La Désirade

Field-trip, March, 25 and 26 th, 2011

Jurassic basement by Lardeaux J.-M. and Corsini M.

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Pliocene-Early Pleistocene carbonate platform

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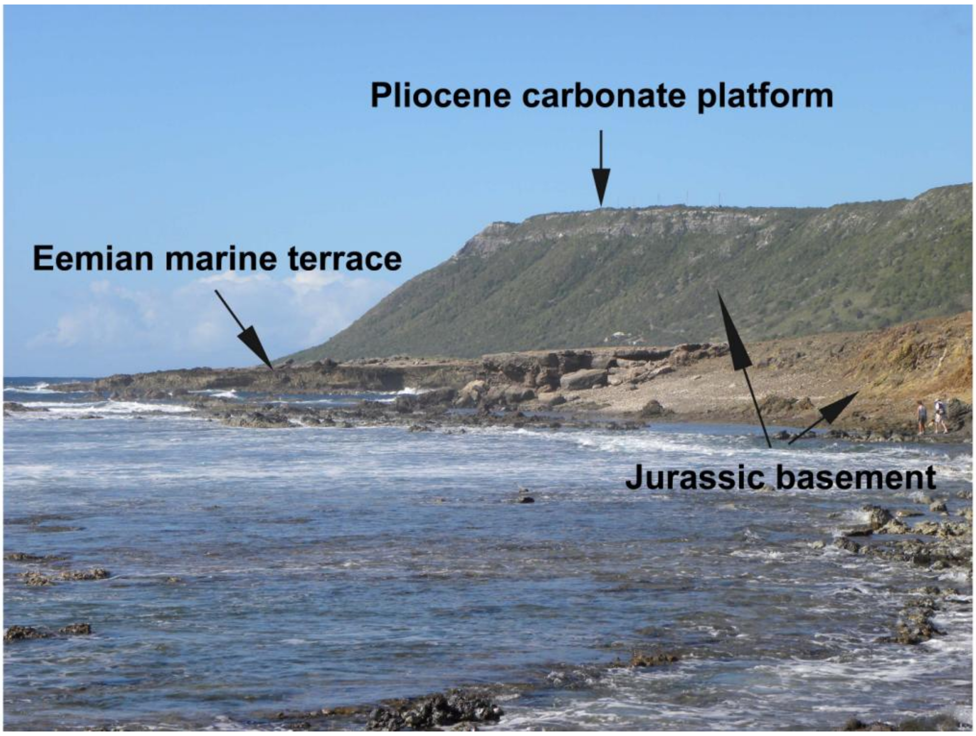

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I – INTRODUCTION

La Désirade Island is the easternmost island of the Lesser Antilles fore-arc, located 150 km West from the subduction front between the subducting Atlantic Plate et the Caribbean Plate (Fig. 1).

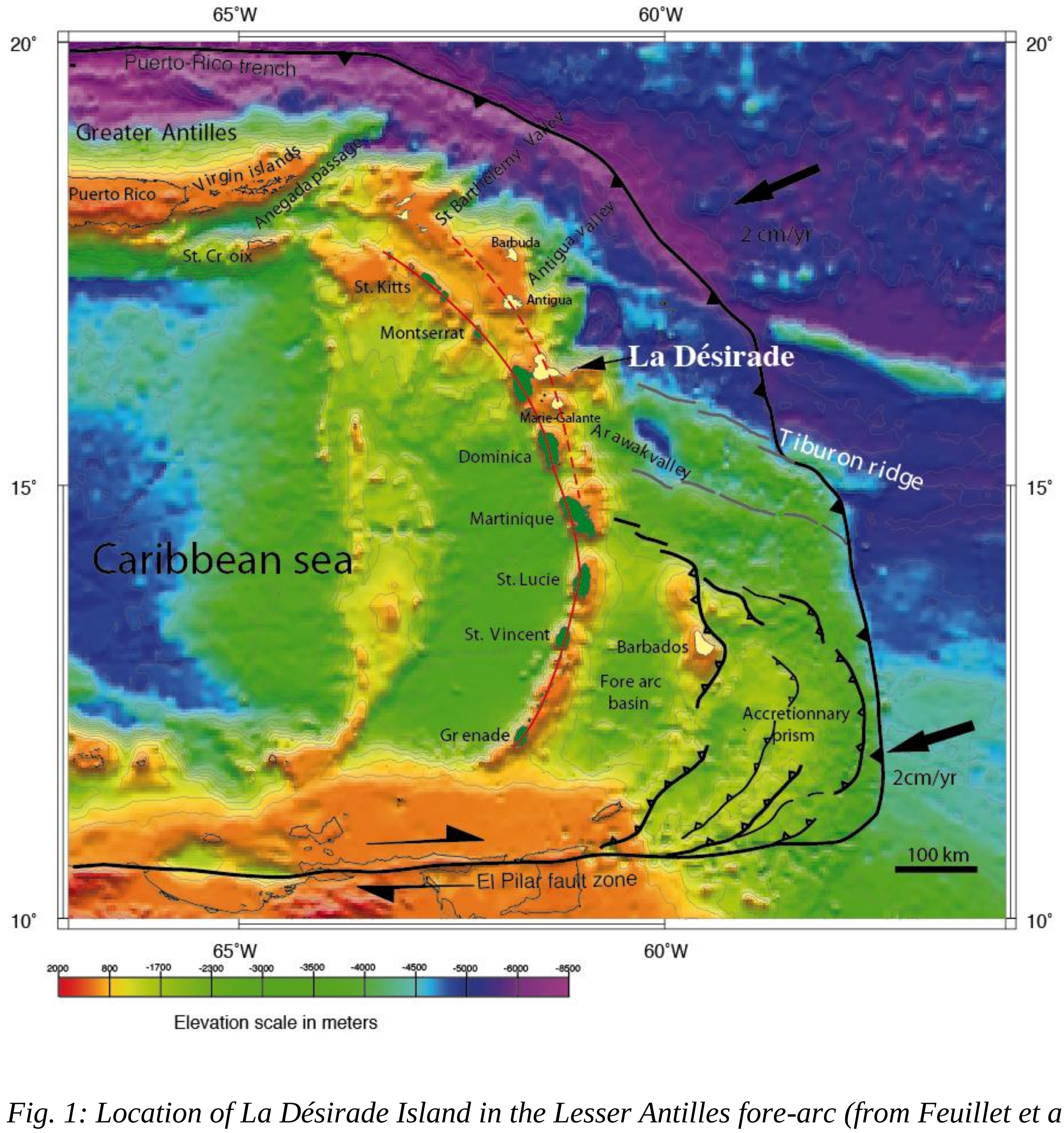

Fig. 1: Location of La Désirade Island in the Lesser Antilles fore-arc (from Feuillet et al., 2002, modified).

The island is 11.5 km long, 2 km large and reaches 276 m in elevation above sea-level. Because of important uplift, La Désirade Island is the only area of the Lesser Antilles arc where the basement of the Caribbean Plate extensively outcrops, overlain by Pliocene carbonate deposits. It is consequently a key area to understand the geodynamics of the Caribbean Plate. New results concerning the basement (day 1) and the Pliocene-Pleistocene carbonate platforms (day 2) are presented (Fig. 2). Stops 1 to 4 (Fig. 2) are devoted to Mesozoic tectonics and metamorphism. Stops 5 to 10 (Fig. 2) are devoted to stratigraphy, sedimentology and Neogene to Pleistocene tectonics.

