Chronologie de l’arc ancien en Martinique :

« First radiometric (K-Ar) ages of the oldest volcanism of Martinique Island : Insights about the onset of arc volcanism in the Lesser Antilles, and calibration of the Oligocene/Miocene boundary »

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First radiometric (K-Ar) ages of the oldest volcanism of Martinique Island: Insights about the onset of arc volcanism in the Lesser Antilles, and calibration of the Oligocene / Miocene boundary.

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Abstract

The present study investigates the timing of emplacement of the oldest volcanic units from Martinique Island in order to constrain the earliest activity of the Older Lesser Antilles Arc, as recorded in this island. The Basal Complex was emplaced between 24.8 ± 0.4 and 24.2 ± 0.4 Ma, and the Sainte Anne Series between 24.8 ± 0.4 and 20.8 ± 0.4 Ma, which, from biostratigraphic data, have been emplaced during Late Oligocene to the Early Miocene. Since lavas bracketing the Oligocene-Miocene boundary yield undistinguishable ages and have homogeneous geochemical features, we tentatively propose an age of 24.5 ± 0.3 Ma for this boundary. Although, it is older than the age of 23.03 Ma used in the last geologic time scale, it is compatible with the age of 24.0 ± 0.1 Ma (Wilson et al. 2002) derived from $^{40}Ar/^{39}Ar$ dating of tephra from Antarctica (McIntosh 2000).

Keywords

Lesser Antilles volcanism, Martinique Island, Oligocene-Miocene boundary, K-Ar dating

Introduction

Due to its particular location where the Older and Recent Lesser Antilles arcs diverge, Martinique Island displays the most diverse geologic history of the arc (Fig. 1). Although the island has been mapped in detail by Westercamp et al. (1989) and dated by whole-rock K-Ar and biostratigraphical methods (Andreieff et al. 1976, 1988; Bellon et al. 1974; Briden et al. 1979; Coulon et al. 1991; Nagle et al. 1976), few absolute ages are available for the oldest volcanic deposits. Furthermore, recent geochronological studies on Basse Terre de Guadeloupe (Carlut et al. 2000; Samper et al. 2007), and in other Lesser Antilles Islands (Harford et al. 2002; Samper et al. 2008), have shown large discrepancies, both regarding magnetic polarity and geological evolution, within the results published during the eighties (Bouysse et al. 1985; Briden et al. 1979; Gadalia et al. 1988), most probably due to the use of whole-rock K-Ar dating and/or analyses of weathered samples. Regarding the oldest volcanic units in Martinique Island, Westercamp et al. (1989) have rejected their own radiometric ages because of their inconsistency with the local biostratigraphy. Thus, the purpose of this paper is to provide a reliable time framework for the early volcanic activity in Martinique Island based on new K-Ar ages.

2. Geologic setting of the Lesser Antilles Island arc

Two hypotheses have been proposed for the origin of the Caribbean plate. The first hypothesis suggests for the Caribbean plate a Pacific origin over the Galapagos hot-spot between 91 and 73 Ma (Duncan et al. 1984; Pindell et al. 2001), while the second favours its formation between the two American plates over several spreading centres (James 2006; Meschede et al. 1998).

The Lesser Antilles Island arc, which results from the westward subduction of the Atlantic plate under the Caribbean plate, has been active since the Early Eocene, based on fossil evidence (Nagle et al. 1976). Southward of Martinique Island, volcanic activity has been almost continuous along the same arc line from the Oligocene to the present. Consequently, the oldest deposits are buried under Plio-Pleistocene volcanics (Fig. 1) and thus do not outcrop. Northward from Martinique, the Lesser Antilles island arc is double (Fink 1972; Martin-Kaye 1969), with the outer older arc to the north-east and the inner active arc to the north-west. The north-eastern branch, the so-called Limestone Caribbees, consists of low-lying islands without recent volcanic centres (Fig. 1), but volcanism may have been active there from Oligocene to Miocene (Briden et al. 1979), with apparent decreasing ages from north to south. After several million years of repose, volcanism resumed westward along the recent arc (Fig. 1), which is still active today.

2.1. The Limestone Caribbees

A limestone plateau that contains nannofossils of Pliocene age constitutes the islet of Sombrero (Bouysse et al. 1985; Fig. 1), whereas Dog islet's basement is composed of altered volcanic deposits covered by Miocene limestones (Maury et al. 1990). On Anguilla Island (91 km^2), black shales of upper Paleocene age are overlain by middle Eocene volcaniclastics and limestones of middle Miocene age (Maury et al. 1990). The basement of Saint Martin (100 km^2) is composed of the Eocene Pointe Blanche formation, which is made of siliceous tuffs and calcareous intercalations (Maury et al. 1990). This formation has been intruded by basalts, andesites and quartz-diorites during the lower Oligocene (Nagle et al. 1976), and covered by limestones of upper Miocene age (Lowlands Formation; Maury et al. 1990). Saint Bartholomew (25 km^2) is mainly composed of submarine volcanic products and calcareous horizons ascribed by Maury et al. (1990) to the middle Eocene, followed by a second volcanic cycle that may have occurred between 36 and 24 Ma (Briden et al. 1979; Maury et al. 1990; Nagle et al. 1976). Barbuda is a low-lying island (174 km^2) composed of uplifted Pleistocene limestones (Maury et al. 1990). The volcanic basement of Antigua (280 km^2), and the overlying unit made of volcanic conglomerates, have ages between 24 and 20 Ma with a surprisingly old age of 38 Ma (Briden et al. 1979; Nagle et al. 1976), but these former ages are suspect with respect to the uppermost limestones unit ascribed to the upper Oligocene (27 – 23 Ma; Maury et al. 1990). The island of Grande Terre (650 km^2) is completely buried by limestones, lying uncomfortably on weathered volcanic deposits (Bouysse et al. 1984; Maury et al. 1990). This Plio-Pleistocene carbonate platform is the thickest (120 m) and the most complete sequence of the Lesser Antilles (Léticée et al. 2005). The island of Marie Galante (150 km^2) is a limestone table of Plio-Pleistocene age, tilted to the southwest due to recent normal faulting (Feuillet et al. 2002), and La Désirade (30 km^2) has an igneous basement of Eocene age, capped by Pliocene limestones (Maury et al. 1990).

