Marine and Petroleum Geology
June 2023, Volume 152 Pages 106264 (20p.)
https://doi.org/10.1016/j.marpetgeo.2023.106264
https://archimer.ifremer.fr/doc/00833/94527/

Paleogeographic evolution and vertical motion of the central Lesser Antilles forearc since the Early Miocene: A potential driver for land fauna dispersals between the americas

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Abstract :

Phylogenetic studies of present-day terrestrial organisms suggest that faunal dispersals between South America and the Greater Antilles may have occurred during the Cenozoic through the Lesser Antilles. However, because of the lack of geological data to unravel the areas that may have emerged along the Lesser Antilles trench, the migration paths used by their ancestors remain unknown. Here, we present novel paleogeographic maps of the central Lesser Antilles (extending from Guadeloupe to Martinique islands) which are built on the basis of onshore and offshore stratigraphic correlations (50 seismic lines, biostratigraphy of 9 dredged and 29 field samples, six sedimentary logs). We find that repetitive episodes of uplift and drowning have occurred in the central part of the Lesser Antilles during the Neogene. Offshore, the Marie-Galante Basin comprises three sedimentary megasequences that deposited between: (i) the Oligocene and Early Miocene, including the extinct arc, (ii) the Middle and Late Miocene and (iii) the latest Miocene and Holocene. These sediments infill a NNW-SEE trending forearc rift that opened during the Early Miocene. The megasequences are separated by subaerial regional unconformities that affect the rift shoulders. Onshore, we show that the lower part of the carbonate platform in Guadeloupe and La Désirade has deposited during the late Messinian. In Martinique, we refine the age of the carbonate deposits belonging to the extinct arc to the Chattian-Burdigalian, and evidence a major subaerial unconformity corresponding to the Middle Miocene. We propose that between Anguilla and Martinique, from north to south, large archipelagos, which are now drowned, have existed during the

early Middle Miocene and the latest Miocene. We suggest that during the Miocene, the Lesser Antilles may have been used as a pathway for land-faunal dispersals from South America.

Highlights

► The Marie Galante Basin comprises three Eocene to present-day seismic megasequences. ► The Marie Galante Basin is an intra-arc rift with two Miocene uplifts. ► Martinique displays an early Middle Miocene uplift. ► ArChipelagos existed by the early Middle and latest Miocene in the Lesser Antilles. ► The Lesser Antilles can be a pathway for Cainozoic terrestrial fauna migrations.

Keywords : Lesser antilles, Neogene, Paleogeography, Guadeloupe Archipelago, Rifting, Seismic stratigraphy, Fauna dispersal

1. INTRODUCTION

Subduction zones experience intense strain inducing significant vertical motions in the overriding plate. Back-arc, arc and forearc domains undergo cycles of hundred to thousand metres scaled uplift and subsidence over temporal scales of 100 ka to 10 Ma (Lallemand and Le Pichon, 1987; Fisher et al., 1998; Sak et al., 2004; Clift and Vanucchi, 2004; Menant et al., 2020). In addition to tectonically-controlled vertical motion, magmatism along the arc can contribute to crustal thickening, both processes leading to land uplift (Ma et al., 2022; Montheil et al., 2022). Along intra-oceanic subduction zones, these processes may thus result in cyclic rise or demise of islands or isthmus, building or

destroying terrestrial connections and possibly connecting/disconnecting nearby continental landmasses. These prompt paleogeographic changes control the existence of emerged pathways for terrestrial fauna and flora. The temporality of the formation and disappearance of such pathways partly dictate the dispersal or isolation of terrestrial species, strongly influencing their biological evolution and biodiversity. The Antilles (*sensu lato)* intra-oceanic subduction zone has evolved in between the North and South America landmasses since the mid Cretaceous (*e.g.*, Pindell and Kennan, 2009; Boschman et al., 2014) and has been identified worldwide as one of the thirty-five biodiversity hotspots (Myers et al., 2000). This subduction zone thus constitutes a fabulous natural laboratory to shed light on the relationships between paleogeography, tectonics, magmatism and biological history.

In the Greater and Lesser Antilles, many Cenozoic terrestrial organisms originated from South America (*e.g*., Hedges, 1996; Itturalde-Vinent and Mac Phee, 1999; Blackburn et al., 2020; Marivaux et al., 2020), while others find their ancestors in North America (*e.g.*, Marivaux et al., 2021). How and when these terrestrial organisms have spread from to reach the isolated Antilles islands remains highly debated. For some authors, a land bridge existed between the South American continent and the Greater Antilles during the late Eocene (between 35 and 33 Ma). These authors either suggested that this land bridge was located along the currently submerged Aves Ridge, a remnant of the Late Cretaceous-Paleocene arc now in back arc position (GAARLandia hypothesis, Itturalde-Vinent and Mac Phee, 1999; Cala-Riquelme et al., 2022) or along the northern Lesser Antilles (GrANoLA land, Philippon et al., 2020) (Fig. 1). Others suggested the existence of an isthmus in the southern Lesser Antilles (late Eocene – Present-day arc) (Bourgade, 2020) and/or long-distance overseas dispersals (Ali, 2012; Ali and Hedges, 2021) (Fig. 1B).

In the Lesser Antilles, the fossil record of terrestrial organisms is presently limited to Upper Pleistocene deposits (*e.g.*, Hedges, 1996; Davalos , 2004; Fabre et al., 2014). The origin, pattern of dispersal and timing of isolation of these organisms remain unknown. For example, colonization of the fossil Oryzomyine rodents in Guadeloupe, Marie-Galante, Antigua and Barbuda took place during

the Late Miocene (Brace et al., 2015) and subfossil genera exhibit peculiar distributions in the different islands of the Lesser Antilles (Durocher et al., 2020). Based on mitochondrial DNA (mtDNA) analyses, Surget-Groba and Thorpe (2013) demonstrated that the appearance of the lizard geckos *Sphaerodactylus vincenti* and *Anolis roquet* occurred at *ca* 12.5 Ma and high divergence rates have been evidenced between northern Martinique-Dominica and southern Martinique-southern Lesser Antilles populations. Moreover, molecular clock data showed that the common ancestor of other *Anolis* lizards from the central and southern Lesser Antilles originated from South America and that speciation events began prior to 25 Ma (Bourgade, 2020). For this author, Martinique would have been a refuge for insular terrestrial faunas as soon as 45 Ma. This island that remained emerged since *ca* 25 Ma might have been a centre of dispersion for species in the Antillean arc since 12 Ma. Molecular clock data further showed that amphisbaenid lizards should have migrated from the Amazon Basin to Hispaniola (Grabosky et al., 2022). These authors suggested that it occurred through the Lesser Antilles during the late Early Miocene or Middle Miocene thanks to both overwater dispersals by the North Brazilian Current and ephemeral formations of islands during glacio-eustatic sea level drops.

Philippon et al. (2020) and Cornée et al. (2021) recently provided evidences for major changes in the paleogeography of the northern Lesser Antilles (*i.e.*, north of Guadeloupe) and its potential role in the dispersal of terrestrial organisms. To understand whether or not past emergent landmasses existed in the central Lesser Antilles as suggested by molecular phylogenetic studies, we reconstruct the paleogeographic evolution of the central Lesser Antilles since the late Oligocene-Early Miocene interval, from north to south between the Marie-Galante Basin and the Martinique Island (Figs. 1 and 2). Our study is based on offshore data acquired during the KaShallow Program (Lebrun , 2009) and new field investigations onshore Guadeloupe, La Désirade and Martinique.

2. GEOLOGICAL SETTING OF THE CENTRAL LESSER ANTILLES (GUADELOUPE, DOMINICA, MARTINIQUE)

2.1. GEODYNAMICAL SETTING

The Lesser Antilles subduction zone results from the westward subduction of the North and South America lithosphere beneath the mantle stationary Caribbean plate, at a speed of 18-20 km.Ma^{-1} (Dixon et al., 1998; DeMets et al., 2010; Boschman et al., 2014) (Fig. 1). To the north and to the south, the Caribbean plate is bounded by two transform faults. To the east, the plate boundary consists in the highly curved Lesser Antilles trench, along which the Lesser Antilles volcanic arc has developed since the Eocene (Martin-Kaye, 1969; Stein et al., 1982; Bouysse and Westercamp, 1990; Bouysse et al., 1990; Pindell and Barret, 1990; Mann et al., 1995). This arc shows a peculiar north-south dichotomy. North of Martinique, an extinct Eocene-Oligocene arc is exposed in the forearc on the islands of Antigua, Saint-Barthélemy and Saint-Martin (*e.g.*, Bouysse and Mascle, 1994; Legendre et al., 2018; Noury et al., 2021; Montheil et al., 2022). This extinct arc is sealed by shallow water carbonate platforms whose ages range between the late Oligocene and the Holocene. From Martinique southward, the modern arc remains at the location of the extinct arc (Fig. 1A).

2.2. GEOLOGY OF GUADELOUPE ARCHIPELAGO

The Guadeloupe Archipelago (Fig. 2) consists of (i) to the West, the islands of Basse-Terre and Les Saintes composed of subaerial volcanic rocks that have formed since 4.3 Ma in the Early Pliocene (Andréïeff et al., 1989; Bouysse et al., 1990; Samper et al., 2007; Zami et al., 2014; Favier et al., 2019) and (ii) to the East, the islands of Marie-Galante, Grande-Terre and La Désirade, made of Pliocene to Pleistocene carbonate platform deposits unconformably lying on Miocene sedimentary rocks or Upper Jurassic igneous rocks (*e.g.*, Andréïeff et al., 1989; Bouysse et al., 1993; Neill et al., 2010 ; Corsini et al., 2011; Cornée et al., 2012; Münch et al., 2013, 2014). Offshore in the Marie-Galante Basin, several submerged flat top shallow banks or plateaus occur (Fig. 2D). Les Saintes Plateau surrounds the volcanic island, the Colombie Bank rests between Basse-Terre and Marie-Galante and the Flandres Bank is located east of La Désirade. To the east, the north-south trending Karukéra Spur separates the Marie-Galante Basin (west) from the outer-forearc Barbados accretionary wedge (east).

2.2.1. Onshore setting

The carbonate platform of Grande-Terre consists of more than 100 m- thick deposits organized into four transgressive-regressive sedimentary cycles, namely Sequences 1 to 4 (Andréïeff et al., 1983, 1989; Garrabé, 1983; Léticée et al., 2005; Cornée et al., 2012; Münch et al., 2014) (Fig. 3). The sequences comprise red algal and coral-rich beds which deposited between the Zanclean and the Calabrian. The sequences are bounded by erosional unconformities that attest for emersion of the island. In Grande-Terre, these sequence boundaries are accurately dated to the Piacenzian (SB0 and SB1) and the Calabrian (SB2 and SB3) (Münch et al., 2014) (ages on Fig. 3). A coral reef terrace that formed during Marine Isotope Stage (MIS) 5e locally fringes the island.

Marie-Galante and La Désirade carbonate platforms share a common stratigraphy with that of Grande-Terre (Fig. 3). In Marie-Galante the platform is 150- m thick. Due to poor exposure, SB0 and SB1 are not clearly identified in the red algal deposits but the change to coral rich unit as well as SB2 and SB3 are correlated with those exposed in Grande-Terre (Bouysse et al., 1993; Léticée, 2008; Münch et al., 2013). The Marie-Galante platform rests unconformably above ten m-thick upper Tortonian tilted tuffaceous marls (Fig. 3). Uplifted and tilted marine terraces formed during MIS5e and MIS7e rim the southeastern part of the island (Battistini et al., 1986; Feuillet et al., 2004). In La Désirade (Fig. 3) the 100- to 120- m thick Pliocene to Lower Pleistocene red algal to coral rich shallow carbonate deposits (Westercamp, 1980; Léticée, 2008; Lardeaux et al., 2013; Münch et al., 2014) rest above a deformed Upper Jurassic magmatic basement (Westercamp, 1980; Bouysse et al., 1983; Mattinson et al., 2008; Cordey and Cornée, 2009; Neill et al., 2010; Corsini et al., 2011). SB1, SB2 and SB3 are also identified, suggesting that the three islands of the Guadeloupe Archipelago experienced synchronous episodes of emersions (Fig. 3). La Désirade Island is also surrounded by a flight of four uplifted marine terraces formed during the Pleistocene interglacial stages MIS 5e (+10m), MIS 9e (+35m), MIS 15 to MIS 17 (+71m), and MIS 19 to MIS 25 (+90m) (Battistini et al., 1986; Feuillet et al., 2004; Léticée et al., 2019).

2.2.2. Offshore setting

Les Saintes consist of 3 to 2 Ma and 0.9 Ma old volcanic islands (Zami et al., 2014) that underwent high temperature hydrothermalism (Vérati et al., 2018; Favier et al., 2019, 2021). The submerged part of the volcanoes is covered by a *ca* 250 m- thick coral reef plateau. Leclerc and Feuillet (2019) suggested that this fringing reefal plateau has been built during glacial cycles of the Middle to Late Pleistocene (since less than 360 ka, MIS9).

The submerged plateau south of Grande-Terre and La Désirade rests between 10 and 20 m below sea level (bsl). Münch et al. (2013) correlated the plateau seismic units with the Grande-Terre carbonate Sequences 3 and 4 and argued that the South Grande-Terre Plateau has been recently tectonically drowned along the E-W trending fault bounding the southern coast of the island.

From seismic interpretations across the Colombie Bank (Münch et al., 2013), a first sequence of outer ramp to basin sediments has been attributed to the Lower Pleistocene (Calabrian, between 1.1 and 1.5 Ma) and correlated with carbonate Sequence 4 in the island of Marie-Galante (Fig. 3). The second sequence of the bank (*ca* 0.1 stwt- thick, Fig. 8 in Münch et al. 2013) rests conformably upon the first one and displays seismic characteristics of reefal build-ups. This indicates that when the island of Marie-Galante emerged by the end of the Calabrian, the Colombie Bank remained below sea level with shallow-water deposits (Fig. 3 and Fig. 10 in Münch et al., 2013).

The Flandres Bank is a narrow carbonate platform that culminates at 40 m bsl at the northernmost tip of the Karukéra Spur. The platform rests unconformably upon the igneous basement of the spur. The carbonate deposits comprise two sequences. The first sequence remains undated, fills the basement depressions and is topped by a flat erosional surface. The second (0.02s twt- thick) is made of Holocene reefal deposits (Andréïeff et al., 1980; Münch et al., 2013; De Min et al., 2015).

The Karukéra Spur is a submerged north-south trending horst that borders the eastern part of the Marie-Galante Basin (Fig. 2). The basement of the spur is composed of igneous rocks like those of

La Désirade Island (Andréïeff et al., 1980). De Min (2014) and De Min et al. (2015) characterized seven seismic units organized into four depositional megasequences above the basement (Fig. 3).

- Megasequence 1 (S1 and S2 in Fig. 3 and MG-MS1 in Fig. 4) infills basement depressions and retrogrades upslope. The uppermost part of the megasequence exhibits Lower Miocene shallow-water limestones. Megasequence 1 is sub-divided into two units and is framed by two erosional unconformities, SB1 at bottom and SB2 at top.

- Megasequence 2 (S3 in Fig. 3 - MG-MS2 in Fig. 4) is made of Middle (?) to Upper Miocene basin deposits organized into a transgressive system tract, topped by an erosional unconformity SB3 dated to the latest Miocene.

- Megasequence 3 (S4 in Fig. 3 - MG-MS3 in Fig. 4) consists of Lower to Upper Pliocene basin marls and reefal deposits.

- Megasequence 4 (S5 to S7 in Fig. 3 - upper part of MG-MS3 in Fig. 4) is made of Gelasian-Calabrian to recent deposits.

During the 1970' and 1980', the Arcante Project (Bouysse and Guennoc, 1983) was devoted to the Marie-Galante Basin. The team collected regional scale geophysical data and 14 rock samples (Fig. S1). The authors described large amplitude vertical motions affecting the forearc related to transient events due to subduction of a buoyant ridge. They suggested large forearc emersion during the Oligocene, followed by a westward (landward) migration of the volcanic islands as the consequence of slab breakoff (Bouysse et al., 1990 and references therein). During the early 2000', the AGUADOMAR project team (Deplus et al., 1998; Feuillet et al., 2002) acquired new seismic and bathymetric data. They described the Marie-Galante Basin as a forearc transverse basin connecting the Montserrat-Harvers strike slip fault that runs along the arc to the trench. The SismAntilles/Thales Was Right program (Hirn, 2001; Kopp et al., 2011; Evain et al., 2011; Laigle et al., 2013) provided crustal scale structure images revealing a rather thick, igneous inner forearc crust (25-28km) beneath the Marie-Galante Basin.