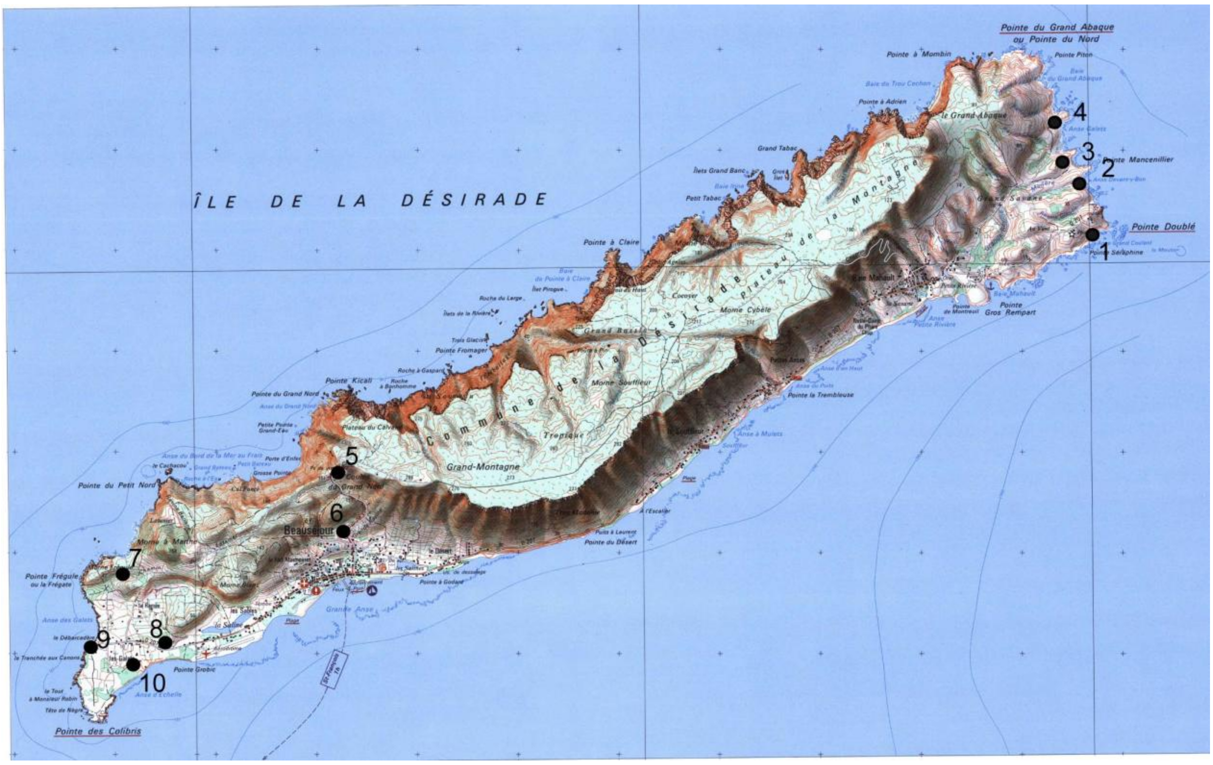

Fig. 2: location of the stops

II – DAY 1: BASEMENT OF LA DÉSIRADE (J.-M. Lardeaux and M. Corsini)

Since Fink (1970), Westercamp (1980), Bouysse et al. (1983) and Mattinson *et al*. (2008), three mains units have been distinguished in La Désirade magmatic basement:

- a northeast volcanic complex composed of meta-basaltic pillow-lavas and interbedded radiolarites (La Désirade ophiolitic complex);
- an acid igneous complex comprising meta-quartz-diorite (trondhjemite of Mattinson et al., 2008) and meta-rhyolitic lavas flows;
- a meta-diabasic/microdioritic dyke swarm complex (upper meta-andesitic group of Westercamp, 1980).

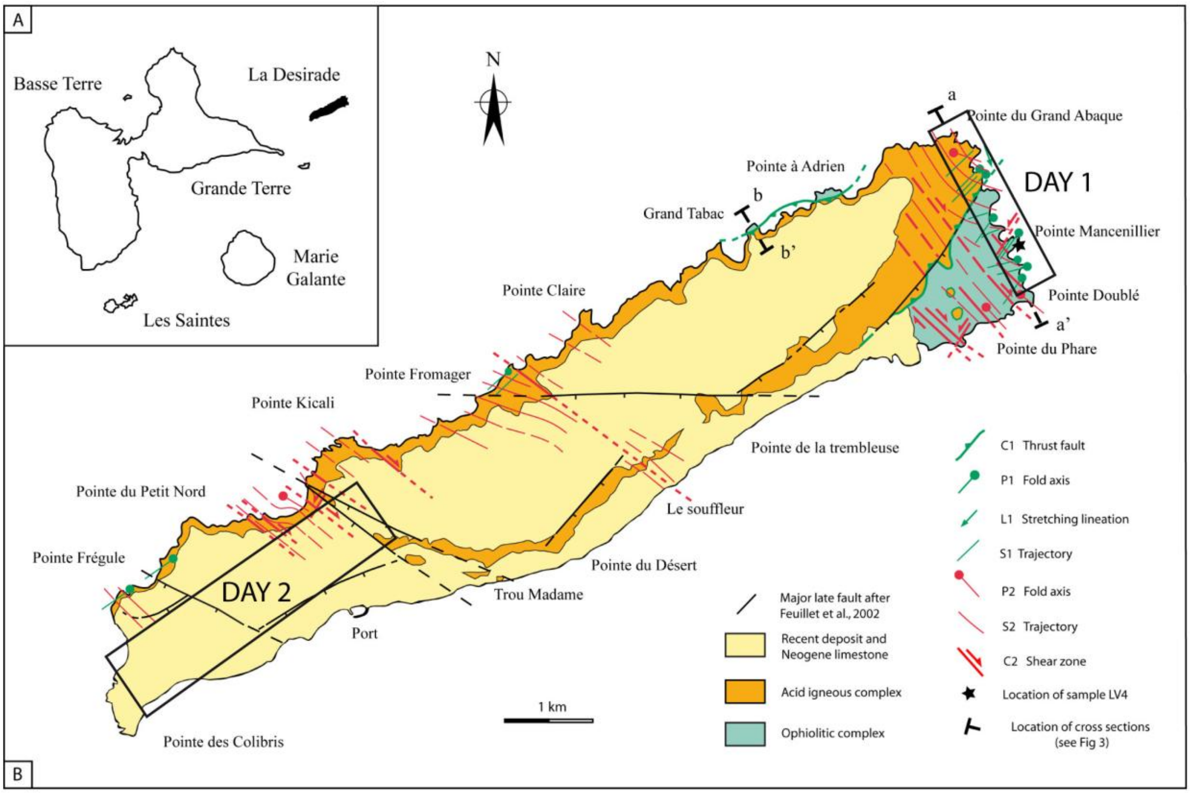

Fig. 3: A) Location of La Désirade Island in the Guadeloupe archipelago; B) Geological map (from Corsini et al., submitted) and areas of investigation during the field-trip.

The structure of the basement had never been investigated. From our Recent works (Corsini *et al*., submitted), the acid igneous complex was thrusted over the northeast volcanic complex (Fig. 3, 4, location of section aa' on Fig.3).

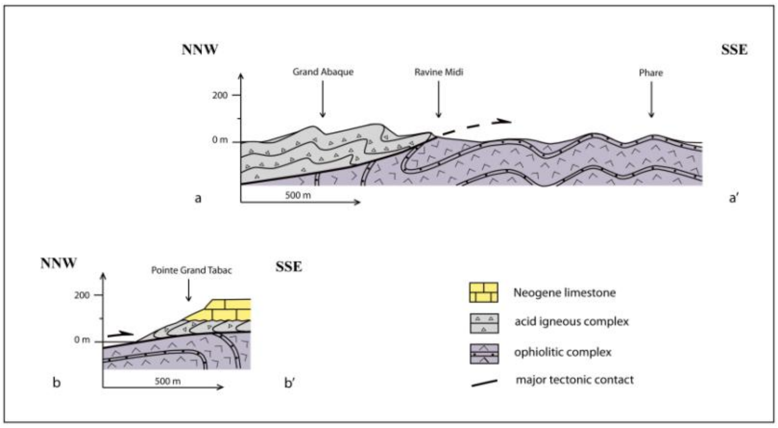

Fig. 4: simplified cross-sections in the northeastern part of La Désirade Island (Corsini et al., submitted)

Stop 1: « Le phare » : ophiolitic unit (pillow basalts, cherts)

The La Désirade ophiolitic complex is interpreted as an ophiolite–type oceanic crust (Mattinson et al., 1973, 1980, 2008; Fox and Heezen, 1975; Dinkelman and Brown, 1977, Le Guen de Kerneizon et al., 1979) or a back arc-related pillow basalts (Fink, 1968, 1970,1972; Bouysse et al., 1983; Maury et al., 1990; Donnelly et al., 1990; Gauchat, 2004; Cordey and Cornée, 2009). However, an origin at a back-arc spreading ridge has gained increasing favour in the light of recent and detailed geochemical investigations (Neill et al., 2010) on La Désirade magmatic rocks. Geological (pillow-lavas, pelagic sedimentation), petrological (abundance of rhyolites and andesites) and geochemical (trace elements patterns) evidences overwhelmingly favour the model of a back-arc basin in a supra-subduction setting. The radiolarian cherts have generated a great deal of attention since the works of Bouysse et al. (1983) and Montgomery et al (1992). Recent biostratigraphic studies of radiolarian bearing cherts show that La Désirade radiolarites are Late Jurassic, ranging from late Kimmeridgian or early Tithonian to early/late Tithonian (Cordey and Cornée, 2009; Plates 1 to 3). In meta-pillowed basalts, the observed association is composed of: albite + chlorite+ clinozoïsite + quartz + actinolite + calcite +/- sphene +/- stilpnomelane +/- ankerite +/- hematite +/- chalcopyrite. In a restricted number of thin sections, we observed also the development of cummingtonite at the expense of magmatic pyroxenes and olivines. Frequently clinozoïsite grains are rimmed or partly replaced by pistacite. These minerals underline both S1 and S2 schistosity planes and related mylonitic bands. Syn-tectonic veins are filled with quartz and calcite fibbers, albite, chlorite and hematite. In meter to decametre–scale faults zones, the meta-basalts are seriously transformed into hydrothermalized breccias in which occurs an association of albite + quartz + chlorite + prehnite +/- laumontite. The latter indicates a late metamorphic evolution under very low grade facies (i.e. Prehnite-Actinolite and Zeolite metamorphic facies).

Stop 2: « Pointe Mancenilliers » : polyphase deformation under Greenshist facies

Two main finite strain patterns corresponding to a compressionnal context have been evidenced.