2.2. Martinique Island

The eastern (La Caravelle) and south-eastern (Sainte Anne) peninsulas of Martinique Island (Fig. 1) are remnants of the Basal Complex (BC) and Sainte Anne Series (SAS) volcanic units (Fig. 2), of Oligocene and Miocene ages, respectively (Andreieff et al. 1988; Grunevald 1965; Westercamp 1972; Westercamp et al. 1980, 1989). These lava flows and volcanic centres, interbedded with sedimentary deposits, were emplaced during the activity of the Older Arc. In order to propose a chronology for these deposits, Andreieff et al. (1988) used the biostratigraphic timescale of Berggren et al. (1985), which is based on the recognition of fossils determined in the Caribbean area.

A small bioclastic limestone deposit (referred as "g3" by Westercamp et al., 1989, Fig. 2a) located at the western end of La Caravelle peninsula directly overlays the Basal Complex at Morne Castagne. It has been determined as Late Chattian (Shallow Benthic zone SBZ23), in Late Oligocene, due to the presence of benthic foraminifera (*Miogypsinoides complanatus* and *Miogypsina panamensis*; Andreieff et al. 1988; Westercamp et al. 1989). Then, reef limestones (referred as "m1a" by Westercamp et al., 1989) with *Miogypsina panamensis, Cyphus, Heterostegina antillea* and *Lepidocyclina canellei* have been deposited during the Early Aquitanian, and are characterized by the absence of *Miogypsinoides* (Andreieff et al. 1988). These 50 m thick limestones outcrop directly over the BC at Pointe la Table (La Caravelle peninsula; Fig. 2A), and between the town Le Marin and Macabou (Sainte Anne Peninsula; Fig. 2B). Their similarity with "g3" limestones could indicate a continuous deposition during a maximum of 1 Myr across the Oligocene-Miocene boundary (Westercamp et al. 1989). In continuity with the "m1a" limestones, the limestones "m1b" record the unrest of volcanic activity with the deposition of volcanic ash and debris into deposit areas located to the north of Sainte Anne peninsula, between Le Marin and Macabou. Their lower part, called Macabou's tuffites, contain some benthic (*L. canelli, M. panamensis, H. antillea, "Operculinoides" panamensis, Spiroclypeus bullrooki*) and planctonic (*Globorotalia kugleri, G. mayeri, Globigerinoides primordius, G. immaturus*) foraminifera, which yield an Aquitanian age (upper Zone N4, Westercamp et al. 1989). A stratigraphic section at Morne Carrière (Fig.2B) shows that these tuffites are overlain by limestones, also referred as "m1b", which are characterized by the same fauna, except the extinction of *Spiroclypeus,* the appearance of *Lepidocclina undosa,* and the presence of evolved Miogypsines (Westercamp et al. 1989). This stage "m1b" is accompanied by the eruption of Sainte Anne Series products, which starts with subaquatic basaltic tuff, followed by the emplacement of small basaltic to andesitic strombolian cones and lava flows, and which ends with dacitic intrusions (Westercamp et al. 1989). Finally, reef limestones (referred as "m1c" by Westercamp et al. 1989) overlie Morne Carrière limestones "m1b" and SAS products to the south of the city of Sainte Anne (Fig.2B). These "m1c" limestones do not have volcaniclastic debris, but contain a poor fauna, with some fragments of *Miogypsina Antillea, Archaias angulatus, Miosorites americanus, Globigerinoides* gr. *Trilobus, "Operculinoides" cojimarensis, Globigerinoides bisphaericus* and *Globoquadrina altispira.* This association of foraminifera with the Zone N7-N8 (*Globigerinatella insieta*) allowed Westercamp et al. (1989) to propose a Burdigalian age for the end of the SAS activity.

Due to the weathering of volcanic deposits and the use of whole-rock material, no reliable radiometric age was previously available for BC and SAS lavas (Andreieff et al. 1988; Westercamp et al. 1989). Furthermore, the few radiometric ages obtained were in disagreement with biostratigraphic subdivisions based on the recovery of foraminifera, and were thus rejected by their authors (Westercamp et al. 1989). But, since the Oligocene and Aquitanian limestones overlie Basal Complex, and, since Sainte Anne Series volcanics outcrops as interbedded within Aquitanian and Burdigalian sedimentary deposits ("m1a-m1b"; Andreieff et al. 1988; Westercamp et al. 1989; Fig. 2), these authors attributed a Late Oligocene age to the BC, and a Late Aquitanian age to the SAS.