2.3. GEOLOGY OF MARTINIQUE AND DOMINICA

Martinique Island comprises three main volcanic and sedimentary units (Bellon et al., 1984; Andréïeff et al., 1988; Westercamp et al., 1989, 1990; Germa et al., 2011), showing a westward decrease in ages. From east to west the island exposes (i) an ancient (latest Oligocene-Early Miocene) arc dating 24.8 ± 0.4 to 20.8 ± 0.4 Ma (K/Ar, Germa et al., 2011); (ii) an intermediate arc with submarine volcaniclastic sediments and numerous dykes to the east and subaerial magmatism to the west (16.12 ± 0.23 - 7.09 ± 0.10 Ma; K/Ar, Germa et al., 2011); (iii) a recent arc (2.36 Ma to present-day; Germa et al., 2011). The oldest arc also presents some intercalated shallow marine carbonate patches that were emplaced during volcanic quiescence episodes (La Caravelle, Sainte-Anne, Macabou) and that have deposited during the late Oligocene and possibly the Aquitanian (Andréïeff et al., 1988; Westercamp et al., 1989). Offshore from the northeastern shelf of Martinique northward, the Oligocene-Early Miocene ancient arc stands beneath the reefal platform of America and Dien Bien Phu Banks (Fig. 1) dating from Pliocene-Pleistocene at least to Holocene (Andréïeff et al, 1980; Leclerc et al., 2015).

Dominica Island is composed of four subaerial volcanic units which date Late Miocene (6.8-5.2 Ma) to present (*e.g.*, Lindsay et al., 2005; Smith et al., 2013). Sparse outcrops of undated "raised limestone" deposits are reported along the western coast, resting onto Upper Pliocene – Lower Pleistocene (3.7-1.8 Ma) volcaniclastic deposits. Offshore, a narrow shelf occurs around the island with Holocene reefal carbonate deposits.

3. METHODS

We present a dataset acquired during the KaShallow cruise (Lebrun, 2009) including high-resolution seismic reflection lines, high resolution multibeam bathymetry and collected rock samples from the Marie-Galante Basin (Fig. 2). The dataset is complemented with seismic and bathymetric data from the Aguadomar (Deplus, 1998) and SismAntilles 1 and 2 cruises (Hirn 2001; Hirn et al., 2007; Laigle et al., 2007).

3.1. SEISMIC REFLEXION PROFILES

In this study we interpreted *ca* 6500 km of seismic reflection lines of various resolution and penetration including KaShallow 1 HR seismic data (sparker source) and SismAntilles 1 multichannel seismic reflection data (4400-8800Ci airguns array source) not shown here. The KaShallow 2 seismic source was an array of six 24-35Ci GI Airguns recorded with a 72 channel – 450 m long streamer (9 or 18-fold stack - far field peak frequency 40-70hz – characteristic penetration *ca* 1-1.5stwt - second two-way-travel-time). The Aguadomar cruise seismic lines were shot with 2 GI airguns of 45/105ci recorded on a 50 m long 6 channels streamer (3-fold stack) and acquired at high speed. This provided a mid-resolution seismic data with a far field peak frequency of *ca* 30-50Hz and a characteristic penetration *ca* 1-2stwt. The cruise aimed at mapping the basin relief, thus lines are rather distant one from the other and oriented N-S, except south of Marie-Galante where they are oriented E-W. Processing of these data included band pass filtering, predictive deconvolution, simple velocity analysis and nmo corrections, stack and constant water velocity time migration.

We determine the seismic facies following conventional seismic facies analysis as first established during the late 70's (Mitchum et al. 1976, Vail et al. 1977, Roksandic 1978, Xu and Haq 2022 and references there in) and interpret the sedimentary sequences based on the nomenclature of Catuneanu et al. (2011). We defined 14 facies illustrating the first order seismic stratigraphy of the basin (supplementary Fig. S2) based on regional setting, external form, internal configuration, reflection amplitude, dominant frequency and reflection continuity of the units. The seismic facies (supplementary dataFig. S2) are interpreted in terms of igneous and sedimentary facies based on dredged samples collected from several of the seismic units (supplementary Fig. S1). We found that the basin comprised six seismic units organised in 3 Megasequences (MG-MS) bounded by regional, partly erosional, unconformities (MG-SB). We investigated the seismic lines of the Marie-Galante Basin referring to the seismic units defined by De Min et al. (2015) across the Karukéra Spur. We cross-correlated all the seismic lines through the basin and spur. We present the line Aguadomar-116-34-119-KaShallow2-080 (Fig. 4 and Fig. S3) to illustrate the structure of the basin along an E-W transect,

perpendicular to the western border of the Karukéra Spur, across the Arawak Sub-basin to upslope the Kubuli Sub-basin. The line KaShallow2-026-060-061-062 (Fig. 5 and Fig. S4) provides a NNW-SSE trending cross section along the Arawak Sub-basin, from the South of the Grande-Terre shelf to the southeastern Arawak Sub-basin. The line trends parallel to the gully shape of the basin (*i.e.* in the direction of the sedimentary transport). The line KaShallow2-051-052 (Fig. 6 and Fig. S5), in the southeastern part of the basin, shows its sedimentary organization and the seismic facies in its deepest part. Finally, the line KaShallow2-090 (Fig. 7 and Fig. S6) extends from the northern Dominica shelf to the southern Grande-Terre shelf, west of Marie-Galante. It trends N-S across the upper part of the Kubuli Sub-basin and crosscuts perpendicularly the N80-100° main fault system of the upslope basin. Despite a large number of studied seismic lines, their variable quality and variations in depth penetration did not allow to build continuous isochron maps throughout the basin.

3.2. Dredges, piston core and ROV sampling

The Karukéra Spur megasequences were dated using descriptions and analyses of ancient dredges collected during the cruises Arcante 1 (Andréïeff et al., 1980) and new samples collected during the KaShallow2 cruise (De Min, 2014; De Min et al., 2015) (Fig. 2C and Fig. S2). In the Marie-Galante Basin, sixteen other sites were sampled during the KaShallow 2 cruise using a Kullenberg piston corer (samples "KS") and eleven others with a CNEXO-Ville rock sampler (samples "CR") (Fig. 2C and supplementary material Fig. S1). Correlated with seismic units, these samples were used to calibrate the age and the paleoenvironment of the sedimentary megasequences. Many of the samples yielded Late Pleistocene to Holocene ages. In this work, we only document the results of new and ancient dredges that yielded older deposits (late Oligocene to Middle Pleistocene) based on their foraminiferal and calcareous nannofossil contents (Fig. S1). During the KaShallow program, we also performed ROV dives and sampled two sites, east and west of the northern coast of Marie-Galante, along one of the most prominent fault scarps in the basin (samples "BMG" and "BC", respectively, Münch et al., 2013) (Fig. 2C and Fig. S1). Dredge KS09_038 on the Karukéra Spur was also reinvestigated to better characterize its foraminiferal content. Ten soft samples were hand-washed over a 65

µm screen and 5 standard smear-slides were prepared for foraminiferal and calcareous nannofossil biostratigraphic analyses, respectively.

3.3. Onshore rock sample analyses

In Martinique, we logged four sections in the carbonate deposits at La Caravelle, Tartane, Grand Macabou and Petit Macabou, the two later outcrops being separated in the field by 500 m (Fig. S7). Twenty-three thin sections were prepared to analyse the foraminiferal content and depositional settings of the onshore sediments.

In Guadeloupe Archipelago, we further refined the age of the carbonate platform of Grande-Terre by sampling the lowermost part of a recently drilled borehole at Morne à l'Eau and reinvestigated the lower part of the La Désirade platform with new samples from Pointe Frégule, in the western part of the island. We prepared four and sixteen thin-sections, respectively (Fig. S8).

Carbonate microfacies were characterized following the nomenclature of Flügel (2006). The standard planktonic foraminifera zonal scheme and bio-event calibrations used in this study are from Wade et al. (2011) and BouDagher-Fadel (2018a). For larger benthic foraminifera, bio-event calibrations are from BouDagher-Fadel et al. (2010), BouDagher-Fadel and Price (2010, 2013) and BouDagher-Fadel (2018b). For calcareous nannofossils, we used bio-event calibrations published by Raffi et al. (2006). Foraminiferal taxa with biostratigraphic significance found in these thin sections are illustrated in Figures S3 and S4.

4. RESULTS

4.1. Seismic stratigraphy of the Marie-Galante Basin

Three sedimentary seismic megasequences MG-MS, up to 2 stwt- thick, limited by regional unconformities MG-SB, are recognized resting above an acoustic basement (Figs. 4, 5, 6, 7, high-resolution seismic lines in Figures S3, S4, S5, S6). From bottom to top, these are:

4.1.1. The basement

The basement (grey in Figs. 4 and 6) comprises transparent to discontinuous, low amplitude and low frequency reflectors displaying a chaotic structure (Facies 1 – Fig. S2 and Fig. 6). The basement is topped by the regional prominent MG-SB1 unconformity (dot red line in Figs. 4 and 6). At Karukéra Spur and beneath the Petite-Terre Sub-basin, MG-SB1 is sharp and underlined by a high amplitude and continuous reflector (*e.g.*, Fig. 4A - CDP8300 to 11000 at *ca* 3,8 stwt). In the southeastern part of the Arawak Sub-basin, MG-SB1 shows few high amplitude, low frequency, continuous and parallel reflectors suggesting that a thin sedimentary unit rests conformably upon the basement (Facies 3 – Fig. S2 and Fig. 4). To the west beneath the Kubuli Sub-basin, the basement is generally hidden by multiples reflections and is too deep to be imaged. The basement crops out in La Désirade and all along the N70° trending crest dominating the *ca* 5000 m deep V-shaped La Désirade Valley (Fig. 2 and Fig. 5 in De Min et al., 2015).

At the basin scale, the basement gently deeps southward along the Karukéra Spur (Fig. 5 in De Min et al., 2015). In the Petite-Terre Sub-basin southward and from the Karukéra Spur westward, the basement steps down toward the Arawak Sub-basin along N90° south-dipping or N150° and N0° west-dipping normal faults, respectively (Figs. 2B and 4, CDP8200 to 13000; Fig. 8). It rests at 4.4 stwt below a 2stwt- thick sedimentary pile in the western Arawak Sub-basin (Fig. 4, CDP 4400). Wide angle seismic data (Kopp et al., 2011) show that the basement unconformity corresponds to the 4.5 km/s “mid crust” boundary that extends further westward beneath the Kubuli Sub-basin at a constant depth. This indicates that *ca* 3.5 stwt- thick seismic units rest above the basement upslope of the Kubuli Sub-basin.

Dredges from the southern flank of La Désirade Valley recovered igneous basement rocks with facies similar to those cropping out onshore La Désirade (dredges ST18 to ST22, ST 28, 44D; Arcante 1 and 2 cruises - Andréïeff et al., 1980; Bouysse and Guennoc, 1983) (Fig. 2), *i.e.* Upper Jurassic magmatic rocks that underwent Albian greenschist metamorphism (*e.g.*, Corsini et al., 2011).

4.1.2. Megasequence MG-MS1:

The MG-MS1 complete sequence can be described in the central and southern parts of the Arawak Sub-basin and in the southern Karukéra Spur (Figs. 4 and 6 and Fig. 5 in De Min et al 2015). At Karukéra Spur, MG-MS1 is 0.60-0.80 stwt- thick at maximum (600 to 700 m- thick). It reaches 1.3 stwt- thick (*ca* 1400 m- thick) in the south-central part of the basin (Fig. 4 at CDP 4400). MG-MS1 comprises two main units with discontinuous to locally continuous, sub-parallel, medium to low amplitude and medium frequency reflectors (Facies F4 and F4' – Fig. S2 and Fig. 4). The lower unit (blue in Figs. 4 and 6, and Fig. 8 in De Min et al. 2015) infills topographic depressions above MG-SB1 and is thicker in the Arawak Sub-basin than over the spur. The upper unit (orange in Figs. 4, 5 and 6, and Fig. 7 in de Min et al., 2015) rests conformably above the lower one and displays an aggradational pattern (Fig. 4 from CDP 8100 eastward and Fig. 6A). Over the Karukéra Spur and in the Arawak Sub-basin northward, MG-MS1 retrogrades onto the erosional basement surface MG-SB1 (Fig. 5 and 10 in De Min et al. 2015). In the Kubuli Sub-basin and south of Grande-Terre, MG-SB1 is too deep to be observed.

At the top of MG-MS1, MG-SB2 is a marbled erosional surface all over the basin. In the southern Arawak Basin, MG-SB2 entails deep into MG-MS1, locally down to the basement (Fig. 6, line K09_52). This deep incision was a submarine passage toward the 5500 m deep outer forearc Martinique Basin to the east (Fig. 2). Over the Karukéra Spur and across the Arawak Sub-basin, MG-SB2 displays local reliefs and MG-MS1 shows truncations below few strong amplitude, low frequency and continuous reflector (Facies F5 – Fig. S2 and Fig. 6A), suggesting that MG-SB2 is subaerial. Westward in the Kubuli Sub-basin, MG-SB2 becomes shallower and is mostly conformable with the underlying deposits. The unit boundary is underlined by low angle onlaps (Facies F6 – Fig. S2 and Fig. 4B). This architecture suggests that MG-SB2 is submarine. MG-SB2 is vertically offset and tilted against the N90°E trending Morne Piton Fault by *ca* 1 stwt down to the north (Fig. 5, line K09-60). MG-MS1 is absent over the northernmost Karukéra Spur, Petite-Terre Sub-basin and in La Désirade (Fig. 2A).

The westward lateral facies variation of MG-MS1 is a remarkable feature. The well bedded units of the Arawak Sub-basin changes into a weakly reflective more or less layered seismic facies in the Kubuli Sub-basin (Facies F6 and F7 – Fig. S2 and Fig. 4B). The facies transition occurs around the deepest part of the boundary between the Arawak and Kubuli Sub-basins (Fig. 4 *ca* CDP4400-4500). Closer to Dominica Island, where MG-SB2 is shallower, Aguadomar profiles (with deeper penetration than the KaShallow seismic lines) confirm that the seismic facies of MG-MS1 is poorly reflective. Such facies, lacking of internal reflections, is also observed close to the active arc beneath the Rodrigue Plateau and in the Les Saintes Channel (brown colour in Fig. 7, and Facies F2 – Fig. S2). We interpret this facies as volcanoclastic deposits or magmatic intrusions from the remnant and present day arc (Fig. 8). We dredged rock samples from the uppermost part of MG-MS1. Dredge KS09_38 in the Karukéra Spur yielded reefal deposits (De Min et al., 2015, sample location on Fig. 2C and Fig. 4 at cdp14500-K09-80) with larger benthic foraminifera (including *Miolepidocyclina mexicana, Heterostegina antillea, Miogypsina tani* and *M. triangulata*) which together indicate that deposition occurred during the Chattian-Aquitanian interval (27.82-20.4 Ma) (Fig. S1). There, both the high amplitude and continuity of the seismic reflectors at the top of MG-MS1 (Facies F5 – Fig. S2 and Fig. 6) contrast with the lower amplitude and very continuous reflectors of the overlying megasequence MG-MS2 (Facies F9 – Fig. S2 and Fig. S6). This suggests a high impedance contrast between MG-MS1 and MG-MS2. We conclude that the deposits with this strong amplitude facies on top of MG-MS1 correspond to a shallow carbonate platform from which sample KS09_38 was collected. The topmost part of MG-MS1 also crops out on the Morne Piton fault escarpment, immediately east of Marie-Galante. ROV samples BMG2 and BMG4 (Fig. 2C and Fig. 5 at CDP3200-K09-60) yielded calcareous marls with abundant Early Miocene calcareous nannofossils and planktonic foraminifera (Burdigalian, between 18.50 and 17.30 Ma) (Fig. S1). Dredges 41D and 43D collected east of Grande-Terre (Fig. 2C) yielded Lower Miocene basin and middle Oligocene outer platform deposits (Andréïeff et al., 1980) (Fig. S1), thus confirming the existence of basin deposits of this age. We conclude that by the end of the Early Miocene, a shallow carbonate platform covered the Karukéra

Spur and eastern Arawak Sub-basin, and that the shallow carbonate platform changes into basin deposits westward (Fig. 2A; Facies 7 – Fig. S2).

4.1.3. Megasequence MG-MS2

MG-MS2 is characterized by a wide variety of types and shapes of seismic reflectors, especially in the Arawak and Kubuli Sub-basins where subparallel, cross bedded, chaotic or lense-shaped geometry, high to low amplitude and generally medium to long continuity reflectors occur (Facies 8, 9, 10 and 11 – Fig. S2).