The first event of deformation D1 displays pervasive folding associated with thrust development. F1 folds display a metric to hectometre wavelength, N30° ± 10° trending steeply dipping axial planes and sub-horizontal axes. F1 folds developed axial planar pressure-solution cleavage S1, with crystallization of quartz, albite, chlorite and epidote. The

D1 deformation event is also characterized by an important thrusting, up to now unknown in this island.

The second deformation event (D2) is featured by a main pervasive cleavage S2 observed at the regional scale associated with upright hectometer wavelength folding (F2) and by the development of narrow shear zones, from centimetres to a few meters thick. These shear zones are steeply dipping and record a strike-slip motion under brittle ductile transition characterized by Greenschist facies mineralogic assemblages.

Two sets of conjugated shear zones are distinguished: main N130° ± 10° striking dextral strike-slip shear zones and N20°± 10° sinistral strike-slip shear zones. The two sets of shear zones are coeval suggesting a nearly N-S shortening direction in the present day coordinates of the la Désirade Island.

Adularia minerals were found in the northeast volcanic complex within a deformed zone oriented N20°± 10° and related to the second deformation event (D2). $^{40}Ar/^{39}Ar$ analyses performed on bulk samples of adularia yield well defined and concordant plateau ages at 106.2 ± 1.7 Ma and 107.2 ± 1.8 Ma.

Stop 3 : « Anse Galets » : overview of the Grand Abaque Thrust

The D1 deformation event is also characterized by an important thrusting, up to now unknown in this island. The thrust fault, here after called the Grand Abaque Thrust, is observed in the north-eastern part of the island, where the acid igneous complex with rhyolitic lavas over thrust onto the ophiolitic unit.

The NE-SW striking Grand Abaque Thrust is characterized by a few meter thick Greenschist facies mylonite mainly formed at the expense of metarhyolites and metabasalts. The thrusting zone is also characterized by the abundance of deformed quartz and epidote-veins attesting for very strong fluid circulations that produced a complete transformation of the rocks in the Greenschist facies. Direction of transport in the shear zone is underlined by a gently north-dipping stretching lineation with a N340° ± 20° trending. The most evident kinematic indicators are shear band cleavages, asymmetric folds and sigmoid boudins. All the kinematic indicators show a top to the southeast sense of shear.

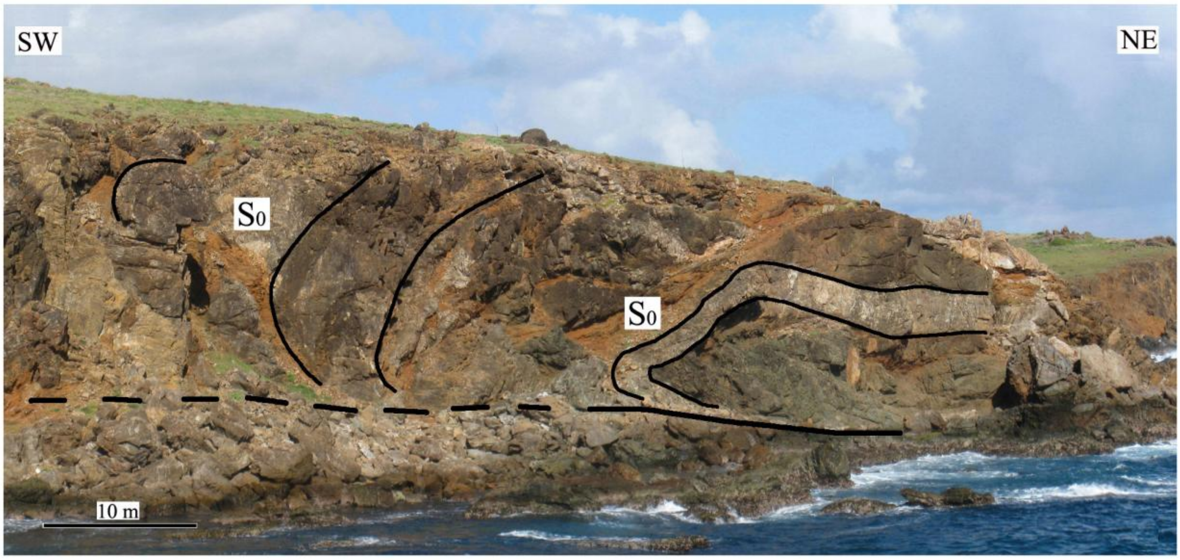

Fig.5: overview of the Grand Abaque Thrust separating the acid igneous complex above from the ophiolitic complex.

Stop 4: «Grand Abaque»: arc related acid igneous complex, metamorphism and deformation history

The acid igneous complex comprises meta-quartz-diorite and meta-rhyolitic lavas flows associated to volcanic breccias.

In meta-rhyolites the observed metamorphic mineralogy is an association of quartz + albite + clinozoïsite +/- stilpnomelane (Fig. 6). These minerals are observed in pressure solution cleavages as well as in veins or micro-fractures crosscutting S1 and S2 planes. Numerous brittle faults developed at the centimetre to meter - scale, which contain late crystallizations of prehnite, laumontite and zeolites. These late phases reflect the progressive cooling of La Désirade basement rocks from Greenschist to Zeolite facies conditions thought time.

Rhyolitic lavas and volcanic breccias are folded and affected by penetrative S1 and S2 schistosity related to (D1) and (D2) compressional event.

In Approaching the thrust zone at the Pointe du Grand Abaque, the F1 folds evolve from upright to reversal and recumbent shape showing that strain intensity is inversely proportional to the distance from the contact of the Grand Abaque Thrust.

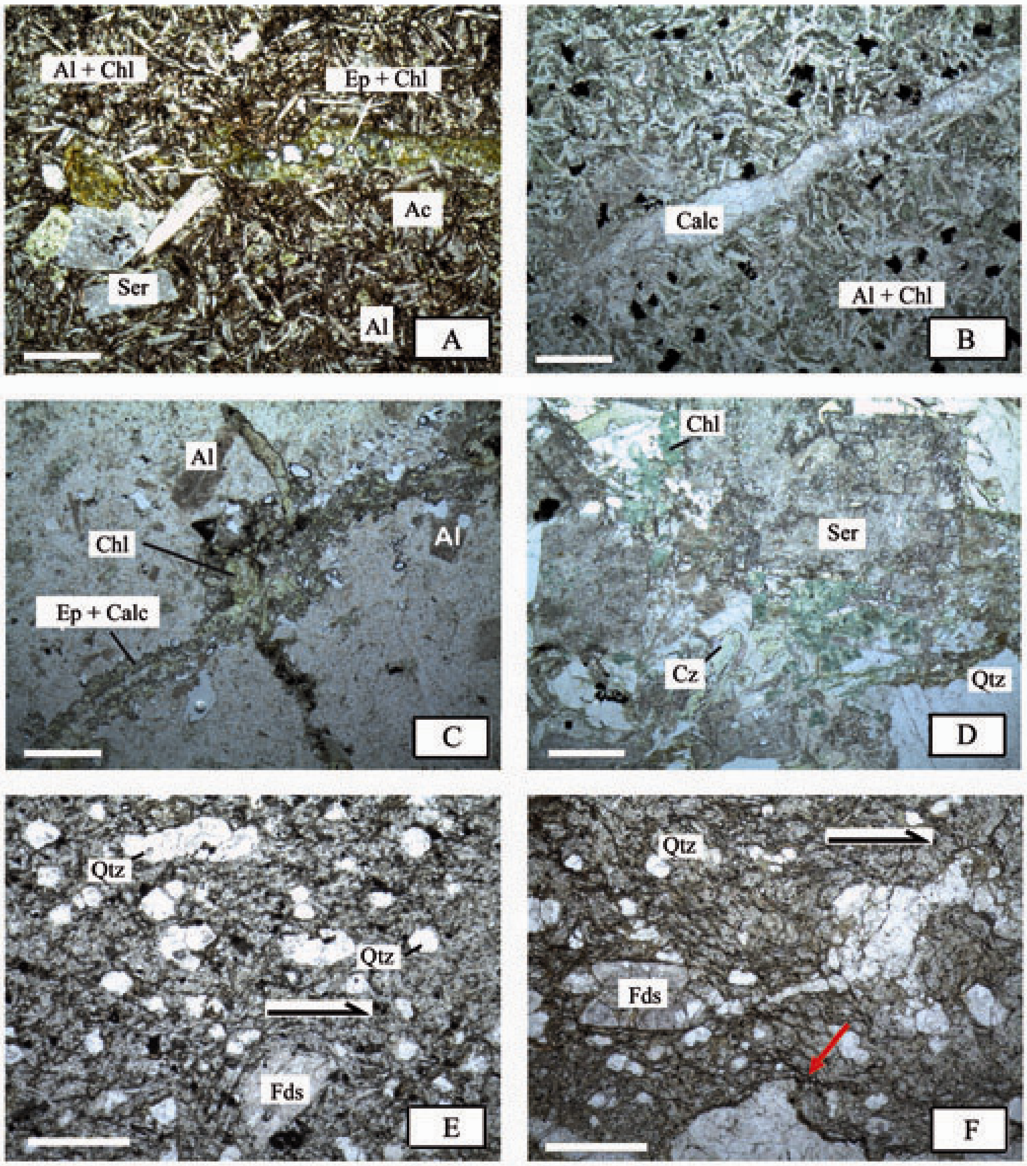

Fig..6:microphotographs showing the Greenschist facies metamorphic and mylonitic assemblages. A: meta-pillowed basalt; B: dyke; C: meta-rhyolitic complex; D: meta-trondjhemitic complex; E and F: mylonitized rhyolite in the Grand Abaque thrust. Ser: sericitized plagioclase, Ac: actinolite, Ep: epidote (cz=clinozoïsite), Chl: chlorite, Qz: quartz, Calc: calcite, Al: albite. Scale bar= 0.5 mm