3. Material and method

3.1. Sampling

The Basal Complex (BC) and Sainte Anne series (SAS) volcanic deposits cover a total area of 61 km^2 on both La Caravelle and Sainte Anne peninsulas (Fig. 2a and b). Three samples were collected within the products of the BC (samples 07MT113 and 07MT115 on La Caravelle, and 07MT82 on Sainte Anne peninsula; squares in Fig. 2), and eleven within those of the SAS (samples 06MT53, 06MT54 and 07MT114 on Caravelle; samples 06MT66, 06MT67, 06MT68, 07MT78, 07MT79, 07MT80, 07MT81 and 07MT83 on Sainte Anne peninsula; circles in Fig. 2). These units are mainly composed of massive prismatic lava flows and small strombolian cones.

3.2. Geochronology: K-Ar dating

In order to provide reliable radiometric ages, hand-size samples without any trace of weathering were selected for unspiked K-Ar dating based on the Cassignol-Gillot technique, which is fully described elsewhere (Cassignol et al. 1982; Gillot et al. 1986). K and Ar were measured separately on the microcrystalline groundmass within the 125-250 µm size fraction, following the removal of phenocrysts using heavy liquids of appropriate densities and a Frantz magnetic separator. The determination of K was carried out by flame emission spectrometry with a relative uncertainty of 1%, and compared with reference material (Gillot et al. 1992). Isotopic analyses of argon were made using a multi-collector 180° sector mass spectrometer similar to the one described in Gillot and Cornette (1986), or using a VG quadrupole mass spectrometer (Rouchon et al. 2008). Both instruments yield identical results, as shown by duplicate analyses from Central Martinique (Germa 2008), as well as by age standards measurements (Rouchon et al. 2008). Both K and Ar were duplicated. The argon signal calibration was performed using the GL-O standard with its recommended value of 6.679×10^{14} atom/g of radiogenic ^{40}Ar, which is equivalent to an age of 95.0 Ma (Odin et al. 1982). The Cassignol-Gillot technique has been successfully applied to calco-alcaline lavas from the Lesser Antilles arc (Carlut et al. 2000; Samper et al. 2007, 2008), and to a wide range of Plio-Pleistocene lava flows to date paleomagnetic reversals and excursions (Quidelleur et al. 1999, 2002, 2003), and to reconstruct volcanic island evolutions (e.g., Tahiti; Hildenbrand et al. 2004). In addition, this technique has also been shown to be a powerful tool to constrain the stage durations of the lower Cretaceous from comparison with the astronomical time scale (Fiet et al. 2006), as well as the timing of large igneous provinces, such as Deccan (Chenet et al. 2007) and Ethiopian trapps (Coulié et al. 2003).

4. Results

4.1. Petrology and Geochemistry

Petrological observations show that BC lavas are porphyritic, with 10 to 40 % vol. of medium sized crystals. Plagioclase is the main mineral, associated with clinopyroxene in a glassy groundmass containing plagioclase microliths. Lavas from SAS have a crystallinity ranging from 3 to 40 %. Grain size varies from a few microns to several millimetres, and mineralogical assemblage is principally made of plagioclase, clinopyroxene, orthopyroxene and rare serpentinized olivine within a glassy groundmass.

BC lavas have basaltic - andesites to andesites compositions with SiO_2 ranging from 52.9 to 60.8 wt%. Their alkaline contents are relatively low and uniform, from 3.62 to 3.97 wt%. SAS lavas vary from basalts to rhyolites with SiO_2 content ranging from 49.1 to 70.5 wt%. Their alkaline contents are low compared to their silica content and range from 2.44 to 6.74 wt%. BC and SAS lavas are part of the same fractionating trend (Fig. 3) and form a unique magmatic series of tholeiitic affinity, with FeO content increasing at the beginning of the differentiation.

4.2. K-Ar ages

For the BC, sample 07MT113 from La Pointe du Diable, on La Caravelle peninsula, yields an age of 24.2 ± 0.4 Ma, and, on the Sainte Anne peninsula, we have dated the sample 07MT82 at 24.8 ± 0.4 Ma (Table 1, Fig. 2).

Regarding the SAS, the two samples from the quarry "La Source", near the city of Le Marin, on Sainte Anne peninsula, yield undistinguishable ages of 24.8 ± 0.4 and 24.4 ± 0.3

Ma (Table 1, Fig. 2B). Also from the Sainte Anne peninsula, sample 07MT80 from the prismatic lava flows at Trou Cadia yields an age of 23.3 ± 0.4 Ma, and a lava flow near Anse La Rose (07MT79) has been dated at 22.9 ± 0.3 Ma (Table 1, Fig. 2B). On La Caravelle peninsula, sample 06MT53 has been dated at 23.4 ± 0.3 Ma. Finally, we have dated the "Orgues de la Caravelle" site from La Caravelle peninsula (07MT114) at 20.8 ± 0.4 Ma (Table 1 and Fig. 2a). With these results, we thus constrain the volcanic activity of the SAS between 24.8 and 22.9 Ma on Sainte Anne peninsula, and between 23.4 and 20.8 Ma on La Caravelle peninsula, where only a few lava flows of this formation outcrop (Fig. 2a).