In the Karukéra Spur, De Min et al. (2015) provided a detailed description of MG-MS2 (termed US3 in De Min et al., 2015). There, MG-MS2 is 0,24 to 0,30 stwt- thick (200 to 300 m) (Figs. 5 and 7 in De Min et al., 2015) and thicker to the south than to the north. As a whole, the megasequence presents one unit with continuous reflectors, intermediate amplitude and high to intermediate frequency, arranged in a retrogradational pattern changing upward in an aggradational one. Rock samples yielded foraminifer-rich massive oozes indicating a basin depositional environment and, in the upper part of the megasequence, peri-reefal limestones with Tortonian to Messinian calcareous nannofossils. MG-MS2 is limited at its top by the sequence boundary MG-SB3. MG-SB3 is mostly conformable with MG-MS2 but displays a clear angular unconformity with the overlying MG-MS3 when observed perpendicular to the N120° and N40° faults cross-cutting the spur (Fig. 2B). To the north of the spur, MG-MS2 is eroded and absent in the hanging walls of the faults.

Elsewhere in the Marie-Galante Sub-basins, MG-MS2 is thicker than in the Karukéra Spur, reaching 0,8 stwt- thick (600 to 700 m) (Figs. 4 and 8), and it is lowered to the west along the N150-N0° faults bounding the spur to the west (Fig. 2B). We distinguish two units in MG-MS2. The lower unit is thicker in the Arawak Sub-basin than in the Kubuli Sub-basin (Figs. 4 and 5). It displays subparallel reflectors with variable amplitudes (Facies F8 – Fig. S2 and Fig. 5). In the Arawak Sub-basin, the lower unit locally shows large and long wavelength incisions filled with well-stratified deposits suggesting erosion by deep-sea currents (Facies F9 – Fig. S2 and Fig. 6 at CDP500-2500). The upper

unit rests unconformably upon the irregular surface except upslope of the Kubuli Sub-basin where it is conformable. The unit is thicker in the Kubuli Sub-basin than in the Arawak Sub-basin. The unit facies corresponds to the F8 facies too (Fig. S2). Along the eastern slope of the Kubuli Sub-basin, the upper unit is arranged in a large lens-shaped, south-eastward prograding pattern (Facies F10 – Fig. S2 and Fig. 5A). Upslope in the Kubuli Sub-basin, the upper unit onlaps and retrogrades onto the unit boundary and becomes conformable and aggrades upward (Figs. 4 at cdp800-1800). Immediately east of Marie-Galante, the upper unit shows channel-levee patterns in the footwall of the Morne Piton fault (Facies F11 – Fig. S2 and Fig. 5B).

North of the Morne Piton Fault in the Marie-Galante Canyon and the Petite-Terre Sub-basin, the two units cannot be distinguished. There, MG-MS2 presents poorly continuous but subparallel reflectors of medium amplitude (Fig. 5, lines K09-26 and K09-60). MG-MS2 displays few low angle onlaps onto MG-SB2 and is aggradational. All megasequences (MG-MS1 and MG-MS2) are tilted to the south against the Morne Piton fault and the N130° faults in the Petite-Terre Sub-basin (Fig. 5). The thickness of MG-MS2 sediments does not vary against the faults suggesting that they are pretectonic.

MG-MS2 lower unit onlaps above MG-SB2 and retrogrades upslope where it becomes concordant with MG-SB2 and aggrades in the uppermost part of the Kubuli Sub-basin (Fig. 4, line Agua116). The sequence boundary MG-SB3 on top of MG-MS2 is irregular with local incisions in MG-MS2, suggesting submarine erosion (*e.g.*, Fig. 4 at cdp8250-8650 and Fig. 5 at K09-61-cdp3400-4200). It is mostly concordant with sediments in the upper part of the Kubuli Sub-basin (Fig. 4 at cdp700-1800 – Fig. 7 at cdp15000-19000). In the footwall of the Morne Piton Fault and in the Marie-Galante Canyon (Fig. 5, line K09-60), MG-MS2 is deeply incised and covered by recent canyon deposits. In the Petite-Terre Sub-basin (Fig. 5, line K09-26), MG-MS2 crops out and is deeply incised. In the northernmost part of the Petite-Terre Sub-basin and northern Karukéra Spur, the unit is missing, suggesting emergence and erosion (Fig. 8). In the Petit-Cul de Sac Marin Sub-basin (PCSM in Fig. 2A), a clear angular unconformity with the overlying MG-MS3 suggests that the surface might correspond

to MG-SB3 but MG-MS2 is hidden below the multiple (Fig. 7A). In the southern Arawak Sub-basin, MG-SB3 is mostly conformable with MG-MS2 with only low angle onlaps of MG-MS3 (Fig. 6, line K09-52).

Dredge samples at sites 39D and CR24 (Fig. 2C and located in Fig. 5) provided marls that indicate a basin depositional environment dating from the Langhian to the Tortonian (Fig. S1). These ages are consistent with the Upper Miocene basin deposits found by Andréïeff et al. (1980) on the basis of dredge samples 41D and 43D (Fig. 2C) collected in the upper part of the La Désirade Valley. As a whole, a Middle to Late Miocene age is assigned to MG-MS2.

4.1.4. Megasequence MG-MS3

MG-MS3 is characterized by well stratified and continuous reflectors (Facies F13, Fig. S2 and Fig. 7) onlapping above MG-SB3, retrograding and aggrading in most of the basin and over the Karukéra Spur (Figs. 4 and 5). In the deepest part of the basin, it shows various facies such as well layered reflectors suggesting clastic deposits (Facies F12 –Fig. S2), local transparent unit slightly incising in the lower unit suggesting mass transport deposits (F12') or downslope prograding deposits (Facies F12 – Fig. S2 and Fig. 5). MG-MS3 comprises two units separated by a remarkable unit boundary locally underlined by truncations, onlaps and a regional high amplitude reflector (Figs. 4D and 6B). MG-MS3 is up to 0.4 stwt- thick (*ca* 400 m) in the southern Arawak (Fig. 6, line K09-52) and central Arawak Sub-basin (Fig. 5 at K09-62-CDP150-4000). It progressively thins to *ca* 0.2 stwt (*ca* 200 m) upslope of the Kubuli Sub-basin and over the Karukéra Spur (Figs. 4 and 5). Along the Morne Piton Fault scarp, MG-MS3 presents channel-levees incising MG-MS2 (Facies F11 – Fig. S2 and Fig. 5). North of the fault in the Marie-Galante canyon, MG-MS3 displays a cross-bedded and lens shaped pattern corresponding to canyon deposits (Fig. 5B). In the Petite-Terre Sub-basin, MG-MS3 only fills narrow depressions. In the PCSM Sub-basin, MG-MS3 shows clear angular onlaps onto MG-SB3 and the upper unit exhibits channel incisions and infillings (Fig. 7A). At Colombie Bank, MG-MS3 upper unit comprises three units topping the bank with strong amplitude reflectors

at the top and pinnacle-like reliefs, typical of carbonate platforms (Facies F14 – Fig. S2 and Fig. 7). This platform conformably rests upon well stratified, continuous, medium to low amplitude reflectors of the lower unit (Münch et al., 2013).

At Rodrigue Plateau, MG-MS3 onlaps onto the plateau or presents a fan shaped pattern when observed perpendicular to the N150° normal faults bounding the plateau to the East (ENE-WSW lines crossing K09-90, Fig. 2A and 2B). At Karukéra Spur, MG-MS3 corresponds to US4 and US5 of De Min et al. (2015). These authors described the two units as well stratified, with continuous reflections. Deposition of the lower unit (US4) is clearly controlled by faults as it is (i) overally retrograding northward, and (ii) tilted eastward. The upper unit (US5) partly covers the basement of the spur. It is organized in a fan shaped pattern against the spur faults and arranged as a thin-sheet unit along the deepest part of the spur. At Flandres Bank, a thin reefal unit (samples CR25 and CR26 – Fig. 2C) caps the spur basement.

Both MG-MS3 units were sampled and provided outer shelf marls turning upward into shallow water reefal deposits. At Karukéra Spur, the lower unit (US4 of De Min et al., 2015) was dated Zanclean to Piacenzian and the upper one (US5) late Gelasian-Calabrian (Fig. S1). The Flandres Bank platform is Late Pleistocene to Holocene (De Min et al., 2015). In the Marie-Galante Canyon, sample KS17 (Fig. 2C) has been deposited during the Zanclean. Albeit the marl samples cannot be correlated to a specific seismic unit, they all indicate a basin environment and may belong to the lower unit of MG-MS3. In the Arawak Canyon, sample KS39 (Fig. 4, line K09-80 at cdp10000; location in Fig. 2C) was collected just above the unit boundary. The dredge provided Piacenzian marls (3.36-3.16 Ma interval), suggesting a middle-late Piacenzian age for the unit boundary. Sample KS47 (Fig. 5, line K09-61 at CDP400, location in Fig. 2C) from the channel levee deposits west of Marie-Galante Island provided Piacenzian bioclastic sandstones (location in Fig. 5). At Rodrigue Plateau west of Marie-Galante, samples KS05 (Fig. 7, at CDP10650, location in Fig. 2C), KS07 and KS08 (Fig. 2C) revealed that the plateau is capped by bioclastic limestones with foraminifera. KS07 has deposited during the Early Pleistocene (planktonic foraminiferal Zone PT1a). The Arcante Cruise samples 17V and 18V

(Fig. 2C), located along the Les Saintes Plateau, provided Pliocene – Pleistocene outer platform limestones. Around the Colombie Bank, samples BC1 and BC2 (Fig. 7 at CDP5200, location in Fig. 2C) yielded wackestones bearing planktonic foraminifera and volcanic minerals with radiometric ages at 1.15±0.12 to 1.33±0.23 Ma (Münch et al., 2014); sample KS13 (Fig. 2C) is a Lower Pleistocene marl; samples Arcante 15D - 16D (Fig. 2C) yielded Pliocene to Pleistocene volcaniclastic calcareous sandstones that deposited under outer ramp platform to basin environments. Samples CR51, CR53 and CR54 (Fig. 2C), collected from units topping the Colombie Bank, provided bioclastic limestones and corals indicating an inner ramp - reefal platform environment. Other dredges from the Arcante cruise in the La Désirade slope (35D, 41D, 42D, Fig. 2C) yielded Pleistocene marls that relate to the upper unit of MG-MS3.

4.2. ONSHORE

4.2.1. Carbonate deposits of eastern Martinique

In La Caravelle Peninsula, the Caravelle and Tartane sections (Fig. 9 and Fig. S7) comprise 4 to 21 m- thick red algal packstones and interbedded coral-red algae biostromes, with abundant rhodoliths. In the Caravelle section, these carbonate rocks rest upon andesitic breccias and lava sills. Foraminiferal assemblages (including *Miogypsinella elongata, Miolepidyclina mexicana*, *Miogypsina gunteri*) and *Paragloborotalia opima* found in the lower part of the section correlate with Zone P21b (early Chattian, 28.82-26.8 Ma). Both foraminiferal assemblages and microfacies indicate an inner to mid ramp, reefal depositional setting. In the Tartane section, similar facies occur above magmatic rocks of the oldest arc. The larger benthic foraminifera are indicative of Zone P22 (Chattian, 26.8-24 Ma).

The Grand Macabou section comprises, from bottom to top (Fig. 9A, B and Fig. S7):

- 0.3 m- thick argillaceous green tuffites;

- 2 m- thick bioturbated red algal grainstones to packstones with planktonic foraminiferal taxa from Zones M1 and M2 (N4-N5a, Aquitanian, 23.03-20.4 Ma);
- 10 m- thick coral grainstones to rudstones with diverse coral colonies in life position (Fig. 9C). The co-occurrence of the larger benthic foraminifera (*Miogypsina triangulata, Miolepidocyclina panamensis* and *Archaias angulatus*) correlates with Zones N4-N5a (Aquitanian, 23.03-20.4 Ma);
- 10.5 m- thick red algal grainstones to packstones with planar cross-bedding and corals between 18 and 19 m above the base of the section. There, the larger benthic foraminiferal assemblages (including *Miolepidocyclina excentrica* and *Miogypsina tani)* correlate with Zone N5b-N8a (Burdigalian, 20.4-15.97 Ma). Both foraminiferal assemblages and microfacies indicate an inner to mid ramp, reefal depositional setting for the whole section;

The Petit Macabou section comprises, from bottom to top (Fig. 9D and 9E and Fig. S7):

- 2 m- thick coral buildups that underwent karstification and are covered by reefal breccias. Karst features and breccia fragments are coated by iron hydroxydes (Fig. 9D). Both larger benthic (*Miogypsina panamensis, M. tani, A. angulatus, Heterostegina antillea, Panorbulinella larvata*) and planktonic foraminifera in the reef and the breccia elements indicate that deposition occurred during the Aquitanian (23.03-20.4 Ma) within Zones N4-N5b;
- 8 m- thick debris flows, coarse-grained turbidites and cross-bedded levels (Fig. 9E) composed of andesitic fragments. Two beds in their lower part yielded larger benthic (*Miogypsina intermedia, H. antillea, Lepidocyclina yurnagunensis, Planorbulina larvata*) and planktonic foraminifera (*Orbulina universa, Sphaeroidinellopsis seminulina, Globoquadrina dehiscens*) corresponding to Zones N9-N13a (Langhian-Serravalian, 15.97-11.8 Ma).

4.2.2. Carbonate deposits of the Guadeloupe Archipelago

In Grande-Terre, the Morne à l'Eau borehole (Fig. S8 – location in Fig. 2C) comprises 80 m- thick red algal grainstones to bindstones, with rhodolith-rich intervals. This succession is interspersed with coarse-grained volcaniclastic and carbonate beds. Four emergence surfaces with karstic features such as gullies and microcaves are identified. Referring to the general organization of the Pliocene-Pleistocene platform of Cornée et al. (2012), the lithological succession of the borehole is typical of its lower part (Sequences 1 and 2 of Cornée et al., 2012). The precise age of the base of the platform remains unknown due to the lack of outcrop. The presently oldest known age corresponds to the late Zanclean planktonic foraminiferal Zone PL2 (La Simonière borehole, *in* Münch et al., 2014). The lowermost part of the deposits in the Morne à l'Eau borehole, between 80 and 77.5 m depths, yielded late Tortonian-Messinian species of *Amphistegina* corresponding to Zones N17-N18 within the 8.6-5.33 Ma interval. Above, between 71 and 72.2 m depths, we found foraminifera that co-occurred during the late Tortonian/Messinian-Zanclean interval, between 8.6 and 3.4 Ma. Consequently, in Grande Terre, the lower part of the Upper Plateaus in Grande-Terre has deposited during the Messinian (Late Miocene).

In La Désirade, at Frégule Cape, the lowest 10 m of the Upper Plateau carbonates above the Jurassic basement yielded larger benthic foraminiferal taxa (Fig. S8 and location on Fig. 2C) that co-occured between the latest Miocene and the Early Pliocene. Comparing the ages obtained in Grande Terre (8.6-5.33 Ma) and La Désirade islands (5.8-3.4 Ma), the lowermost part of the carbonate platform in the Guadeloupe Archipelago has deposited during the late Messinian (Zone N18, between 5.8 and 5.33 Ma).

4.3. AGE MODEL AND ONSHORE-OFFSHORE CORRELATIONS IN THE GUADELOUPE ARCHIPELAGO AND MARTINIQUE

The age of the MG-SB1 unconformity in the deepest part of the Marie-Galante Basin remains uncertain (Fig. 10) because of the lack of dredge and borehole samples. However, sample 43D collected nearby La Désirade Valley indicates that this unconformity is older than the Middle Miocene

and could be as old as the Eocene considering the 1300-1400-m thickness of MG-MS1. MG-MS1 is topped by a Lower Miocene shallow water carbonate platform to the east but remains in basin conditions to the west. The western side of the shallow carbonate platform was probably limited by the sub-meridian faults bounding the western flank of the Karukéra Spur now buried in the Arawak Sub-basin (Fig. 4, at line Agua119). We hypothesise that the facies change that occurs westward and upslope in the Kubuli Sub-basin (Fig. 4B) may correspond to a lateral change between basin deposits and volcanic and/or volcaniclastic deposits of the ancient late Eocene – late Oligocene arc (Fig. 8). Indeed, (i) the facies change is observed at the vicinity of the volcanic line of the ancient arc, (ii) MG-MS1 deposits are contemporaneous with the activity of the ancient arc, *i.e.* during the late Eocene to the latest Oligocene (Germa et al., 2011; Legendre et al., 2018; Bosch et al., 2022), (iii) basin deposits show imbricated, sometimes onlapping or parallel reflectors, with east dipping low amplitude reflectors that could correspond to the arc trenchward slope. By the end of the Early Miocene, MG-MS1 emerged to the east, giving rise to the erosional surface MG-SB2 over the Karukéra Spur and eastern Arawak Sub-basin, and the basement crops out north of the spur and in La Désirade (Fig. 10). In Martinique, the ages of the magmatic rocks belonging to the ancient arc have been considered to range between 24.8 ± 0.4 and 20.8 ± 0.4 Ma (latest Chattian-Aquitanian) (Germa et al., 2011), but the arc activity started earlier, during the early Chattian, as shown by the age of the carbonate deposits resting upon volcanic rocks at La Caravelle (Fig. S7 and Fig. 10).

