, 3, 4**
	Lebrun	Jean-Frédéric	PU UA	12	MCS and WAS data acquisition, processing and interpretation	**3, 4**
	Léticée	Jen-Len	PAST UA	24	Sedimentology, paleo-environment	**1, 3, 5**
	Mazabraud	Yves	MdC UA	6	Tectonics	**1, 3**
	Merzeraud	Gilles	MdC UM	12	Sedimentology, paleogeography	**1, 5**
	Monié	Patrick	DR2 CNRS	6	Geo- Thermo-chronology	**1**
	Noury	Mélanie	MdC UA	12	Geo- Thermo-chronology	**1**
	Oliot	Emilien	MdC UM	6	Tectonics, metamorphic petrology	**1**
	Philippon	Mélody	MdC UA	18	**Co-PI Task 1**, Tectonics, metamorphic petrology, kinematic modelling	**0, 1, 4, 5**
	Tibéri	Christel	CR1 CNRS	6	Gravimetry, seismology analysis	**3, 4**
	X	X	PhD	36	Marine geophysics (ANR funding)	**3**
Partner 2 - ISEM	**Antoine**	**Pierre-Olivier**	**PU UM**	**16**	**Partner 2 coordinator, Co-PI Task 2,** paleomammalogy	**0, 2, 5**
	Adnet	Sylvain	MdC UM	6	Vertebrate paleontology (marine taxa), paleoenvironmental reconstruction	**1, 2, 5**
	Catzeflis	François	DR2 CNRS	3	Mammalogy, biological resources (expertise)	**2**
	Condamine	Fabien	CR2 CNRS	15	**Co-PI Task 5**, Diversification/extinction models, (paleo)biogeography	**0, 2, 5**
	Delsuc	Frédéric	DR2 CNRS	5	Molecular phylogeny, biogeography, ancient DNA	**2, 5**
	Fabre	Pierre-Henri	MdC UM	12	**Co-PI Task 2**, Molecular phylogeny, (paleo)biogeography	**0, 2, 5**
	Hautier	Lionel	CR1 CNRS	2	Mammalogy and morphometrics	**2**
	Marivaux	Laurent	CR1 CNRS	12	Paleomammalogy	**2, 5**
	X	X	Post-doc	18	Diversification and paleobiogeography (ANR funding)	**5**
Partner 3 -	**Marcaillou**	**Boris**	**MdC UNS**	**16**	**PI Task 3, MCS data acquisition and**	**0, 3, 4**

Geoazur					**processing, depth migration.**	
	Beslier	Marie-Odile	CR1 CNRS	6	MCS data processing and interpretation	**3**
	Charvis	Philippe	DR IRD	4	WAS data processing and interpretation	**3**
	Hassani	Riad	PU UNS	12	**Co-PI Task 4**, numerical modeling	**0, 4**
	Laigle	Mireille	CR1 CNRS	12	MCS and WAS data processing and interpretation	**3, 4**
	Mercier de Lepinay	Bernard	CR1 CNRS	6	Sub-surface geophysical data processing and interpretation	**3, 5**
	Schenini	Laure	IE IRD	6	MCS processing	**3**
	Yates	Ben	IE IRD	4	MCS and WAS data processing	**3**
	X	X	Post-Doc	12	numerical modeling (ANR funding)	**4**

I.Proposal’s context, positioning and objective(s)

I.1. Objectives and scientific hypotheses

The purpose of the GAARAnti project is to unravel couplings between deep Earth processes and biological evolutionary phenomena through an innovative and original multi-disciplinary approach combining Earth and Life Sciences.

A global biodiversity hotspot – Due to their geological history and insular condition, the Caribbean Islands are regarded as one of the 25 originally proposed biodiversity hotspots (**Fig. 1**; Myers *et al.*, 2000), characterized by a rich and highly endemic plant and vertebrate biodiversity. Compared to other island systems, we still know little regarding the evolutionary and ecological processes responsible for the origin of this biodiversity. This region has played a significant role for the Neotropical biodiversity as a whole; the West Indies have triggered high speciation rate (e.g. Matos-Maravi *et al.*, 2013) and may have served as a biogeographical crossroad and species pump to invade and colonize South America (e.g. **Lewis et al., 2015**). However, a better understanding of how this biodiversity has originated, has been maintained or lost over time requires an interdisciplinary approach combining multiple layers of data from ecology, distribution areas, fossils, and genetics, as well as paleogeography, paleoclimate and geodynamic.

***Figure 1**: Map of the Caribbean Islands Biodiversity Hot Spot (Critical Ecosystem Partnership Fund report, 2010).*

An ongoing scientific debate – The Caribbean Islands focused the attention of biogeographers and paleontologists over the last decades and gave birth to one of the most intriguing challenges in biogeography: the Cenozoic origination of terrestrial organisms of the Greater Antilles. The biogeography and disjunctions within the examined biological groups were interpreted with respect to divergence times, fossil records, and geological events such as the formation of the Greater Antilles Islands and the Aves Ridge paleo-arc. This led to a passionate debate on the historical biogeography of the Caribbean concerning the relative roles of over-water dispersal (Hedges, 1996) and vicariance mechanisms through the Aves Ridge (GAARlandia hypothesis; Iturralde-Vinent & McPhee, 1999) in shaping its fauna and flora. Among an increasing compendium of phylogenetic data now available for a wide array of recent organisms, some are consistent with the dispersal model (**Fabre *et al.*, 2014**) whereas others match the vicariance model instead (McPhee, 2009; Bacon *et al.*, 2012). Current biogeographical models are based upon poorly defined paleogeographical reconstructions and the Lesser Antilles arc is generally not considered in these reconstructions (e.g. Dávalos, 2004; McPhee & Iturralde-Vinent, 1995). However, the northern Lesser Antilles seem to be connected to the Aves Ridge, as suggested by present day bathymetry (**Fig. 2a**) and geology of the Anguilla bank (e.g. Bouysse *et al.*, 1985).

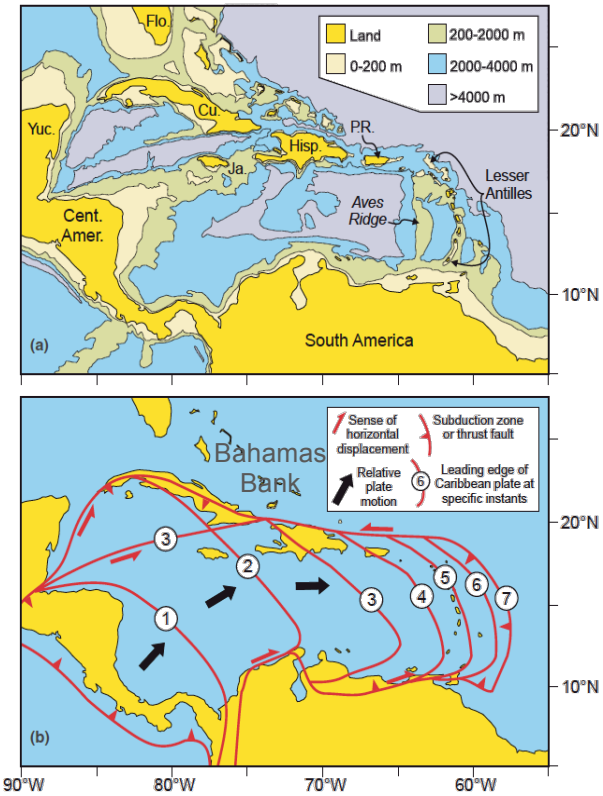

Figure 2: Maps of the Caribbean and adjacent regions showing (a) simplified bathymetry and (b) schematic development of the Caribbean plate during the Late Cretaceous and Cenozoic (Ali, 2012).

Geodynamical context and questions – The Greater and the Lesser Antilles (GA, LA) result from the eastward rollback of the subduction of the proto-Caribbean plate beneath the Caribbean plate since the Late Cretaceous (**Fig. 2b**). This subduction zone narrowed during early Paleogene times (between steps 2 and 3; solid red lines in **Fig. 2b**) when it collided with the Bahamas Bank. The Paleogene Aves Arc then splitted in relation with the stretching of the eastern edge of the plate and gave rise to the LA Arc (steps 4–7) whereas the remnant part of Aves arc, now termed Aves Ridge was supposed to subside. The Aves paleo-arc is almost *terra incognita* since the 1980’s while the LA subduction dynamics (erosive vs. accretionary active margin), the deformation of the overriding plate (partitioning or not) and the existence of a northeastern Aves Ridge-LA block are strongly questioned (e.g. Lopez *et al*., 2006, **Feuillet *et al*., 2010**; **De Min *et al*., 2015**; Symithe *et al*., 2015). The subduction dynamics has a strong impact on the creation and the removal of terrestrial surfaces in relation to volcanism, sediment accretion, tectonic erosion or subduction of asperities, which superimpose on a dynamic topography caused by slab dynamics and mantle circulation. However, in the Eastern Caribbean, neither (1) a precise timing nor (2) the duration of the emersion and submersion of numerous islands nor (3) any estimates of the surface of emerged lands at different time slices since the Eocene are known. New data must be acquired especially in the offshore domain as our recent works in the Guadeloupe Archipelago reveal the existence of an unknown sunk island in the fore-arc with repeated emersions and submersions since the late Miocene (**Münch *et al*., 2013, 2014; De Min *et al*., 2015**). LA, from north of St Lucie to Puerto Rico, are of peculiar interest because this region remained in a relatively elevated position since the Paleogene and is today composed by numerous islands and shallow water banks. Its emersion has not only been related to tectonics but also to climate changes and related sea-level variations (e.g. glaciation-induced). It represents a unique key area to improve the paleogeographical reconstructions and emerged surface quantification for post-Paleocene times.

The GAARAnti project will generate and foster novel collaborative works between geologists and biologists in order to provide new results to achieve the following main objectives:

♦**Refining the knowledge of the structure of the Aves Ridge and the northern Lesser Antilles back-arc domains**. This objective, crucial to test the hypothesis of a land bridge through the Aves Ridge (GAARlandia hypothesis), will be achieved through the 7 weeks-long geophysical marine cruise called GARANTI (**G**eodynamical conditions for **A**ves **R**idge and the Lesser **ANTI**lles arc splitting) and scheduled from May 6 to June 25, 2017.

♦**Establishing new paleogeographical reconstructions from onshore-offshore studies**. This objective will be achieved through seismic lines analysis and selected islands studies in order to (1) refine the Cenozoic basins chronostratigraphy, (2) identify main emersion/submersion episodes and their origin (tectonics and/or climate) and 3) quantify and compare the timing and duration of vertical motions of the Aves and LA arcs.

♦ **Unraveling the couplings between geological and biological timescales**. This objective will be achieved through phylogenetic studies on recent, sub-fossil, and fossil mammal species allowing the comparison of divergence times with an integrated chronostratigraphy of geological series. A secondary objective is to refine in some cases chronological constraints for molecular inferences that are still debated. Such a multidisciplinary approach is innovative and may lead to intercalibration of biological and geologic clocks, further calibrated by paleontological findings.

♦**Proposing updated and well-constrained (paleo-)biogeographic scenarii.** Phylogenetic analyses on exhaustive taxonomic samples of Recent, sub-fossil, and fossil mammalian species from the West Indies and adjacent areas (DNA-based, morphology-based, plus total evidence) will allow us to propose updated and well-constrained biogeographical scenarii on distinct land mammal groups (sloths, rodents, and primates, plus bats), and to compare them to the evolutionary history of other taxonomic groups of similar dispersal ability, available from the literature.
♦**Estimating the main parameters controlling the topography dynamics** through numerical and analog modeling. Indeed, the tectonic processes controlling volcanic arcs migrations through space and time within dynamic subduction frames are a fundamental issue that remains poorly understood. We aim at understanding how deep subduction processes may generate topography variations and hence provide (or remove) "stepping stones" for mammal sweepstake dispersals through times.
♦**Teasing apart the contribution of each potential driver in shaping the Caribbean biodiversity**. Relying on innovative modeling techniques, such as maximum likelihood birth-death models, we will specifically study and estimate the underlying processes (speciation, extinction, and dispersal) responsible for the generation and maintenance of the regional biodiversity pattern combining biological factors (clade competition and diversity dependence) and abiotic parameters (temperature, sea level changes, and island area size).

The aforementioned breakthroughs will lead to a better understanding of the role of subduction dynamics in promoting or impeding terrestrial mammal dispersals.

I.2. Originality and relevance in relation to the state of the art

Despite their biological richness, the West Indies (WI) host extremely depauperate and highly endemic non-volant mammalian communities (Steadman et al., 1984). Native land mammals are restricted to two "insectivore" species in Cuba and Hispaniola (*Solenodon*; e.g. MacPhee, 2009) and ~11 large rodents (hutias), with a vicariant distribution on GA islands. This condition is even more stressed for the LA, hosting no native terrestrial mammals but bats nowadays. Dozens of native species have disappeared in the last millennia, due to over-hunting or competitors introduced by Amerindians and Europeans (Giovas et al., 2012).

Compared to extant communities, the native mammalian guilds were startlingly more diversified in WI, as notably demonstrated by GAARAnti members and external collaborators. These guilds included sloths (**Delsuc and Douzery, 2009**), primates (e.g., **Marivaux et al., 2016**), rodents (**Fabre et al., 2015**), and "insectivores" (Roca et al., 2004), mostly documented in the GA (MacPhee, 2009). Although currently meager, the mammalian fossil record suggests a complex and dynamic Cenozoic biogeographical history (Dávalos, 2004; Dávalos and Turvey, 2012), with North American (rhinos and four-limbed "sea cows"; Eocene, Jamaica; Domning, 2001) or South American incomers (Oligocene caviomorph rodents and sloths, Puerto Rico; Miocene primates and rodents, Cuba; MacPhee & Iturralde-Vinent, 1995; Vélez-Juarbe et al., 2014; Pujos et al., 2017). The current fossil record of land mammals is extremely poor in the LA (Pliocene: Grenada; Pleistocene: Anguilla/Saint-Martin, Barbuda; historical (rodents); MacPhee et al., 2000), which blurs the origin, timing, and evolutionary pattern of such lost biodiversity (e.g., Brace et al., 2015). The post-Paleogene sedimentary record of these islands (see ***Task 1***), promising for further fossil findings, has not been intensely investigated in that purpose thus far, and GAARAnti paleontologists are experienced for discovering fossils in such challenging conditions (e.g., **Antoine et al., 2016**).

Disentangling such a paleobiodiversity dynamics will require both a time-constrained evolutionary framework for Caribbean rodents, primates, and sloths (phylogenies), and integrating climatic, eustatic, and geodynamic data for the last 40 Ma. We propose to achieve these objectives in the same project, that is a major originality of GAARAnti project. We will gather morpho-anatomical features and molecular data, in order to infer total-evidence phylogenies and perform time-calibrated analyses on recent, recently extinct, and fossil species. Succeeding in such a challenge also implies to consider much wider taxonomic samples, by assembling related species from any potential biogeographical sources, i.e. New World landmasses (**Antoine et al., 2017**). The development and use of

biogeographical and diversification models will allow deciphering the role of potential factors, either biotic or abiotic (sea-level fluctuations, temperature, and emerged land area). This workflow will strongly benefit from the ongoing NeotroPhyl and SOURCE projects (**Table in section II.3.2**), dealing with Neotropical mammal phylogeny and Guiana fossil record, respectively. They are funded by the CEBA Laboratory of Excellence (Labex) and already gathered all GAARAnti mammalogists and paleontologists.

In the last decades, onshore investigations of West Indies geology have been mainly focused on subduction magmatism or volcanic and seismic hazards. Most studies on sedimentary series, magmatic/metamorphic basement cropping out predate the 1990s (e.g. Christman, 1953; Martin-Kaye, 1959; Tomblin, 1975; Briden et al., 1979; Andreieff et al., 1983, 1989; Bonneton & Vila, 1983; Mascle & Westercamp, 1983; Brasier & Donahue, 1985). In the meantime, our group (partners 1 and 3) refined the onshore Miocene to Pleistocene geology of the Guadeloupe archipelago (Partners 1 and 3: **Cordey & Cornée et al., 2009**; **Cornée et al., 2012**; **Lardeaux et al., 2013**; **Léticée et al., 2005**; **Münch et al., 2013, 2014; Vérati et al., 2016; Zami et al., 2014**) and correlated it to the offshore domain (**Münch et al., 2013; De Min et al., 2015**). We propose in this project to apply the integrated approach we have successfully applied in Guadeloupe to selected islands from Puerto Rico to Tobago in order to propose paleogeographic reconstructions at different time slices. This will also allow refining mammal biostratigraphy and thus intercalibrating biological and geologic clocks. At LA scale, it appears that the sedimentary basins display a southward decreasing age of their earliest infill from North to South: Paleocene in Anguilla, Eocene in St Croix, St Martin, St Barthélémy; Oligocene in Puerto Rico and Antigua; Miocene in Guadeloupe (Marie Galante), Martinique, Grenadines and Grenada; Pleistocene in Tobago and Blanquilla (**Fig. 3**). The northeastern LA will be a specific target because of the occurrence of Paleogene sedimentary and volcanic rocks suggesting that they were connected to the emergent Aves arc. As far as we know, no studies of vertical motions have been conducted on basement rocks. Some members of the consortium have just started a study in St Martin to reconstruct the cooling/exhumation history of outcropping Oligocene granodiorites with HT to LT thermochronometry (INSU/Tellus, **Table in section II.3.2**). The preliminary results may indicate a fast cooling episode and a total exhumation of ~4-5 km before 20 Ma. This approach should be conducted, in parallel with basins analysis quantifying the subsidence history, in every island where the basement crops out, in order to detail the timing of vertical motions and emersions.

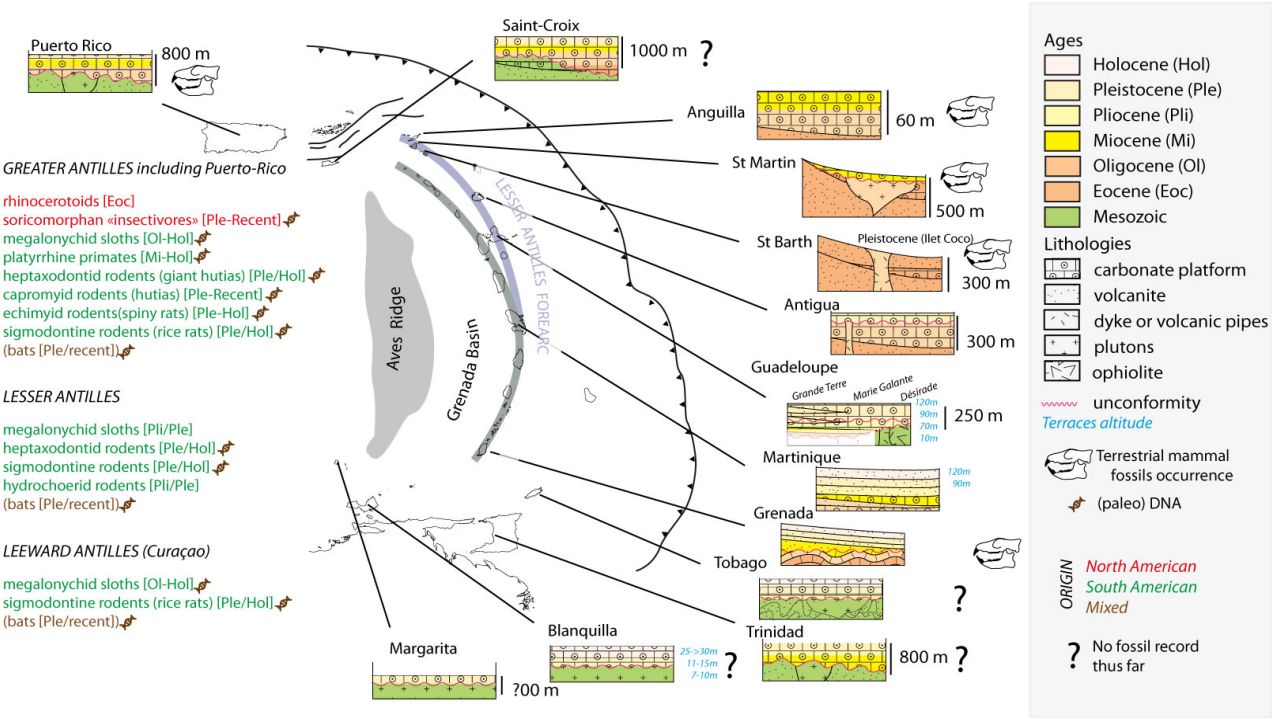

***Figure 3**: Synthesis of onshore geological data of West Indies with indications of basement and sedimentary cover lithology and age, thickness of the sedimentary cover (when it is known), Quaternary terraces and known occurrences of terrestrial mammal fossils. References used to build the figure are those quoted in the text.*

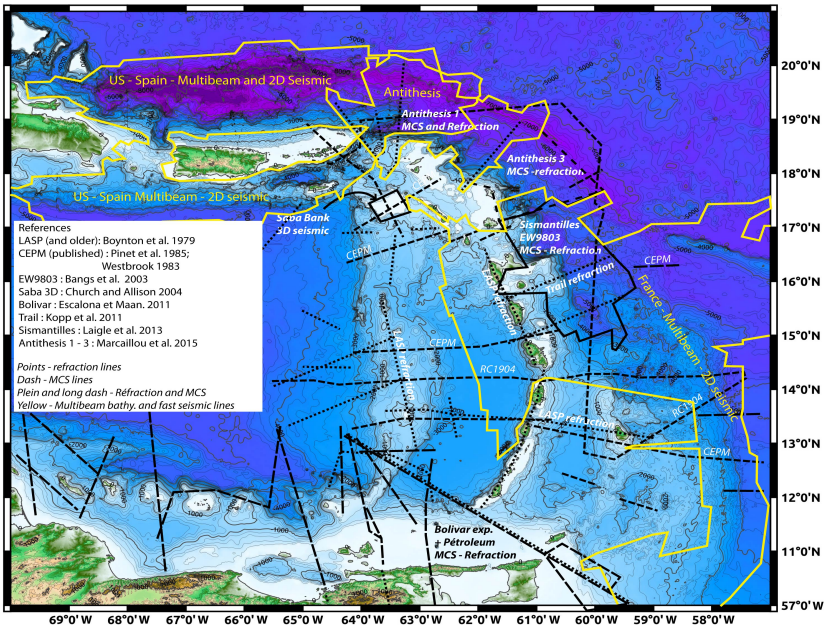

***Figure 4**. Synthesis of offshore geophysical data of West Indies. References used to build the figure are those quoted in the text.*

Offshore geology has received much more attention through numerous marine geophysical surveys presented in **Fig. 4**. Most recent studies of the northeastern LA were mainly conducted by members of the consortium (**Partners 1 and 3**: KASHALLOW 2008–2011, SISMANTILLES 2001, 2007, GWADASEIS 2009, BATHYSAINTES 2010, AntiTheSis 2014–16, GARANTI 2017; **Table in section II.3.2**) and yielded numerous publications in the last years (e.g. **Kopp et al., 2011; Evain et al., 2013; Gailler et al., 2013, 2017; Laigle et al., 2013a and b; Münch et al., 2013; Leclerc et al., 2014; De Min et al., 2015**). However, it must be stressed that the back-arc domain, especially the Aves Ridge, has been scarcely studied in the 1980s (Bouysse et al., 1985; Boynton et al., 1979; Westbrook, 1983; Pinet et al., 1985) and its structure and evolution are still poorly known. To the south, the Grenada basin, i.e., the most studied area to the west of the LA arc, has been interpreted either as a back-arc basin opened since the Late Cretaceous (Bouysse, 1988), as an intra-arc basin opened by the late middle Eocene (Pindell & Kennan, 2009), or more recently as an inverted fore-arc basin opened in Paleocene times (Aitken et al., 2011). However, this study revealed a long-lasting subsidence history with a major middle Miocene unconformity that may correlate with fluvial-littoral complex cropping out in Grenadines (Aitken et al., 2011). On the flanks of the Aves Ridge, dredged sediments indicate shallow-water to continental environments in the late Eocene–early Miocene interval (Nagle, 1972). Thus, the Aves Ridge and the Grenada Basin have to be further investigated to unravel the post-Paleocene paleogeographic evolution and associated geodynamic processes. The northern part of the present-day LA back-arc domain up to the Aves Ridge is now a key area to study because it has undergone less subsidence than the Grenada basin *s.s.* and may thus have preserved the early markers of the geodynamic history. Thus the GAARAnti project benefits from numerous marine geophysical cruises and it relies more peculiarly on the GARANTI-2017 cruise (PIs: **J.F. Lebrun and S. Lallemand**).

West Indies paleogeography was reconstructed for the last time in the 1990s (**Stephan et al., 1990**; Iturralde-Vinent & Mc Phee, 1999). These paleogeodynamic reconstructions were based on the 1980s onshore and offshore geological databases that have been greatly improved and updated since that time. Thus paleogeographic reconstructions need to be refined. These reconstructions mainly proposed the edification of a land bridge along the Aves Ridge from the Late Cretaceous to the Eocene, followed by the drowning of this continuous relief between South America and the GA, during the Oligocene. They completely ruled out the occurrence of land-masses in LA arc since Paleocene times despite the great affinities between northern LA islands and the Aves Ridge. Furthermore, recent studies by the GAARAnti consortium revealed a complex paleogeographic history for the Guadeloupe archipelago the emerged surfaces of which may have been at least twice as wide as the present-day ones at different periods since the Miocene (**Münch et al., 2013; De Min et al., 2015**). Therefore, paleogeography of the West Indies needs to be refined and GAARAnti would offer a unique opportunity to gather world-leading specialists on that region.

I.3. Risk management and methodology

As the GAARAnti project propose an innovative and original multi-disciplinary approach, combining Earth and Life Sciences, many methods have to be implemented and integrated and the project is

partly risk-taking. Consequently, ***Task 0*** is devoted to coordination in order to guarantee the effective cooperation and communication among all participants, particularly between biologists and geologist, as well as efficient decision-making.

As many of our objectives will be achieved through field investigations (***Tasks 1 and 2***) and an oceanographic cruise (***Task 3***), we take into account climatic risks, such as cyclones, and missions will be scheduled off the cyclonic season (GARANTI cruise is already scheduled in May-June 2017). If some technical problems occur during the oceanographic cruise, the fleet agency often allows extra days to complete the main targets (e.g. AntiTheSis 3 was re-scheduled in 2016 after technical unforeseen troubles during AntiTheSis 1 in 2014-15). However, many members of the consortium have a great experience in field works and oceanographic cruises in tropical region since more than 15 years, ensuring the achievement of objectives. From a paleontologist perspective, GAARAnti is a risk-taking project, as almost no fossil mammal record has been published from LA so far. Nevertheless, our team has a decade-long experience in finding fossil vertebrates and associated organisms in so-considered "azoic" deposits, especially under challenging tropical conditions (see **Antoine et al., 2016**), which maximizes the chances of considerably increasing our knowledge of the mammalian paleodiversity from LA. Moreover, our team will get access to unpublished fossil and recently extinct mammal collections from the LA and Puerto-Rico hosted in European museums.

Technical risks, related to analytical works on both biological and geological samples (***Tasks 1 and 2***), are already handled every day by each partner and in case of breakdown of analytic devices, we will be able to perform analysis from laboratories networks of CNRS-INSU or -INEE to which partners belong. Risks related to the modeling part of the project (***Tasks 4 and 5***) rely mainly on the development of codes. However it must be pointed out that the codes we will use have been written or developed by members of the consortium (RPANDA: **Condamine et al., 2013**; **Morlon et al., 2016**; ADELI 2D/3 D: **Hassani et al., 1997**; **Bonnardot et al., 2008**; Christensen's 2D code: **Arcay, 2012**).

II. Project organisation and means implemented

II.1. Scientific coordinator

Ph. Münch (51 years old), coordinator of the GAARAnti project, is full Professor at university of Montpellier and Deputy Director of partner-1 (GM) which comprises 161 persons including 42 phD and post-docs. The project coordinator was previously head of the team "Dynamique de la Lithosphère" at GM and Deputy Director of his former laboratory at the university of Marseille. The project coordinator also was PI of eight national research programs (DyETI, Chantier Antilles, CNRS-INSU, Actions Marges), of a WP in a european project (FP7-IRSES) and of two marine cruises in fore-arc and back-arc settings (Antilles, Mediterranean). Thus, he has a solid experience in the management of more or less large teams and of scientific projects (CV in appendix). The project coordinator is used to collaborate in projects with members of partners 2 and 3 (Nat Geo Grant #9971-16 and Labex CEBA with **partner 2**; Ka-Shallow 2006-2009; Antithesis 2014-2016; GARANTI-2017 with **partner 3**) and of course with partner 3 members (e.g. INSU Syster, Tellus; MEDYNA; PHC Toubkhal). At last, it must be pointed out that geologists from Pointe-à-Pitre have been associated to GM since 2015, that implying constant and numerous contacts with the project coordinator/Deputy Director of GM.

The project coordinator will be fully involved in the project and at different levels. He, together with all task PIs, will be in charge of monitoring the progress of research activities, as well as making decisions regarding the organization of the project (***Task 0***). He will be also co-PI of the most integrative task of the project (***Task 5***) in order to ensure the gathering of various results from all other tasks necessary to perform birth-death models. He will participate to the GARANTI cruise (***Task 3***) scheduled before the beginning of the project. During the campaign he will be in in charge of leg 3 (core sampling/dredging) with J.J. Cornée (co-PI task1). Eventually, he will take part in some field and analytical (geo- thermo-chronology) works during the course of the project (***Task 1***).

II.2. Consortium

The GAARAnti project is a striving and multidisciplinary pioneer project at the frontier of geological

and biological sciences; it brings together many experts in Geodynamics, Structural geology, Sedimentology, Geo- and Thermo- chronology, Geophysics, Paleontology, Molecular biology, Phylogeny, Geo- and Bio-modeling in a common aim. Overall, this justifies the size of Consortium (35 researchers and engineers) regrouped in three main partners. The consortium has been built in order to fulfill the different specific objectives of five tasks and on its ability to achieve to unravel the role of LA subduction dynamics in the promotion or blocking of terrestrial faunas dispersal between South America and the Greater Antilles.

As the geological record is mainly located offshore (***Task 3***), many (15) collaborators from **partners 1-GM and 3-GéoAzur** are involved in a marine cruise (GARANTI cruise, 48 days offshore) in order to conduct new (since the 1980's!) geophysical and geological acquisitions in the back-arc domain and to process and study acquired data in the course of the project. Members of partners 1 and 3 involved in Task 3 have a great experience at sea since more than 20 years. They have participated to numerous oceanographic campaigns, notably in the LA since 15 years, and some of these campaigns were led by some members of the consortium (SISMANTILLES: **M. Laigle**, KaShallow**: J.F. Lebrun** and **Ph. Münch**; AntiTheSis: **B. Marcaillou** and **J.F. Lebrun**; GARANTI: **J.F. Lebrun** and **S. Lallemand**) (**see refs in section I.2**). Moreover some members of the consortium are renowned for their works: S. Lallemand was rewarded, in 2013, by the Silver Medal of CNRS and M. Laigle, B. Marcaillou and J.F. Lebrun obtained, in 2015, a scientific award from the Simone et Cino Del Duca foundation of the Institut de France for the project of "OBservatoire SIsmologique Virtuel de la subduction Antillaises".

Onshore studies (Tasks 1 and 2) will be multi-proxies (basin analysis, substratum exhumation history and mammal paleontology) and necessitate the involvements of collaborators from **partners 1 and 2-ISEM**. The teams "Géologie des Réservoirs et des Ressources" and "Dynamique de la Lithosphère" from **partner 1** are largely involved in the project and work together on subduction dynamics since more than10 years, and particularly on vertical motions of the overriding plate, thanks to basin analysis and exhumation histories of substratum rocks, mainly in the Mediterranean and LA subduction zones (**see refs in section I.2**). Biologists and paleontologists from **partner 2** have a renowned experience on Cenozoic Neotropical mammals and associated vertebrates (***Tasks 2 and 5***; phylogeny and biogeography; e.g. **Fabre et al., 2014**; **Antoine et al., 2016, 2017**). They have been working together in Amazonia and French Guiana for the last decade, further benefiting from fruitful partnership with their external collaborators network (e.g. **Delsuc et al., 2016**), regarding adjacent landmasses. The consortium gathers world-leading authorities on xenarthrans, rodents and primates, and their biogeography that are already working together in the course of international programs led by members of the consortium (Labex CEBA - SOURCE project: **P.O. Antoine**; ERC ConvergeAnt and Labex CEBA - Neotrophyl project: **F. Delsuc**).

II.3. Means of achieving the objectives

II.3.1 Description by Task

♦***Task 0*: Coordination**

The project leader and the task PIs will be in charge of monitoring the progress of research activities, as well as making decisions regarding the organization of the project. One meeting, including around 20 participants, will be held every year in Montpellier. These meetings will be based on scientific presentations from all tasks followed by discussion, insuring the circulation of information among the consortium. We plan to invite some external collaborators to these milestone meetings in order to benefit from their expertise and to favor exchanges beyond the formal partner members. These annual meetings will be complemented by quarterly visioconferences gathering the coordinator and the task leaders, to check the running of the tasks and if ever, identify early emerging limits or problems and find adequate solutions. In addition, regular information meetings between participants involved in the same task will be scheduled. At last we will propose special sessions on various issues at national (RST, APF) and international congresses (EGU, IPC5, Evolution) in order to communicate regularly with expert networks and more largely.

We are confident in a successful synergy between participants because some of them share long-standing collaborations insuring an informal but efficient flow of information and results and because

many of them are involved in more than one task (see Summary table). Two partners of the project, GM and ISEM, are located in Montpellier and in the same building, thus facilitating regular communication and informal meeting organization. In addition, the collaborators located in LA have been administratively attached to Geosciences Montpellier since 1/01/2015. Moreover paleontologists from partner 2 are used to collaborate with both geologists from **partner 1** and biologists from **partner 2.**

The scientific program involves five scientific tasks that are tightly interconnected (**Fig. 5**) towards one objective: unraveling the relationships between the evolution of the Neotropical terrestrial Caribbean biodiversity and dynamics of the Lesser Antilles subduction zone. Four tasks have been identified based on required expertise and one (***Task 5***) is specifically devoted to gather all the results from other tasks into integrative model(s). They can be summed up as follow (**Fig. 5**).

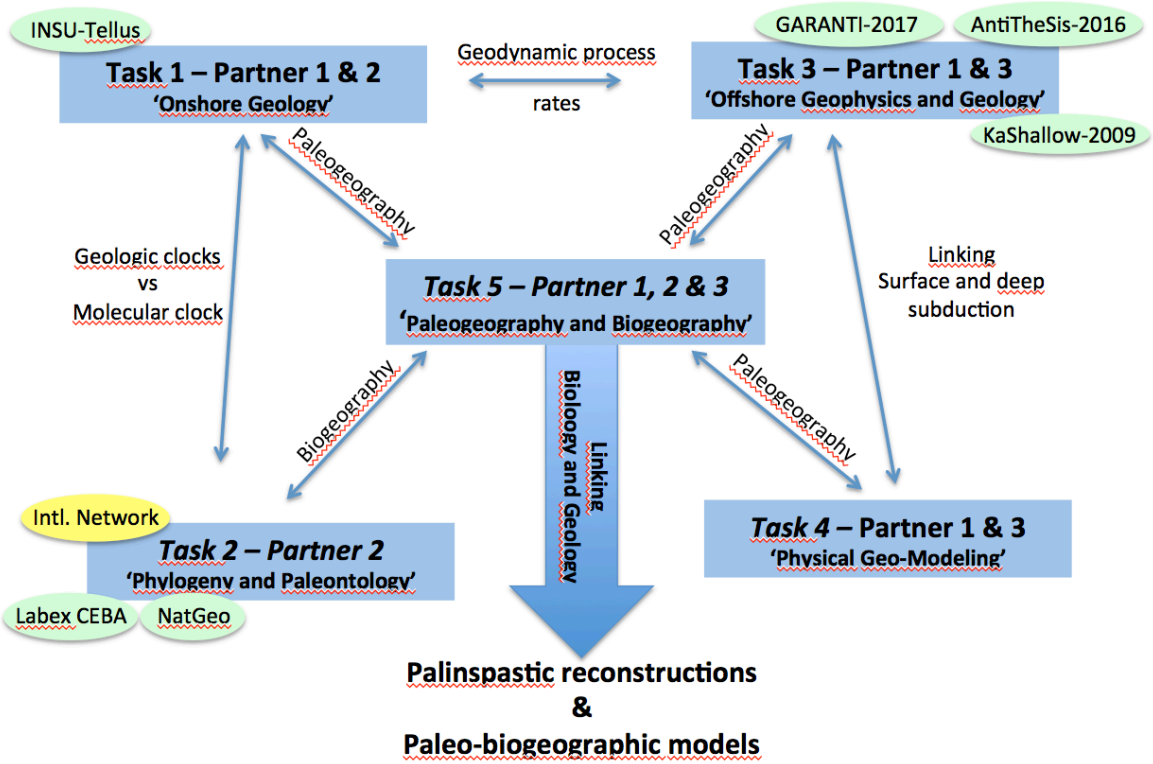

Figure 5. *Articulation between the five different scientific tasks of* ***GAARAnti*** *project and surrounding projects, led by members of the GAARAnti consortium, and which will co-fund some aspects of our work (see section 4.3, Context).*

♦*Task 1*: Onshore geology: Quantification of vertical motions PIs: M Philippon (GM) & JJ Cornée (GM)

Formal partner members: N. Arnaud (geo-thermochronology), M. Bonno (geo-thermo-chronology), D. Bosch (geochemistry), JL Léticée (carbonate sedimentology), Y Mazabraud (tectonics), G. Merzeraud (sequence stratigraphy), P. Monié (geo-thermo-chronology), M. Noury (geo-thermo-chronology), E. Oliot (metamorphic petrology).

External collaborators (Experts): J.C. Braga (Univ Granada; tropical carbonates, red algae), M. Bernet (IsTerre, Univ. Grenoble; fission tracks), M. BouDagher-Fadel (NHM, London; large benthic foraminifers), H. Drinia (benthic forams, paleobathymetry), Y. Fietzke (GeoMar, Kiel, U-Th datations), M. Melinte (nannofossils, biostratigraphy), S.F. Mitchell (Univ Kingston, Jamaica; Neogene corals of West Indies), F. Quillévéré (planktonic forams, biostratigraphy), D. Van Hinsbergen (Utrecht University, paleomagnetism).

Objectives **–** This task aims at refining the Eocene to present day paleogeographic evolution of the Lesser Antilles through paleo-environmental reconstructions and accurate chronostratigraphic constraints, which is key for studying the dispersals of terrestrial faunas (***Tasks 2, 5***). Onshore-offshore correlations (***Task 3***) will permit to establish the paleogeography from Aves Ridge to the fore-arc. Task1 will provide vertical motion rates in different parts of the arc to validate subduction modeling (***Task 4***). Four key periods are identified: Late Oligocene (arc extinction), early Miocene (westward arc migration), late Miocene (large scale extension) and Pliocene-Pleistocene (climate - tectonic interactions). The targeted islands are: (1) Puerto Rico and St Croix, along the northern limit

of the arc; (2) Anguilla, St Martin, St Barthélemy and Antigua in its northern part; (3) Martinique and Grenada in its central part; (4) Tobago and Venezuelan islands near its southern limit (**Fig. 3**).

Methodology – In order to provide a quantitative estimate of the net vertical motions (*i.e.* corrected from the signal related to sea level variations) at different places through Cenozoic this task will combine basin analysis, low temperature thermochronometry and structural analysis.
- Basin analysis. Reference synthetic sections will be established and accurately dated using an integrated approach (**Münch et al., 2014**) including micropaleontology (foraminifers and calcareous nannofossils), magnetostratigraphy and $^{40}Ar/^{39}Ar$ dating. Sedimentological, paleontological (corals, mollusks, red algae, selachians, foraminifers…) and stable isotopes studies will be conducted. The combination of the results will lead to (1) an accurate reconstruction of paleoenvironmental changes through time, especially paleobathymetric variations at each locality (**Guinot et al., 2012**); (2) estimate uplift or subsidence by adding or subtracting eustatic amplitudes (Miller et al., 2011) and elevation to paleobathymetric results; (3) regional correlations using high-resolution sequence stratigraphy (**Merzeraud, 2009**). Paleo-shorelines and their dating (U-Th datings on aragonitic organisms) will also be used for Quaternary deposits. Onshore-offshore correlations will be insured as all these features are found in the northern arc at shallow depth (**Leclerc et al., 2014**) (***Tasks 3, 5***).
- Structural analysis will allow identification of the main onshore faults responsible for local vertical motion, their kinematics and their offsets. These results are necessary to better constrain vertical motion calculations, especially concerning syn-sedimentary activity and post-deposition movements.
- Basement P, T, t history. Petro-geochemistry and low temperature thermochronometry (Fission Tracks and U-Th/He on both zircon and apatite) will allow obtaining the cooling/exhumation history of the basement rocks. Thermodynamic and thermal modelings will provide P, T paths and T,t histories, respectively.

Deliverables – • Refined and new integrated chronostratigraphic and sequence stratigraphy frames for Cenozoic sedimentary basins. Regional correlations.• Dating the basement rocks and modeling its cooling/exhumation history.• Accurate dating of sites containing mammalian fossils for phylogenetic inferences (***Task 2***).• Paleobathymetric changes for each studied island.• Mapping of regional and local emersion surfaces.• Quantification of vertical motions and their timing.• Deciphering climatic and tectonic driving forces of the vertical motions (especially for the Quaternary). • Onshore-offshore correlations (***Task 3***). • A major contribution to paleogeographic maps (***Task 5***).

Risk assessment – As this task is mostly based on field investigations, we will schedule our missions during intercyclonic periods. In case of breakdown of our analytic devices, we will be able to perform analysis in the geochemistry laboratories network of CNRS-INSU.

♦*Task 2:* Recent and fossil mammals from Lesser Antilles and their biogeographical bearing

PIs: PH Fabre (ISEM) & PO Antoine (ISEM)
Formal partner members: S. Adnet (marine vertebrates), F. Catzeflis (West Indian mammals), F. Condamine (multi-taxon West Indian biogeography), F. Delsuc (mammalian phylogeny), P.-H Fabre (West Indies mammalian phylogeny and biogeography), L. Hautier (mammalian morphology, fieldwork), L. Marivaux (paleomammalogy, fieldwork).
External collaborators: J Vélez-Juarbe (Los Angeles Museum), R MacPhee (AMNH), M Iturralde-Vinent (MNHN, La Habana); M Sánchez-Villagra (Zurich Museum), C Jaramillo (STRI), R Salas-Gismondi (MHN Lima, Peru), F Pujos (IANIGLA, Argentina).

Objectives – We will collect an exhaustive sampling of WI land mammals, for reconstructing their phylogeny (DNA, ancient-DNA, and morpho-anatomy), based on published proxies and new data regarding living, recently extinct, and fossil taxa. Paleontological fieldwork will be undertaken in Trinidad and Tobago, St-Martin+St-Croix (near GA) and La Blanquilla (near South America), to enhance the meager fossil record from the LA (MacPhee, 2009). Taxonomic groups of interest are sloths, platyrrhine primates and rodents. All these data will allow for better constraining phylogenetic frames of their Caribbean representatives. This integrated work (phylogeny + paleontology) will feed alternative hypotheses likely to best match the biogeographical distribution of WI mammals, in terms of pathways (GAAR vs. LA), geographic origin, timing, and biogeographical processes (vicariance/dispersal/island hopping). Any results from this task will be a primary input for the Task 5.

Methodology –

- Sampling (field and museums). Palaeontological fieldwork, co-funded by **NeotroPhyl**, will be undertaken through three campaigns in key insular sedimentary units likely to yield land mammal remains (fluvio-tidal channels, lahars, cave deposits). Targeted islands are Trinidad/Tobago, St-Martin-St Barth-Anguilla (LA) and near the AR (La Blanquilla, St-Croix), and stratigraphic intervals include the: *a)* Eocene-Oligocene transition (icehouse Earth), likely to explain the earliest dispersals of caviomorphs, sloths, and monkeys from South America; *b)* Miocene, likely comprising dispersal/vicariant events for monkeys, sloths, and rodents; and *c)* Pleistocene-Holocene interval, with rodents, sloths, and monkeys (**Fig. 2**). We will prospect, screen wash clays or loose sediments, and acid-etch indurate rocks, for finding fossils. Members of the consortium will also consider pollen (expert: C. Jaramillo) and aquatic vertebrates (experts: **S. Adnet**, R. Salas-Gismondi, J. Vélez-Juarbe) allowing for paleoenvironmental reconstructions (vegetation cover, salinity, and paleobathymetry). In tight connection with ***Task 1***, an integrated chronostratigraphic approach (**Münch et al., 2014**) will allow refining mammal biostratigraphy in LA.

- Phylogenetic methods (all specimens). The team will use novel protocols for extracting/amplifying DNA, achieved on Caribbean rodents (**Fabre et al., 2014**), and design in-silico reconstructed ancestral sequences, for inferring extinct taxa phylogenies, as performed on glyptodonts (**Delsuc et al., 2016**).

- Geometric morphometrics (all specimens). These non-destructive methods are complementary to phylogeny-based methods. As such, they are either likely to test phylogenetic hypotheses or to bring further information regarding biogeographical patterns. Specimens will be photographed in museum collections, and processed through photogrammetry (Agisoft Photoscan software).

Deliverables – Mammalogists and paleomammalogists of our consortium will provide comprehensive and time-constrained phylogenies for platyrrhine primates (three–six extinct species; MacPhee, 2009), sloths (~15 extinct species; Pujos et al., 2017), and rodents (11 living and 35 extinct caviomorph species; ~15-20 extinct muroid species). These phylogenetic results will deliver a key input for the ***Task 5***, to be confronted with results of other tasks (geological data and tectonic models). This task will have a positive return to society, in disseminating knowledge about mammalian history in LA, before and during Amerindian times (Caribs), and after the arrival of Europeans. This will allow for providing first-hand information for pupils, students, and civil society from LA about introduced mammals and their bearing on past/recent/future Caribbean biodiversity as a patrimony to care about.

Risk assessment – From a (paleo-)mammalogist perspective, GAARAnti is a risk-taking project, as very few fossil mammals have been discovered so far in LA. The virtual lack of fossil record in LA/Aves Ridge islands may be then confirmed a posteriori, if no fossil specimen of interest is unearthed during GAARAnti. However we are confident in our ability to increase the knowledge of the mammalian paleodiversity from LA: e.g., a preliminary one-week long fieldtrip has taken place in February 2017 with the help of local amateurs and has confirmed the occurrence of fossil mammal remains (hutia rodents among others) on all islands from the Anguilla bank, which is particularly promising. DNA degrades also faster under tropical conditions, which may somewhat discard analyzing some non-living specimens, either stored in museums or found during GAARAnti. Phylogenetic works may be complicated as DNA degrades faster under tropical conditions. However, thanks to loans, we have already obtained several subfossil samples (rodents, sloths), some of which have already been successfully sequenced through preliminary experiments, ensuring the feasibility.

♦*Task 3*: Offshore geological and geophysical records of the tectonic evolution of the subduction zone PIs: B Marcaillou (GA)& S Lallemand (GM)

Formal partner members:D. Arcay (geophysics), M.-O. Beslier (MCS), P. Charvis (WAS), J.J. Cornée (sedimentology), A Heuret (geodynamics), M Laigle (WAS), JF Lebrun (WAS and MCS), JL Léticée (sedimentology), B Mercier de Lepinay (geophysics), P Münch (magmatic petrology), E. Oliot (metamorphic petrology), L Schenini (MCS), B Yates (WAS) and a requested PhD student (ANR funding).

External collaborators: P. Mann (Houston Univ.), A. Agranier (Université de Bretagne Occidentale, UBO), MA Bassetti (CEFREM, Perpignan), D Graindorge (UBO), F Klingelhoefer (IFREMER), M. Melinte (GeoEcoMar, Bucarest), M. Paulatto (Imperial College London), F Quillévéré (Univ Lyon I), C. Padron (Simon Bolivar Univ., Caracas), F. Audemard (INVISIS).

Objectives – In this task we aim to explore the largest portion, now submerged, of the area that might have been used as a “land bridge” between South America and GA, i.e., the Aves Ridge and the LA arc (see rodent’s silhouettes in Figure 6). Indeed, we clearly lack of constraints regarding the back-arc region, except in its southern part and including the Aves Ridge, as explained in chapter I.2 (State of the Art). The GARANTI cruise (May-June 2017; PIs: **J.-F. Lebrun & S. Lallemand**) will likely provide enhanced geophysical and geological constraints on the splitting of the Mesozoic arc into a remnant arc (Aves Ridge) to the west and an active arc (LA) in the east in Early Cenozoic times (***Task 1***). We expect to largely improve the timing and progress of the tectono-magmatic phases including arc splitting, back-arc rifting (B) and spreading (A), remnant arc cooling and subsidence (E), active and past LA arc and fore-arc tectonic evolution including uplift and subsidence (C), interaction with the Bahamas Bank continental lithosphere in the northern part during the Paleogene (C, D) (**Fig. 6**). We will also explore the possibility of a structural boundary (F) segmenting the eastern part of the Caribbean plate into a northern and a southern domain that might behave independently. To address these key questions, we will exploit geophysical data from the GARANTI cruise in the back-arc domain all the way along the Aves Ridge (E), with connecting lines into the arc domain (C), that will combine deep seismic to get the deep structure, high-resolution seismic to map the sedimentary architecture and deformation style, and rock sampling to calibrate our 3D interpretations (**Fig. 6**).

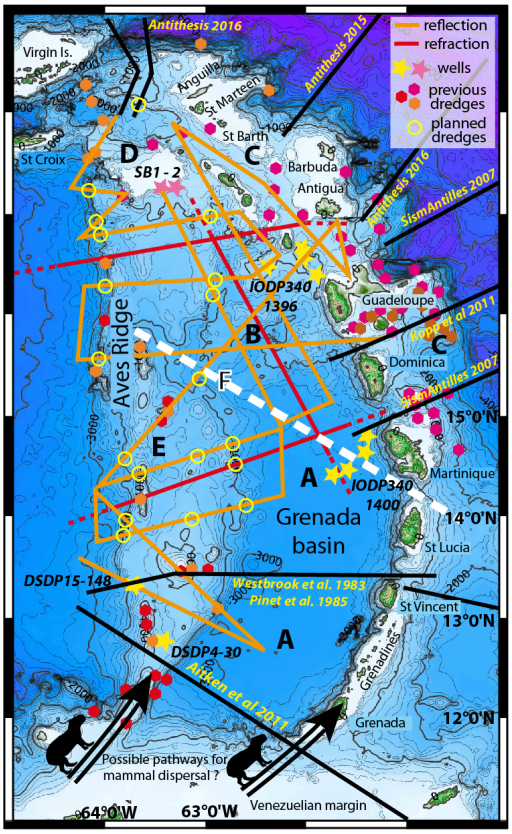

Figure 6*: Working plan during GARAnti cruise: WAS lines in red (20 days), MCS in orange (20 days) and sampling sites with yellow circles (7 days). Stars are academic or petroleum wells (used as stratigraphic references for seismic lines calibration). The white dotted line outlines a possible segmentation of the system. A-F letters refer to the main text.*

Methodology - An extensive set of 3 WAS, 20 MCS and multiple rock data (20 dredging sites) will be acquired in due time onboard R/V L’Atalante (May-June 2017), allowing data reduction to be performed by PhD and Master students during the timeframe of the ANR project. MCS will provide constraints on the geometry of the major upper crustal units and resolve the top of the crust, whereas WAS will provide deeper constraints on its geometry down to the Moho at a kilometric resolution. Several newly acquired seismic lines will be linked with previously acquired ones (SismAntilles, AntiTheSis, US surveys) as well as DSDP drilling sites. MCS data will be pre-processed onboard and further processed in our laboratories with advanced seismic processing up to pre-stack depth migration on the *Geovation®* software of the CGG company (e.g. **Laigle et al., 2013**; **Marcaillou et al., 2016**). WAS data quality will also be checked onboard with a preliminary inversion of the first arrival times of the recorded seismic phases. The deep structures and the 2D velocity field will be constrained through a joint inversion of the refracted first arrival-times and of the reflected secondary arrival-times with the *Tomo2D* code (Korenaga et al., 2000), following a strategy already used in Geoazur (e.g. **Badji et al., 2015**). Dredge samples analysis will include facies analysis for sedimentary rocks in order to provide evidences for paleo-environmental deposit conditions of sedimentary units identified on seismic section (including shallow reefal environment and/or emersion). Petrologic studies, major, trace, and isotopic elements analyses for magmatic or metamorphic rocks will give clues relative to the magmatic activity along the Aves Ridge. The biostratigraphic ages determination and radiochronologic datation will provide chronostratigraphic constraints onto the seismic stratigraphy. The exact location of dredge samples along the seismic lines, together with sismostratigraphic facies interpretation correlated through the seismic grid will allow characterizing the basin architecture in space and time and thus will provide constraints onto the strain and vertical motions history of the Grenada Basin and the Aves Ridge.

Deliverables **–** Refined crustal velocity distribution across the arc, the back-arc and the Aves Ridge along 3 cross-cutting transects will constrain the deep crustal structure and Grenada Basin global architecture. Basin analysis, through sequence stratigraphy, and sample analysis (with ***Task 1***) will constrain the splitting of the arc and thus the Aves arc history. The quantification of the duration of

uplift / subsidence periods together with paleo-environmental constraints will allow the spatial determination of emerged areas through times (***Task 5***). Tectonic interpretations will provide a renewed understanding of geodynamical processes responsible for evolution of the Aves Ridges and Grenada Basin and thus key constraints for modeling (***Task 4***).

Risk assessment – see I.3. Sampling sites in complement with available drill/dredge/core data could be too scattered or too shallow for characterizing all deep seismic units. Such a situation will reduce our resolution for the early Cenozoic events and possibly force us to consider several scenarii that will be likely constrained by analog or numerical models. Considering the main target, i.e., providing paleo-geographical reconstructions for the Cenozoic interval in the eastern Caribbean, seismic facies interpretation will reasonably assure to provide crucial new constraints.

♦*Task 4*: Physical modeling of subduction-induced vertical motions PIs: D. Arcay (GM) and R. Hassani (GA).

Formal partner members: F. Garel & M. Philippon (kinematic and numerical modeling), C. Tibéri and C Cadio (geophysics), A. Heuret, B. Marcaillou, M. Laigle, S Lallemand and JF Lebrun (geodynamics), 12 months post-doc fellow (ANR funding)
External collaborators: F. Funiciello (Roma Tre)

Objectives – In this task, we intend to model subduction-induced surface motions in the Lesser Antilles using numerical, analog, and kinematic approaches. We will first focus on the Guadeloupe archipelago, as accurate geological records of 3D motions since ~40 Ma are there available (**Cornée et al., 2012; Münch et al., 2014; De Min et al., 2015**), then extend the study area to the Lesser Antilles arc and back-arc domains: Our models should provide insights on the set-up promoting extensive stresses either normal to the ridge (responsible for Aves arc splitting), or, on the contrary, parallel to the Aves ridge (see ***Task 3***). Several mechanisms triggering surface motions will be tested:
- in 2D: slab dip angle variations resulting from aseismic ridge subduction and slab breakoff (Bouysse and Westercamp, 1990); surface kinematic and trench motion changes, and effects on arc stresses (**Arcay et al., 2008**); adjustment in subducting slab morphology (**Garel et al., 2014**).
- in 3D, modeling the Lesser Antilles specificities: (i) trench curvature and convergence obliquity, as a convex trench favors compression instead of extension within the upper plate (**Bonnardot et al. 2008**; (preliminary experiment in **Fig. 7**); (ii) collision with the buoyant Bahamas Plateau at the Northern boundary; and (iii) subduction of ridges perpendicular to the trench (Barracuda and Tiburon; Martinod et al., 2013). Lastly, we will test different lateral boundary conditions (N and SE boundaries), especially the West-East slab tearing along the Southeast transform boundary.

Methodology – Topography evolution depends on (1) tectonic deformation of the whole lithosphere and (2) deep slab-mantle coupling and associated viscous flows, generating dynamic topography. Item (1) depends on elasto-plastic rheology, while item (2) on ductile flow laws. Simulating (1) and (2) simultaneously (Faccenda et al. 2012) requires huge computational resources, hard to manage at subduction scale. We prefer to combine complementary simulation codes, easier to handle and largely developed by the team. Brittle-elastic plates (1) will be simulated using ADELI 2D/3D (**Hassani et al., 1997**; **Bonnardot et al., 2008**), whereas dynamic topography (2) will be computed using Fluidity 2D/3D (**Garel et al., 2014**) or Christensen's 2D code (**Arcay, 2012**). A benchmark will be performed to assess each modeling tool's sensitivity. A new ADELIDF version will allow for computing topography evolution by fully coupling elasto-plastic plates to the viscous mantle, in 2 and 3D (**Cerpa et al., 2014, 2015**), but only in limited cases where plate-mantle couplings are not too strong. Such modeling will be devoted to the required 12 months post-doc. To benchmark numerical results, analog experiments will be carried out in Laboratory of Experimental Tectonics (collab. F. Funicielo ; Roma Tre Univ.) by monitoring surface topography

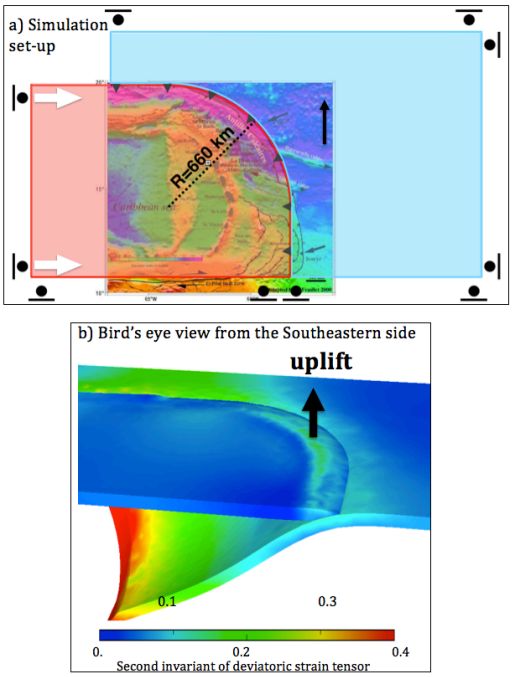

Figure 7*: Preliminary 3D modeling of the Lesser Antilles subduction zone using ADELI3D.*

thanks to a laser beam (e.g., **Husson et al., 2012**). Finally, outputs of 2D and 3D models will serve as tightening paleo-geographic and kinematic reconstructions, using GPlates software.

Deliverables – Seismic imaging (e.g. van Benthem et al., 2013, **Laigle et al., 2013**) will constrain the interplate and subducting slab geometries. Surface gravimetry (e.g. **Gailler et al., 2013**) will point to local deformation patterns (e.g. subsident basin), while spatial gravimetry and gradiometry will help in estimating local plate elasticity and isostasy. From our modeling, we will extract scaling laws linking subduction parameters (velocities, obliquity…) and surface motion characteristics: amplitude, vertical velocity, and time-scale. These outputs will be carefully analyzed in relation to ***Tasks 1* and *3*** results, to adjust the modeling strategy. Moreover, subduction model integration with paleo-kinematic reconstructions will serve as inputs for ***Task 5***. At last, as the relationship between deep geodynamics and surface deformation remains a fundamental issue in geodynamic modeling, our results will interest a broad community of scientists.

Risk assessment – Our modeling built at the subduction system scale will not include surface processes likely to affect topography changes, such as erosion/sedimentation and obviously, eustatism. However, Tasks 1 and 3 might provide estimates of recorded erosion/sedimentation rates, that we will add/substract to the velocity of surface motion predicted by our simulations. An erosion subroutine had nevertheless been successfully implemented in the ADELI2D version (Steer et al., 2011), which might be a possible solution to partly compensate this hindrance and estimate its influence.

♦*Task 5:* Reconciling Lesser Antilles mammalian record and Caribbean (paleo)-geography
PIs:F Condamine-ISEM & Ph Münch-GM

Formal partner members: S. Adnet (paleoenvironmental reconstruction), P.-O. Antoine (paleo-biogeography), J.-J. Cornée (paleogeography), F. Delsuc (biogeography), P.-H. Fabre (biogeography and paleo-biogeography), J.L. Léticée (paleogeography), L. Marivaux (paleo-biogeography), B. Mercier de Lepinay (paleogeography), G. Merzeraud (paleogeography); M. Philippon (geodynamic reconstruction, G-Plate modeling) and a requested 18-months post-doc fellow (ANR funding).
External collaborators (Experts): H. Morlon (ENS Paris, UMR 8197; mathematics applied to ecology), B. Vrielynck (Istep, UPMC & *Commission de la Carte Géologique du Monde*; palinspastic and paleotectonic maps)

Objectives - This task aims at answering the following question: ***How was Caribbean biodiversity generated and maintained, and how geological changes affect(ed) this biodiversity?*** The objective of this work package aims at teasing apart the contribution of each potential driver in shaping the Caribbean biodiversity; namely we will test for the role of different biotic and abiotic (physical) factors. We will specifically study the underlying processes responsible for the generation and maintenance of the biodiversity pattern in the region. For this purpose, we will set up and conduct a meta-analysis making use of the biological data generated in the form of dated phylogenies combined with the paleogeographic data both generated during GAARAnti.

Methodology – We will use macroevolutionary approaches based on a maximum likelihood framework (**Figure 8 in appendix**), comprising three steps, to unravel the general evolutionary trends.

Step 1 consists of a synthesis of biological and paleontological data (taxonomy, phylogeny and ecology) on one hand and of onshore/offshore geological data on the other hand. All available data will be geo-referenced in a single GIS-based project allowing drawing palinspastic and biogeographical maps at different time-slices (collab. B. Vrielynck) (e.g. Barrier & Vrielynck, 2008).

Step 2 consists in using/developing birth-death models. This step will be the main focus of the post-doc fellow. This step will aim at testing the:
• Role of global and abrupt historical events. We will infer the main periods of diversification and test their potential relation to past environmental changes using episodic birth-death models following the TreePar approach (Stadler, 2011). The diversification dynamics within the Caribbean Islands will be interpreted under three main macroevolutionary models: (1) '*cradle of diversity*' hypothesis, (2) '*museum of diversity*' hypothesis, (3) '*turnover*' hypothesis. Contrasting these three hypotheses for many groups will contribute to a better understanding of the macroevolutionary trend governing Caribbean biodiversity through time.
• Effects of past climatic (temperature and eustatic) changes. To gain further insight into the role of past climatic fluctuations, we will estimate the clade-specific responses to past environmental changes

using a continuous birth-death diversification model (**Condamine et al. 2013**). This model estimates whether speciation and/or extinction responded positively or negatively to warming (and cooling) events, and to what extent. However, the global climate profile (Zachos et al., 2008) may have differed at regional scales. The generation of sea-water temperature estimations from the ***Task 1*** will be used as a better proxy for the Caribbean climate variations over the Cenozoic. We will compare the fit and performance of the two climate profiles (global and regional). This will allow understanding the role of climate fluctuations on the Caribbean island system where species diversity is high and the level of endemism highly elevated.

• Role of the land area size over time. We will investigate diversification dynamics allowing the incorporation of new geological data into the diversification model as already stated for temperature and eustatic change variables (**Condamine et al. 2013**). In this case, we will make use of the estimated land surface (area size, in km^2) that was above water, and thus available for terrestrial organisms over the course of the Cenozoic (***Tasks 1 and 3***). In applying this model to Caribbean clades, we aim at (1) testing whether speciation and/or extinction rates were linked to the surface area available, (2) testing the theory of island biogeography that states the "island" species-area relationships (MacArthur and Wilson, 1967), and (3) extending the species-area theory that is mostly (if not entirely) based on ecological studies to geological timescales.

• Estimation of geographic range evolution. To infer the evolution of geographic ranges we will rely on probabilistic approaches based on the Dispersal-Extinction-Cladogenesis (DEC) model (Ree and Smith, 2008), notably with the use of the recently developed DECX model (**Beeravolu and Condamine under revision**). The DEC/DECX approach allows the comparison of alternative biogeographical models using maximum likelihood to select the key processes that have shaped the clade's biogeography. In using our refined paleogeographic scenarii, we will create a time-stratified framework that will represent the appearance/disappearance of islands. We will explain the ancestral origin and the colonization routes of our focal clades by comparing a set of biogeographical models with parameters mirroring cladogenetic and/or anagenetic processes. This could potentially highlight the role of now sunken islands (i.e. paleo-islands), as it has been evidenced in other regions (e.g. Canary: Mairal et al., 2015; New Caledonia: **Condamine et al. 2017**).

Step 3: The third step of the task will have the main objective at **developing a new type of birth-death model that aims at integrating several potential factors simultaneously**. **F Condamine** will handle this part with H. Morlon (authors of RPANDA; **Morlon et al., 2016**) as an external expert of birth-death models and with the help of the post-doc fellow. We will set up a model testing approach in which the diversification can be correlated to each variable individually or correlated to multiple variables simultaneously. The explanatory power of the different models will be assessed using the corrected Akaike Information Criterion and Akaike weights. Comparing the fit of each model, we could select the best-fitting one. Doing so, one can assess whether a single factor (abiotic or biotic) or both abiotic and biotic factors triggered the past diversification.

Deliverables: Palinspastic and biogeographical maps will be a first deliverable of this Task. **The constructed database will also be an open access deliverable**. It will lead to the inference of macroevolutionary processes (speciation and extinction) that shaped Caribbean evolutionary radiations for the focal groups. We aim at identifying general trends on the key determinants, may they be ecological or historical, that have contributed to the origin and maintenance of the regional biodiversity. We also hope to unveil the role past environmental changes played on the clades' diversification.

Risk assessment: This task is intimately linked to the previous tasks, which will provide the solid grounds for the phylogenetic data, and climatic/geological models. Time-calibrated phylogenies are a prerequisite to realize the objectives of this task. Indeed estimation of diversification rates requires a robust and fully resolved topology and accurate estimates of branch lengths and species divergence times. However, the proposed team (***Task 2***) is a world-leading group on the phylogeny and fossil record of Neotropical mammals, and has already accumulated genetic and fossil data for all the groups under survey. The climatic and geological data are also a key component to achieve the objectives of this task. Furthermore, geological and climatic data are in hands of the team, even if they require a specific treatment and compilation to be efficiently used.

II.3.2 TABLE of previous/ongoing projects in connection with GAARAnti

Title of the call for proposals, source of funding	Project title	Name of coordinator	Starting date/End date	Grant amount	Part.	Name	Person. Month
					Of the person involved in this proposal		
Appel d'offres hauturier, Flotte océanographique Francaise, INSU/IRD/IFREMER	GARANTI	J.F. Lebrun & S. Lallemand	May 6 2017/ June 25 2017	62 200€ (INSU support to campaign) 2 295 000€ (ship’s cost for 51 days) 30 000€ (supplementary budget from **GAARAnti partners**) =2 387 200€	15	Arcay Beslier Cornée Heuret Laigle Lallemand Lebrun Léticée Marcaillou Mercier-de-Lépinay Münch Oliot Phillipon Schenini Yates	2 2 1 1 1 2 2 1 1 2 1 1 1 1 1
Appel d'offres hauturier, Flotte océanographique Francaise, INSU/IRD/IFREMER	AntiTheSis (2 legs for technical reasons)	B. Marcaillou & F. Klingelhoefer	Dec. 2013/ Jan. 2014 May 2016	2 790 000€ (ship’s cost for 62 days)	7	Graindorge Klingelhoefer Laigle Lallemand Lebrun Marcaillou Schenini	1 2 1 1 2 2 1
Appel d'offres hauturier, Flotte océanographique Francaise, INSU/IRD/IFREMER	KaShallow	J.F. Lebrun & Ph. Münch	Jan. 2009/ Feb. 2009	1 125 000€ (ship’s cost for 25 days)	5	Cornée Lebrun Léticée Marcaillou Münch	1 1 1 1 1
INSU-Tellus, CNRS-INSU	INSU-Tellus	M. Philippon	Jan. 2017/ Dec. 2017	8 500€	6	Cornée Lebrun Léticée Münch Noury Philippon	3 1 3 3 6 6
Committee for Research and Exploration of the National Geographic Society	Late Neogene in Bolivian highlands: rise of the Andes - demise of mammals?	F. Pujos	Jan. 2017/ Dec. 2017	20 000$	3	Antoine Marivaux Münch	3 3 3
Annual Call, Labex CEBA	SOURCE	P.O. Antoine		19 654€	4	Antoine Heuret Marivaux Münch	3 1 3 1
Consolidator Grant, ERC	ConvergeAnt	F Delsuc	2016-21	1,880,569€	2	Delsuc Hautier	48 12
Strategic Project, CEBA Labex	NeotroPhyl	F Delsuc	2016-19	250,000€	6	Delsuc Condamine Hautier Fabre Antoine Marivaux	6 12 3 9 3 3

II.3.3 TASKS SCHEDULE

TASKS	2017	2018				2019				2020				2021				Partner(s)
	O-N-D	J-F-M	A-M-J	J-A-S	O-N-D	J-F-M	A-M-J	J-A-S	O-N-D	J-F-M	A-M-J	J-A-S	O-N-D	J-F-M	A-M-J	J-A-S	O-N-D	
T0 - Coordination meetings	■				■				■				■				■	1,2,3
T0 - Final report and publications												■	■	■	■	■	■	1,2,3,4,5
T1 - fieldtrips		■	■			■	■			■	■							1
T1 - LT thermochonology samples preparation and analysis				■	■	■	■	■	■	■	■	■	■	■	■	■		1
T1 - Geochronology samples preparation and datings				■	■	■	■	■	■	■	■	■	■	■	■	■		1
T1 - Sedimentological samples preparation and studies				■	■	■	■	■	■	■	■	■	■	■				1
T1 - Micropaleontological samples preparation and studies				■	■	■	■	■	■	■	■	■	■					1
T1 - Paleobathymetric reconstructions								■	■	■	■	■	■	■	■			1
T1 - Quantification of vertical motions										■	■	■	■	■				1
T2 - fieldtrips		■	■			■	■			■	■							2
T2 - fossil preparation and processing			■	■	■		■	■	■		■	■	■					2
T2 - fossil analysis				■	■	■	■		■	■	■		■	■	■		■	2
T2 - museum visits			■			■			■									2
T2 - DNA sampling and processing (recent specimens)			■	■			■	■	■	■	■							2
T2 - ancient DNA sampling and processing (field, museomics)		■	■	■			■	■	■	■	■	■						2
T2 - phylogenetic analyses (molecules/anatomy/total-evidence)				■	■	■	■	■	■	■	■	■	■	■	■	■	■	2
T2 - geometric morphometric analyses				■	■	■	■		■	■	■		■	■	■		■	2
T3 - PhD					■	■	■	■	■	■	■	■	■	■	■	■		1
T3 - Geophysical data processing	■	■	■	■	■	■	■	■	■									1,3
T3 - Samples preparation and studies (geochro., sedi., petro, pal.)		■	■	■	■	■	■	■	■									1,3
T3 - 2D refraction modelling and MCS interpretation				■	■	■	■	■	■	■	■	■	■					1,3
T3 - Basin structural and stratigraphical quantitative models									■	■	■	■	■	■	■	■	■	1,3
T4 - 2D subduction numerical modeling		■	■	■	■	■	■	■	■	■	■	■	■	■	■			1,3
T4 - 3D subduction numerical modeling								■	■	■	■	■	■	■	■	■		1,3
T4 - Kinematical reconstructions								■	■	■	■	■	■	■	■	■		1,3
T4 - post-doc										■	■	■	■					1
								■	■	■	■							3
T5 - palinspastic reconstructions										■	■	■	■	■	■			1,2,3,4
T5 - analyses of biogeographic histories										■	■	■	■	■	■			2
T5 - diversification models (RPANDA and DDD)										■	■	■	■	■	■			2
T2- mixed models to be developed													■	■	■	■	■	1, 2
T5 - post-doc										■	■	■	■	■	■			2

II.3.4 BUDGET

Budget: TOTAL REQUEST: **494 810** € (+ 39 584.8€; 8% OH: OverHeads). **We have excluded from this budget all costs related to the participation of Consortium members to international congresses; costs will be requested to our institutions.**

♦**Partner 1–GM** (missions/meetings: **70 950€,** equipment: **6 000 k€,** outreach services**: 13000€,** internal services**: 35 000** €, operating costs: **10 600k€,** staff: **108 720€**, **Total: 244 270€** + 19563.2€ OH).

*MISSIONS and MEETINGS (**70 950€**+ 5672€ OH):*
- Meetings ANR: 4 meetings in Montpellier with 10 travels including 3-4 overseas flights (all partners). **30 450€** (***Task 0***) - Field investigations: 6 missions of 15 days for 3 persons (2 flights overseas / mission) with car rental and accommodations. **40 500€** (***Task 1***)

*EQUIPMENT (**6 000€**+480€ OH):*
- 3 computers. 6 000€ (***Tasks 1, 3 and 4***)

*OUTREACH SERVICES **(13 000 €**+1 040€ OH**)***
- Stable isotopes on carbonates**:** 100 samples. **2 000 €** (***Tasks 1 and 3***) – Datings U/Th on coral from uplifted marine terraces: 10 samples. **3 000€** (***Task 1***) - Apatite Fission Tracks dating: 10 samples. **3 000€** (***Tasks 1 and 3***) - Micropaleontology (forams and nannofossils): 200 samples. **5 000 €** (***Tasks 1 and 3***)

*INTERNAL SERVICES **(35 000€**+2 800€ OH**)***
- Thin sections (regular and polished). **2 400€** (***Tasks 1 and 3***)- Crushing, sieving and mineral separation. **3000€** (***Tasks 1 and 3***) - Paleodirection of the magnetic field and ages constraints.**1 000€**

(***Task 1***) - SEM analyses with EDAX analyses: **1 200€** (***Task 1***) - EPMA: X sessions. **3 000€** (***Tasks 1 and 3***) - X-Ray diffraction. **1 200€** (***Task 1***) - $^{40}Ar/^{39}Ar$ datings: 30 samples. **15 000€** (***Tasks 1 and 3***) - U-Th/He dating on apatite and zircon from basement rocks: 20 samples. **8 200 €** (***Tasks 1 and 3***)

*OPERATING COSTS **(10 600€**+848€ OH**)***
- Consumables and large capacity storage. **10 600€** (***Tasks 1, 3, 4***)

*STAFF (**108 720€**+8 697.6€ OH):*
- 3 years PhD grant. **94 320€** (***Task 3***)- Students Stipends: Master 2 students (for a total of 24 months). **14 400€** (***Tasks1, 3 and 4***)

♦**Partner 2–ISEM** (missions and meetings: **36 000€,** equipment: **3 500 k€,** outreach services: **28 000€,** staff: **93 420€**, **Total: 160 920€** + 12 873.6€ OH)

*MISSIONS and MEETINGS (**37 000€**+ 2 960 € OH):*
- Meetings. **4 000€** (***Tasks 2 and 5***) - Field and Museum investigations: 3 field trips for 5 persons (total: 50 days) and 1 mission to visit museums for 1 person (21 days). **33000€** (***Task 2***)

*EQUIPMENT (**3 500€** + 280€ OH):*
- Agisoft Photoscan (software). 3 500€ (***Task 2***)

*OUTREACH SERVICES **(28 000 €** + 2 520€ OH**)***
- DNA extraction, NGS library. **15 000 €** (***Tasks 2***) - Ancient DNA analyses (McMaster). **10 500€** (***Task 2***) - Publication Fees. **2 500€** (***Tasks2 and 5***)

*STAFF (**93420€**+ 7473.6€ OH):*
- 18 months Post-doc (exp < 2 years). **82 620€** (***Task 5***) - Students Stipends: Master 2 students (for a total of 18 months). **10 800€** (***Tasks 2 and 5***)

♦**Partner 3–GeoAzur** (missions and meetings: **8 000€,** equipment: **5 600 k€,** operating costs: **300€,** staff: **75 720€**, **Total: 89 620€**+ 7169.62€ OH)

*MISSIONS and MEETINGS (**8 000€**+ 640€ OH):*
- Tasks meetings in Brest (3 persons), Montpellier (4 persons) and Pointe à Pitre (2 persons). **8000€** (***Task 3 and 4***)

*EQUIPMENT (**5 600€** + 448€ OH):*
- 2 laptops. 2 200€ (***Task 3***) - 2 workstations. 3 400€ (***Task 3***)

*OPERATING COSTS **(300€** + 24€ OH**)***
- External hard-drive (2). **300€** (***Tasks 3 and 4***)

*STAFF (**75 720€**+ 6 057,6€ OH):*
- 12 months Post-doc (exp 2-7 years). **66 720€** (***Task 4***) - Students Stipends: Master 2 students (for a total of 15 months). **9 000€** (***Tasks 3 and 4***)

III. Impact and benefits of the project

External collaborators (Experts): J.-Y. Cariou (EA 4538–CRREF), A. Delplanque (Communication-GM), C.-H. Fargue (CDST Martinique), T. Forissier (EA4538–CRREF), G. Potiron (CCSTI Guadeloupe).

Dissemination will target both the scientific/research community (universities and research institutions worldwide) and a broader non-specialist audience (civil society, scholars, students, teachers, media). For all audience, a website will provide a clear and concise outline of the networking activities, outcomes, calendar of events and downloadable documents. Periodic updates of activities and news will be also share through social networks (Facebook, Instagram) or blogs. These online dissemination activities will be realized with the help of the Communication Service of partner 1. Media will be addressed by press releases and digital material (images, short descriptions of tasks, highlights of scientific results).

Consortium members will primarily disclose their results through submission to international peer-

reviewed journals in which the investigators have already published, such as multidisciplinary journals: *Nature, Nature Geosciences, Science, PNAS, Curr. Biol, Am. J. Sci., Systematic Biology, Geology, Ecology Letters, Gondwana Res, EPSL, Annual Reviews, Proc Roy S B, JGR* or in disciplinary journals: *Mol Phyl Evol, BMC Evol Biol, J Hum Evol, J Syst Palaeontol, Zool Scripta, J Vertebr Paleontol, J Mammal Evol, Mammalia, Journal of Geodynamics, GGG, Tectonics, Tectonophysics, PEPI,Mar. Geol., Palaeogeogr. Palaeclimatol. Palaeoecol.*

Consortium members will also propose and organize special sessions on various issues (geology, geodynamics, paleontology, phylogeny, biogeography) at national (RST, APF) and international congresses (AGU, EGU, IPC5, Evolution) in order to disseminate and share results most largely with the scientific community. As our results will challenge the GAARlandia hypothesis that is highly debated since 20 years, we are confident that proposed sessions should be looked upon very favorably.

Consortium members will also feed internet databases (SISMER, GENBANK, DRYAD, **MORPHOMUSEUM** and MORPHOBANK).

A complementary goal of the GAARAnti project is to promote the preservation of both the geological and paleontological patrimony of Antilles by conveying up-to-date scientific knowledges. Hence two local institutions of scientific popularization are associated to the GAARAnti project: "*Archipel des Sciences*" coinciding with the "*Centre de Culture Scientifique, Technique et Industrielle*" (G. Potiron) in Guadeloupe and the "*Centre de Découverte des Sciences de la Terre*" in Martinique (C.-H. Fargue). They will help to organize and host an exhibition and conferences built upon the main results of the **GAARAnti** project at the end of year 4. These organizations are used to collaborate with members of Consortium from Guadeloupe and Guyane universities.

Scientific popularization will also target scholars and undergraduate students, especially from the "*Ecole Supérieure du Professorat et d'Education*" (ESPE) of Guadeloupe in which most members of Consortium from the Antilles University are involved. We plan to interact with future teachers of primary school and 'Sciences de la Vie et de la Terre' high school teachers. Indeed the project scientific topics are largely overlapping scholar programs, peculiarly the one of the last year scientific high school ('Terminale'). Teachers, as well as students, will also be addressed through a dedicated section of the web site containing non-technical articles, digital presentations for the use in the classroom and links with the Geosciences Information of Teachers GIFT Program of the European Geosciences Union (EGU) organized by the EGU Committee on Education. In collaboration with the *Centre de Recherches et Ressources en Education et Formation* (EA 4538; T. Forissier and J.-Y. Cariou), a didactic valorization plan of technics, methods and results of the **GAARAnti** project will be developed. Considered as researcher apprentices, groups of students will follow the offshore GARANTI marine cruise during which they will experience the on-board work and life, as well as some field works. Different groups of students from Guadeloupe, Martinique and Guyane will participate and their results will be investigated following the "Context Effect for Science Learning" method (Forissier et al., 2014). Thus, beyond the popularization of the results of the GAARAnti project towards scholars, this collaboration will also lead to scientific publications in didactic sciences.

We will also popularize our results through the "*Fêtes de la Science*"/"*Faites de la Science*"/"*FestiSciences*" among others, i.e. annual events in French universities dedicated to Science popularization for students and civil society. Our results are likely to be illustrated through TV documentaries as some members of Consortium are used to participate in:

J.-F. Lebrun, J.-L. Léticée and P.-O. Antoine: "The Journey of Continents", Arte Discovery;
P.-O. Antoine, L. Marivaux: "The Mystery of the pink dolphin", France5, TV Brazil;
P.-O. Antoine, F. Delsuc, L. Hautier: "Land of Giants", Ushuaïa TV, Canada.

Current mammal diversity is a poor subsampling of their past and amazing diversity. West Indies have suffered the extinction of giant rodents, insular sloths, or primates, likely due to human colonization. A lack of evolutionary and biogeographical knowledge could lead to misleading decisions and inaccurate conservation programs. As such, our project will allow extrapolation from that on the current erosion of biodiversity in the fifth major tropical biodiversity hotspot. At last, this project will also provide valuable insights to evaluate the possible impact of climate changes and related sea-level variations on the dispersal of terrestrial mammals and associated faunas and floras.