5. Discussion

5.1. Onset of the older arc activity in the Lesser Antilles

Eight new radiochronologic ages and associated geochemical data on Martinique Island show that the earliest volcanic activity has been quite continuous on both southern and northern parts of the island. The continuous reef linking the two oldest peninsulas of Martinique, which is remnant of the old volcanic front now covered by later limestone deposits, extends northward, on the submarine blanks of the Limestone Caribbees. The few available ages from these islands are in conflict with biostratigraphical data (e.g., Antigua; Maury et al. 1990), or considered as erroneous due to hydrothermal weathering (e.g., St Martin; Maury et al. 1990). Our new ages show that volcanism has been active in the 25 to 20 Ma time interval in Martinique (Table 1), and probably, within the whole older arc. This is in agreement with both main plate-tectonic models proposed for the Cenozoic history of the Caribbean plate (Meschede et al. 1998; Pindell et al. 2001), which suggest that the transition from the Aves Ridge to the Lesser Antilles magmatic arc activity occurred in the Eocene. Only reef limestones of Burdigalian age (Early Miocene) are found in the oldest part of

Martinique (Fig. 2), which is interpreted as evidence for the end of the older arc volcanic activity around 20 Ma, before it resumed westward at about 16 Ma (Germa 2008; Westercamp et al. 1989). These ages between 25 and 20 Ma obtained here from Martinique (Table 1) constrain the end of activity of the older arc and have broad consequences onto the geodynamic of the Caribbean Plate, more precisely on the migration from the older to the recent Lesser Antilles arc. The westward jump on the northern arc is supposed to have been triggered by the subduction of aseismic ridges, which flatten the slab (Bouysse et al. 1988; 1990). Alternatively, it could be attributed to the fracturing of the upper plate, with normal faults organized in horsts and grabens perpendicular to the arc, due to arc-parallel extension. This extension results form oblique convergence between the Caribbean and North American plates (Feuillet et al. 2002).

5.2. Insights on the Oligocene – Miocene boundary

Our ages, between 24.8 and 20.8 Ma, together with the Late Chattian to Late Aquitanian biostratigraphic constraints available for this early volcanic activity in Martinique are in conflict with the age of the Oligocene-Miocene boundary (OMB) from the most recent geological time scale (GTS2004; Gradstein et al. 2004). However, there is an ongoing regarding the age of this boundary and significant differences up to 1 Ma still remain. The OMB, which also marks the base of the Neogene System and the transition from a globally warm to colder climate, coincides at the stratotype section at Lemme-Carrosio, in Italy, with the older end of Chron C6Cn.2n (Steininger et al. 1997). It has been constrained at 23.8 ± 1.0 Ma from a dataset of nineteen K-Ar and one Rb-Sr ages from the Chattian, and five K-Ar ages from the Aquitanian Stages (Berggren et al. 1995; Harland et al. 1990). Although associated with a rather large uncertainty, such age is used as the only tie point from early Oligocene to the mid Miocene interval (i.e., between 33.7 and 14.8 Ma) for calibration of the geomagnetic polarity time scale based on the seafloor-spreading model (Cande et al. 1992; 1995). Recently, this age has been challenged by astronomically derived ages (Shackleton et al. 2000) from deep-sea sediments of DSPD Holes 522 and 522A from the South Atlantic Ocean, with a rather low sedimentation rate of (<0.5 cm/kyr; Hsü et al. 1982). Using stable carbon isotopes, paleomagnetic and nannofossil data, tuned to the astronomical solution La93 (Laskar et al. 1993), these authors proposed a much younger age of 22.9 ± 0.1 Ma (Shackleton et al. 2000), which is now used in the GTS2004 (Gradstein et al. 2004). However, based on highly deposited sediments (>50 cm/kyr) and intercalated volcanic layers from CRP-2/2A core from beneath the Ross Sea (Cape Robert, Antarctica), Wilson et al. (2002) proposed a revision of the OMB age at 24.0 ± 0.1 Ma. They support their age obtained from $^{40}Ar/^{39}Ar$ analyses of tephra horizons, $^{87}Sr/^{86}Sr$ ages, diatom and calcareous nannofossils biostratigraphy and magnetostratigraphy, by suggesting a mismatch of three 406 ky eccentricity cycles in the previous astronomically derived age. Furthermore, the weighted mean $^{40}Ar/^{39}Ar$ ages of 23.98 ± 0.13 Ma (n=19) and 24.22 ± 0.03 Ma (n=52) considered by Wilson et al. (2002) were obtained by McIntosh (2000) from single crystal laser fusion of sanidine phenocrysts from tephra layers and volcanic clasts. All ages were calibrated relative to Fish Canyon Tuff sanidine (FCTs) using an age of 27.84 Ma (Deino et al. 1990). Although the FCTs is intensively used as a neutron flux monitor for the $^{40}Ar/^{39}Ar$ dating techniques, large discrepancies remain regarding its absolute age in the geochronological community. The presently most widely used value is 28.02 ± 0.16 Ma (Renne et al. 1998), but ages from 27.56 Ma (Lanphere et al. 2001) to 28.10 ± 0.04 Ma (Spell et al. 2003) have been proposed. Recently, Kuiper et al. (2008) revised the earlier astronomical calibration of FCTs (Renne et al. 1994) and assigned a new age significantly older of 28.20 ± 0.05 Ma. Such age proposed for FCTs is 1.3% older than the one used by McIntosh (2000), thereby shifting the age of the OMB inferred by Wilson et al. (2002) at 24.3 Ma.