In the Marie-Galante Basin, foraminiferal and calcareous nannofossil assemblages indicate that the age of the unconformity MG-SB2 ranges between the late Burdigalian (top of MG-MS1) and the Langhian-Late Miocene interval (oldest known age of MG-MS2). To the south, in Martinique, we also recognized a subaerial unconformity between the Burdigalian limestone deposits at Grand Macabou and the Middle Miocene volcaniclastic deposits at Petit Macabou (Fig. 9 and Fig. S7). Consequently, an erosional unconformity corresponding to the latest Burdigalian-Langhian interval occurs in the central Lesser Antilles (Fig. 10).

MG-MS2 sediments further indicate that the entire Marie-Galante Basin remained deep during the Middle and the Late Miocene (Fig. 10). Faults along the western side of the Karukéra Spur enhanced the spur relief, leading to thinner and more conformable and stratified deposits over the spur than in the basin. The Arawak Sub-basin was fed by south-eastward directed turbiditic prograding systems indicative of sediment transport from the upslope of the Kubuli Sub-basin. In the westernmost part of this sub-basin, sediments are intruded by the volcanic formation of the arc (Fig. 7 – *e.g.*, Agoucha volcano). In the Petite-Terre Sub-basin and probably beneath the South Grande-Terre platform, MG-MS2 is tilted to the south along the N110° and N130° trending faults, and eroded. In the southern Arawak Sub-basin, the southern tip of the spur is downthrown and opens a passage for the sediments toward the outer fore-arc basins. During deposition of MG-MS2, the sediments infilled this passage (Fig. 6 at line K09-52).

In the Marie-Galante Basin, the age of unconformity MG-SB3 (Fig. 10) is estimated to range between the Late Miocene (Serravalian-Tortonian, youngest age for MG-MS2) and the Early Pliocene (Zanclean, oldest age of MG-MS3). Onshore, in the Marie-Galante Island, upper Tortonian (8.57 ± 0.43 Ma, Münch et al., 2014) tuffaceous marls are unconformably overlain by Pliocene to Lower Pleistocene shallow water carbonate deposits (Upper Plateaus; Bouysse et al., 1993; Münch et al., 2013). Based on our investigations, the lowermost part of these carbonates deposited during the late Messinian in the Morne à l'Eau borehole and in La Désirade Island (Fig. S4). Consequently, onshore data allow to refine the age of the MG-SB3 to the Messinian, while it was previously considered to be late Tortonian-early Zanclean (Bouysse et al., 1993; Münch et al., 2013). Offshore, the main internal unit boundary within MG-MS3 can be assigned to the middle Piacenzian. Indeed, the lower unit correlates with the Zanclean and the lower part of the upper unit with the late Piacenzian (Arawak and Kubuli Sub-basins). Onshore this unit boundary correlates with the middle Piacenzian emersion surface occurring within the carbonate platform in Grande-Terre, Marie-Galante and La Désirade (SB1, Fig. 3). In Grande-Terre, this surface is overlain by the index unit named Pliocene Volcano-sedimentary unit (PVS) (Cornée et al., 2012; Lardeaux et al., 2013; Münch et al., 2014).

MG-MS3 (Fig. 10) dates latest Miocene to present. During this period, the Karukéra spur recorded a general drowning and tilting trenchward. The Arawak and Kubuli Sub-basins continued to fill with clastic deposits in a basin environment. On the margins of these sub-basins, reefal platforms were built up (La Désirade, Grande-Terre, Marie-Galante). By the middle Piacenzian, all the basin recorded a transient emergence event of its shallow platforms (unit boundary in MG-MS3) that is also recorded in La Désirade and Grande-Terre Islands Grande-Terre (SB1 surface in Cornée et al., 2012 and Münch et al., 2014; Figs. 3 and 10). During deposition of the upper unit of MG-MS3, the islands of La Désirade, Grande-Terre and Marie-Galante emerged while the Colombie bank evolved from a slope to a shallow water reefal platform. Concomitantly, subaerial volcanism along the present-day volcanic arc developed, first in Dominica since the Messinian then in Les Saintes and northern Basse-Terre during the Zanclean. Shallow reefal platforms built up around these new islands.

To summarize, MG-MS1 has deposited on an erosional surface at the top of an igneous basement. It dates Eocene (?) to late Burdigalian and is partly contemporaneous with volcanism since the early Chattian at least. An uplift episode occurred at the Burdigalian-Langhian transition, then MG-MS2 deposited in a rift basin between the Langhian and the Messinian. By the latest Messinian, a second uplift occurred, then MG-MS3 deposited between the latest Messinian and the Holocene.

5. Discussion

5.1. Depositional settings and paleogeographic evolution since the late-Early Miocene in the Guadeloupe archipelago, Dominica and Martinique

Our correlations of onshore and offshore data (Fig. 10) allow us to reconstruct the paleogeographic evolution of the whole Guadeloupe Archipelago, Dominica and Martinique with emerged and drowned areas, starting from the late Oligocene - Early Miocene (uppermost part of MG-MS1) (Fig. 11). We do not restore tectonic motions back in time and present our reconstruction based on the present-day geographic maps. However, the relative position of the studied islands should have been

very close to the present-day one since the Lower Miocene (*e.g.*, Pindell and Kennan, 2009; Boschman et al., 2014).

During the late Oligocene-Early Miocene (ca 25-17 Ma, uppermost part of MG-MS1, Fig. 11A), the Karukéra Spur and possibly western Grande-Terre were capped by shallow-water carbonate deposits evolving eastward to basin deposits. Westward, the Karukéra Spur was larger than today, bounded to the west by N150° west dipping faults now buried beneath the Arawak Sub-basin (Fig. 4, at line Agua119). Further west, basin deposits dominate in the Arawak Sub-basin. The shallow water areas, with a similar water depth than the banks today surrounding the islands of the Lesser Antilles, were located at the hinge between the inner forearc and the deep outer-forearc deep basins. The only emergent area along the Karukéra Spur at this time was a small island in the footwall of a NE-SW trending normal fault. Following the interpretation of Boucard et al. (2021), the V-shaped basins found along the Lesser Antilles, among which the La Désirade Valley, were actively opening prior to the Late Miocene. Because MG-MS1 onlaps northward on the Karukéra Spur and is missing in its northern part and in La Désirade, we suggest that the hinge of the N70° trending basin wall was cropping out too, as an emerged (or very shallow) narrow area parallel to the scarp. The southern extent of the Karukéra shallow platform is unknown because of the deep erosion that entails its southern part. The facies transition in the Kubuli Sub-basin may indicate the presence of volcaniclastic deposits from volcanoes of the remnant arc. This arc would have extended from Martinique to Antigua, passing at the longitude of the Kubuli Sub-basin and Marie-Galante Island. In Martinique, Burdigalian carbonates of the Macabou area indicate a drowning of the subaerial upper Oligocene-Lower Miocene volcanic arc.

By the Early-Middle Miocene transition (ca 17-16 Ma, unconformity MG-SB2, Fig. 11B), the Karukéra Spur and possibly eastern Grande-Terre were emergent. We did not find evidence for shallow water carbonate platforms around the emergent areas, only marly deposits in the Marie-Galante Basin, which remained below sea level. In Martinique, an uplift occurred between the late Early Miocene

and the Middle Miocene, responsible for an emersion surface and a localized erosion of the Burdigalian deposits.

During the early Middle Miocene (ca 16-13 Ma - lower unit of MG-MS2, Fig. 11C), the Marie-Galante Basin and previously emergent areas underwent a drastic drowning. Faults bounding the Karukéra Spur to the west offset MG-SB2 down to the west. Shallow-water carbonate deposits are restricted to the western margin of the Karukéra Spur along the summit of a narrow horst. At the same time, mid to outer platform volcaniclastics were emplaced in shallow-water banks, east of Grande-Terre and the Karukéra Spur. Dredges and seismic profiles analyses evidence a deepening to possibly 1000 m paleowater depth for the deepest part of the Marie-Galante Basin, most probably accommodated by large NNW-SSE parallel to the trench normal faults responsible for the present-day configuration of the basin. As the Arawak Sub-basin deepened, large submarine channels where then carved, and gravity-driven deposits (*e.g.*, mass flows, turbidites) were emplaced. In its deepest part, SSE-ward prograding turbiditic deep-sea fans and lobes developed, and contouritic facies occurred along the steep western edge of the Karukéra Spur. South of the Karukéra Spur and probably thanks to faults transverse to the spur that drown its southern part, submarine erosion entailed deep into the previous units and opened a passage for the sediments toward the deep outer forearc basins. Upslope in the Kubuli Sub-basin, MG-MS2 capped the volcanoclastic deposits of the remnant arc. In Martinique, the oldest arc was also drowned, contemporaneously with the onset of volcanic activity of the Middle Miocene arc. New subaerial volcanic centres developed, and submarine volcaniclastics were deposited at their foot above the previously emergent areas of the Macabou area. North of Martinique, the Middle Miocene corresponds to a period of volcanic quiescence.

During the late Middle and Late Miocene (ca 13-7 Ma - upper unit of MG-MS2, Fig. 11D) the configuration of the Marie-Galante Basin persisted. In the basin, deep-sea fans and lobes prograded SSE-ward toward the deepest part of the basin, fed by canyons that entailed the Kubuli Sub-basin around the present-day Marie-Galante Island. In the northern part of the Karukéra Spur, sedimentation recorded a new episode of uplift attested by shallow-water carbonate deposits while its southern

part remained in deeper marine conditions, suggesting a regional tilt of the spur toward the SSE. At the same time, an intensive volcanic activity occurred in Martinique (Germa et al., 2011).

During the latest Miocene (ca 7-5.8 Ma - MG-SB3, Fig. 11E), the physiography of the Guadeloupe Archipelago changed substantially. The whole area recorded a regional uplift. As a result, Grande-Terre, the northern Karukéra Spur, the Petite-Terre Sub-basin, Marie-Galante and the Rodrigue Plateau constituted tens of kilometres wide islands. The Arawak and Kubuli Sub-basins continued to deepen SSE-ward with turbiditic and contouritic deposits. The N110° Morne Piton fault system, cross cutting the Marie-Galante island, was incipient as attested by onlaps of MG-MS3 onto the uplifted MG-SB3 when observed perpendicular to the fault. Contemporaneously, aerial volcanism resumed in eastern Dominica between 7 and 5.3 Ma while volcanic activity decreased in Martinique.

During the latest Miocene - Early Pliocene (5.8-3.4 Ma - lower unit of MG-MS3, Fig. 11F) a second drowning episode occurred in the Guadeloupe archipelago. The former emerged islands underwent shallow carbonate sedimentation, dominated by red algal facies, as well as mid platform fine-grained deposits (Grande-Terre, La Désirade, northern Karukéra Spur, Marie-Galante, Rodrigue and Les Saintes Plateaus). The Marie-Galante Island carbonate platforms built up along the N110° Morne Piton fault scarp shoulder. Sedimentation of MG-MS3 in the Arawak and Kubuli Sub-basins was retrogradational and aggradational above MG-SB3, attesting for distal clastic basin infilling. As the Morne Piton Fault scarp developed, the main canyon system feeding the Arawak Sub-basin progressively jumped at the toe of the fault scarp forming the present-day Marie-Galante Canyon. To the north of this canyon, the Petite-Terre Sub-basin remained as an elevated area. It was not covered by MG-MS3 but incised by deep canyons controlled by the N130° fault system. Only the northern tip of Karukéra Spur remained emerged. The spur then progressively tilted eastward. Submarine and aerial volcanism resumed all along the present-day arc since *ca* 4 Ma in Les Saintes Channel (Henri et al., 2022) and in Northern Basse-Terre (Favier et al., 2019). In Dominica, volcanism was active during the Early Pliocene and in Martinique both submarine and aerial volcanisms built the central part of the island. By the end of the Early Pliocene, a short uplift episode led to the emersion of western

Grande-Terre. This event is recorded in the offshore basins by a low angle unconformity (unit boundary in MG-MS3).

During the Late Pliocene-Early Pleistocene (ca 3.4-1 Ma - MG-MS3 upper unit, Fig. 11G), the Karukéra Spur continued to tilt ESE-ward. A carbonate platform covered most of its northern half while the southern one deepened to a thousand of meters below sea level. The Rodrigue Plateau was covered by MG-MS3 deposits and a carbonate platform started to build up around the active volcanoes of Les Saintes. A coral carbonate platform covered Grande-Terre, Marie-Galante Island and La Désirade. In the Marie-Galante Basin, deep-sea deposition occurred. Aerial volcanoes developed in central Dominica, Les Saintes, northern Basse-Terre and western Martinique.

Since the Middle Pleistocene (< 1Ma, Fig. 11H), the configuration of the Marie-Galante Basin has remained close to its present configuration. The bathymetry reached *ca* 2000 m bsl in the Arawak Sub-basin and the Karukéra Spur was a submerged shoal. A narrow carbonate platform was emplaced on the Flandres Bank while the southern part of the spur deepened to *ca* 1700 m bsl. Concomitantly, La Désirade Island raised up to 270 m above sea level. The carbonate platforms were subsequently dissected by normal faults: N150° faults in La Désirade, N90°, N130° and N40° faults in Grande-Terre and N110° faults in Marie-Galante. Uplift in the PCSM Sub-basin, between Marie-Galante and Basse-Terre, led to the development of the carbonate platform of the Colombie Bank along the shoulder of the Morne Piton Fault. In Les Saintes, a carbonate platform built up around the now extinct volcanoes. Volcanic activity continued in central and southern Guadeloupe and in Dominica. La Soufrière active volcano in Guadeloupe is nowadays the summit of the Lesser Antilles with an elevation of 1497 m above sea level. Analyses of marine terrace elevations have evidenced vertical motions during the last 1 Ma. These studies showed that La Désirade is still uplifting, although the motion is slowing down (Léticée et al., 2019). Marie-Galante is rising too, part of the movement being due to the active Morne Piton Fault (Feuillet al., 2004). Grande-Terre remained stable or has slowly drowned to the West (Feuillet et al., 2002). Both the submerged Les Saintes and Martinique platforms subsided (Leclerc et al., 2016; Leclerc and Feuillet., 2019). Geodesic data have further suggested a general 1

– 2 mm. yr^{-1} regional subsidence of the arc and a slow uplift of La Désirade (Van Rijsingen et al., 2022).

5.2. Correlation with the northern Lesser Antilles and vertical motions in the northern and central Lesser Antilles

We evidence a major unconformity MG-SB2 extending from the Marie-Galante Basin to Martinique corresponding to the latest Burdigalian-Langhian interval (Figs. 10 and 11B). This unconformity is subaerial all along the Karukéra Spur. The spur was probably a N-S elongated island on the eastern border of the Marie-Galante Basin. Such an unconformity was also identified in the northern Lesser Antilles from the Anguilla Bank to the Antigua Bank where it is recognized as the SB4 unconformity (Fig. 10) corresponding to the latest Burdigalian-early Langhian interval (Cornée et al., 2021). Recent seismic investigations have shown that SB4 is also present to the east in the outer forearc, offshore St Barthélemy and Antigua, in V-shaped basins that are oblique to the trench (Legendre et al., 2018; Philippon et al., 2020; Boucard et al., 2021). Consequently, we propose that the unconformity MG-SB2 of the Marie-Galante Basin may be coeval with the regional unconformity SB4 of the northern Lesser Antilles and with the Middle Miocene unconformity of Martinique. This unconformity appears therefore of regional extent and may be related to a major event. In the northern Lesser Antilles, SB4 has been interpreted as resulting from a forearc uplift with temporary emersion of extensive archipelagos (Boucard et al., 2021; Cornée et al., 2021), like in the central Lesser Antilles (Fig. 12A). During the Middle and Late Miocene, the northern and the central Lesser Antilles subsided and most of archipelagos disappeared (Fig. 12B). The subsidence of the Lesser Antilles forearc has been related to basal tectonic erosion of the upper plate during subduction (Münch et al., 2014; De Min et al., 2015; Boucard et al., 2021). Boucard et al. (2021) suggested that this process is responsible for the landward arc retreat that occurred between the latest Oligocene and the Pliocene. Our interpretation that the sediments of MG-MS2 capped the volcanoclastic deposits of MG-MS1 in the Kubuli Sub-basin corroborates the hypothesis that the central Lesser Antilles arc also retreated westward during this interval.