II – DAY 2: PLIOCENE-EARLY PLEISTOCENE SEDIMENTARY COVER (J.-J. Cornée and Ph. Münch)

The carbonate deposits which cap the basement have been considered as Early Pliocene because of the occurrence of planktonic foraminifers in the southwestern part of the island (Westercamp, 1980). The Pliocene limestones have been described as coral-limestones that formed the upper plateau of the island, abruptly changing into fore-reef deposits to the Southwest (*op. cit.*). They have also been considered as composed of three main units (Léticée, 2008): a lower unit with red algae-rich bioclastic and rhodolithic limestones, a mid unit with sandy wackestones and an upper unit with coral-rich limestones.

The general lithostratigraphic succession of La Désirade is difficult to establish because of steep cliffs, vegetation and Recent carbonate crusts which often hide the host rock. Nevertheless, from sparse observations and examination of cliffs on the northern side of the island, a general 120 m thick succession can be reconstructed, from bottom to top (Fig. 7):

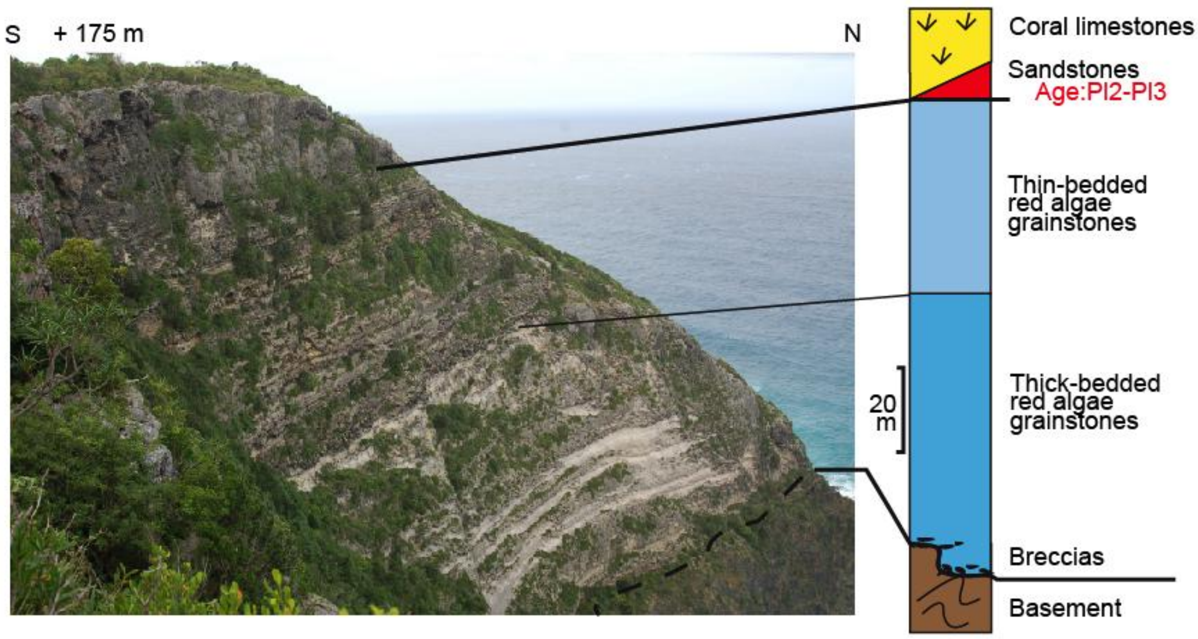

Fig.7: general succession of La Désirade Island at Pointe Adrien

- 1 to 5m thick breccias with up to metre-scale blocks from the basement. Locally, pieces of coral colonies, molluscs and red algae are present. Conglomerates were deposited on an erosional surface with reliefs reaching tens of metres high;

- 20 to 55 m thick, metre-bedded red algae-rich to rhodolithic limestones sometimes dolomitized. In most of the island grainstones to packstones yield red algae, molluscs, large benthic foraminifers (Amphisteginids) and variable amounts of planktonic foraminifers. The algal assemblages consist of various proportions of *Hydrolithon boergesenii*, *Mesophyllum* species, *Lithothamnio*n sps., *Lithoporella*, thin *Lithophyllum* plants (*L.* gr. *L. pustulatum*) and *Sporolithon* sp. (det. JC Braga), indicating a 20-70m depth. In the southwestern part of the island we have also observed some coral patches with *Acropora*, *Montastraea* and *Porites*. The facies are interpreted as deposited in an eastward gently dipping inner to mid ramp setting.

- 40 m thick, decimetre to metre-bedded grainstones. This part of the carbonate deposits is poorly known, or outcropping in cliffs or eroded. To the Northeast, facies comprising red algae and large foraminifer grainstones have been identified. To the Southwest, in the uppermost part of the Morne à Marthe hill, facies comprise grainstones with cross-stratifications. Grainstones are dominantly composed of fragments of red algae, molluscs and echinoids. As for the underlying unit, the facies are interpreted as deposited on a low angle, inner to mid ramp dipping to the East. The top of this unit is a sharp surface.

- a 10 of m thick sandstones to wackestones with basement-derived millimeter-sized fragments and planktonic foraminifers. The unit has only been observed in the northeasternmost and in the southwesternmost parts of the island (stops 8 and 10). Facies are interpreted as deposited in mid to outer ramp setting, indicating a major drowning of the underlying carbonate ramp. In the Route de La Montagne area several samples provided new biostratigraphic information indicating a Late Zanclean to Early Piacenzan age (4.31 – 3.16 Ma, time calibration from Lourens et al., 2004, Raffi et al., 2006 and Wade et al., 2011):

PLANKTONIC FORAMINIFERS (det F. Quillévéré) :
Orbulina universa, *O. bilobata*, *Sphaeroidinellopsis seminulina*, *S. kochi*, *Globigerinella siphonifera*, *Globigerinoides obliquus*, *G. extremus*, *G. quadrilobatus*, *G. sacculifer*, *Globigerinoides ruber*, *G. conglobatus*, *Dentoglobigerina altispira*, *Globoquadrina baroemoensis*, *Neogloboquadrina acostaensis*, *N. humerosa*, *Globoconella puncticulata*, *Truncorotalia crassaformis*, *Globorotalia tumida*, *Menardella miocenica*, *M. limbata*, *M. exilis*, indicating Zone PL2-PL3, Late Zanclean to Early Piacenzian.
CALCAREOUS NANNOFOSSILS (det. M. Melinte-Dobrinescu, Pl. 4):
Braarudosphaera bigelowii, *Calcidiscus leptoporus*, *C. macintyrei*, *Coccolithus pelagicus*, *Discoaster pentaradiatus*, *D. brouweri*, *Helicosphaera sellii*, *H. carteri*, *Pseudoemiliania lacunosa*, *Reticulofenestra haqii*, *R. minuta*, *R. minutula*, *R.pseudoumbilicus*, *Sphenolithus abies*, *Scyphosphaera sp.*, *Thoracosphaera saxea*,

indicating the uppermost part of Zones NN13/15 biozone to the lower part of Zones NN16 (Martini, 1971), or Zones CN10c/11-CN12aA (Okada et Bukry, 1980), Late Zanclean to Early Piacenzan.

- 10 to 20 m thick limestones with locally coral reefs. They only outcrop at the top of the carbonate deposits in the northeastern part of the island. These are organized in metre-thick beds with more or less isolated colonies in a grainstone matrix. The coral association is dominated by branching *Acropora* and massive *Montastraea* colonies, interpreted as originating from an in inner platform environment. The age of this unit is unknown. Because of its structural position in the platform, it is considered as Piacenzian in age.

Stop 5: lower part of the carbonate platform

The lowermost part of the carbonate platform outcrops along the Calvaire road, where it exhibits several conglomeratic beds changing upward into red algae-rich beds (Fig. 8).

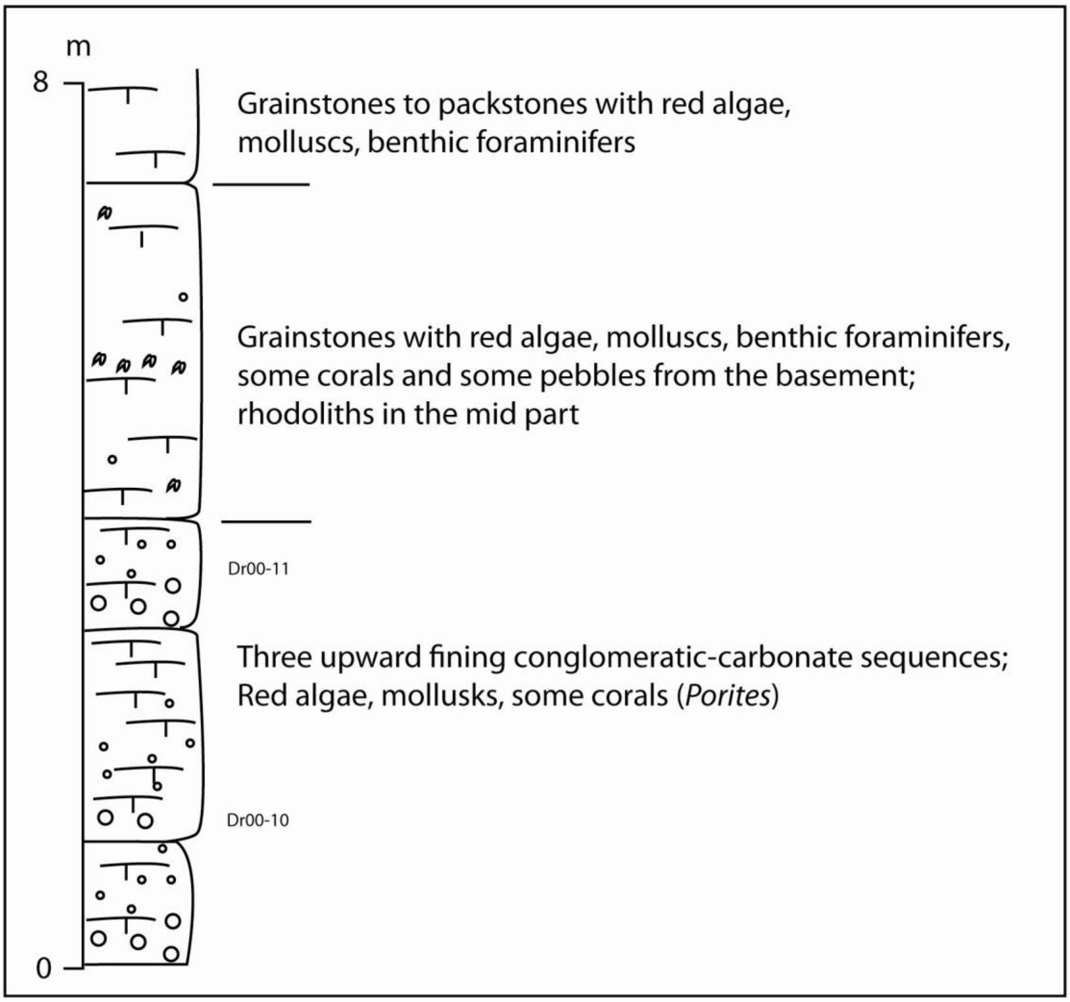

Fig.8: the lower part of the Pliocene carbonate deposits along the Calvary road.

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Stop 6: Pliocene reefal facies

In the Beauséjour quarries, southwestern part of the island, coral patches can develop in the lower part of the skeletal carbonate deposits (Fig.9). The coral association is dominated by thin-branched *Acropora* and *Montastraea* colonies. *Diploria*, *Porites* and Mussid colonies can also be found.

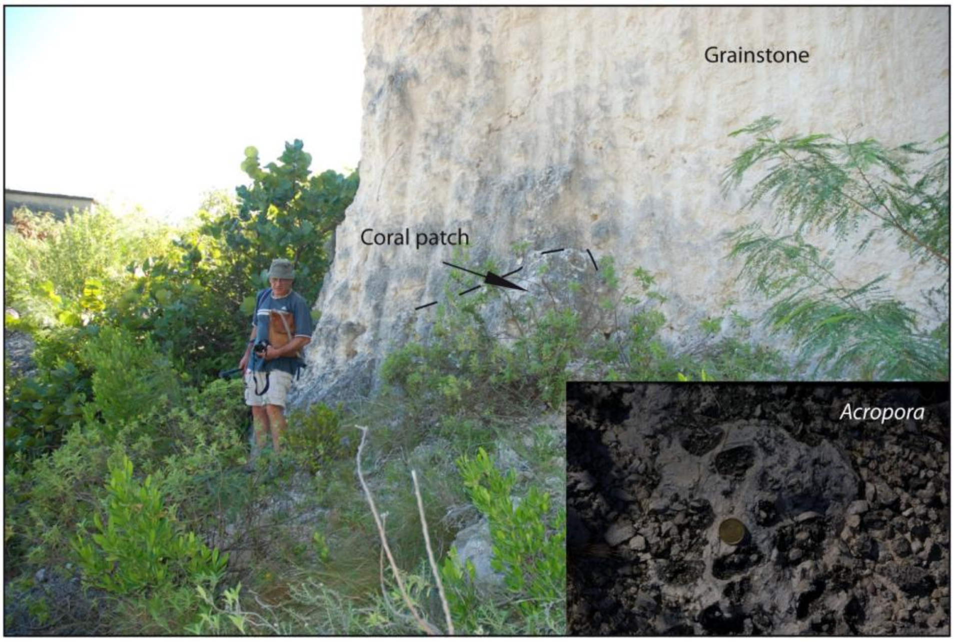

Fig.9: coral patches in the lower part of the Pliocene carbonate deposits, Beauséjour quarry.

Stop 7: relation basement-carbonate platform

This outcrop allows the observation of the base of the carbonate deposits onto the basement. Conglomerates are composed of angular, decimeter-sized blocks issued from the basement and embedded in a carbonate matrix.

Stop 8: Pliocene tectonics

Near the airport, an ancient quarry along the D207 road allows investigating the Pliocene syn-sedimentary tectonics. Eastward, some massive red algae limestones outcrop. They are part of the lower units of the La Désirade carbonate platform. Westward, some grainstones to wackestones outcrop with reworked fragments of red algae limestones. These deposits are crosscut by a roughly N-S trending fault sealed by the Eemian terrace (Fig. 10). Coarse-grained carbonate breccias are localized near the fault plane. The size of the fragments decreases westward. West of the fault, dips progressively change from around 30° near the fault plane to 10° farther, where isolated blocks of red algae limestones are embedded in the sediment. Conclusively, the fault is considered as active during the deposition of the sediments in the hangingwall of the fault.

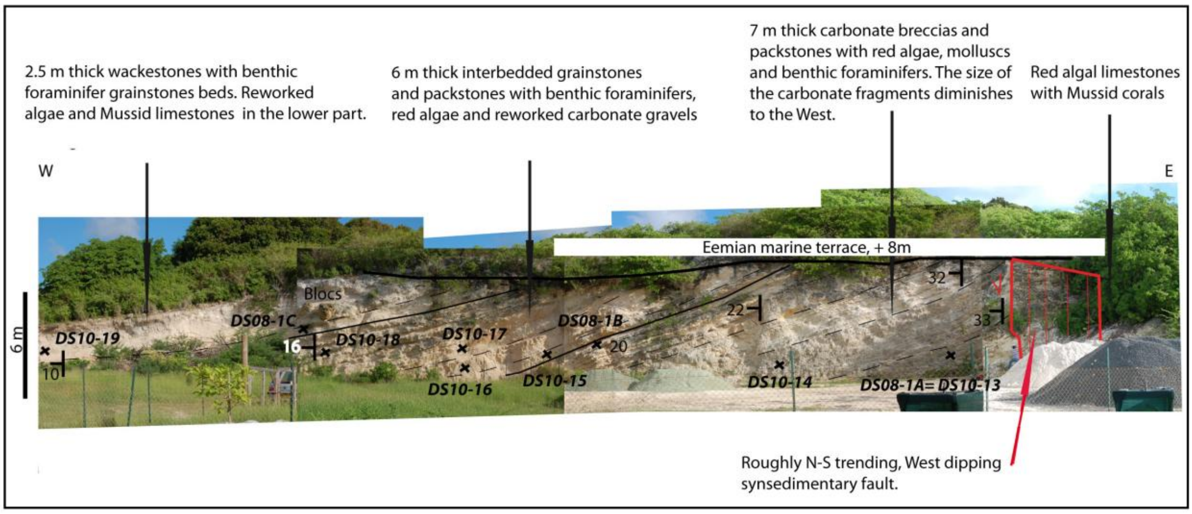

Fig.10: synsedimentary faulting in the D 207 road quarry. Numbers refer to dated samples.

Grainstone beds display abundant benthic foraminifers dominated by *Operculinoides cojimarensis*, *Operculinoides* sp. and *Amphistegina* sp. of debated age (Baumgartner-Mora, 2004). The age of the sediments, and of the synsedimentary activity of the fault, is Late Zanclean to Early Piacenzan based on new micropaleontological investigations:

PLANKTONIC FORAMINIFERS (det. F. Quillévéré):

Orbulina universa, *Sphaeroidinellopsis seminulina*, *S. kochi*, *Globigerinella spiphonifera*, *Paraturborotalia woodi*, *Globigerinoides quadrilobatus*, *G. sacculifer*, *G. extremus*, *G. conglobatus*, *Dentoglobigerina altispira*, *Neogloboquadrina acostaensis*, *N. humerosa*, *Globorotalia tumida*, *Menardella menardii*, *M. exilis*, indicating Zones PL2-PL3, Late Zanclean to Early Piacenzan.

CALCAREOUS NANNOFOSSILS (det. M. Melinte-Dobrinescu, Pl. 4):

Braarudosphaera bigelowii, *Discoaster brouweri*, *D. tamales*, *D. pentaradiatus*, *Calcidiscus leptoporus*, *C. macintyrei*, *Florisphaera profunda*, *Helicosphaera sellii*, *H. carteri*, *Pontosphaera japonica*, *Pseudoemiliania lacunosa*, *Reticulofenestra haqii*, *Sphenolithus abies* (abundant), *Thoracosphaera saxea*, indicating Zones NN16-NN17 of Martini (1971), respectively subzones CN12 a-c of Okada & Bukry (1980), latest Zanclean to earliest Piacenzan.

Consequently, during the Late Zanclean-Early Piacenzan the whole Désirade island was drowned and deposits where emplaced into mid to outer platform setting. At this time syn-sedimentary extensional tectonics was recorded. After this episode, shallower conditions prevailed as sedimentation returned to inner reefal platform conditions (northeasten part of the island).

Stop 9: Early Pleistocene coral-reefs

The Pleistocene reefal complex only outcrops in the Pointe of Colibri area, in the southwestern part of the island. It is composed of a around 10 m thick bioclastic beds and reefal beds which prograde westward (Fig. 11). Bioclastic beds comprise bioturbated grainstones with trough cross-stratifications and hummocky cross-stratifications, indicative of an upper shoreface environment. Reefal beds comprise coral boundstones with Mussid corals, *Montastraea cavernosa*, *Acropora cervicornis*, *Porites* sp., *Agaricia* sp. and *Diploria labyrinthiformis*. This latter coral species is considered of Pleistocene to Recent. These reefs are similar to those found in the "Calcaire à Agaricia Formation" in Grande Terre, which have been seen Latest Gelasian (Münch *et al*., this congress).

Fig. 11: Early Pleistocene coral reefs at Pointe Colibri.

Stop 10: relation between Pliocene and Pleistocene deposits

In the Anse à Galets, an ancient quarry allows to investigate the relationships between the Pliocene wackestones and the bioclastic facies of the Early Pleistocene (Fig. 12).

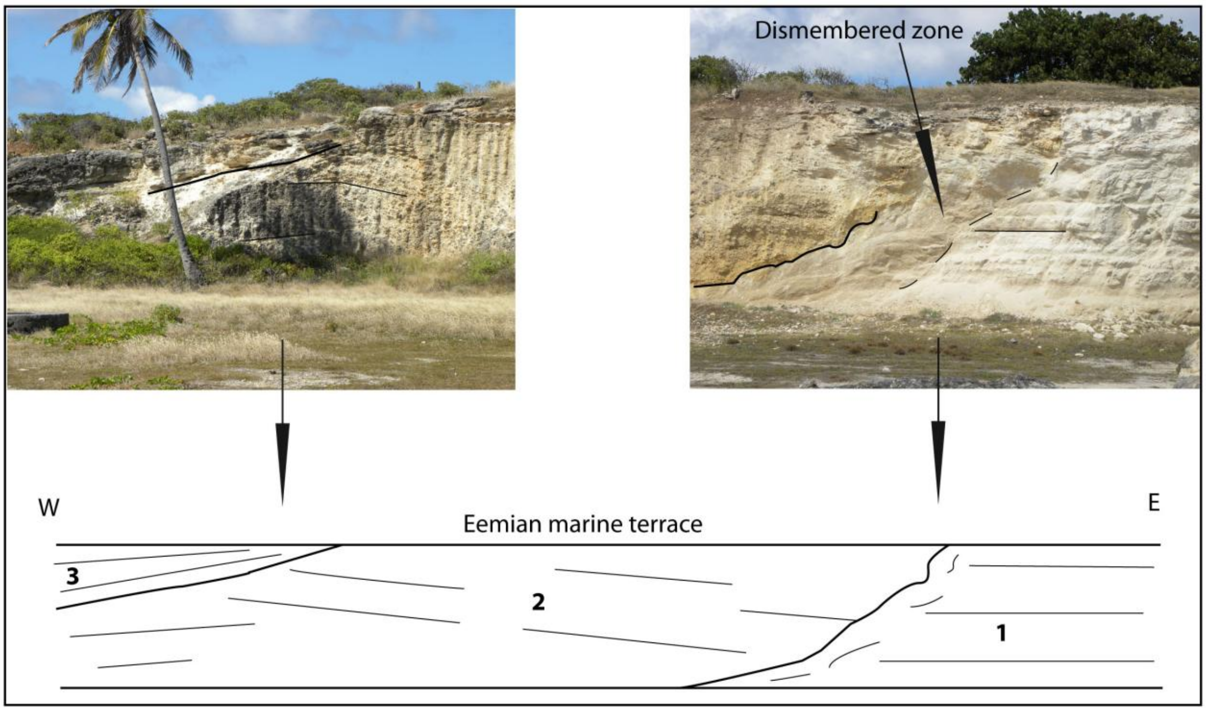

Fig. 12: geometric relationships between Pliocene and Pleistocene deposits at Anse à Galets quarry. Not to scale.

Three sedimentary units can be distinguished (numbers refer to Fig. 12):

1: subhorizontal wackestones to packstones in the eastern part, with planktonic foraminifers. These are similar to those of stop 8 and microfossils also suggest an Early Piacenzan age (see below). To the West the deposits are dismembered along an erosional surface. Several samples provided abundant microfauna:

INDEX PLANKTONIC FORAMINIFERS (det. F. Quillévéré)

Sphaeroidinella dehicens, S. seminulina, S. kochi, Pulleniatina sp., Globigerinoides extremus, G. conglobatus, G. obliquus, Neogloboquadrina acostaensis, N. humerosa, Dentoglobigerina altispira, Globoquadrina baroemoenensis, Menardella pertenuis, M. exilis, M. miocenica, M. multicamerata, M. limbata, Truncorotalia crassaformis, T. crassaformis viola, indicating the Zone PL3, Early Piacenzan (3.52– 3.41 Ma, calibration interval from Wade et al., 2011).

CALCAREOUS NANNOFOSSILS (det. M. Melinte-Dobrinescu, Pl. 4)

Discoaster tamalis, D.pentaradiatus, D. brouweri, Calcidiscus leptoporus, C.macintyrei, Pseudoemiliania lacunosa, Pontosphaera multipora, Helicosphaera carteri, Rhabdosphaera clavigera, Scyphosphaera spp, Syracosphaera pulchra, small reticulofenestrids, indicating a Piacenzan age (3.52 - 2.801 Ma, calibration interval from Raffi et al., 2006).

2: above are rhodolith-rich rudstones with low angle, large-scale cross stratifications. Their age is unknown. They contain microfossils of Late Zanclean-Early Piacenzan age which are probably reworked.

3: West-dipping grainstones to rudstones in the western part. These are related to the Early Pleistocene reefal deposits of the neighbouring stop 9. They contain abundant pieces of red algae and molluscs. Calcareous gravels and pieces of coral colonies (*Montastraae*) are also found. Trough cross-stratifications and hummocky cross-stratifications are present. This units onlaps unit 2 and thickens to the west.

Between the Late Zanclean-Early Piacenzan and the Early Pleistocene, La Désirade underwent two relative sea-level drops responsible for the erosional surfaces observed in the Anse à Galets quarry. Late Pliocene deposits have not been identified. During this time the sedimentation was continuous all over Grande Terre (Leticee, 2008; Leticee *et al*., this congress). The peculiar sedimentary organization of La désirade is interpreted as the consequences of early tectonic uplifts of the island, leading to repeated emersions and littoral carbonate deposition in restricted areas. **Most of La Désirade was emergent since Late Pliocene times**. Its southwesternmost part has been momenteanously rimmed by Early Pleistocene reefs. At last, Eemian reefal terraces have also been uplifted between 2 and 9 metres in elevation along the present-day coastline (Feuillet et al., 2004).

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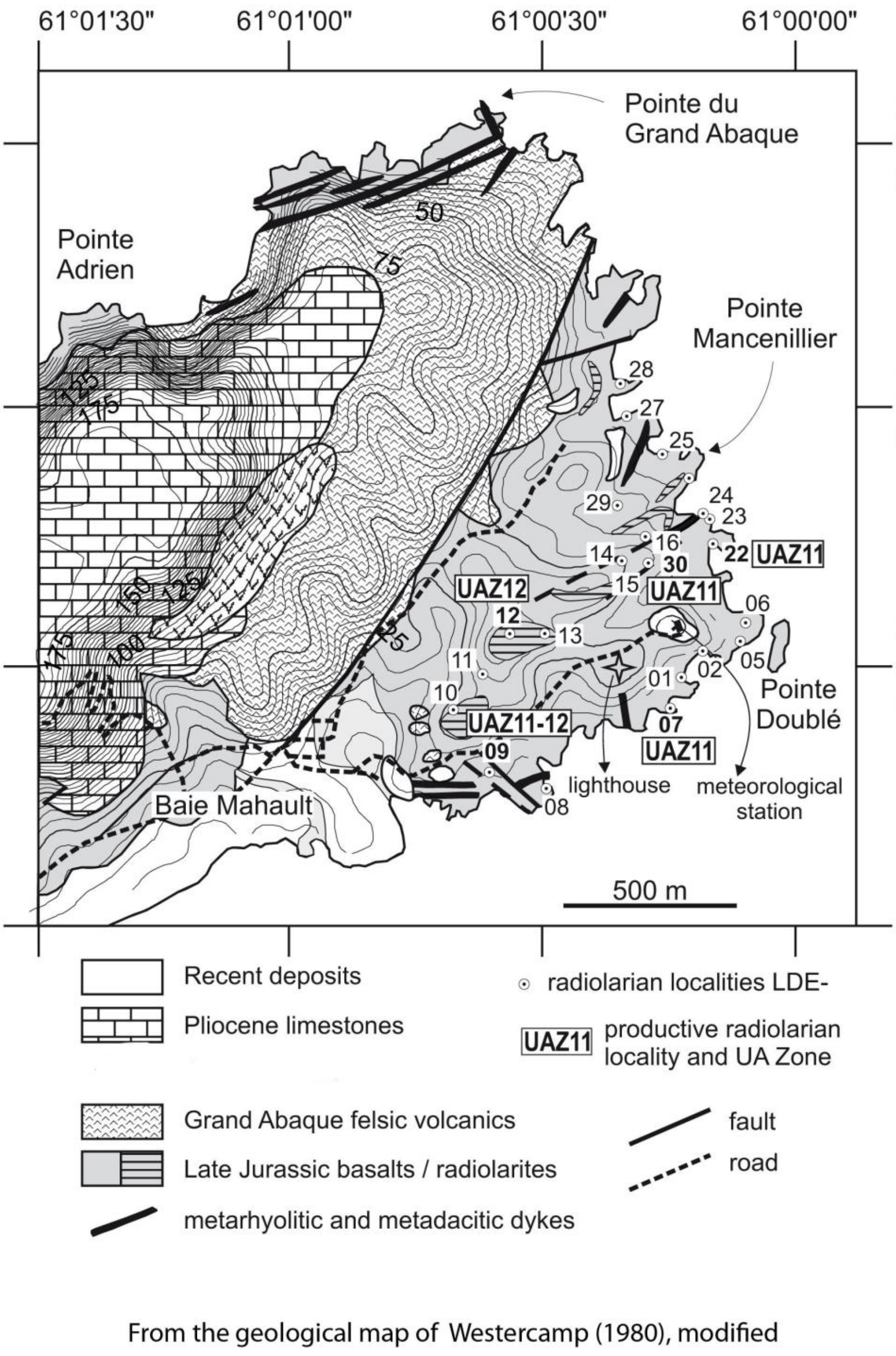

Plate 1 (Cordey and Cornée, 2009)

Location of the radiolarian localities.

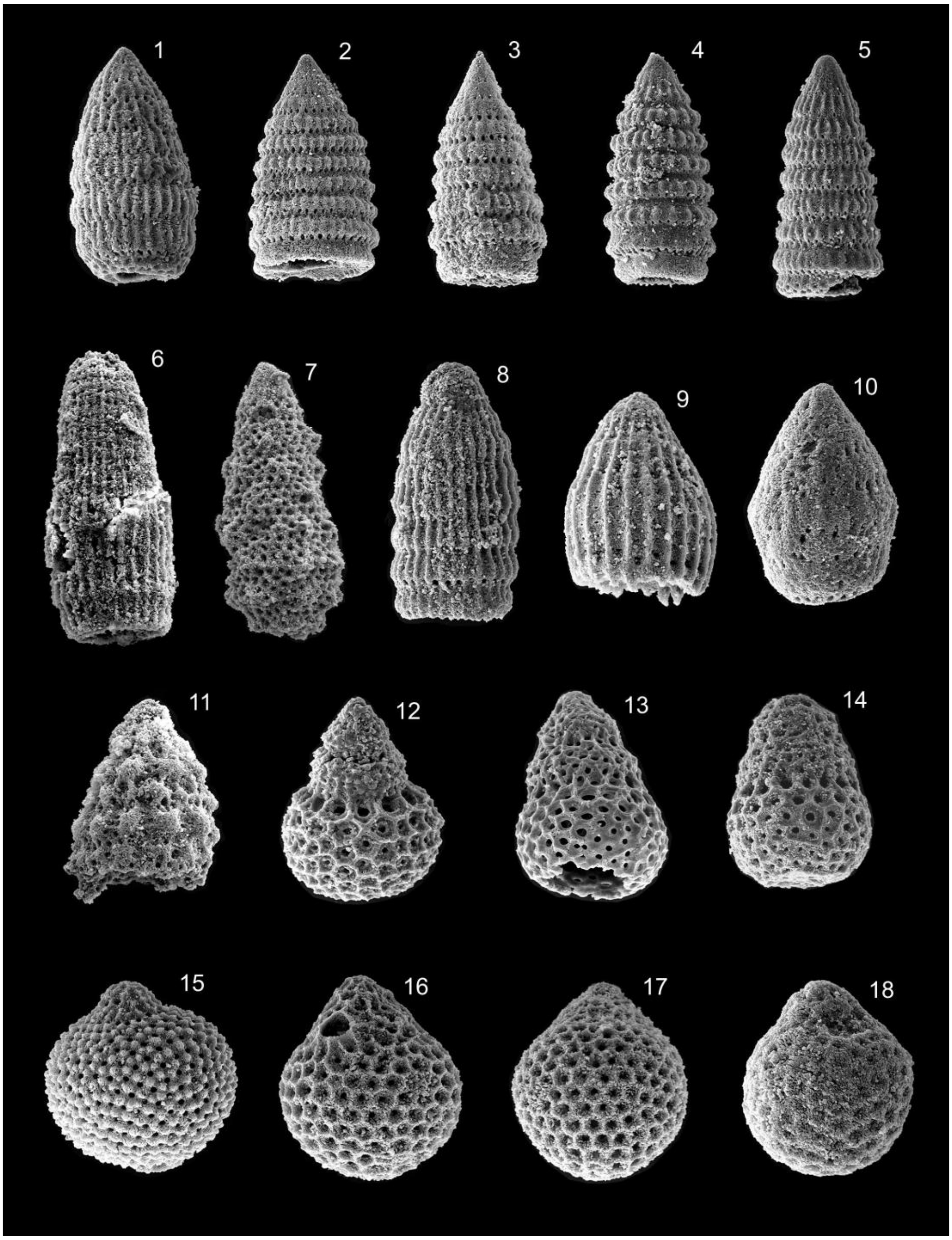

Plate 2 (Cordey and Cornée 2009).

Late Jurassic radiolarians from La Désirade cherts (Scanning Electron Microscope). Figures: taxon, sample number, database picture number, maximum width.
1. *Loopus* sp., LDE12, p10, 345 µm; 2-3. *Pseudodictyomitra* spp., LDE12, 3, 520 µm; p4, 420 µm; 4. *Pseudodictyomitra carpatica* (Lozyniak) LDE12, p5, 380 µm; 5. *Loopus primitivus* (Matsuoka & Yao), LDE12, p6, 330 µm; 6. *Archaeodictyomitra excellens* (Tan), LDE9, p5, 385 µm; 7. *Tethysetta* sp. cf. *dhimenaensis*, LDE30, p7, 430 µm; 8. *Archaeodictyomitra* sp., LDE12, p13, 365 µm; 9. *Thanarla* sp., LDE12, p11, 360 µm; 10. *Loopus* sp., LDE12, p18, 365 µm; 11. *Xitus gifuensis* Mizutani, LDE12, p8, 460 µm; 12. *Sethocapsa accincta* Steiger, LDE22, p19, 410 µm; 13-14. *Sethocapsa* sp., LDE22, p17, 375 µm; p24, 345 µm; 15. *Williriedellum* sp., LDE12, p19, 505 µm; 16-17. *Zhamoidellum* sp., LDE12, p23, 465 µm; LDE22, p15, 400 µm; 18. *Zhamoidellum* sp. aff. *ovum* Dumitrica, LDE12, p20, 395 µm.

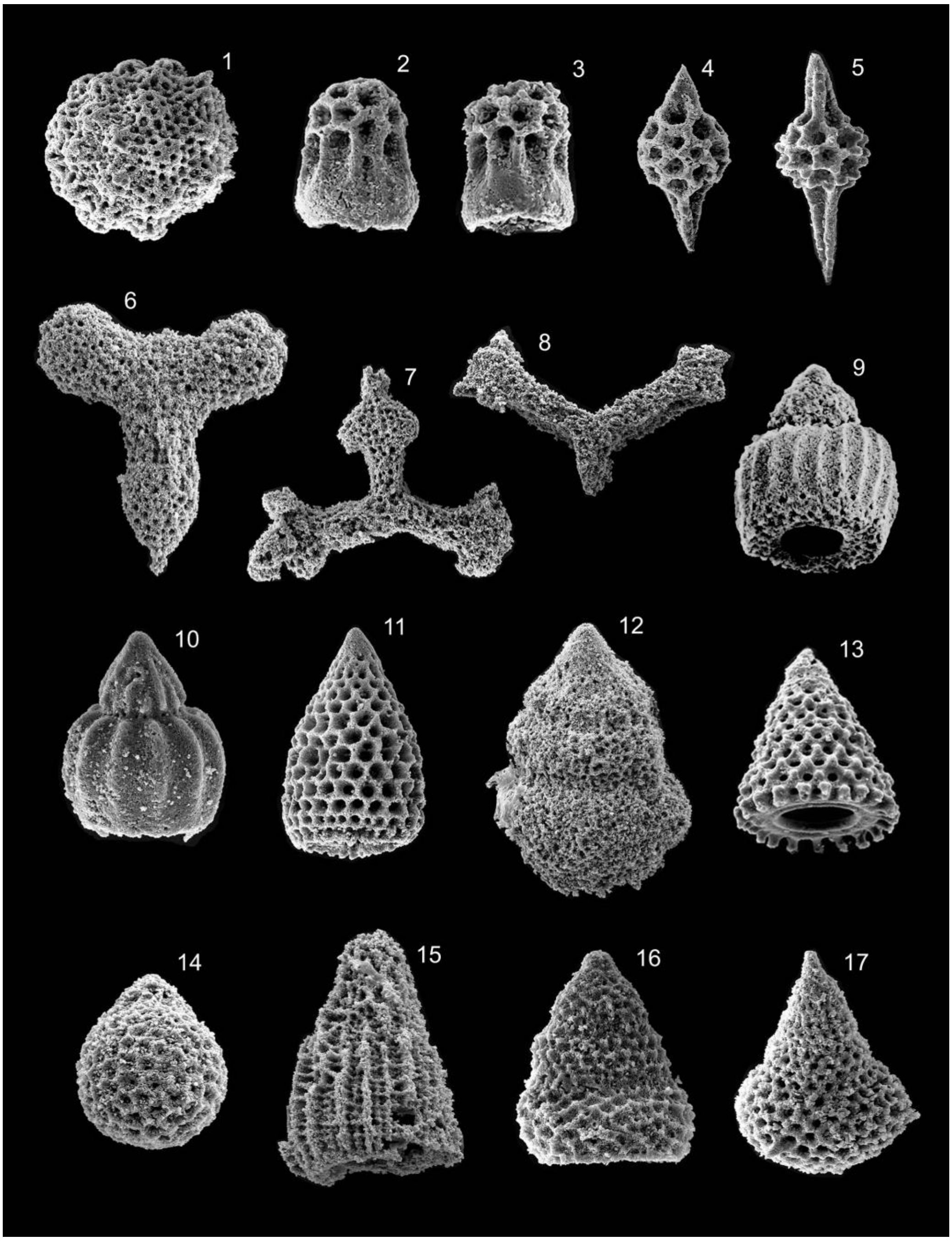

Plate 3 (Cordey and Cornée 2009).

Late Jurassic radiolarians from La Désirade cherts (Scanning Electron Microscope). Figures: taxon, sample number, database picture number, maximum width. 1. *Praeconocaryomma* sp., LDE22, p1, 745 µm; 2-3. *Vallupus hopsoni* Pessagno & Blome, LDE22, p11, 370 µm; p12, 310 µm; 4. *Pantanellium whalenae* Pessagno & MacLeod, LDE22, p21, 365 µm; 5. *Pantanellium squinaboli* (Tan), LDE22, p22, 290 µm; 6-7. *Paronaella* spp., LDE30, p5, 1200 µm; p4, 1200 µm; 8. *Angulobracchia* sp., LDE30, p6, 1250 µm; 9. *Eucyrtidiellum ptyctum* (Riedel & Sanfilippo), LDE7, p5, 120 µm 10. *Eucyrtidiellum pyramis* Aita, LDE12, p14, 200 µm; 11. *Pseudodictyomitrella* sp. aff. *tuscanica* (Chiari, Cortese & Marcucci), LDE12, p2, 550 µm; 12. *Obesacapsula* sp. cf. *verbana* (Parona), LDE30, p3, 1100 µm; 13. *Parvicingula* sp., LDE22, p25, 385 µm; 14. *Zhamoidellum* sp., LDE12, p17, 375 µm; 15. *Hsuum* sp. aff. *cuestaense* Pessagno, LDE30, p11, 470 µm; 16. ?*Eucyrtidiellum* sp., LDE12, p22, 400 µm; 17. ?*Sethocapsa* sp., LDE22, p3, 580 µm.

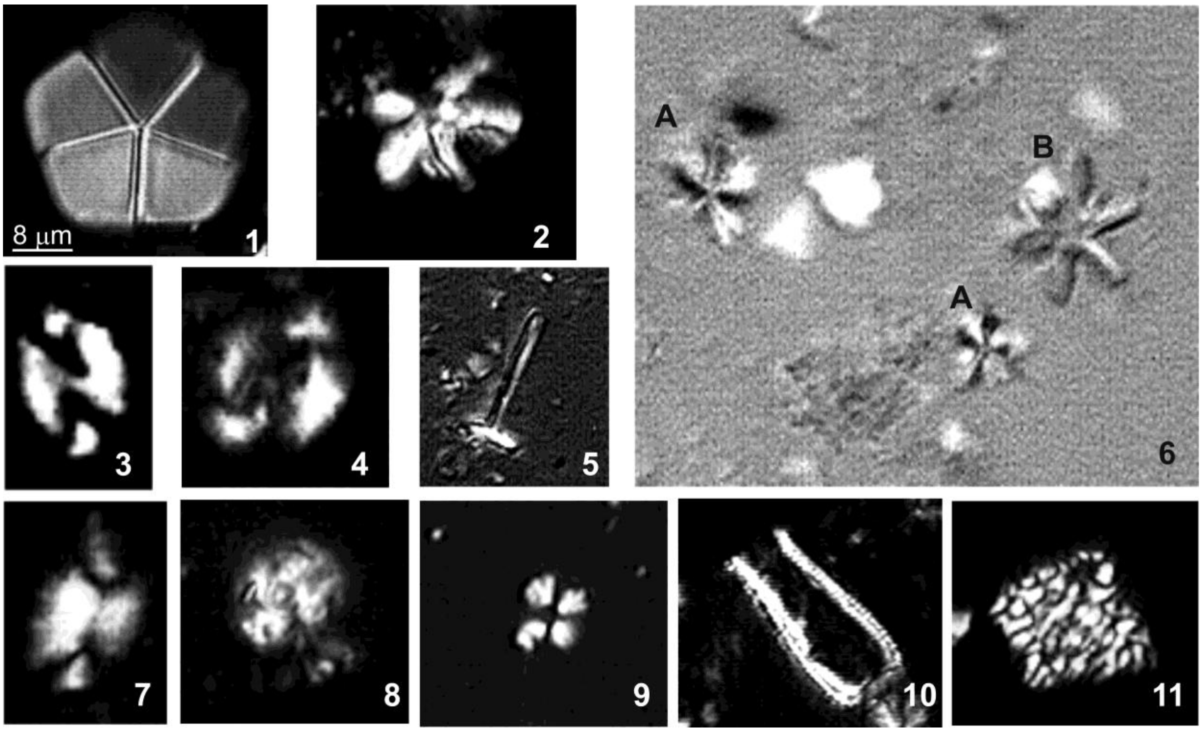

Plate 4: calcareous nannofossils (det. Melinte-Dobrinescu)

All microphotographs at LM (light microscope), crossed nicols,
except Fig. 6 in transmitted light. Scale bar for all figures 8 microns

Fig. 1 – *Braarudosphaera bigelowii* (Gran & Braarud, 1935) Deflandre, 1947; Late Zanclean.
Fig. 2 – *Discoaster pentaradiatus;* Early Piacenzian.
Fig. 3 – *Helicosphaera selli* (Bukry & Bramlette, 1969) Jafar & Martini, 1975; Early Piacenzian.
Fig. 4 – *Reticulofenestra pseudoumbilicus* Gartner, 1969; Late Zanclean.
Fig. 5 – *Rhabdosphaera clavigera* Murray & Blackman, 1898; Early Piacenzian.
Fig. 6 – A: *Sphenolithus abies* Deflandre in Deflandre & Fert, 1954; B: *Discoaster brouweri* Tan, 1927, emend. Bramlette & Riedel,1954; Late Zanclean.
Fig. 7 – *Helicosphaera carteri* (Wallich, 1877) Kamptner, 1954; Early Piacenzian.
Fig. 8 – *Calcidiscus macintyrei* (Bukry & Bramlette, 1969) Loeblich & Tappan, 1978; Early Piacenzian.
Fig. 9 – *Calcidiscus leptoporus* (Murray & Blackman, 1898) Loeblich & Tappan, 1978; Late Zanclean.
Fig. 10 – *Syracosphaera sp;* Early Piacenzian.
Fig. 11 – *Thoracosphaera saxea* Stradner, 1961; Late Zanclean.