Since the geochemical signatures of both BC and SAS series do not show any major difference (Fig. 3), volcanic activity in Martinique was most probably continuous across the Chattian to Aquitanian interval. Therefore, we can extract interesting insights from our new age data from the BC and SAS regarding the timing of the OMB. Samples 07MT113 and 07MT82 from the BC, which are the youngest expression of Oligocene volcanism in Martinique, yield a weighted mean (Taylor 1982) age of 24.50 ± 0.28 Ma. Samples 06MT66 and 06MT67 from the SAS, attributed to the early Miocene from their intercalation within Aquitanian limestones (m1b), yield a weighted mean age of 24.54 ± 0.24 Ma. Since all these samples are undistinguishable at the 1-sigma level (Fig. 4), their weighted mean age of 24.52 ± 0.18 Ma provides our best analytical estimate for the OMB. In order to take into account the systematic uncertainty of about 1.4 % introduced by the argon and potassium calibrations (e.g., Gillot et al. 1986; Quidelleur et al. 2003), the age of the OMB derived from the early volcanic activity in Martinique is conservatively expressed at 24.5 ± 0.3 Ma.

Sample 06MT66, the oldest sample from the Miocene, is the key sample here. Fortunately, it is also the best-constrained age from our study because both groundmass and plagioclase phases yield fully consistent ages despite potassium content varying by a factor of 5 (Table 1). This provides an internal test to support that K loss due to weathering and that excess argon carried by plagioclase phenocrysts, are not a concern here. The ages of 24.9 ± 0.4 and 24.8 ± 0.4 Ma obtained for the groundmass, and 24.8 ± 0.4 Ma for plagioclase phase, yield a mean age of 24.8 ± 0.4 Ma (Table 1). An external test is provided by the agreement at the 1-sigma level with the age of 24.4 ± 0.3 Ma, obtained for 06MT67 (Table 1), sampled in the same quarry, but with clearly distinct petroglogical features.

When a 2 sigma uncertainty is considered, our age of 24.5 ± 0.3 Ma for the OMB in Martinique island is compatible with the poorly defined age of 23.8 ± 1.0 Ma proposed for this boundary by Berggren et al. (1995), as well as with the most recently published age of

24.0 ± 0.1 Ma (Wilson et al. 2002). Furthermore, if a more realistic uncertainty of at least 1% is used for this latter age (Kuiper et al. 2008), or if is recalculated at 24.3 ± 0.1 Ma based on the newly proposed value for FCTs (Kuiper et al. 2008), it agrees with our new determination from Martinique at the 1-sigma level. On the other hand, our age is significantly older than the age obtained by astronomical calibration of South Atlantic Ocean deep-sea sediments (Shackleton et al. 2000). Because our age is obtained by a different approach and technique, we think that our new K-Ar data provides a strong support for an older age of the OMB. The discrepancy between our value and the age of Shakleton et al. (2000) could arise from eccentricity cycles mismatch as previously proposed (Wilson et al. 2002), and/or to the challenge of retrieving high resolution calibration in such a relatively low sedimentation rate environment.

Finally, note that the calibration of our K-Ar ages was recently checked using analyses of the MMhb-1 standard, first proposed at 520.4 ± 1.7 Ma (Samson et al. 1987). We obtained an age of 525.0 ± 2.1 Ma (Fiet et al. 2006), which is undistinguishable from the age of 523.1 ± 2.6 Ma proposed relative to 28.02 Ma for the FCTs standard (Renne et al. 1998), and, even, closer to the recalculated value of 526.5 Ma, if the newly proposed age of 28.20 Ma is considered for FCTs (Kuiper et al. 2008).

Conclusions

The K-Ar Cassignol-Gillot dating technique has been used on carefully separated groundmass from lava flows and domes from Martinique Island to better constrain the timing of the volcanic activity along the Older Lesser Antilles Island arc. We provide here the first reliable radiometric ages from the Basal Complex and Sainte Anne Series units. Based on our dataset of eight new ages, the following interpretations arise. First, the activity of the old Lesser Antilles arc took place at least between 24.8 ± 0.3 to 20.8 ± 0.4 Ma, which yields a younger bound for the migration of the volcanic activity towards the younger, still active, Lesser Antilles arc. Second, our K-Ar ages show that these early lava flows and strombolian cones were emplaced from 24.8 ± 0.3 to 20.8 ± 0.4 Ma, i.e., from the Late Chattian (Oligocene) to the Late Aquitanian (Miocene), as previously inferred from field relationships between reefal limestones and volcanic products of the Basal Complex and the Sainte Anne Series (Andreieff et al. 1988; Westercamp et al. 1989). Moreover, the undistinguishable ages obtained here for the late Aquitanian and early Chattian lavas allow us to propose an age of 24.5 ± 0.3 Ma for the Oligocene-Miocene boundary. Such age is significantly older than the age of 23.03 Ma used in the recent GTS2004 (Gradstein et al. 2004), but is compatible at the 1-sigma-level with the more recent age of 24.0 ± 0.1 Ma (Wilson et al. 2002), although with a more reasonable uncertainty of 1% (i.e., 0.2 Ma) assigned to this value, or when it is shifted to 24.3 ± 0.1 Ma based on the newly proposed age of 28.20 Ma for the $^{40}Ar/^{39}Ar$ standard FCTs (Kuiper et al. 2008). The discrepancy between the two previously published ages highlights the need for additional constraints, such as that from the present study, to better define the age of the transition from the Paleogene to Neogene period.

Finally, we conclude that, when applied to carefully selected lavas, and on groundmass separated within a narrow density range, the K-Ar Cassignol-Gillot technique is a very powerful tool to reconstruct the past history of volcanic islands and to contribute to the calibration of the geologic time scale.