In the Guadeloupe archipelago, we evidence a second major unconformity MG-SB3, estimated to be late Messinian based on our onshore-offshore correlations (Fig. 10). At that time, new islands were formed in the western part of the Marie-Galante Basin and along the shallowest part of the Karukéra Spur to the north. In the northern Lesser Antilles, the SB5 unconformity similarly corresponds to the late Messinian/early Zanclean interval, as for example in Barbuda (Cornée et al., 2021). Consequently, we propose that MG-SB3 correlates with SB5 (Fig. 10). During the late Messinian, new archipelagos appeared from the Anguilla Bank to Martinique, coeval with new subaerial volcanic activity that started to build the first islands of the present-day arc (Fig. 12). MG-SB3 (= SB5 of the northern Lesser Antilles) has been related to transient uplift of the Lesser Antilles forearc during basal erosion processes (De Min, 2014; Münch et al., 2014; De Min et al., 2015; Boucard et al., 2021). Subsequently, the Lesser Antilles forearc subsided from the Zanclean (Early Pliocene). Finally, a latest uplift episode led to the emergence of the present-day islands of Grande-Terre, Marie-Galante and La Désirade at *ca* 1.2 Ma (Cornée et al. 2012; Münch et al. 2014) whereas the Karukéra Spur recorded continuous subsidence. Over the whole studied time interval, islands first occurred to the east at the Karukéra Spur. Later, new islands developed further west from Grande-Terre to Marie-Galante while the spur subsided. Such a temporal evolution may be related to tectonic erosion of the margin that induced a westward migration of the flexural bulge of the upper plate, resulting in a landward migration of the emerged areas.

Eustatic sea level changes did not play a significant role in the appearance or drowning of Neogene islands. Indeed, their amplitude is limited to some tens of meters (Miller et al., 2020). Moreover, when islands were formed during the latest Burdigalian-early Langhian and the latest Messinian (Fig. 11B and E), the sea level was rising and not falling. Thanks to high resolution and good coverage of available geophysical and chronostratigraphic constraints, our study allows: (i) a better understanding of the regional causes responsible for cycles of drowning and uplift of forearc crustal blocks and (ii) to figure out the periodicity of these cycles. Although our dataset is restricted to the central Lesser

Antilles since the late-Early Miocene, we show that uplift and subsidence affecting the forearc occurred several times, during about 2-4 million years. Peri-Pacific forearcs show similar tectonic cycles with a comparable frequency and an amplitude of several hundreds of meters (Menant et al., 2020). These drowning/uplift "cycles" are attributed to transient underplating of sediments at the base of the forearc, responsible for uplift and followed by basal erosion responsible for subsidence/drowning (Menant et al., 2020). The accurate quantification of the amplitude of these vertical motions affecting the Lesser Antilles forearc still remain unravelled and this could be achieved through deep-sea drillings. At regional scale, from the northern (Cornée et al., 2021) to the central Lesser Antilles (this work), the subduction arc region (*sensu lato*) also recorded Ma- long alternating episodes of drowning and uplift (Fig. 12).

5.3. The Lesser Antilles: a Miocene pathway for terrestrial fauna migrations between the Greater Antilles and South America?

Based on the results obtained in this work and the recently published paleogeographic data collected from the northern part of the Lesser Antilles (Philippon et al., 2020; Cornée et al., 2021), we find that islands have episodically existed in the region during the Miocene. This is especially the case during the early Middle Miocene and the latest Miocene, when important uplift events occurred in the northern Lesser Antilles forearc, *i.e.* the Kalinago and the Marie-Galante rift basins. These former emerged lands were separated from each other by tens to a hundred of kilometres wide seaways, and were likely about ten times larger than the present-day islands.

In which manner terrestrial animals, and especially those who are intolerant to salinity (*e.g.*, amphibians), dispersed from continental areas to oceanic islands is still a debated topic. Several processes have been proposed, as for example land bridges, large floating islands, small-sized natural vegetation rafts, swimming, storms, birds, low salinity paths in oceans (*e.g.*, Measey et al., 2006; Ali and Huber, 2010; Townsend et al., 2011; Ali and Hedges, 2021; Ali et al., 2021). Here, we demonstrate that along the Lesser Antilles subduction zone, between Anguilla to the north and Martinique

to the south, no continuous land bridge has occurred since *ca* 17-16 Ma. Besides Quaternary glacio-eustatic sea level changes that may have triggered episodic emergences (Cornée et al., 2021), we evidence that wide archipelagos punctually emerged and drowned as a consequence of large-scale tectonic processes.

Blackburn et al. (2020) discussed the mechanisms of dispersal of some early Oligocene frogs from South America to Puerto Rico, and they consider that further studies are necessary to understand the origins of the Greater Antilles fauna. Based on an updated compilation of the diversity of 35 terrestrial vertebrate clades (within amphibians, mammals and reptiles) and the geological work of Garrocq et al. (2021) in the Aves Ridge, Ali and Hedges (2021) concluded that the GAARlandia hypothesis has to be rejected and that the mechanisms of dispersal should be re-evaluated in the Caribbean. From molecular phylogenetic analyses of the spider *Antillatus*, a clade endemic of the current Greater Antilles which originated in the northern part of South America, Cala-Riquelme et al. (2022) concluded: (i) that their common ancestor first occurred in Hispaniola about 25 Ma ago and migrated through the GAARlandia landbridge; (ii) that Hispaniola should have been a nucleus of terrestrial dispersal toward Cuba and Puerto Rico prior to their separation; and (iii) that multiple dispersal and island-speciation events occurred during the Middle and Late Miocene, when these islands were formed. Based on genomic phylogeny studies, Schools et al. (2022) proposed that diploglossid lizards dispersed twice from South America to the Greater Antilles, first during the Oligocene and then during the Miocene. Additional recent findings have shown that during the late Eocene, the GrANoLA landmass emerged as a result of a regional compressional event that affected the northern part of the Antilles from Puerto Rico to St. Barthélemy (Philippon et al., 2020) (Fig. 1B). Both the estimated age of the GrANoLA and paleontological data confirm that large islands, hundreds- kms wide, have existed in the northeastern Caribbean, connecting the Greater and Lesser Antilles (Fig. 1B). Moreover, the northern Lesser Antilles (from Antigua to Anguilla) may also have played a role later during the

Cenozoic because the region underwent several episodes of emergence of archipelagos, notably during the late Oligocene, the early Middle Miocene, at the Miocene-Pliocene transition, and during the most severe glacials of the Quaternary (Cornée et al., 2021) (Fig. 1B).

In the southern Lesser Antilles, molecular phylogeny studies of current insular frog and lizard species (Bourgade, 2020; Grabosky et al., 2022) suggest that ephemeral archipelagos played a role in connecting South America, Martinique and Hispaniola. Nevertheless, geological data are crudely missing in these areas to better constrain such a hypothesis. The initial dispersal of some reptiles and amphibians from South America to the Lesser Antilles (*e.g.,* Prates et al., 2015) has been explained by the hypothetical existence of the Isthmus of Matina (connecting Martinique to Tobago) during the middle Eocene (Bourgade, 2020). The later author also hypothesized the existence of a Matïgwana Island (connecting Martinique to St Lucia) during the late Eocene-early Oligocene. Matïgwana has been proposed as a refuge where the speciation and increasing endemism of some lizards (Prates et al., 2015) and now extinct rodents might have occurred (Bourgade, 2020). South of St Lucia, the presence of wide emerged islands during the Neogene is also highly suspected. In St Vincent-Les Grenadines-Grenada islands, Eocene and Miocene deep-sea deposits are cropping out, indicating that severe vertical motion affected these islands (Speed et al., 1993; Donovan and Jackson, 2013).

Our study shows that tectonics played a significant role in the uplift and emergence of archipelagos in the central Lesser Antilles during the early Middle Miocene and the latest Miocene. Such uplifted islands may have also existed in the southern Lesser Antilles as suggested by molecular phylogenetic data (Bourgade, 2020; Grabosky et al., 2022). The resulting proximity between emerged landmasses may have favoured short distance oversea dispersals of some terrestrial fauna and their subsequent speciation, at least during the Miocene. Consequently, besides long-distance oversea or land bridge hypotheses, we propose that the diachronous vertical motions along the arc and resulting emersion episodes and changing paleogeography of the Lesser Antilles may also have played a significant role in the dispersal and speciation of terrestrial fauna during the Miocene. Our hypothesis needs now to

be further tested by new paleontological research in the Lesser Antilles and new geological investigations in the southern Lesser Antilles. This would notably allow to better constrain the paleogeographic evolution and the potential connection or land proximity between the southern Lesser Antilles and South America. Such constraints are necessary to precise the kinematic reconstructions that will allow to refine the paleo-locations of past islands in the Lesser Antilles since the late Eocene.

6. CONCLUSIONS

Our integrated study of seismic lines, together with biostratigraphic analyses of dredged and core samples and correlations with new onshore data from Guadeloupe and La Désirade, show that the Marie-Galante Basin comprises three sedimentary megasequences lying above an Upper Jurassic deformed basement: an Eocene (?) to upper Burdigalian megasequence (MG-MS1), a Middle Miocene to Upper Miocene megasequence (MG-MS2) and an uppermost Miocene to present-day megasequence (MG-MS3). The MG-SB2 sequence boundary dates late Burdigalian-Langhian and is also identified onshore in Martinique. The age of the MG-SB3 sequence boundary dates late Messinian. The opening of the Marie-Galante Basin has been controlled by NNW-SSE trending normal faults that have been active since the Oligocene. The megasequences are separated by regional unconformities which have been partly erosional and subaerial in the shoulders of the main fault systems of the Marie-Galante Basin and the Karukéra Spur. Our paleogeographic reconstructions reveal that tectonically-controlled archipelagos took place between Anguilla Bank and Martinique during the early Middle Miocene (MG-SB2) and the latest Miocene (MG-SB3), and that magmatic activity has occurred since the latest Miocene. Such emergence periods exhibit a cyclic pattern of several million years. This suggests that repeated episodes of underplating/erosion at the plate interface may have accounted for part of the vertical motion in the forearc. The Miocene archipelagos were much wider than today, with islands of tens to hundred kilometres wide, separated by narrower seaways. Considering the available biodiversity in the southern Lesser Antilles, we suggest that short distance overwater dispersals may also have driven migrations and speciation of terrestrial fauna in the Lesser Antilles during the Neogene.

Acknowledgments

Authors thank the Parc Naturel Régional de Martinique for field support in the Caravelle botanical and geological reserve and for sampling authorizations. We thank Olivia Urity for help during field trips in Martinique and B. Leru for scientific discussions. We are indebted to the crew and the scientific party of the KaShallow cruise (https://doi.org/10.17600/9020010). We are also indebted to the French BRGM who allowed us to study the Morne à l'Eau borehole (Project FEDER C3AF), and to C. Deplus for providing Aguadomar cruise data.

This work has been funded by the French KaShallow cruise program (https://doi.org/10.17600/9020010) and the INSU-SYSTER program OBLISUB. The Région Guadeloupe supported L. De Min PhD grant.

We would like to dedicate this work to our colleague Professor Marcelle Boudagher-Fadel who passed away on June, 29th, 2022. She provided invaluable information about foraminifers, leading to an improved understanding of the stratigraphy and paleoenvironments in the Caribbean region, among many other places. We also want to thank our colleague Jean-Len Léticée who passed away on December, 21st, 2022 for his pioneering PhD work (2008) on the Grande-Terre carbonate platform.

Data Availability

Bathymetric and seismic data are available at Sismer data repository from the cruises DOI : Aguadomar cruise - https://doi.org/10.17600/98010120 - KaShallow cruise https://doi.org/10.17600/9020010 – SismAntilles 2 cruise https://doi.org/10.17600/7010020

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Figure captions

Figure 1. A) Geodynamic setting of the eastern Caribbean. Bathymetry from the GEBCO (2014); AB: America Bank; DB: Dien Bien Phu Bank; TBR: Tiburon Ridge. B) Possible pathways for past dispersals of terrestrial fauna in eastern Caribbean. White box: studied area. 1: Aves Ridge, Paleogene; 2: Orinoco – southern Antilles, *e.g.*, Bourgade (2020); 3: Northern Lesser Antilles, Paleogene, Neogene

Figure 2. Seismic lines location, structural setting, location of dredges and toponomy in the Marie-Galante Basin. Background relief map is from the GEBCO (2014); high resolution relief is a digital terrain model from multibeam bathymetric data acquired during the Aguadomar, Sis-mAntilles 2 and KaShallow cruises (French Oceanographic Fleet); Islands relief is from the SRTM (https://doi.org/10.5066/F7PR7TFT). A) Location of seismic reflection data; pink and yellow bold lines are section presented in Figs. 4 to 7 and supplementary material Figs. S3 to S6. Dashed bold lines are seismic lines over the Karukéra Spur, referred in text and published by De Min et al. (2015). B) Structural map re-interpreted from Feuillet et al. (2002), De Min et al. (2015) and Leclerc et al. (2016) ; ticks lines are normal faults. Orange bold line is the north-ern boundary of MG-MS1 megasequence. Dashed bold line indicates the western extent of the MG-MS1 carbonate platform as it can be interpreted from seismic facies. C**)** Rock samples location. MàL: Morne à l'Eau drill, PF: Pointe Frégule outcrop. D) Toponymy : island names are in bold. CB: Colombie Bank, GT: Grande-Terre, LSP Les Saintes Plateau, PCSM: Petit Cul de Sac Marin, RP Rodrigue Plateau.

Figure 3. Synthetic lithostratigraphic logs, major unconformities, correlations and ages across car-bonate platforms of the Guadeloupe archipelago islands and adjacent submerged Karukéra spur and Colombie Bank.

Figure 4. Line drawing and interpreted section of the seismic lines Aguadomar 116 -34 and 119 and KaShallow K09_80 extending from the Rodrigue Plateau (west) to the Karukéra Spur (east). Location in Fig. 2A. The cross-section illustrates the architecture of the Kubuli and Arawak Sub-basins, including the westward deepening of the basement beneath MG-MS1, the lateral facies transition of MG-MS1 deposits toward the remnant arc and the eastward prograding architecture of MG-MS2 and MG-MS3. Black rectangles outline location of facies illustrated and described in supplementary material Figure S2, as well as location of enlargements A, B, C and D illustrating some characteristic parts of the seismic lines that are described in the text. An uninterpreted section and a larger line drawing image are available in supplementary material Figure S3.

Figure 5. Line drawing and interpreted section of the seismic lines KaShallow K09_26-60-61-62 in the central part of the Marie-Galante Basin. Location in Figure 2A. The cross-section illustrates the transition between the South Grande-Terre Plateau downslope toward the Arawak Sub-basin extending NNW-SSE between the Kubuli Sub-basin outer slope and the faulted Karukéra Spur eastern border. Black rectangles outline location of facies illustrated and described in supplementary material Figure S2, as well as location of zooms A and B illustrating some characteristic parts of the seismic line that are described in the text. An uninterpreted section and a larger line drawing image are available in supplementary material Figure S4.

Figure 6. Line drawing and interpreted section of the seismic lines KaShallow K09_51-52 in the south-eastern part of the Arawak Sub-basin. Location in Figure 2A. The cross-section illustrates the deep incision of MG-SB2 in the southern Arawak Sub-basin, the peculiar facies of MG-MS1 uppermost unit and significant internal incision into MG-MS2 in the northern Arawak Sub-basin. Black rectangles outline location of facies illustrated and described in supplementary material Figure S2, as well as location of zooms A and B illustrating some characteristic parts of the seismic line that are described in the text. An uninterpreted section and a larger line drawing image are available in supplementary material Figure S5.

Figure 7. Line drawing and interpreted section of the seismic line KaShallow K09_90 in the western part of Marie-Galante Basin. Location in Figure 2A. The cross section illustrates the landward most part of the Kubuli Sub-basin with volcanic intrusions, cross cuts the Colombie Bank carbonate platform northward through the Morne-Piton Fault into the Petit Cul de Sac Marin Sub-basin. Black rectangles outline location of facies illustrated and described in supplementary material Figure S2, as well as location of enlargement A illustrating some characteristic parts of the seismic line that are described in the text. An uninterpreted section and a larger line drawing image are available in supplementary material Figure S6.