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Figures and Table captions

Figure 1 : (A) Map of the Lesser Antilles Island arc. Location of the Older volcanic arc is shown by the black dashed line, and the Active arc by the grey dashed line.

(B) Zoom on Martinique Island, French West Indies. The different main volcanic units are distinguished, and main volcanoes are indicated. Traces of Older and Active Arcs are shown, as well as the intermediate arc (Vauclin-Pitault chain).

Figure 2 : Location of samples from Basal Complex (black symbols) and Sainte Anne Series (white symbols) volcanic units within (A) La Caravelle (squares) and (B) Sainte Anne (circles) peninsulas. Big symbols correspond to dated samples with K-Ar ages obtained in this study. Non-dated samples are shown with smaller symbols and written in italic.

Figure 3 : TAS diagram of samples from Basal Complex from La Caravelle (open squares) and Saint Anne (open circles) peninsulas, and from Sainte Anne Series from La Caravelle peninsula (black squares) and from Sainte Anne peninsula (black circles). Data from Labanieh, thesis in progress.

Figure 4 : K-Ar ages with 1-sigma error bars of samples dated in this study for the Basal Complex and Sainte Anne Series versus the geologic time scale 2004 (Gradstein et al. 2004) and the one from Berggren et al. (1995). Circles correspond to samples from Sainte Anne Peninsula, squares represent samples from La Caravelle peninsula, black symbols are for BC samples and white symbols for SAS samples.

Table 1 : K-Ar ages obtained in this study on groundmass separates. Column headings indicate sample name, name of the site location, geographic coordinates (latitude and longitude) in degrees, the material molten (gms: groundmass, fdpr: feldspar), potassium concentration in percent, type of used spectrometer (QMS: quadrupole mass spectrometer, SMS: sector mass spectrometer, see text), concentration of radiogenic (*) ^{40}Ar* in percent, number of atoms/g of radiogenic ^{40}Ar*, age and one sigma (σ) uncertainty in Ma. For each sample, mean age and uncertainty, calculated by weighting each analysis with the amount of ^{40}Ar* (%), are also indicated (in Ma).