Figure 8. 3D representation of the Marie-Galante Basin seen from the south-east illustrating the relationships between the upper plate igneous crust, the remnant and active arc and the Marie-Galante Basin sedimentary infill. M-G.: Marie-Galante Island.

Figure 9. Field views of the Martinique outcrops. Upper left panel: simplified geological map of Martinique with organization of the remnant, intermediate and present day arcs. Locations of La Caravelle, Tartane, Grand and Petit Macabou sections are indicated. A) simplified stratigraphic organization of Caravelle Peninsula and Macabou areas carbonate platform intercalated within the remnant arc formation (not to scale). Grand Macabou area: B) Aquitanian, coral-rich part of the section; C) detailed view of a coral-rich bed. Petit Macabou area: D) top of karstified and bored Aquitanian coral-rich bed with iron coatings (arrows; oblique view); E) Middle Miocene cross bedded volcaniclastic deposits with larger benthic foraminifera. See also supplementary material Figure S7 for detailed cross sections, stratigraphic and depositional settings descriptions, as well as larger benthic foraminifera determinations and biostratigraphic age calibrations.

Figure 10. Age model reconstructed from correlations of onshore and offshore sedimentary sequences between the northern and central Lesser Antilles. Naming from authors: MS: megasequence; S: sequence; U: unit; SB and UB: sequence and unit boundary, respectively. GT: Grande-Terre, MG: Marie-Galante, Des: La Désirade.

Figure 11. Paleogeographic maps of the Marie-Galante Basin area since the late Oligocene-Early Miocene to present. Each step is interpreted based on the sedimentary architecture of the basin as determined on the seismic line and described in the text. A) At the top of MG-MS1, B) during MG-SB2 sequence boundary stand, C and D) during deposition of MG-MS2 lower and upper units respectively, E) during MG-SB3 stand, F and G) during deposition of MG-MS3 lower and upper units respectively, and H) since the Middle Pleistocene. Dredge samples from the various units are indicated at each step. Samples description is reported in supplementary material Figure S1.

Figure 12. Three steps cartoon illustrating the changing paleogeography of the central and northern Lesser Antilles during the Miocene, interpreted from this work and Cornée et al. (2021). Maximum extent of islands occurred during the late-Early Middle Miocene and the latest Miocene offering wide lands for species dispersion, while general drowning during the Middle to Late Miocene and since the Early Pliocene reduced islands superficies and increased sea distance leading to isolate populations and driving speciations.

Supplementary data

Figure S1: micropaleontological analysis and depositional environments of samples dredged in the Guadeloupe archipelago (Arcante and KaShallow cruises).

Figure S2: illustration of the seismic facies from the Marie-Galante Basin and Karukéra Spur, their description and interpretation. Each facies is identified on seismic lines of Figures 4 to 7. Interval between black horizontal lines is 0.2s twt except for facies 14, 0,1s twt. Yellow-black images are high resolution seismic data from the KaShallow 2 cruise; Red-Blue images are medium resolution seismic data from the Aguadomar cruise; Grey image is from very high resolution (sparker source) seismic line from the KaShallow 1 cruise (in Münch et al. 2013).

Figure S3: Aguadomar seismic lines 116-034-119 and KaShallow 2 K09_80 (top) and interpretation (bottom) from the Rodrigue Plateau to the Karukéra Spur across the Kubuli and Arawak Sub-basins. Location in Figure 2A.

Figure S4: KaShallow 2 seismic lines - K09_26-60-61-62 (top) and interpretation (bottom) from the South Grande-Terre Plateau to the southern Arawak Basin. Location in Figure 2A.

Figure S5: KaShallow 2 seismic lines - K09_51-52 (top) and interpretation (bottom) across the south-western part of the Arawak basin. Location in Figure 2A.

Figure S6: KaShallow 2 seismic line KS09_90 (top) and interpretation (bottom) across the western Kubuli Sub-basin, the Colombie Bank and the Petit Cul de Sac Marin Sub-basin. Location in Figure 2A.

Figure S7: cross-sections, stratigraphy, depositional settings, larger benthic foraminifera and biostratigraphic age calibrations of the carbonate deposits in eastern Martinique (Caravelle, Tartane, Grand Macabou and Petit Macabou).

Figure S8: photographs of some of the larger benthic foraminifera in sample KS38 south of the Karukéra Spur (location in Figure 2C). Cross-sections, stratigraphy, depositional settings, larger benthic foraminifera (and photographs) and biostratigraphic age calibrations of the lower part of the carbonate deposits (Upper Plateaus) in Guadeloupe Morne à l'Eau borehole (location in Figure 2C) and La Désirade at Pointe Frégule (location in Figure 2C).

Figure

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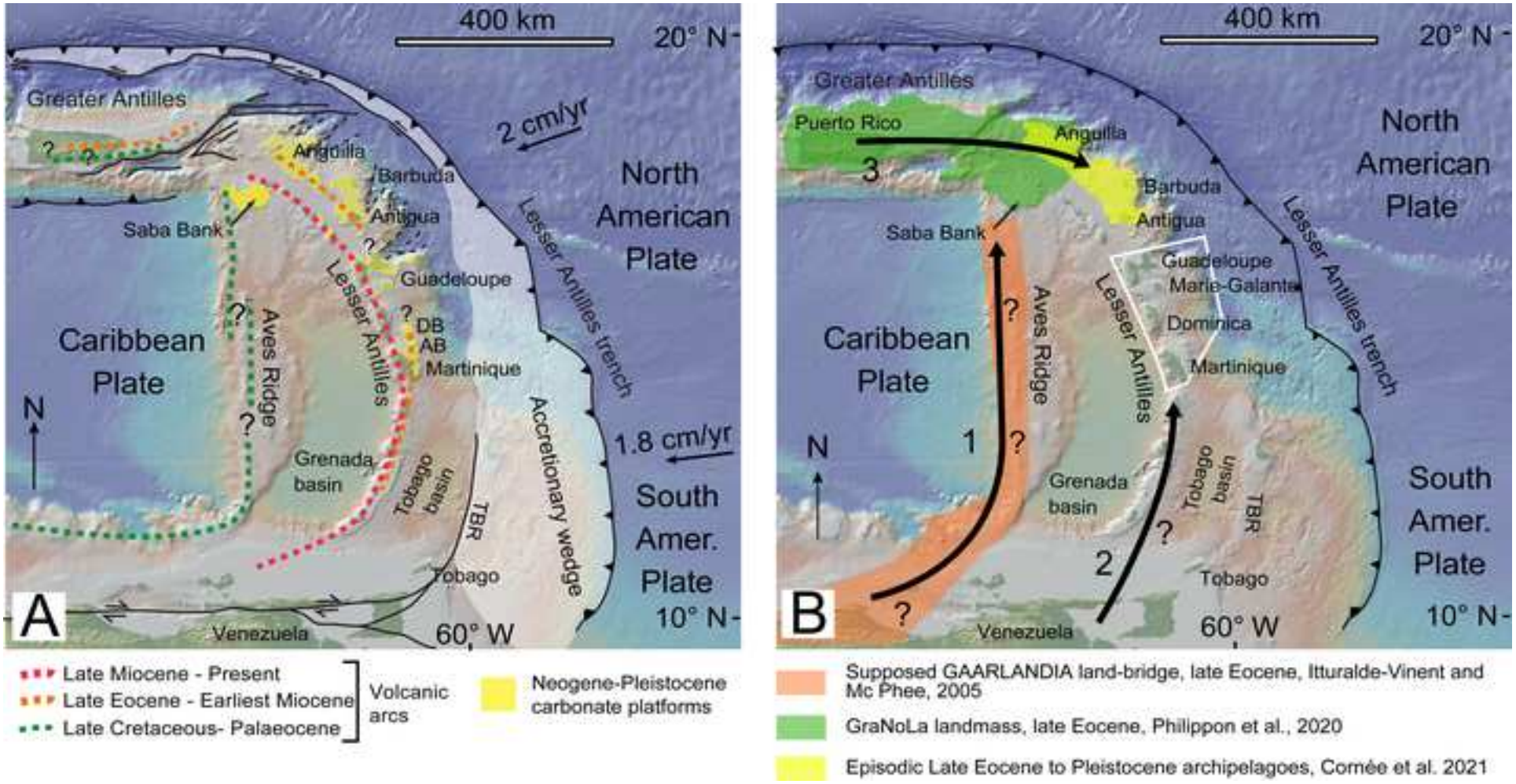

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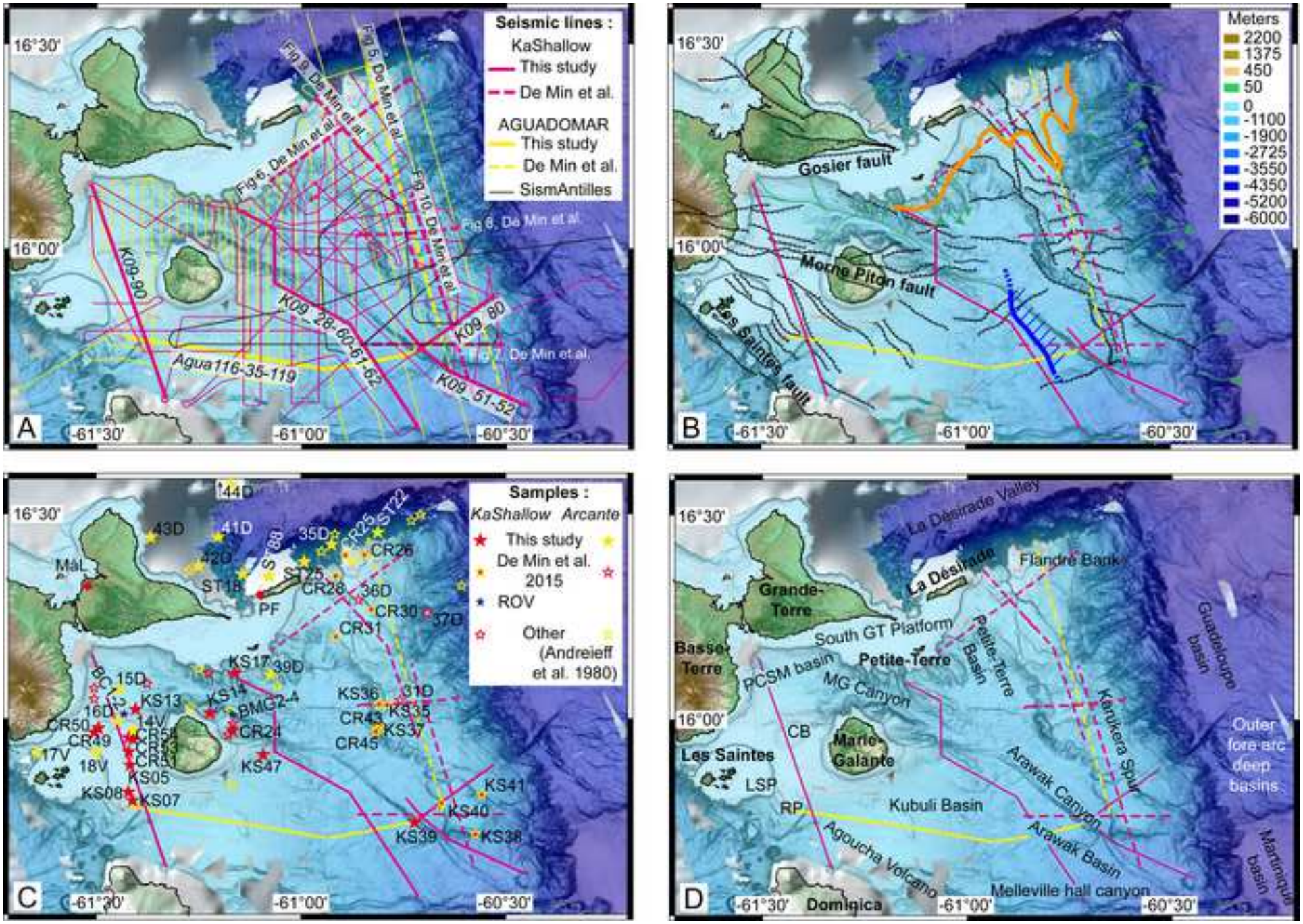

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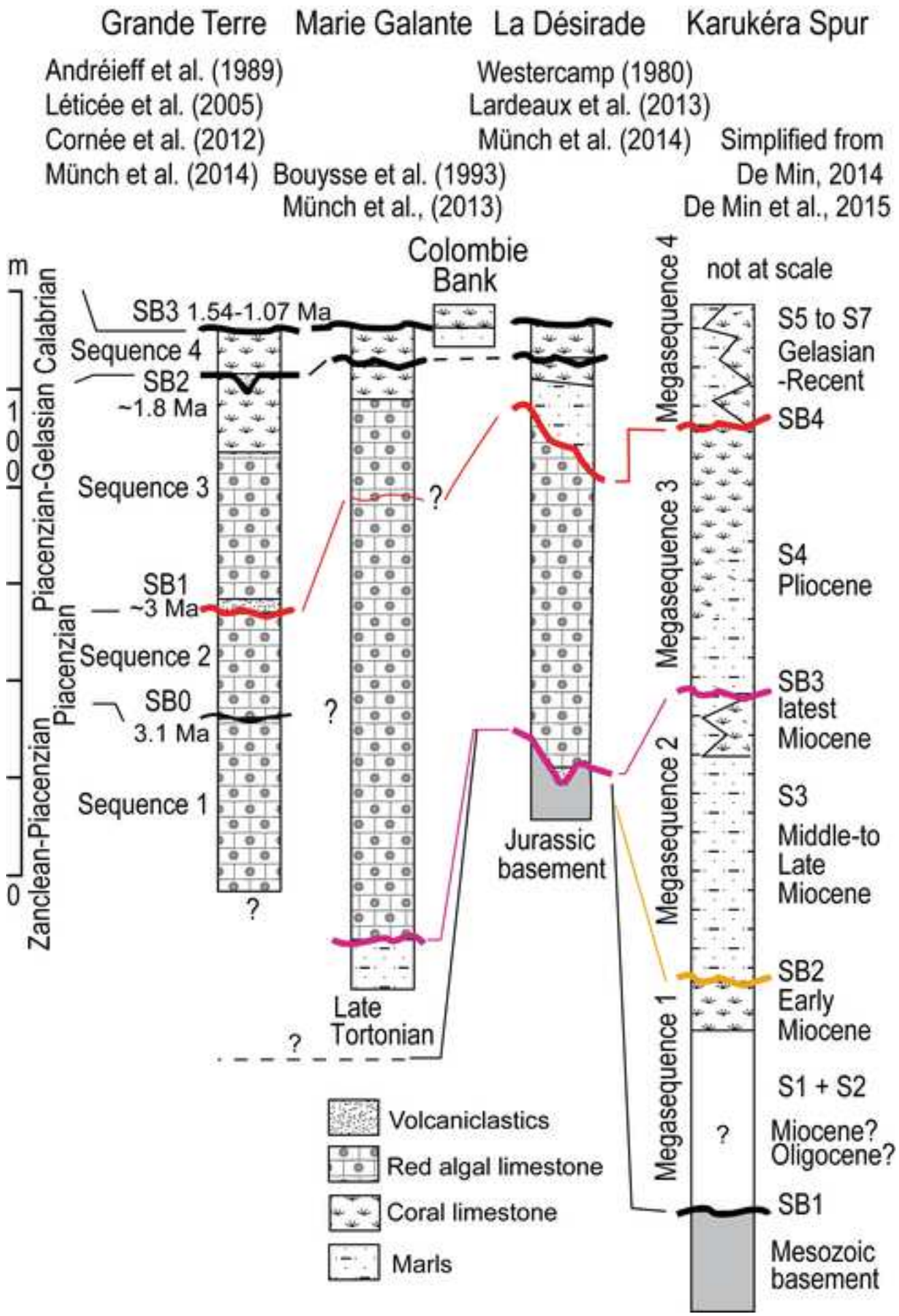

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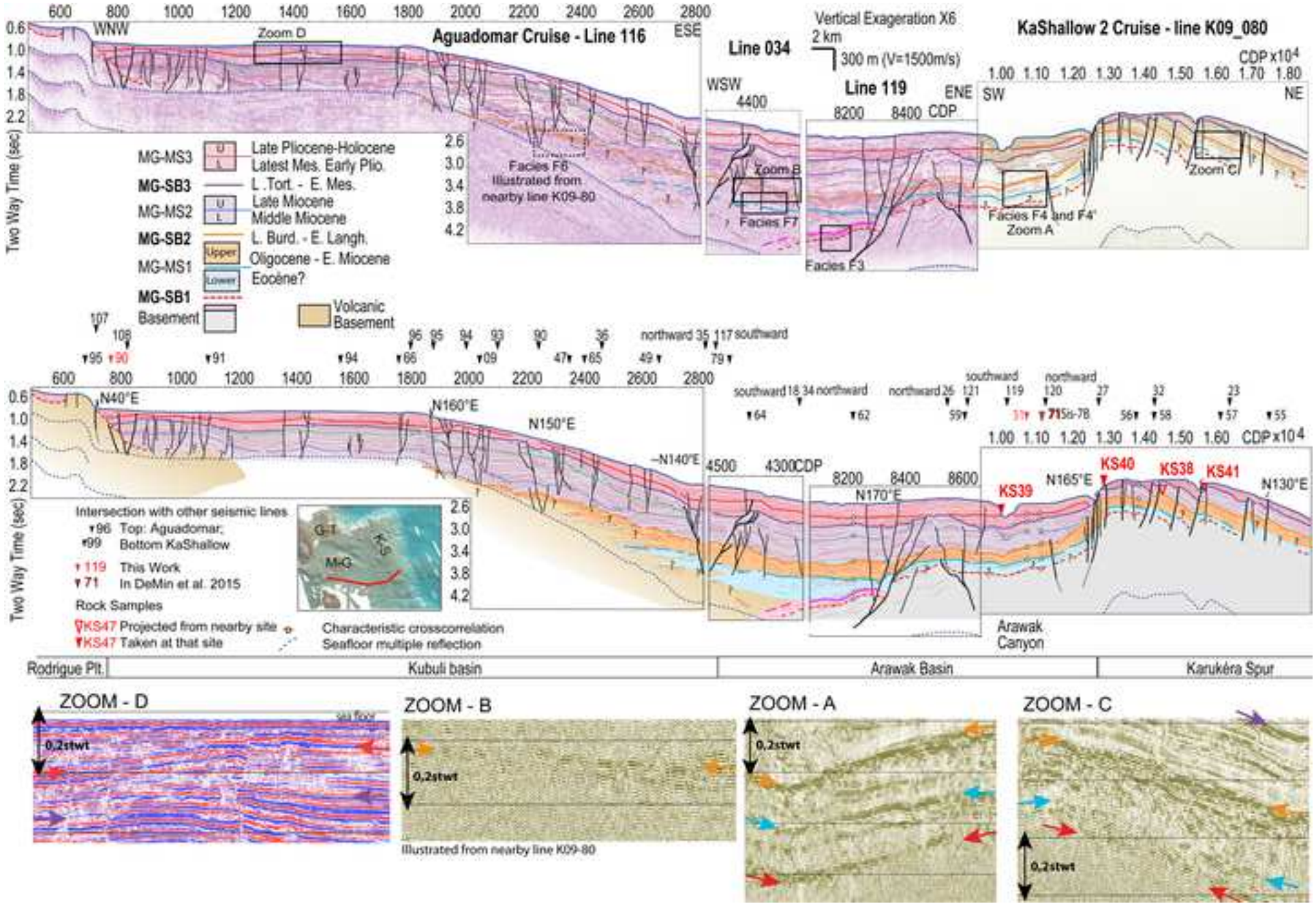

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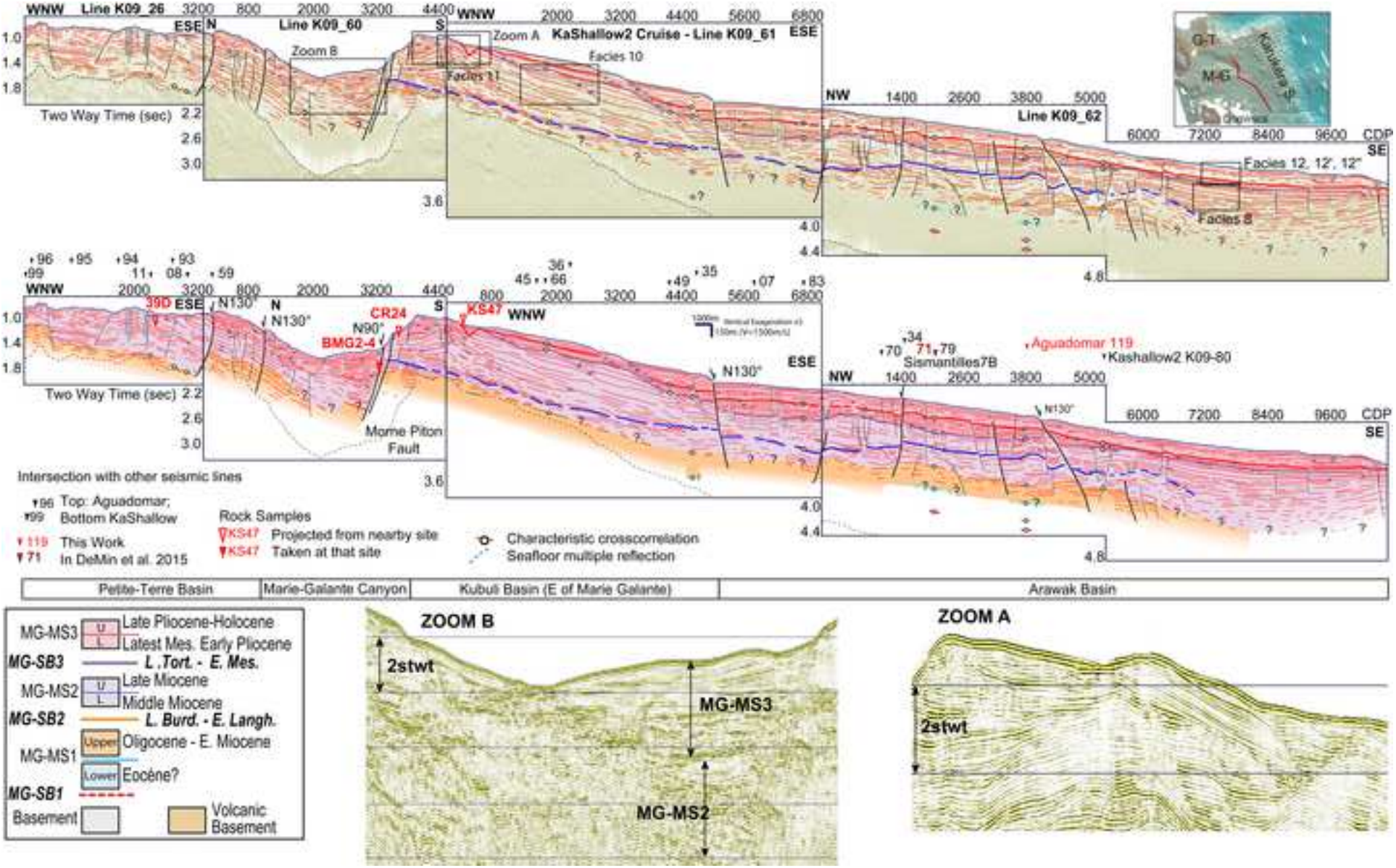

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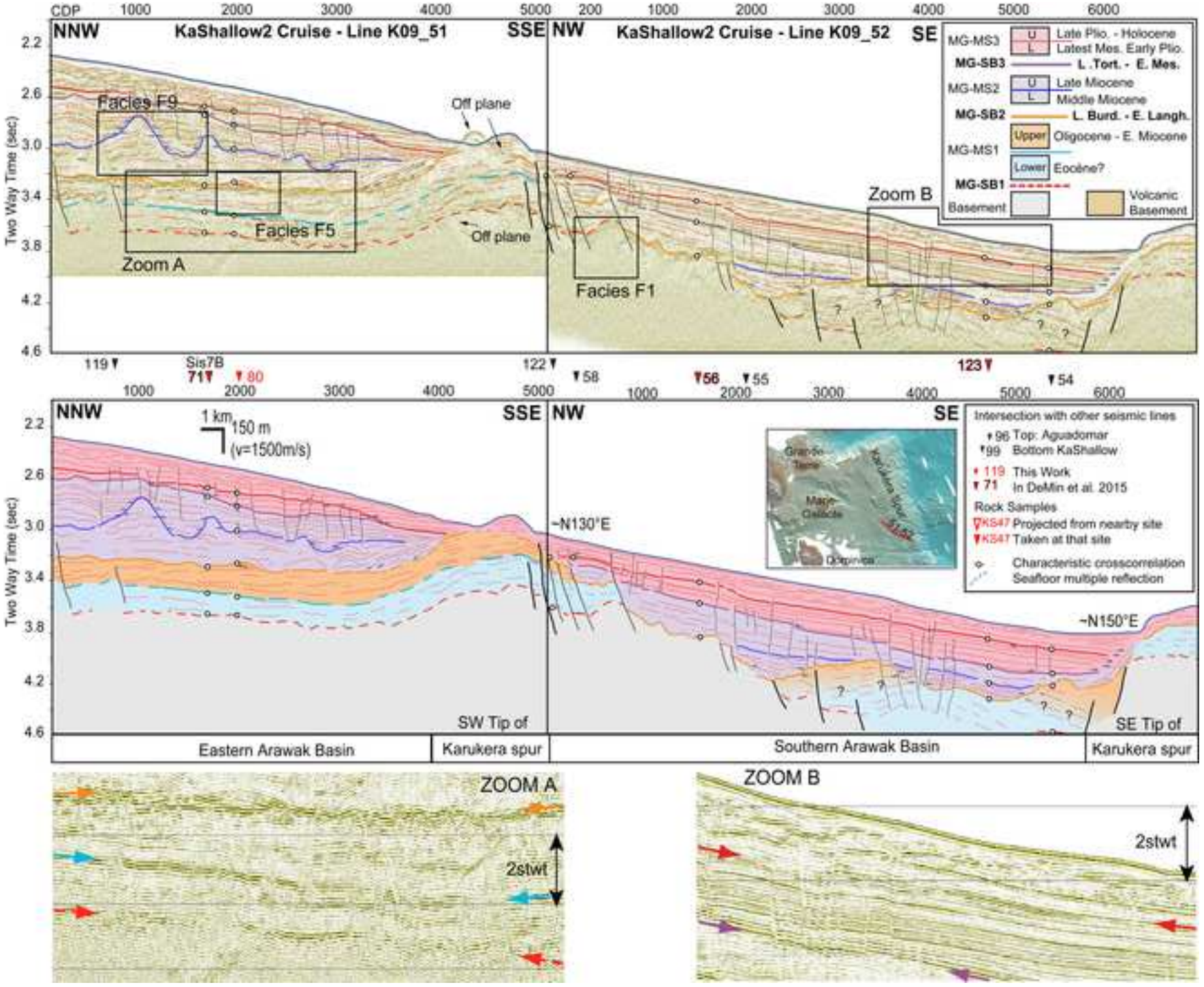

Figure

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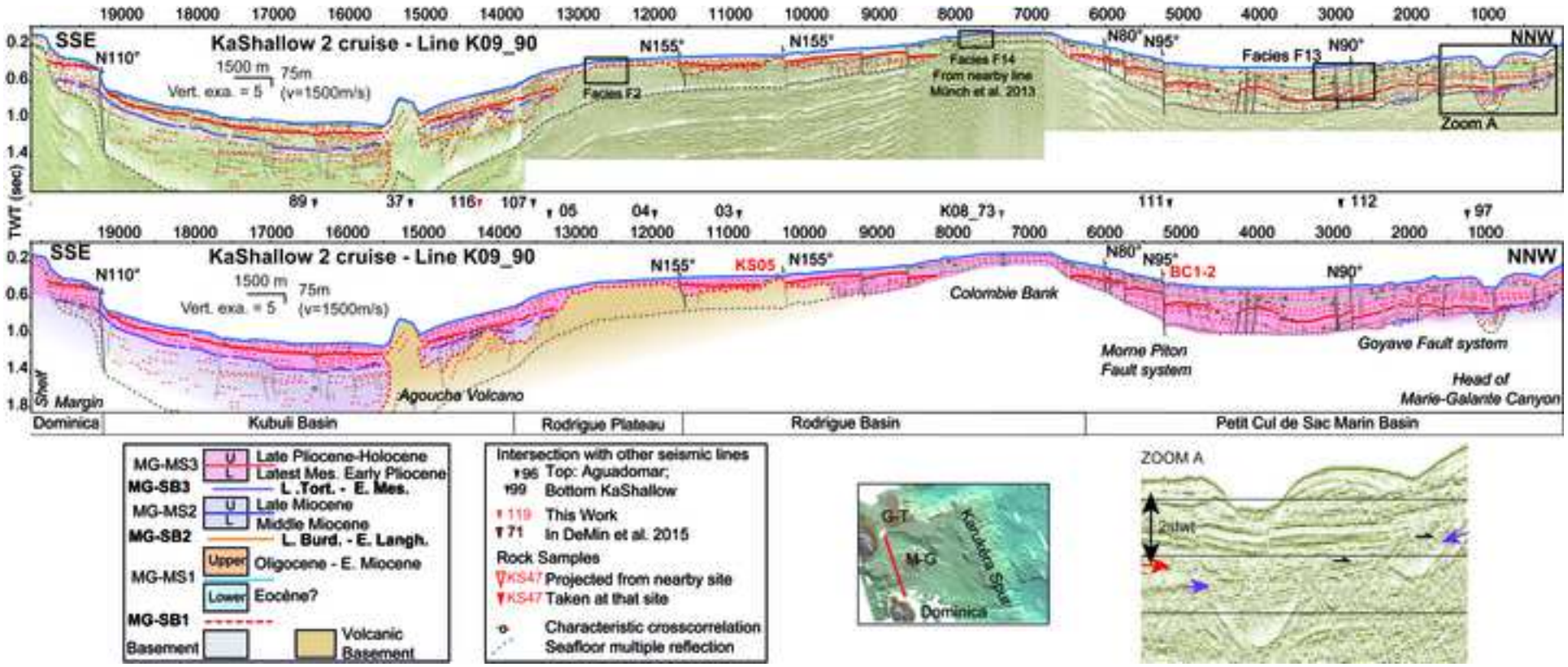

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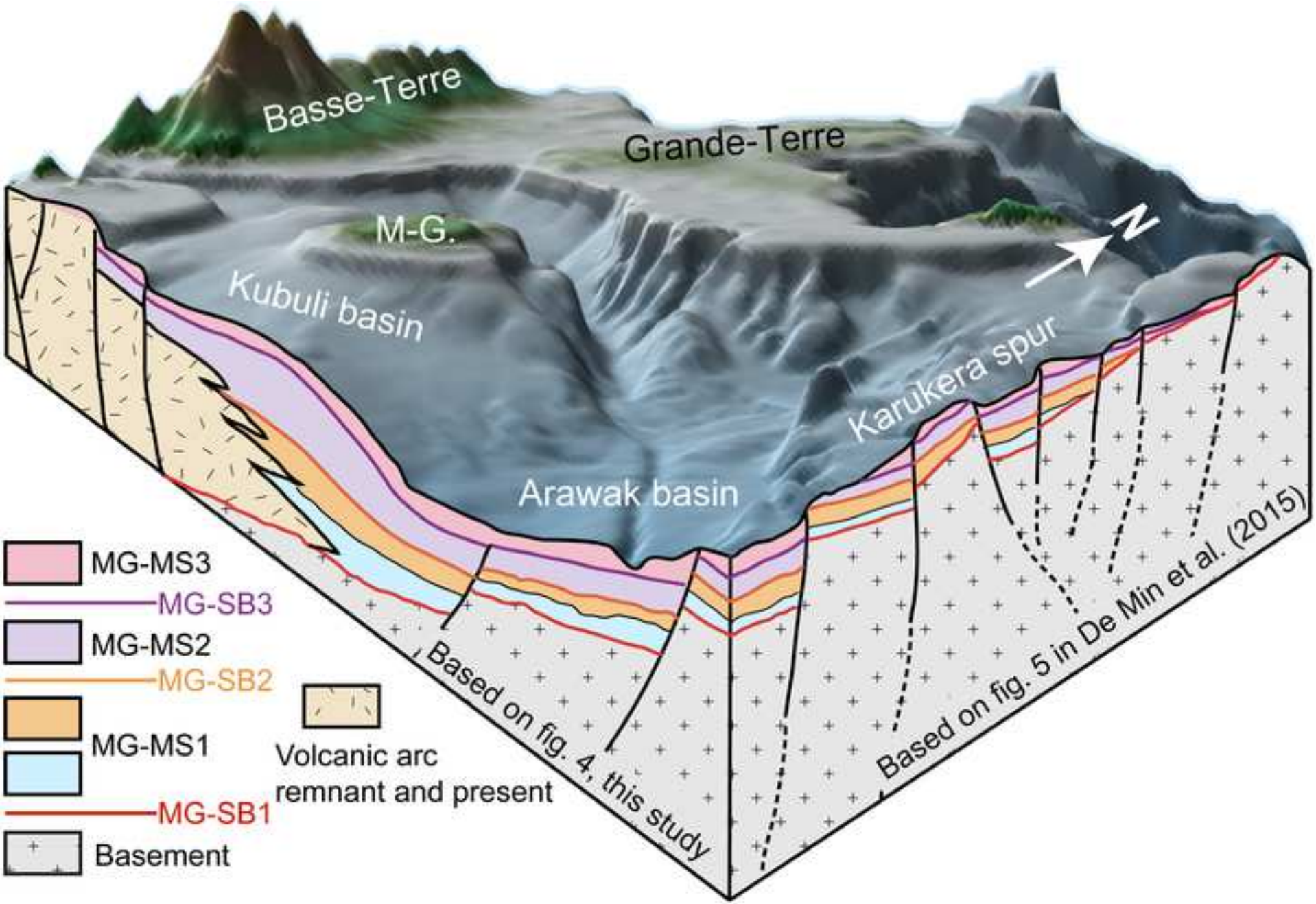