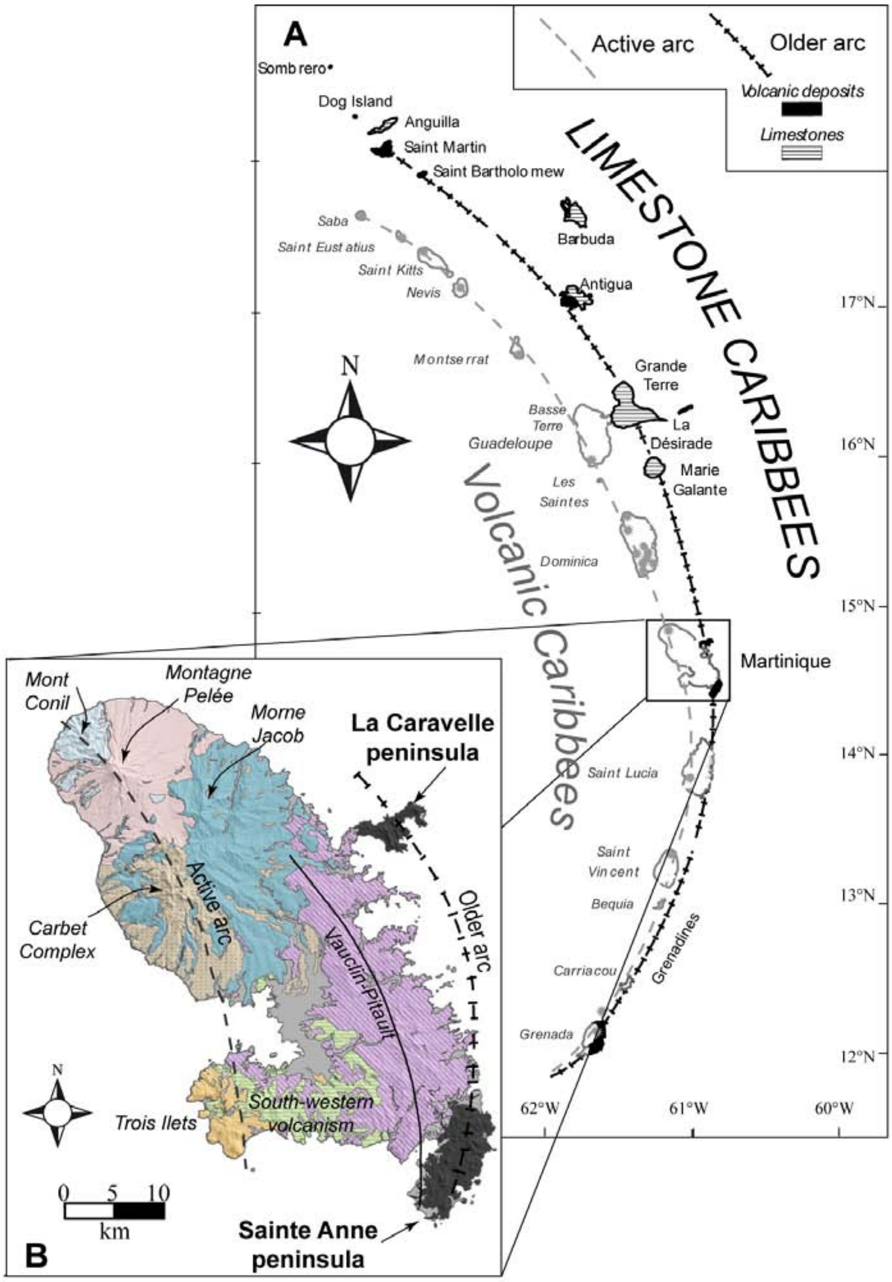

Figure 1
Germa et al., 2009

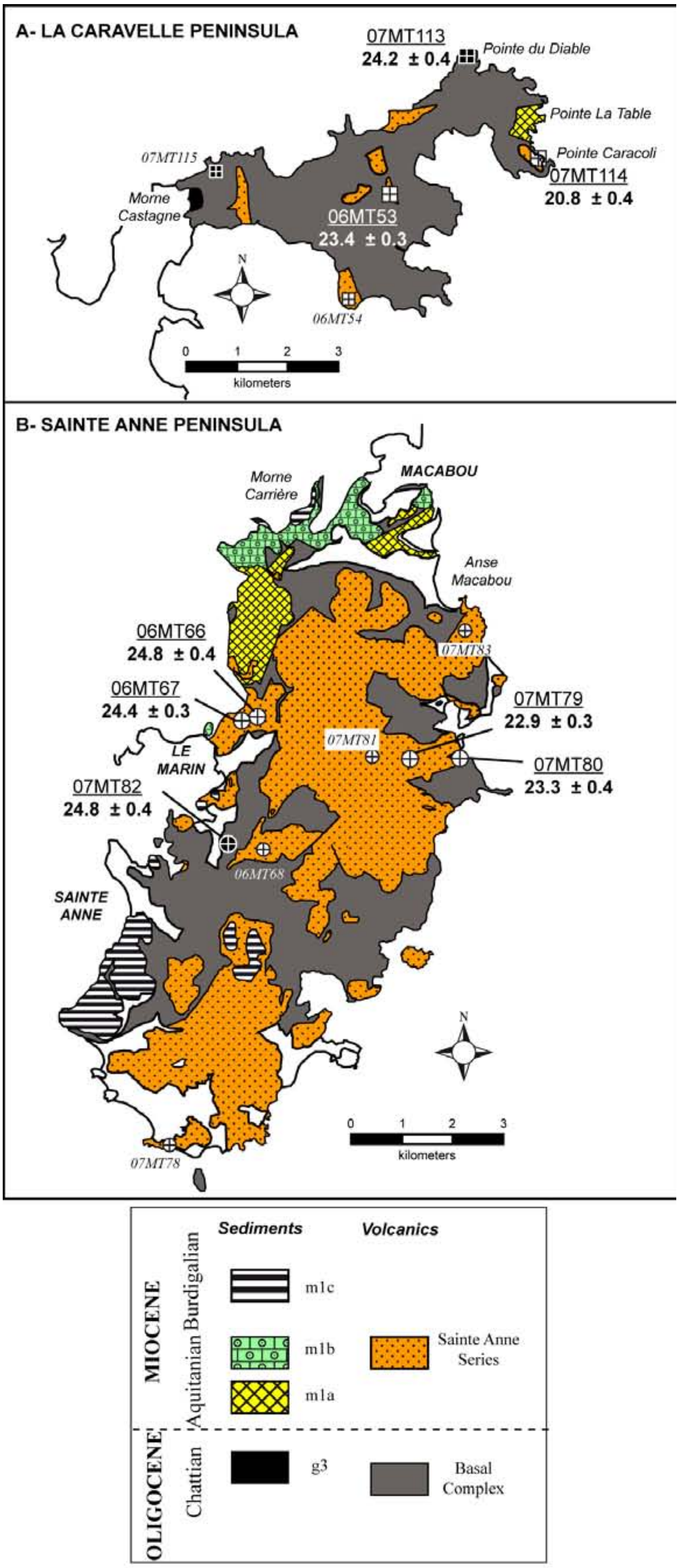

Figure 2
Germa et al., 2009

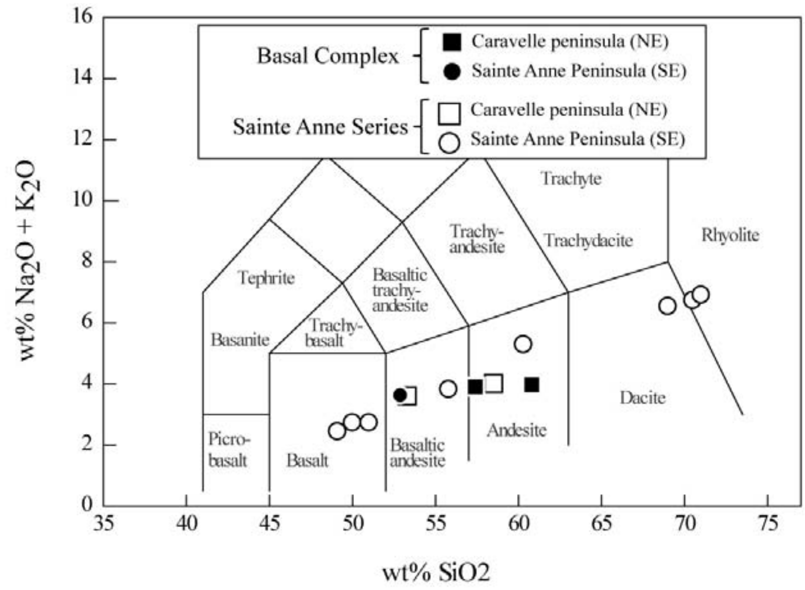

Figure 3

Germa et al., 2009

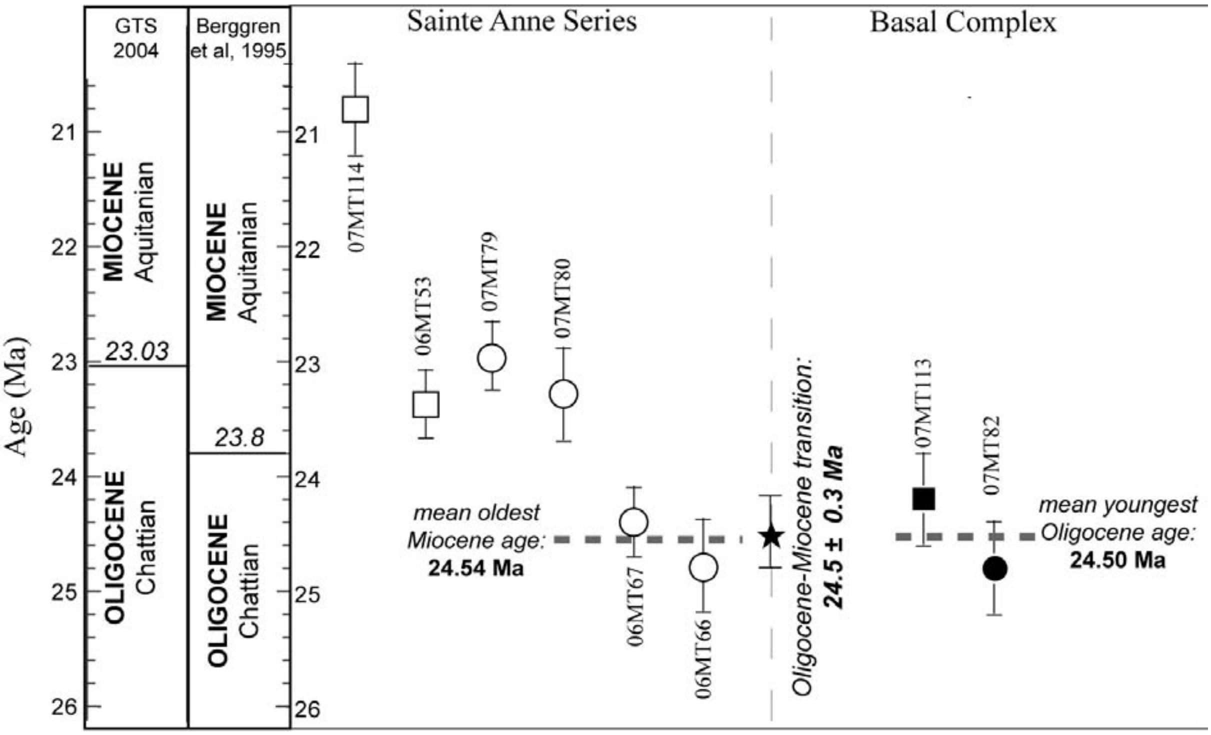

Figure 4
Germa et al., 2009

Table 1
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Sample	Location	Lat °N	Lon °W	Material	K (%)	Spectro-meter	^{40}Ar* (%)	^{40}Ar* (at/g)	Age ± 1σ (Ma)	Mean age ± 1σ (Ma)
					Basal Complex					
07MT113	Pte du Diable	14.779	60.888	gms	0.831	QMS	39.4	2.117E+13	24.2 ± 0.4	
						QMS	42.0	2.104E+13	24.1 ± 0.4	24.2 ± 0.4
07MT82	Montdésir	14.449	60.863	gms	0.488	QMS	22.5	1.307E+13	25.5 ± 0.4	
						QMS	31.5	1.250E+13	24.4 ± 0.4	24.8 ± 0.4
					Sainte Anne Series					
07MT114	Pte Caracoli	14.760	60.873	gms	0.923	QMS	13.6	2.026E+13	20.9 ± 0.4	
						QMS	13.1	2.014E+13	20.8 ± 0.4	20.8 ± 0.4
07MT79	Anse La Rose	14.468	60.827	gms	0.852	QMS	28.6	2.044E+13	22.8 ± 0.4	
						QMS	28.7	2.062E+15	23.0 ± 0.3	22.9 ± 0.3
07MT80	Trou Cadia	14.467	60.818	gms	0.409	QMS	32.2	1.030E+13	24.0 ± 0.4	
						QMS	41.6	9.808E+12	22.8 ± 0.4	23.3 ± 0.4
06MT53	H° Balata	14.757	60.901	gms	0.653	SMS	46.5	1.612E+13	23.5 ± 0.3	
						SMS	41.2	1.598E+13	23.3 ± 0.3	23.4 ± 0.3
06MT67	La Source	14.474	60.859	gms	1.173	SMS	68.9	2.989E+13	24.2 ± 0.3	
						SMS	64.7	3.038E+13	24.6 ± 0.4	24.4 ± 0.3
06MT66	La Source	14.474	60.859	fdpr	0.212	SMS	73.1	5.543E+12	24.9 ± 0.4	
				gms	1.166	SMS	82.9	3.052E+13	24.9 ± 0.4	
							81.9	3.036E+13	24.8 ± 0.4	24.8 ± 0.4