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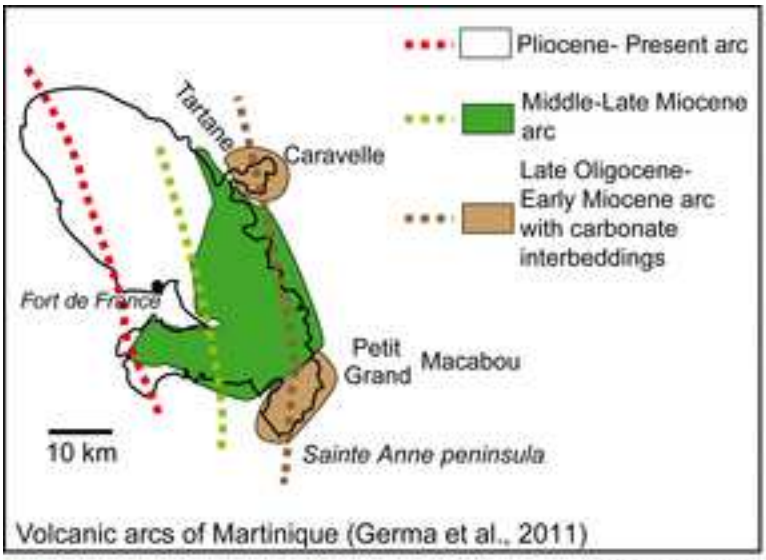

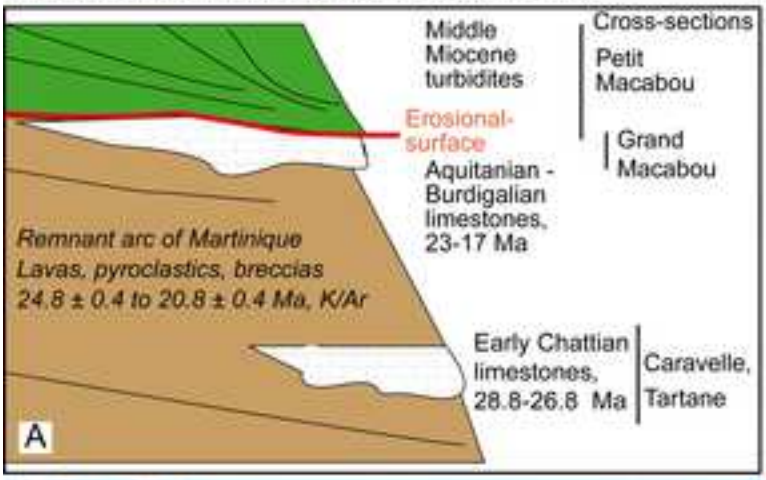

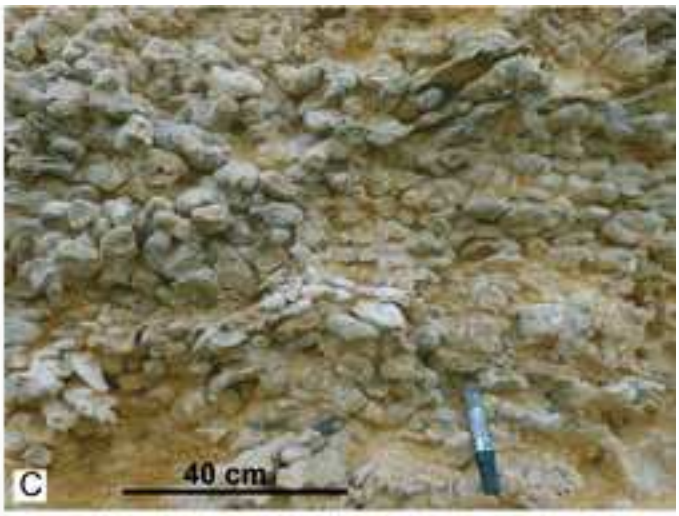

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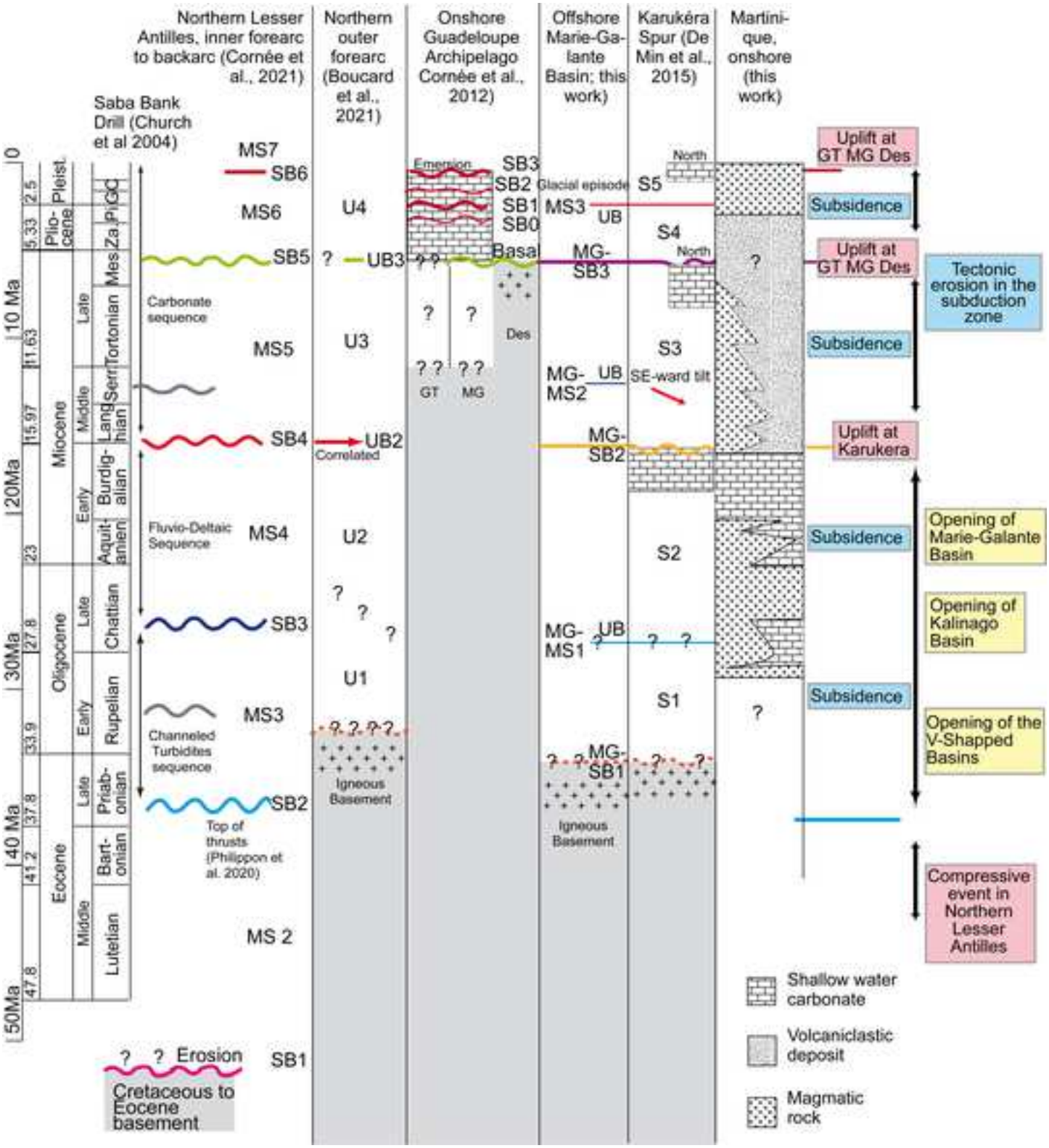

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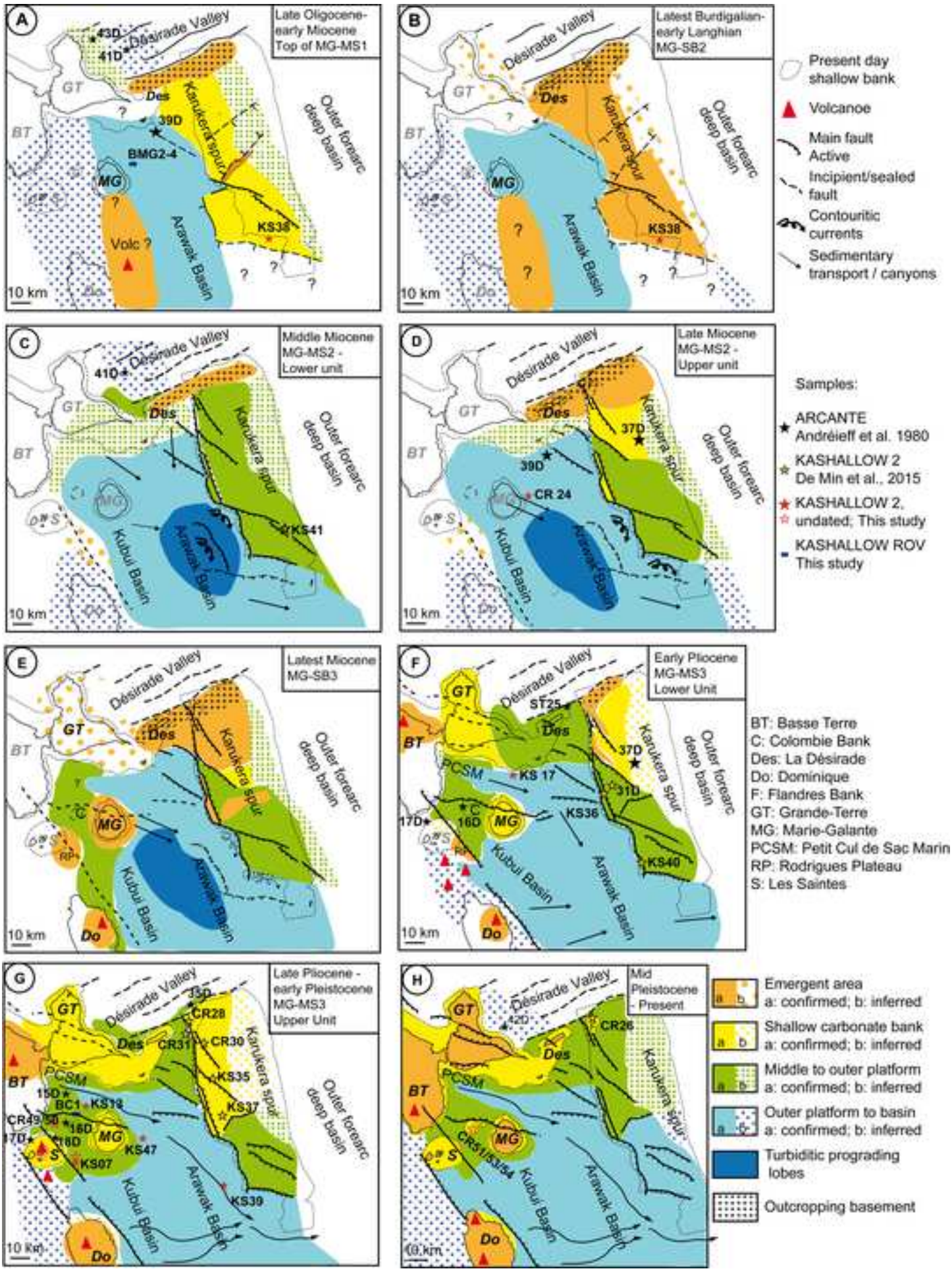

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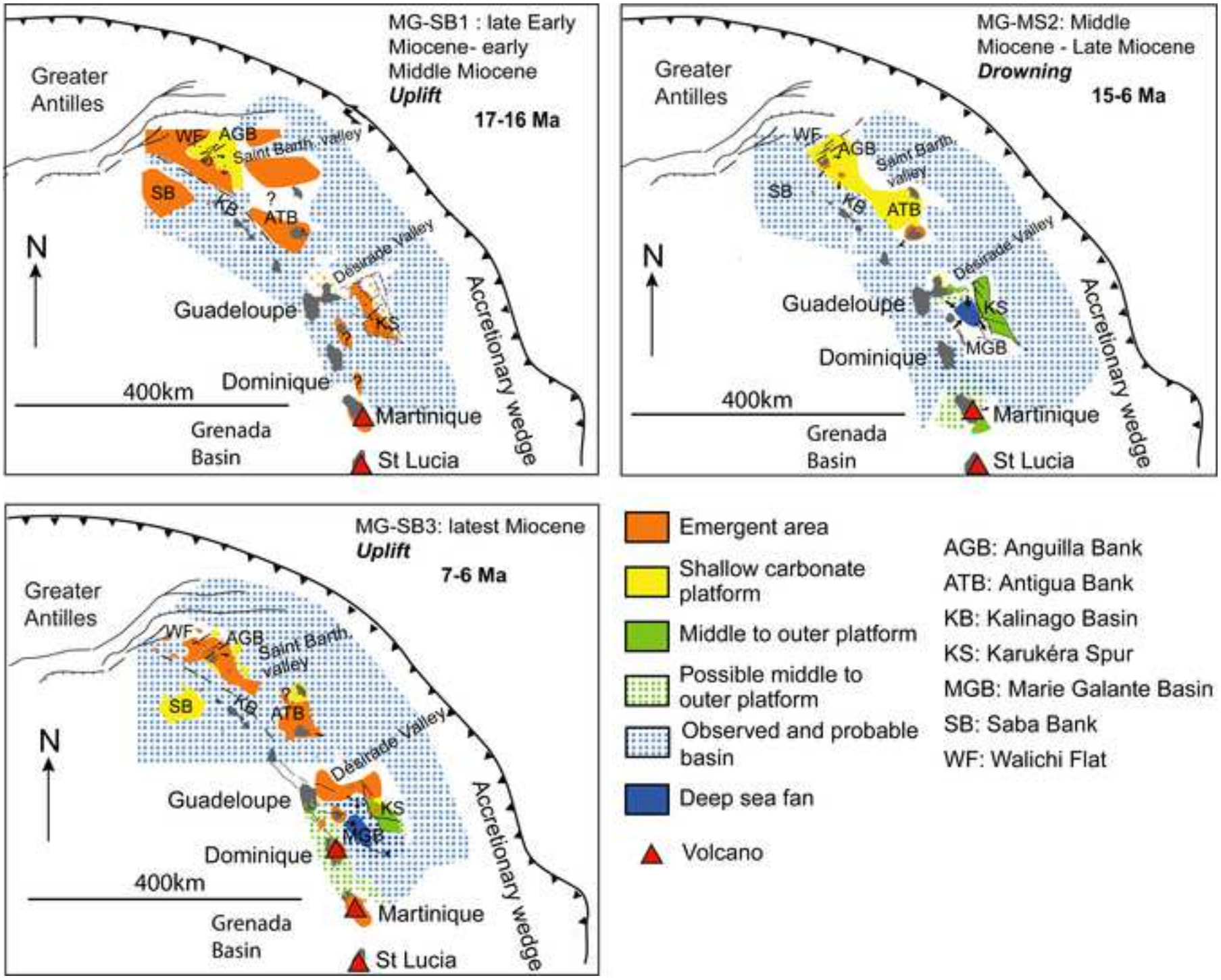

Declaration of interests

☒The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: