Geological Field Trips and Maps

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A Miocene Mediterranean Strait: The Bonifacio Formation, Southern Corsica

Tidalites 2022 - 10th Congress of Tidal Sedimentology.
Pre-congresss Field Trip T2, Matera, Italy

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Cover page Figure: The old village of Bonifacio, perched on tthe limestone cliff.

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Abstract

The Bonifacio Basin trip is part of the 10th International Congress of Tidal Sedimentology (Tidalites), Matera, Italy, 2022. The guide aims at documenting a number of selected outcrops located along the cliffs forming the Corsican side of the Corsica-Sardinia Strait. The objective is to illustrate the evolution of sedimentary dynamics of the Miocene deposits, which were emplaced above the crystalline Paleozoic basement of the strait. After an initial stage of volcanoclastic sedimentation locally preserved above the basement, two third-order sequences of marine deposition are recorded. The first one, dated to the late Burdigalian, is dominantly composed of wave-dominated siliciclastic deposits and shoreface-attached patch reefs. The second one, dated to the Langhian, has an upward increase in clastic carbonates, progressively dominated by red algae. While wave dynamics still dominates in the lowstand shoreface deposits of this sequence, currents progressively arise as water depth increases, finally forming very large submarine dune fields migrating toward the west, a direction parallel to the present-day strait. Cross-bed geometry and carbonate fabrics suggest a tidal origin for these deposits. It is suggested that the Langhian transgression, together with a tectonic drowning of the strait, was responsible for the propagation of the Western Mediterranean tide into the Corsica Basin (the former Tyrrhenian Sea). Tidal currents were progressively damped after the Miocene, due to the uplift of the eastern part of the strait, where the basement emerged in the Lavezzi and Maddalena Islands.

Key words

Mediterranean, Corsica, Miocene, Tidal, Strait, Dunes, Bars, Channels, Clastic, Carbonates.

Program summary

The present field trip is the second (T2) of a series of pre-congress geological excursions associated with the 10th International Congress of Tidal Sedimentology (Tidalites), Matera, Italy, 2022. It aims to present and discuss arguments for interpreting current-dominated, offshore clastic carbonates of the Miocene Bonifacio Formation as produced by tidal currents during the tectonic drowning of the Corsica-Sardinia Strait.
The trip focuses on selected sites, from which the main features of the sedimentology and stratigraphy of the Miocene deposits of Bonifacio Basin can be shown and discussed, from the facies scale (biota, bedforms) to the largest scale of the southern cliffs (geobodies, sequence stratigraphy, tectonics). It aims not only to address

the tidal signature of the deposits, but also to highlight the structural evolution of the basin, a clue to the understanding of the change from non-tidal to tidal dominance in the shallow-water marine environments.
The proposed program is suitable for a two-day trip. The itinerary from one outcrop to the other, by the main roads (Fig. 1), as well as the parking options, can be adapted thanks to the highly detailed TOPO25 IGN maps (see supplementary materials). Some outcrops require a short walk from the car parking place, mostly along easy trails (indicated on the TOPO25 IGN map), but in some cases there is a need for some hiking along the shore platforms to see better the exposures. The schedule integrates the time necessary for discussion of participants on each of the selected stops.

DAY 1 – The first day is devoted to the lower part of the Miocene succession, aiming to set up the background geology of the basin and the onset and development of tidal dynamics. Specific attention will be paid to the change from volcaniclastics to terrigenous siliciclastics and finally to carbonate-dominated deposits. More specifically, the biota will be examined in the scope of replacement of pioneering reefs by progressively deeper-setting carbonate factories. In the morning of the first day, the first stop (T2.1.1) is one of the few places to observe the lowermost Miocene unit of the Bonifacio Basin: the Balistra Formation, in the beautiful sightseeing of the beach of Balistra Bay. The next stop of the morning (T2.1.2) is devoted to the second unit, the Cala di Labra Formation. After the lunch, likely a picnic on the shore of Cape Pertusato, the third stop (T2.1.3) is focused on the lowermost, Pertusato Member of the Bonifacio Formation.

DAY 2- The second day is focused on the stratal architecture of the cross-bedded deposits of the Bonifacio Member, in order to discuss the bedforms at various scales. The first stop of the day (T2.2.1) is at one of the few places where it is possible to access the base of the high cliffs of the Bonifacio Bay: the Anciennes Batteries site. The trail down to the shore crosscuts most of the Bonifacio Member succession, introducing the discussion about the onset of tidal dynamics and associated environmental changes. The town of Bonifacio and inner cliffs of the Bonifacio ria offer various exposures to reconstruct these deposits in 3D. In addition, the stop at the citadel (T2.2.2), provides amazing scenic views of the coast up to Pertusato Cape. Lunch time in Bonifacio is also a way to enjoy the harbour and, maybe, to purchase a piece of red coral from the Bonifacio Strait, historically important for local jewelry. However, the large-scale stratigraphic features exhibited by the coastal cliffs can be discovered from the sea only. This is the purpose of the boat trip scheduled in the afternoon (T2.2.3), on behalf of the marine wildlife park (*Réserve Naturelle des Bouches de Bonifacio*).

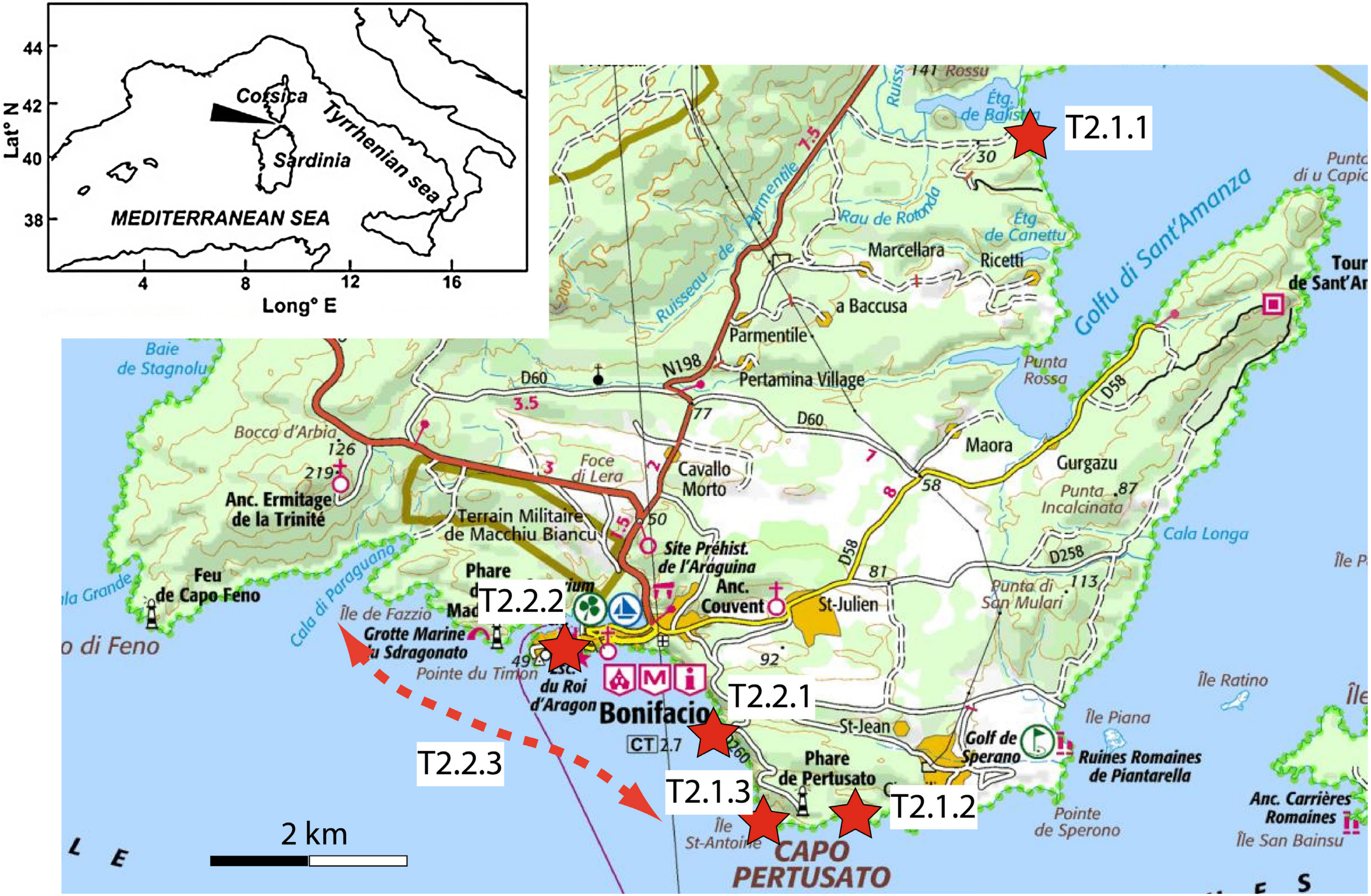

Fig. 1 – Part of the 1:100,000 IGN topographic map of southern Corsica, with the itinerary stops indicated. Dotted arrow in stop T2.2.3 indicates the coastal area covered by the boat trip. Source: IGN Top100 Ajaccio-Bonifacio. Inset map: location of Southern Corsica (arrow) in the Western Mediterranean.

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Safety

Hiking shoes are necessary for the field trip, as some parts of the trails across the cliffs down to the shore are steep. Avoid rainy days (hopefully rare!) as the trails also can be slippery. The mobile telephone network may not operate is some places. The boat trip will be on behalf of the Marine Park of Bonifacio (*Parc Marin des Bouches de Bonifacio*), including insurance. This is basically the same boat as for tourist excursions, mostly along the cliffs at short distance from the shore. The necessary gear is provided by the Park staff (life jackets). However, participants should be aware that depending on conditions at sea, they may need medication against seasickness. In case of large waves, the trip will be cancelled.

Hospitals

Centre hospitalier de Bonifacio, Lieu-dit Valle, F-20169 Bonifacio. Tel +334 95 73 95 73.
Emergency call, as everywhere else in France, is 112 (routing to Fire department, Mountain rescue, road accident…).

Accommodation

Bonifacio is an enjoyable vacation place to stay for some days before the Tidalites 2021 Congress. There are too many accommodation possibilities to list them in this guide. However, most of them are available upon request to the Tourist Office of Bonifacio (https://www.bonifacio.fr/).

Brief overview of geology of Corsica

Corsica and Sardinia form a continental block separated from mainland Europe during the Western European Oligocene rifting. This rifting initiated in the North Sea, propagated to the Rhine graben an ended through opening of the Western Mediterranean basin during the early Miocene. As a consequence, the Corsican geology reflects that of the fronting mainland of SE France (Provence and Côte d'Azur). The western part of the island is dominated by Paleozoic rocks of the continental crust emplaced during the Variscan orogeny (Fig. 2). The Mesozoic and Paleogene deposits have been eroded during two uplift stages related

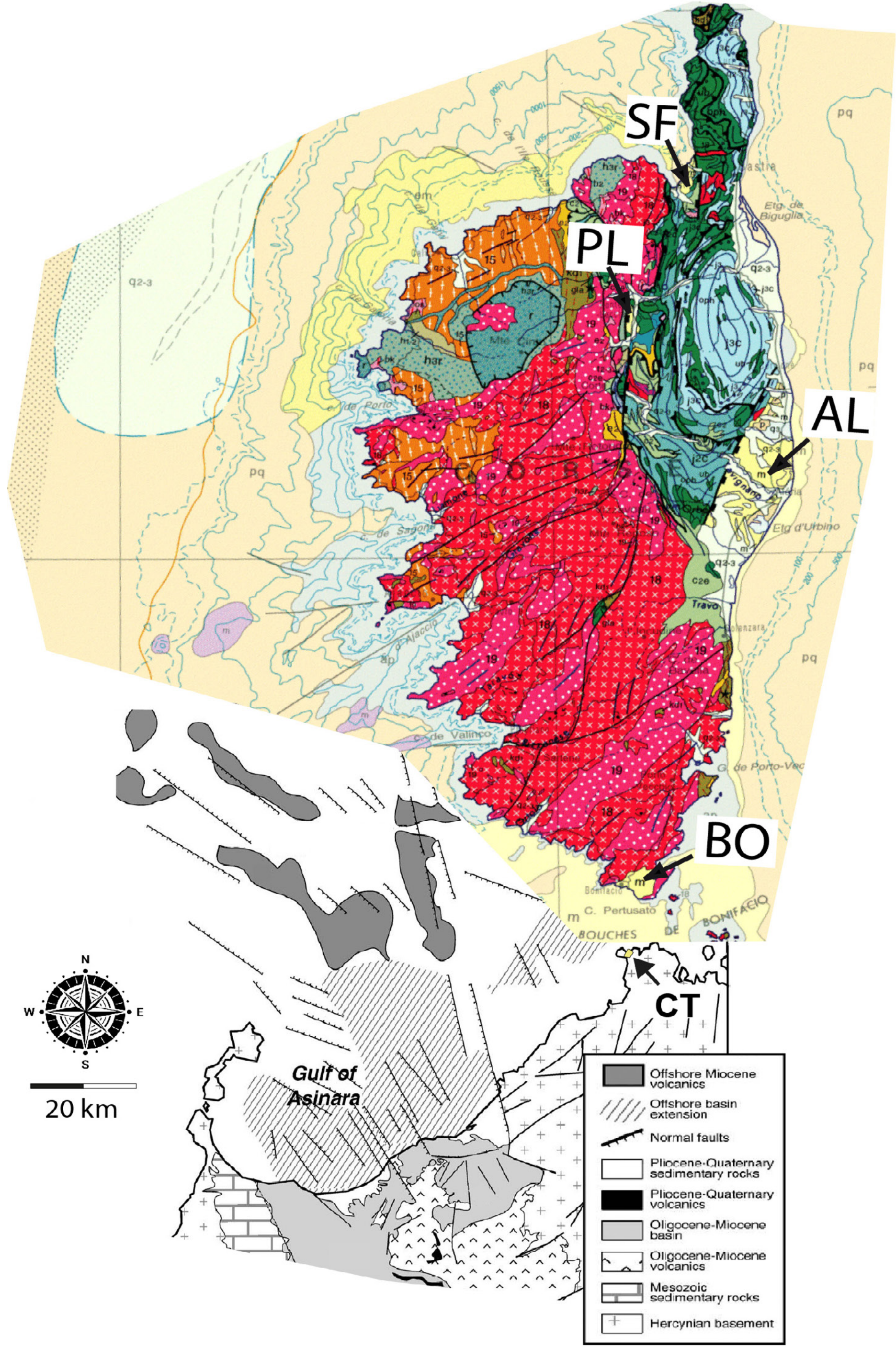

Fig. 2 – Color map: part of the 1:1,000,000 BRGM geological map of France. The western part of Corsica (dominantly red/pink/orange patterns) corresponds to the Variscan basement of Western Europe, dominantly composed of magmatic and metamorphic rocks of the continental crust (350-250 Ma). The North and East (dominantly green and blue patterns) corresponds to the nappes of the internal zones of the Alps thrusted westward during the Late Cretaceous-Paleogene. They are composed of flysch metasediments and ophiolites. The Cenozoic deposits mostly comprise remnants of Miocene basins: Saint-Florent (SF), Ponte Leccia (PL), Aléria (AL) and Bonifacio (BO), the latter extending seaward across the Corsican-Sardinian Strait. Miocene volcanic rocks also crop out at the seabed on the western margin (purple pattern). The Plio-Quaternary cover is locally thick, under the influence of supply by the Rhône deep-sea fan (light green tongue). Source: InfoTerre/BRGM. Black and white map: northern termination of the Sardinian Rift basin, showing its offshore extent and relationship to faults. Modified from Oudet et al. (2010). There is only one outcrop of Miocene on the Sardinian side of the strait, at Capo Testa (CT).

to the Oligocene rifting (Jakni et al., 2000). The northeastern part is composed of metamorphic nappes of flysch and ophiolites thrusted from the SE during the alpine orogeny, before the southward drifting and anti-clockwise rotation of the Corsican-Sardinian block (see syntheses by Séranne, 1999; Molli, 2008). Few remnants of the Paleogene foredeep sedimentation are preserved, mostly because Corsica was the source for these sediments (the famous Annot flysch in southeastern France, where Arnold Bouma defined the "Bouma" turbidite sequence). Starting in the Oligocene, extension proceeded, leading to Miocene grabens such as those of Ponte Leccia and Aleria in Corsica, and the larger Sardinian rift to the South (Fig. 2). During the post-rift stage, the Corsican-Sardinian block rotated anticlockwise by about 45° from 20,5 to 15 Ma (Speranza et al., 2002; Gattacceca et al., 2007) (Fig. 3). Sinistral strike-slip faulting occurred at this time, and a transfer fault propagated eastward within the Corsica-Sardinia plate to the Bonifacio Strait area, associated to volcanic activity (Finetti et al., 2005; Oudet et al., 2010). During the late Miocene, the northern Corsica experienced renewed uplift (Jakni et al., 2000; Cavazza et al., 2001), and compressional deformation occurred in the Saint-Florent basin (Cavazza et al., 2007). The Miocene basins preserved onshore Corsica have contacts against the basement and internal unconformities that reflect these stages of deformation, through uplift and erosion of the margin shorelines (Orszag-Sperber and Pilot, 1976; Ferrandini et al., 2003). The two basins where outcrops are numerous and large enough to record a variety of facies indicative of the past coastal dynamics are Saint-Florent (Ferrandini et al., 1998; Cavazza et al., 2007; Brandano and Ronca, 2014) and Bonifacio (references below).

The Corsican-Sardinian Strait

The present-day Corsican-Sardinian Strait (called the "*Bouches de Bonifacio*" in French or "*Bocche di Bonifacio*" in Italian) is 12 km wide in its narrowest part and 65 m deep at maximum (Fig. 4). It connects the Western Mediterranean to the Tyrrhenian Sea (Fig. 1). Most of the Miocene deposits crop out on the French border of the strait, where they form an uplifted plateau dominated by carbonate rocks onlapping the Corsican-Sardinian Variscan granitic basement. (In French the term "*causse*", or "*piale*" in Corsican, is used to designate such a plateau as it is composed of carbonate rocks.) Where it intersects the Miocene Bonifacio plateau, the shoreline is backed by a up to 90 m high cliff. Where the coast is formed by basement rocks, it has a lower relief and a more complex pattern of capes and small bays. The *Bonifacio causse* is slightly tilted toward the south, extending in most of the submarine areas of the western side of the strait (Fig. 4). By contrast, the Lavezzi and Maddalena islands, and surrounding seabed in the eastern part of the strait, are composed of the basement

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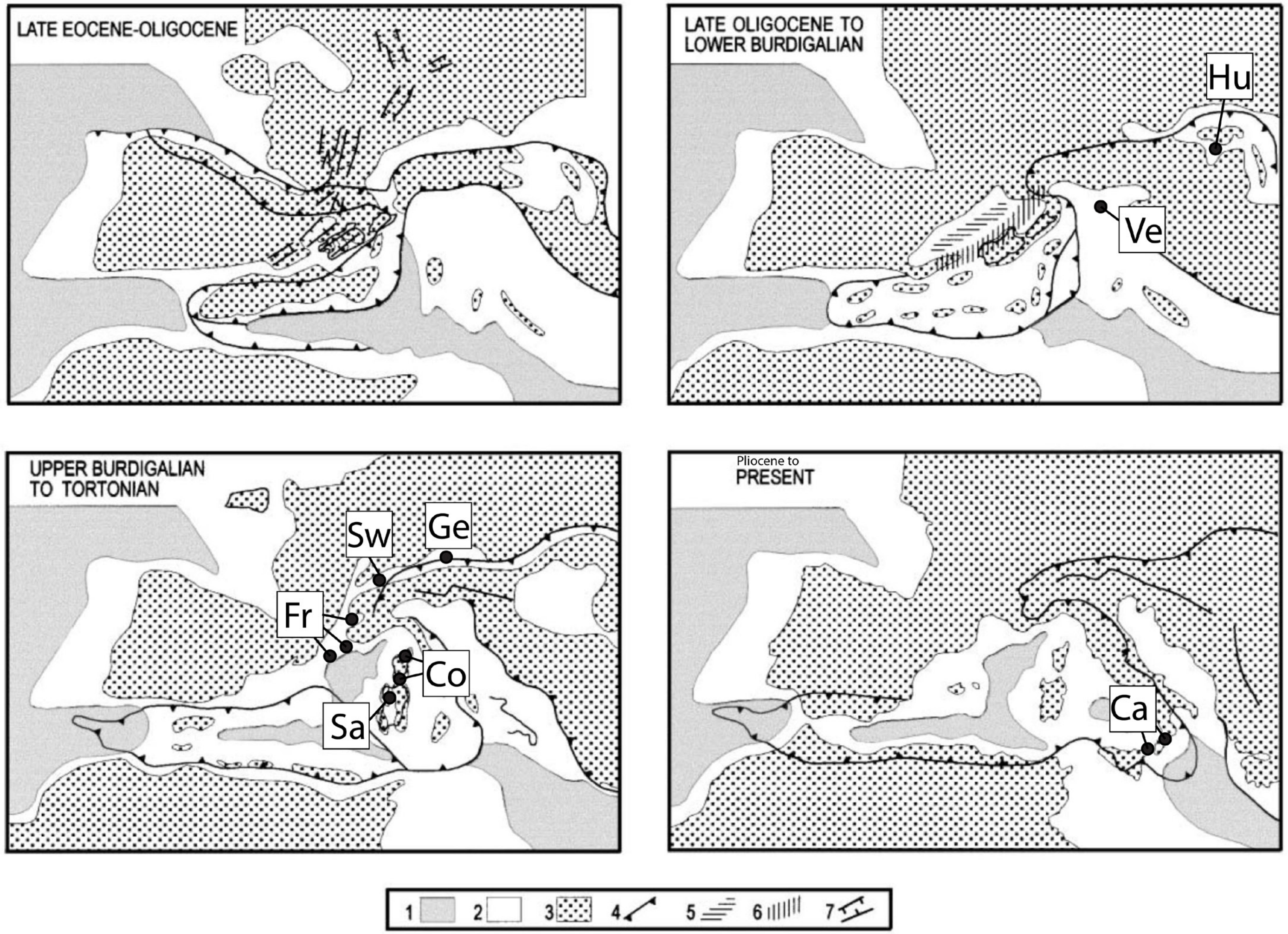
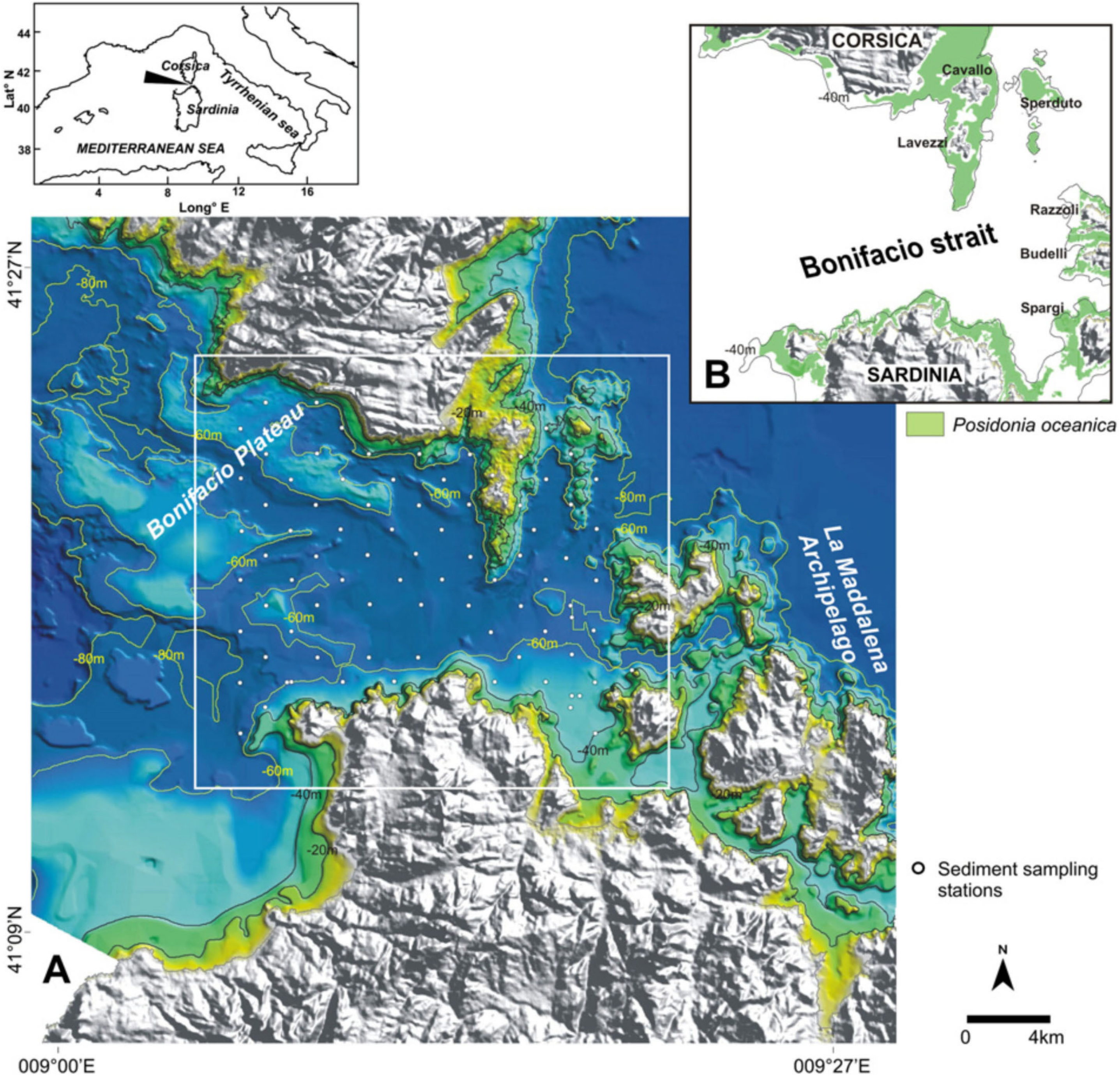
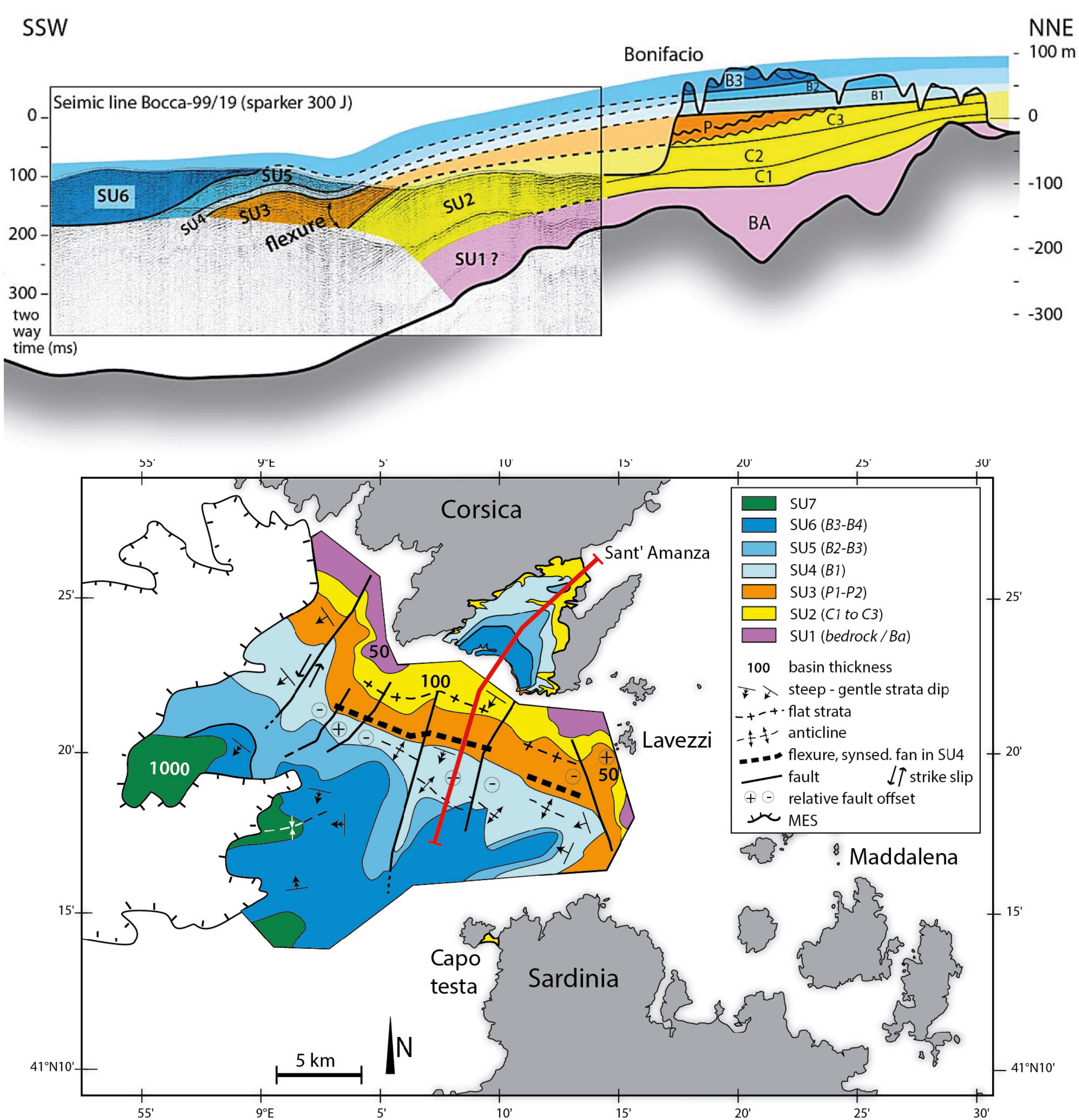


Fig. 3 – Paleogeographic evolution of the Western Mediterranean (modified from Casula et al., 2001). Corsica and Sardinia form a continental block that rifted off Southern France during the early Miocene, leading to the opening of the Western Mediterranean as a back-arc basin related to subduction of Africa beneath Europe. Due to trench retreat, back-arc extension moved then eastward and the Tyrrhenian Sea opened in turn during the middle to late Miocene. The accretionary prism emerged to form the mountains of the Italian peninsula. The drifting of the Corsica-Sardinia block, coeval to deposition of the lower Miocene of Corsica, occurred when the connection to Atlantic Ocean was still wide opened between Europe and Africa, allowing the Atlantic oceanic tide to propagate into the Western Mediterranean and reach the peripheral foreland basins that were developing at that time in the Alpine foreland. (1) oceanic crust; (2) submarine continental crust; (3) emerged continental crust; (4) active fold belts; (5) crustal thinning; (6) volcanic arcs; (7) rifts. Numerous other paleogeographic reconstructions challenge the complex connections between peri-Alpine seaways during evolution of the forelands and opening of the Western Mediterranean, as for example Rögl (1998) and other references considered in Reynaud et al. (2012a). These connections switch on and off through time the tidal dynamics of those basins. Examples of basins and publications showing tidal deposits at each stage of this paleogeographic evolution: Hu: Hungary (e.g. Sztanó and De Boer, 1995); Ve: Venetia (e.g. Massari et al., 1986); Fr: SE France (e.g. Lesueur et al., 1990; Besson et al., 2005; Reynaud et al., 2006, 2012a, 2012b; Kalifi et al., 2020); Sw: Switzerland (e.g. Homewood and Allen, 1981); Ge: Germany (e.g. Bieg, 2005); Co: Corsica (e.g. André et al., 2011; Reynaud et al., 2012a); Sa: Sardinia (e.g. Longhitano et al., 2017; Andreucci et al., 2017; Telesca et al., 2020); Ca: Calabria (e.g. Colella and D'Alessandro, 1988; Longhitano, 2011; Rossi et al., 2017).



rocks. Only one small outcrop of Miocene is present along the Sardinian side of the strait (at Capo Testa, Fig. 2), recording the late Burdigalian marine transgression over the area, with a nearshore depositional system similar to that exposed on the Corsican side (Monleau et al., 1996; Ferrandini et al., 2010; Brandano et al., 2010). Some images of the Variscan basement beneath the Miocene are provided by seismic profiles,

Fig. 4 – Morphology of the Corsican-Sardinian strait (modified from De Falco et al., 2011). A: The Bonifacio Plateau corresponds to the submarine top of the Miocene deposits that crop out onshore. It is dissected by karstic paleovalleys shaped during the Quaternary sea-level lowstands. The white box corresponds to the *Posidonia* meadows map in B. These green algae produce amounts of felt balls that accumulate in sheltered embayments. Razzoli, Budelli and Spargi islands belong to the Maddalena Islands. Lavezzi, Cavallo and Sperduto islands form the Lavezzi Islands.



showing up to 500 m of Miocene, composing a progradational wedge of the western margin of the Corsica-Sardinia block (Berra et al., 2019). To the South, this margin basin connects to the Castelsardo basin (northern part of the Sardinian rift, Fig. 2), but during the early to middle Miocene a rift shoulder may have separated it from the basin located in the strait area (Thomas and Gennesseaux, 1986; Oudet et al., 2010). The western border of the submarine part of the Bonifacio plateau is truncated by a large Messinian canyon (Fig. 5), buried beneath a

Fig. 5 – Top: Correlation of seismic units (SU) identified in Bonifacio Strait with Miocene stratigraphic units outcropping in the onshore part of the strait (Ba: Balistra, C: Cala di Labra, B: Bonifacio formations and members). Bottom: Geologic map of Miocene units based on reflection seismics (Quaternary cover, less than 20 m thick, not displayed). The location of the cross-section displayed above is indicated by the red line. MES: Messinian Erosion Surface. Modified from Reynaud et al. (2012a).

Lower Pliocene progradational wedge dominated by fine-grained sediments, locally intruded by volcanics (Guennoc et al., 2005).

The Miocene seismic units mapped off the main cliffs of *Bonifacio causse* can be correlated with the main formations and members of the onshore stratigraphy (Santiago, 2010; Reynaud et al., 2012a) (Fig. 5). The connection between the Western Mediterranean and the East Corsica Basin also existed along the topographic depression occupied by the *Bonifacio causse*, the Miocene strata being continuous to the Sant'Amanza Gulf (Fig. 6). Offshore Sant'Amanza Gulf, eastward offlapping Miocene and Pliocene strata are present, correlated as far south to the east of Lavezzi islands (Pluquet, 2006; Voisin, 2013). Thin, isolated Miocene outcrops on the sea bed in the valleys between the Lavezzi and Maddalena islands suggest that the connection with the eastern side of the strait also existed across this area. Thus, the Miocene deposits similar to those of the Bonifacio plateau might have existed in the eastern part of the strait, but they were eroded due to post-Miocene uplift of the area, another consequence of which was the emersion of the *Bonifacio causse* (Reynaud et al., 2012a).

The *Bonifacio causse* comprises surficial and subterraneous karstic networks, some of which are crosscut by the coastal cliffs. The submarine part of the Bonifacio plateau is dissected by a network of valleys that may also have a karstic origin (ca. *polje* valleys) (Fig. 4). However, little is known about the post-Miocene evolution of the area. From unpublished high resolution seismic profiles, the Quaternary cover above the Miocene strata or Variscan basement is less than 10 m thick, at the exception of some sills or passageways between Lavezzi Islands (Voisin, 2013). By contrast, the surficial sediment cover is better known, and has been extensively mapped (Pluquet, 2006; see supplementary materials). Siliciclastic, coarse-grained sediments locally form the present-day coastal prism, restricted to small bays or in the lee of headlands down to 15 m water depth. The upper offshore is largely colonized by *Posidonia* meadows. In the offshore, the top of submerged highs of the Bonifacio Plateau, in about 40-50 m water depth, are composed of bedrock. In the deeper parts of the strait, clastic sediments are present. They are dominated by clastic carbonates produced by benthic organisms in shallower waters (mostly red algae), swept off by waves and reworked by current drifts. Maximum grain size of those sediments decreases from 2 mm to carbonate mud with increasing water depth. However, in spite of microtidal conditions, bioclastic gravel ribbons and banner banks are found isolated and maintained by strong currents down to the deepest valleys of the strait. The pattern of the gravel ribbons parallels the strait passageways between the submerged highs and islands. The processes at play in these bedforms are not fully understood. While moored ADCP time series analysis suggests minor interplay of the M2 tidal component (Gerigny et al., 2011), numerical models mostly evidence rotary cells or gyres controlled by storm winds (De

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Falco et al., 2011), a feature contrasting with the current veins implied by the gravel ribbon fields. However, it seems that carbonate mud is only present in the center of the gyres (Pluquet, 2006).

The Miocene of Bonifacio

The stratigraphy of the onshore part of the Miocene Bonifacio Basin was studied for decades and exploration of the subsurface undertaken for water resource assessment. Several wells have been cored and the granitic basement imaged by means of geoelectrical surveying (Dörfliger et al., 2002; supplementary materials), so that the geometry of the basin in strike and cross sections is relatively well constrained (Fig. 6). The recently revised 1:50,000 geological map integrates all the available data (Orsini et al., 2011; see supplementary materials). The Miocene Bonifacio Basin comprises three formations, reviewed below.

Balistra Formation

The lowermost one, the Balistra Formation, is mostly composed of continental, reddish silty sandstones with pebbly intervals made up of angular granite-rich conglomerates. Several volcaniclastic levels are interbedded, consisting mostly of ash and lapilli with the signature of dacitic magmas. The areal distribution of these layers shows that the magma had a local origin. The location of well-identified layers at various altitudes suggests a paleo-landscape with significant relief. This formation lacks fossils, so that its base could not be dated precisely. The volcaniclastics have yielded ages ranging from 20 to 17 Ma BP (Gattacceca, 2001; Spella et al., 2001; Ferrandini et al., 2003; Orsini et al., 2011), indicating that the Balistra Formation was emplaced during the drifting of the Corsican-Sardinian block, which is also the time of maximum volcanic activity in Sardinia (Casula et al., 2001). The best outcrop of this formation will be visited at stop T2.1.1.
Above the Balistra Formation, the Miocene deposits are fully marine, with an overall change from siliciclastics at the base to clastic carbonates at the top. They are composed of two formations, defined by Ferrandini et al. (2002): Cala di Labra and Bonifacio formations. The faunal content of these deposits was studied by several authors who provided the biostratigraphic, paleoenvironmental and sequence stratigraphic framework (Orszag-Sperber and Pilot, 1976; Galloni et al., 2001; Ferrandini et al., 2002, 2010; Galloni, 2003; Brandano et al., 2008; Jadoul et al., 2009; André et al., 2011; Orsini et al., 2011; Tomassetti and Brandano, 2013; Galloni and Cornée, 2014; and several master student reports). Synthesizing these data and linking the onshore stratigraphy with

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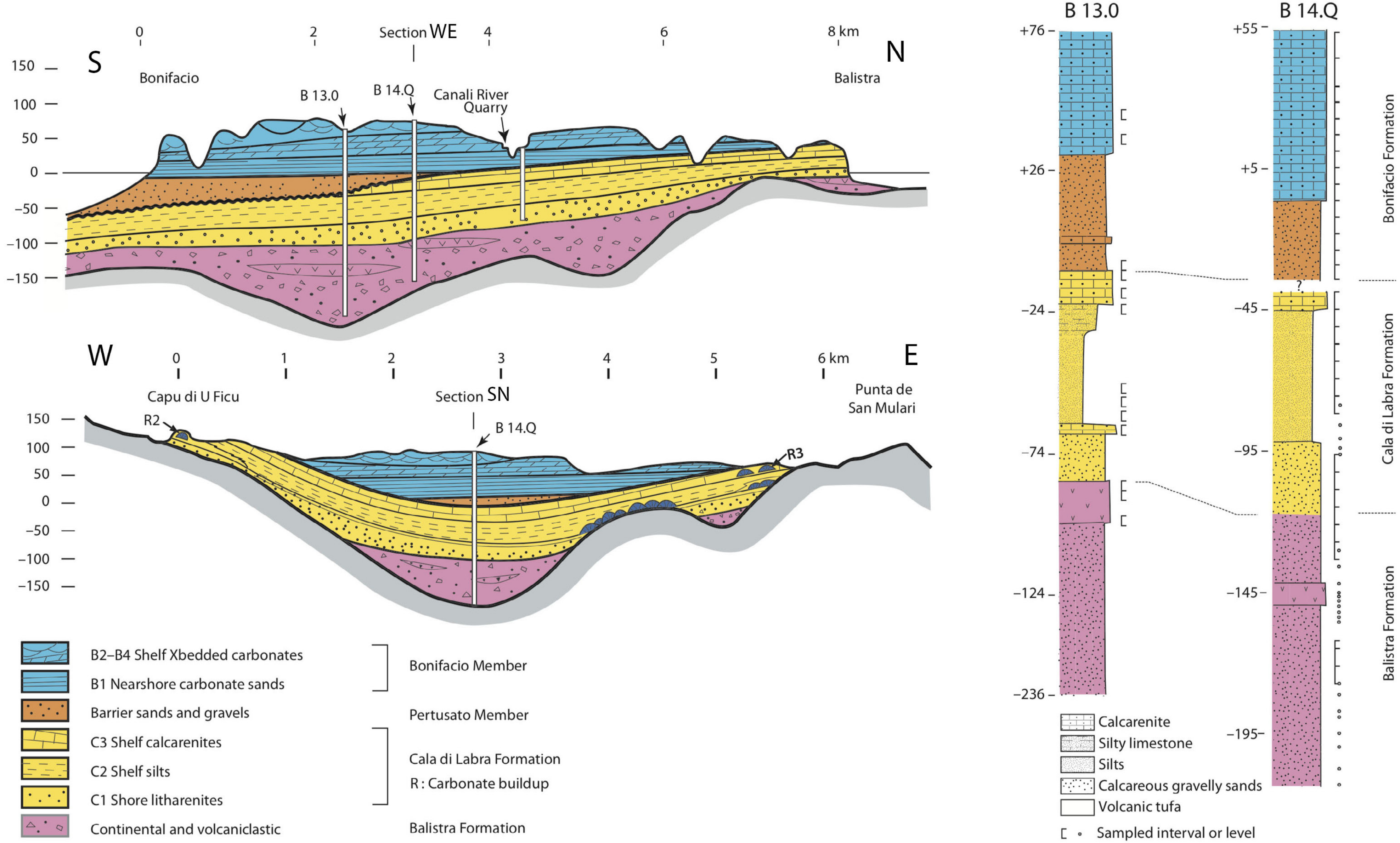


Fig. 6 – Cross sections of the onshore part of Bonifacio Basin (modified from Reynaud et al., 2012a). The section SN is the one displayed in Fig. 5 Top. The geometry of the stratigraphic units in subsurface is controlled by resistivity profiles and wells (B13 and B14). The logs were reconstructed based on cuttings from the wells. Note that the fold mostly predates deposition of the Bonifacio Member.

marine high resolution refection seismic data, Reynaud et al. (2012a) propose a general evolutionary model of the Bonifacio Basin, in which the two main Miocene marine depositional sequences are separated by a tectonic phase that creates the Corsica-Sardinia Strait and triggers tidal dynamics in the basin. These two sequences correspond to the Cala di Labra and Bonifacio formations defined by Ferrandini et al. (2002) (Fig. 7).

Cala di Labra Formation

This formation records the early Miocene transgression over the area. Dominantly siliciclastic to mixed carbonate-siliciclastic, it is characterized by a high diversity in the marine fossil record, allowing to delineate several biostratigraphic ages indicating the upper Burdigalian (Ferrandini et al., 2002). It comprises high energy carbonate reefs that have been extensively studied (Galloni et al., 2001; Galloni, 2003; Tomassetti et al.,

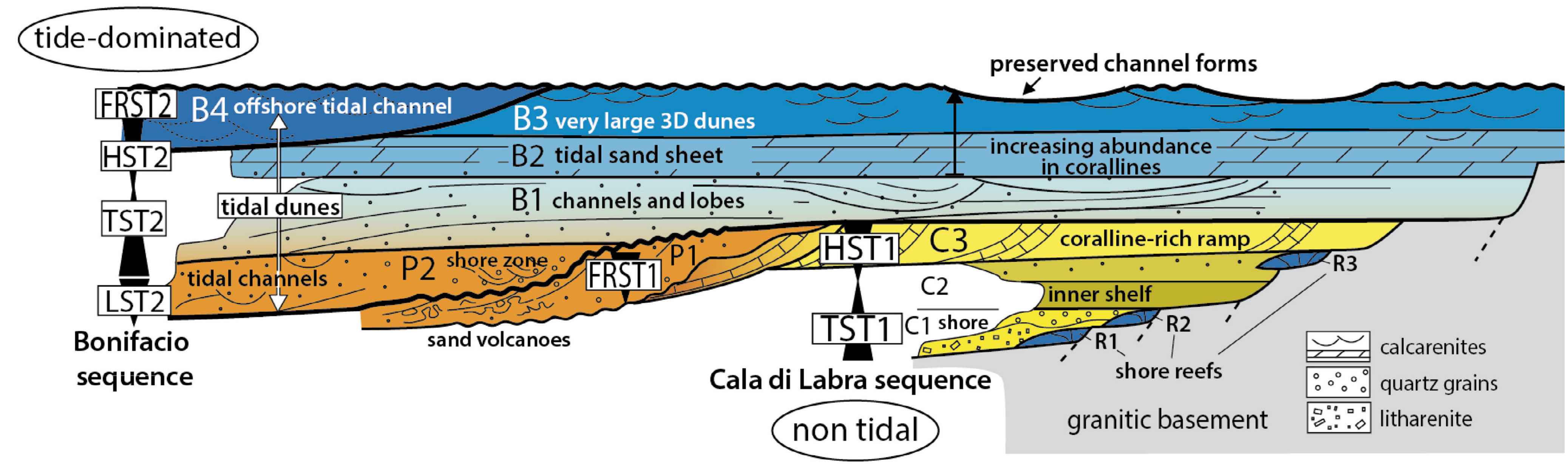


Fig. 7 – Sequence stratigraphic interpretation of the Miocene marine formations of Bonifacio (modified from Reynaud et al., 2012a). The Cala di Labra Formation comprises units C1 to C3. The Bonifacio Formation comprises the Pertusato Member (P1 and P2) and the Bonifacio Member (B1 to B4). This section is a synthetic sketch of the observations made on the southeastern basin border, from Cala di Labra to Anciennes Batteries.

2012; Tomassetti and Brandano, 2013; Galloni and Cornée, 2014; Brandano et al., 2016). Three stages of reef development are recognized, showing evolution of the depositional setting through sea-level changes (Galloni and Cornée, 2014). The first stage (R1, Fig. 7) corresponds to colonization of the granitic bedrock by pioneering associations of scleratinian corals in flat and massive fringing reefs. The second and third reef stages (R2 and R3) are progressively dominated by red algae, forming bioclastic wedges above submarine paleohighs. The reefs are buried beneath clastic deposits forming a transgressive-regressive cycle. The transgressive tract (C1 to lower part of C2 in Fig. 7) consists of coarse-grained siliciclastics supplied by basement erosion, grading up to offshore silts (Ferrandini et al., 2002; Reynaud et al., 2012a). The regressive tract is characterized by a coarsening-up, clastic-carbonate succession culminating with the progradation of a read algae packstone ramp (C3 in Fig. 7). The onset of red algae production may reflect a change from an isolated embayment to a wider and more open-marine setting. In contrast with this sequence stratigraphic interpretation, Tomassetti and Brandano (2013) interpret the R1 reef as an offshore patch reef and the immediately overlying siliciclastic unit as a regressive coastal wedge, implying two third-order sequences in the formation. On the basis of strontium isotopes (Brandano and Policicchio, 2012), they also suggest an older Burdigalian age for the lower sequence. The best outcrop of this formation, in the type-locality of Cala di Labra, will be visited at stop T2.1.2.

Bonifacio Formation

The Bonifacio Formation forms the main cliff from Cape Pertusato to Cala di Paraguano (Fig. 1). It is composed of two members, the Pertusato Member and the Bonifacio Member, defined by Ferrandini et al. (2002). Based on planktic and benthic microfossils (*Miogypsinidae*), the Bonifacio Formation is Langhian (Ferrandini et al., 2010).
The Pertusato Member is exclusively observed in the outcrops surrounding Pertusato Cape (see geological map in supplementary material). No stratigraphic fossil was found in this deposit. It forms a wedge bounded by erosion surfaces, that pinches out landwards and eastwards. The facies have been studied in detail by André et al. (2011). They are composed of siliciclastic, feldspar-rich lithoclastic sand and gravel, with sparse marine fauna, and westward synsedimentary sliding. André et al. (2011) interpreted this deposit as a wave-dominated shoreface wedge prograding to the WNW from Cape Pertusato to Anciennes Batteries (respectively stops T2.1.3 and T2.2.1, Fig. 1). This suggests that the SSW-NNE oriented basement ridge that links Punta du Sperono to Punta di u Capicciolu (Fig. 1) possibly formed the eastern border of the basin in this sector at that time.

The Bonifacio Member forms the entire coastal cliff from Anciennes Batteries to Cala Paraguano. It has been described in detail by André et al. (2011). The main feature of the Bonifacio Member is the ubiquitous presence of crossbedding, the tidal signature of which has been revealed by Barthet (2006), Barthet et al. (2009), and further documented by André et al. (2011) and Reynaud et al. (2012a), the latter suggesting the onset of tidal dynamics in the Pertusato Member. Reynaud et al. (2012a) recognize 4 units in the Bonifacio Member, B1 to B4. B1 is dominated by litharenithic sandstone with a small amount of bioclasts, mostly bryozoans, bivalves, echinoids and barnacles. Barely bioturbated, it is organized in arcuate to trough compound cross-sets with reactivation surfaces, forming tidal bars cross-cut by channels locally infilled by slumped deposits. This unit is thought to be related to a nearshore environment by André et al. (2011) and Reynaud et al. (2012a). B2 comprises an increasing amount of clastic carbonate, dominated by red algae, with minor bryozoans and echinoids. Mostly composed of extensive flat strata with internal trough cross-lamination and echinoid burrowing, it is interpreted as an offshore tidal sand sheet of 2D subtidal dunes (Reynaud et al., 2012a). These dunes would be the first evidence of large-scale offshore flows across the Bonifacio Strait. B2 grades upward to B3, which is petrographically similar but with a coarser quartz and carbonate fraction (coralline algae rods). B3 is organized in very large trough cross-beds several meters thick, with internal cross-lamination locally suggesting reverse flows (André et al., 2011). The trough cross-beds in B3 would have been formed by very large 3D subtidal dunes migrating toward the west. B4 is a 20 m-thick unit that can be seen in the large-scale panoramic view from the sea. It is similar to B3 in lithology but with less prominent cross-bedding (maybe due to weathering and calcite precipitation on the cliff). It appears to infill a kilometer-wide incision on top of the B3, although this feature hasn’t been documented in detail.

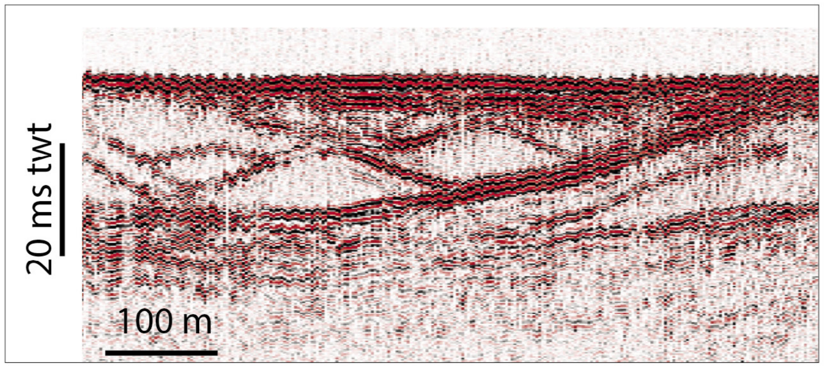
Brandano et al. (2009), Jadoul et al. (2009), André et al. (2011) and Reynaud et al. (2012a) interpret the Pertusato Member as a regressive tract following the sequence of Cala di Labra Formation. Reynaud et al. (2012a) suggest a tectonically forced regression at origin of the folding and tilting of the Bonifacio Basin (Fig. 6). All these authors interpret the lower part of the Bonifacio Member as the next transgressive tract. On the basis of the aggradational geometry of B2, Brandano et al. (2009) and Jadoul et al. (2009) infer a continuous transgression until B3, while André et al. (2011) and Reynaud et al. (2012a) suggest that the maximum flooding stage could coincide to the massive red algae supply at the bottom of B2. Jadoul et al. (2009) interpret the “prograding submarine dunes” and the thickening-up of dune cross-beds from B2 to B3 as criteria for a highstand tract. The large cross-beds in B3 are clearly produced by large migrating (not prograding) subaqueous dunes, but the thickening-up of dune cross-beds would rather indicate an increase in water depth, and/or the progressive increase in supply of sediment in front of a tidal-transport pathway (see Fig. 13.19a in Reynaud and Dalrymple, 2012). Regression is not documented in B3 but Reynaud et al. (2012a) also inferred a highstand tract from their interpretation that the overlying unit B4, deposited in continuity of B3, should be incised due to the Langhian sea-level fall.

Bonifacio Formation: the remnant of a Miocene Tidal Strait

Several paleocurrent roses obtained from various measurements (parting lineations, flute casts, echinoid spines orientation, or dune foreset dip) are produced by Barthet (2006), Brandano et al. (2009), Jadoul et al. (2009), André et al. (2011), Rossi (2011), Reynaud et al. (2012a). All of them show the consistency of westward-directed currents during deposition of the Bonifacio Member. High-resolution seismic profiles suggest the extension of the unit B3 into the central part of the strait, where cut-and-fill structures similar in size and orientation to the large trough cross-beds are observed (Reynaud et al., 2012a) (Fig. 8). It is suggested, therefore, that the westward currents in the Bonifacio Member would be forced by a process of funneling in a corridor that could correspond to the Bonifacio Strait. The seismic profiles show that the Miocene strata are folded following a syncline, the axis of which might follow the strait axis. This deformation would correspond to the unconformity between the Cala di Labra and Bonifacio formations (Reynaud et al., 2012a). It would have caused the drowning of the strait axis, initiating the tidal circulation across the strait or, at least, allowing strong currents to be established.

Some seismic profiles suggest over-deepening of the syncline by erosion (Fig. 9), a feature that could correspond to the incision of B4 into B3 (Fig. 7).

Thus, the marine Miocene deposits of Bonifacio Basin would record two contrasted stages of evolution. During the first stage, recorded in the Cala di Labra sequence, carbonates were restricted to coastal reefs and ramps, and the deepest part of basin were low



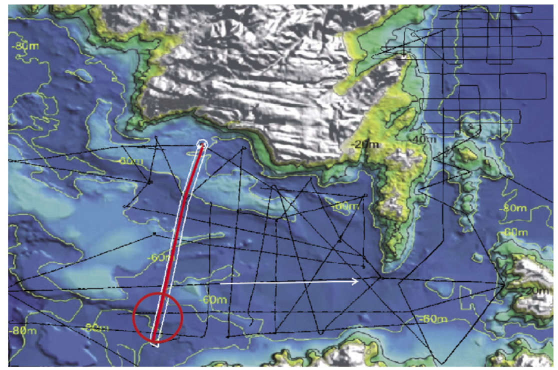


Fig. 8 – High-resolution sparker seismic profile showing cut-and-fill structures similar to the very-large 3D dunes in unit B3. Modified from Voisin (2013). The map on the right shows the location of the full profile. The red circle indicates the location of the displayed part.

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energy environments. During deposition of the Pertusato Member, the strait would have started to form, with subsidence in its axis and southward tilt of the norther border, where the onshore part of Bonifacio plateau is now emergent (Fig. 5). Active tectonics is recorded by soft deformation facies in the Pertusato Member (André et al., 2011; Reynaud et al., 2012b).

The increase of offshore carbonate production and the strong currents recorded after this stage cannot be related to a significantly higher eustatic sea level in the Langhian than in the late Burdigalian (Miller et al., 2020). It is therefore the consequence of a major change of the regional paleogeography. The most likely cause is the opening and deepening of the Bonifacio Strait and generalized subsidence on its margins.

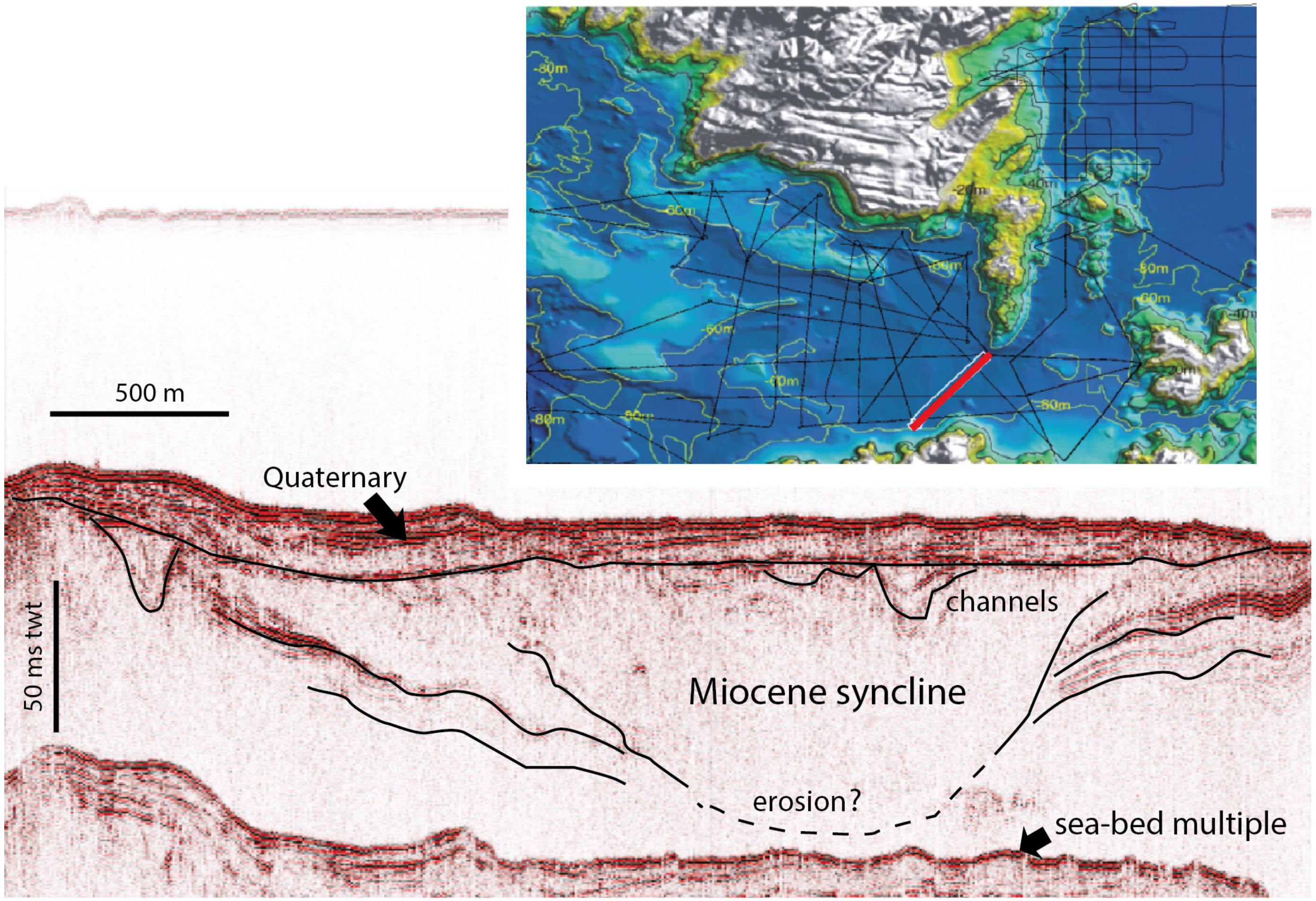

Fig. 9 – High resolution sparker seismic profile of the narrowest part of the strait, in about 75 m water depth. It shows a syncline of Miocene strata with channels incised at the top, beneath a thin cover of Quaternary deposits (modified from Museur, 2014). The syncline appears to be over-deepened by an intra-Miocene erosional unconformity. Reynaud et al. (2012a) interpret this feature as a tidal scour related to the Langhian sea-level fall.

During the early Miocene, the Tyrrhenian Sea did not exist, and the marine domain to the East of Bonifacio Strait corresponded to the south of the Corsica Basin (Pascucci et al., 1999), a back-arc rift basin with possibly deep water, as indicated by turbiditic facies observed in drill-hole cuttings (Cornamusini and Pascucci, 2014). This basin was bordered to the west by the Corsica-Sardinia island, and to the east by the emergent Apennines. It was likely connected to the Western Mediterranean to the north by a narrow passageway, and to the Tethys to the south, across a wide shelf (Fig. 4, see more detailed maps in Dercourt et al., 2000). Originated in different amphidromic systems, and having travelled across contrasted topographies, the tides on both sides of the Bonifacio Strait would have had a different phase and range, *i.e.* a different elevation at each time. Therefore, the related hydraulic gradient caused strong tidal currents to form across the strait. This mechanism is common in most tidal straits, inasmuch as they are narrow and short, and can create strong currents even in microtidal settings. This is the case, by instance, for the Strait of Messina (Colella, 1990; Longhitano, 2018).

In the early Miocene, the connection with the Atlantic Ocean was still wide and deep enough for the Atlantic tide to propagate into the Mediterranean more efficiently than it does at present (cf. Candela, 1991) (Fig. 3). In consequence, tidal transport pathways would have been larger, not restricted to the tidal necks of straits. The tidal strait model of Longhitano and Chiarella (2020) suggests that the center of the strait should be an exposed bedrock, bedload parting zone in the up-current area of the main deposit (the 'intermediate strait', where dunes are formed and preserved). Applied to the Bonifacio Strait, the proximal zone would have existed to the east of the present-day strait, which unfortunately is also the area where the basement was uplifted and erosion occurred after the Miocene. There is no data on the sedimentology of the Miocene preserved further east on the Tyrrhenian side of the strait, or west of the Bonifacio plateau, where distal facies are predicted by the model.

Comparison with the Miocene tidal carbonates of southeastern France

The Miocene tidal deposits of Bonifacio have well-known counterparts in the conjugate margin Miocene basins of south-eastern France (Provence, Rhône and Languedoc), which have provided findings as regarding to the architecture of tidal bedforms (Lesueur et al., 1990; Reynaud et al., 2006; Reynaud et al., 2012b; Kalifi et al., 2020), and the relationship to incised valleys (Besson et al., 2005) and carbonate systems (Reynaud and James, 2012; James et al., 2013). A common feature is that, in Languedoc and Provence, coarse-grained clastic carbonates form tide-dominated transgressive systems tracts infilling valleys incised in structurally-controlled depressions or across topographic necks of the shallow-water shelves. By contrast, highstand systems tracts are composed of fine-grained deposits with more siliciclastic content, infilling the structural lows or topping abruptly the transgressive systems tracts on the highs. As regarding to the tidal signature of facies, most of the

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deposits are subtidal and reflect the offshore dynamics. Paleocurrents are highly asymmetrical, and commonly colinear, parallel to the submarine valleys. As regarding the carbonates, in several studies, there is a strong link between water depth, hydrodynamics and the carbonate factory. The strongest currents bring about the larger bedforms and the highest content in red algae, while the quieter settings are dominated by a variety of heterozoan communities. Finally, several case studies show the downstream change from coarse-grained cross-bedded deposits to finer grained, mud-dominated facies at the outlet of passageways (e.g. Reynaud et al., 2006). All these elements build a framework that makes the Western Mediterranean a world-class destination for field training in tidal sedimentology.

Day 1

Stop T2.1.1 – Balistra beach
Coordinates: 41°26’15’’N, 9°13’20’’E

Topic: Miocene continental volcaniclastics

At about 7,5 km to the north of Bonifacio along the RT10 road, an unpaved road heads eastward over the granitic basement approximately two kilometers down to the beautiful Balistra Beach, a sand spit isolating the small lagoon of Francolu River and associated salt marshes. South of the beach, an ingnimbritic tuff forms a white cliff about 6m high (Fig. 10). This is one of the best exposures of the Balistra Formation, recording the first stage of Miocene sedimentation in the Bonifacio Strait area. The tuff bears angular glass clasts, reworked lithoclasts and numerous crystals of (in order of decreasing abundance): plagioclase, biotite, quartz, amphibole, clinopyroxene and magnetite. A few other outcrops of this formation have been identified (Tre Padule de Frasselli, Franculu, Maora in Corsica, and U Colbu in Sardinia). It has been recognized also in boreholes (Padule Magiore, Funtanaccia and Pomposa). Radiometric ages of the Balistra Formation have been obtained by various methods, all indicating the Burdigalian: 17,8 ± 1,5 Ma (K/Ar measured on biotite by Bellon, 1976); 19,2 ± 0,5 Ma (K/Ar measured on volcanic glass by Ottaviani-Spella et al., 1996, 2001); and 20,7 ± 0,1 Ma ($^{40}Ar/^{39}Ar$ measured on plagioclase by Ferrandini et al., 2003).
On the beach, the volcanic tuff rests above a reddish, continental deposit derived from the weathering of the granitic basement. The top of the tuff is a ravinement surface above which the Cala di Labra Formation is preserved.

Stop T2.1.2 – Cala di Labra bay
Coordinates: 41°22’02’’N, 9°11’30’’E

Topic: Marine flooding, reefs and facies before the onset of tidal dynamics

The road to Cape Pertusato gives access to a parking place (road from Bonifacio to Pertusato Cape - D260: 41°22’25’’N, 9°10’45’’E) from which several tracks can be walked to reach the shore at Cala di Labra (Fig. 11). Likely derived from the ancient Greek word kalòs, “cala” means “small bay” in Corsican and other old Mediterranean languages. The tracks down to the shore provide some scenic views of the eastern side of the bay, where

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Fig. 10 – Outcrop of Balistra Formation at Balistra beach (Stop T2.1.1). The white cliff is composed of volcanic tuff, overlying the granitic basement exposed on the rocky shore.

Fig. 11 – Itinerary to stops T2.1.2 to T2.2.1. Google Earth Image.

the Cala di Labra Formation onlaps the granitic basement. The best view is that from the sea (Fig. 12). The onlap can be observed on the shore. It shows the lowermost reef (R1, Fig. 7), which is dominated by scleratinian corals (*Porites*, *Favites*, *Tarbellastraea, Heliastraea, Favia* and *Thegioastraea*), together with a diverse fauna of foraminifers (*Miogypsinidae*, *Amphisteginidae*, *Miliolidae*) and rare planktic forms that allow assignment of the unit to the upper Burdigalian (*Globorotalia archeomenardii* and *Globigerinoides sicanus*). Debris of crustaceans (barnacles), worms (serpulids), bryozoans and echinids are also present in the matrix of the reef. The levels above can be observed on the western side of the bay, where they are exposed on a cliff, up to the contact with the overlying Bonifacio Formation. The reef is buried beneath a gravel-rich, crudely bedded lithoclastic succession with miogypsinids and echinids (*Clypeaster*), interpreted as a foreshore deposit. This deposit grades to a quartz-rich litharenite with abundant bryozoan and echinoid bioclasts, showing at the top undulated beds with iron oxide cementation fronts. Wood logs bored by bivalves have been found in this level, which coincides with the reef R2 (not visible here). The next facies is a sandy siltstone forming a recessive layer beneath the cliff overhang (Fig. 12). Glauconite-rich, this facies contains pectinids and echinoids, and planktic foraminifers indicative of the upper Burdigalian (base N7: occurrence of *Globigerinoides trilobus, Gl. bisphericus, Gl. altiaperturus, Globoquadrina dehiscens, Helicosphera ampliaperta*; and absence of *Catapsydrax dissimilis* and *Globigerinoides sicanus*). The occurrence in this silt of ostracods, a small clypeasteridae (*Echynocyammus* sp.), as well as the bryozoan *Batopora rosula* suggests a quiet depositional setting in about 40 m-deep water (Moissette, 1996). This facies corresponds to the maximum flooding of the Cala di Labra sequence in Reynaud et al. (2012a) (Fig. 7). The top of the silt is marked by a boxwork of burrows (*Glossifungites* isp.) buried a fine-grained calcarenite dominated by bryozoans, with preserved infaunal echinoids (*Echinolampas* sp.) and numerous planktic foraminifers. This facies is abruptly overlain by a sand-rich packstone of bryozoans, red algae and echinoids forming a prominent overhang of the upper part of the cliff (Fig. 12). This unit is made up of steep, westward-dipping clinoforms composing a progradational wedge anchored on the granitic basement. It is interpreted as a carbonate ramp forming the top of the highstand tract of the Cala di Labra sequence (Fig. 7).

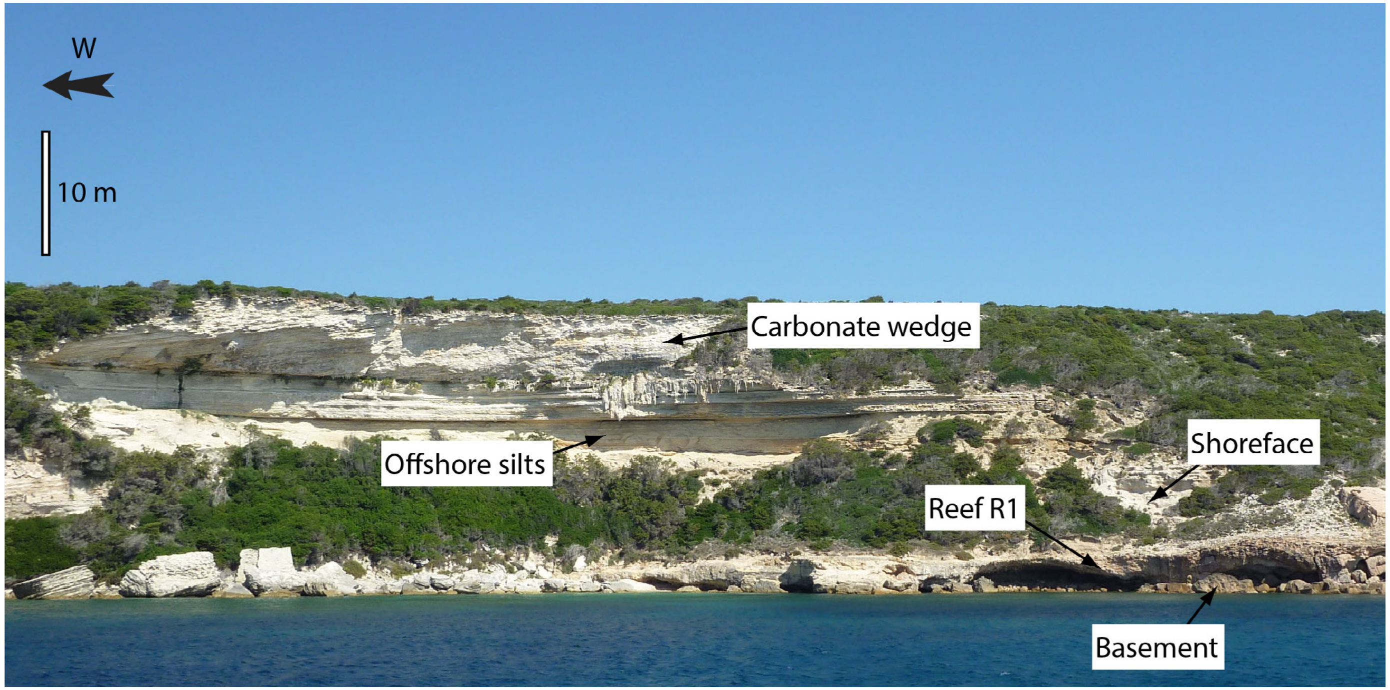

Fig. 12 – View of Cala di Labra Formation from the sea at Cala di Labra (Stop T2.1.2). The upper part will be seen to the left of the outcrop. This section is represented in Fig. 7 (offshore silts correspond to inner shelf facies, and carbonate wedge to coralline-rich ramp).

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Stop T2.1.3 – Pertusato Cape
Coordinates: 41°22’02’’N, 9°10’51’’E

Topic: Wave dynamics at the lowstand shoreline, syn-sedimentary tectonics

From Cala di Labra to Pertusato Cape, the trip follows the track up to the western cliff (Fig. 11), and then crosscuts the bush (“*maquis*”, the French word to describe the Mediterranean forest of green oaks and chestnut trees) down to the Saint-Antoine Island, at Cape Pertusato. There, an open karstic pit that can be accessed for swimming, offers a perfect mix between a geologic and touristic stop. The walk along the shore platform between Saint Antoine Island and the western cliff of Cala di Labra offers good exposures of the Pertusato Member of the Bonifacio Formation (see supplementary materials). Three facies of the Pertusato Member can be observed: (1) To the East, facies of Unit 1 in André et al. (2011) or P1 in Reynaud et al. (2012a), corresponding to cross-bedded calcareous sandstones and sandy calcarenites with numerous bioclasts of echinoids, barnacles, celleporid bryozoans, pectinids and red algae. (2) To the West, sandy litharenites with syn-sedimentary faults and various soft-deformation and water escape features (Fig. 13), and a reddish clayey-silty decimeter-thick layer that forms a marker level (Fig. 14). This facies is erosionally covered by fining-up gravel successions, corresponding to the bottom of Unit 3 in André et al. (2011) or P2 in Reynaud et al. (2012a). These facies are interpreted as foreshore deposits, with a maximum regression at the scour surface. The gravelly facies grades upward to (3) overall fining-up litharenites with rare bioclasts (barnacles, bryozoans, echinoids, scleratinians and fish teeth). This latter facies, which is well expressed around Saint-Antoine island and can be observed with further details at Anciennes Batteries as well (next stop), locally exhibits landward-directed sigmoidal bedding infilling scours within an overall westward-dipping strata succession (Fig. 15). The fossil content and taphonomy indicates a high-energy shoreface setting.
The track up from this terrace to the “*piale*” allows viewing of the overlying section, but this will be the topic of the next stop.

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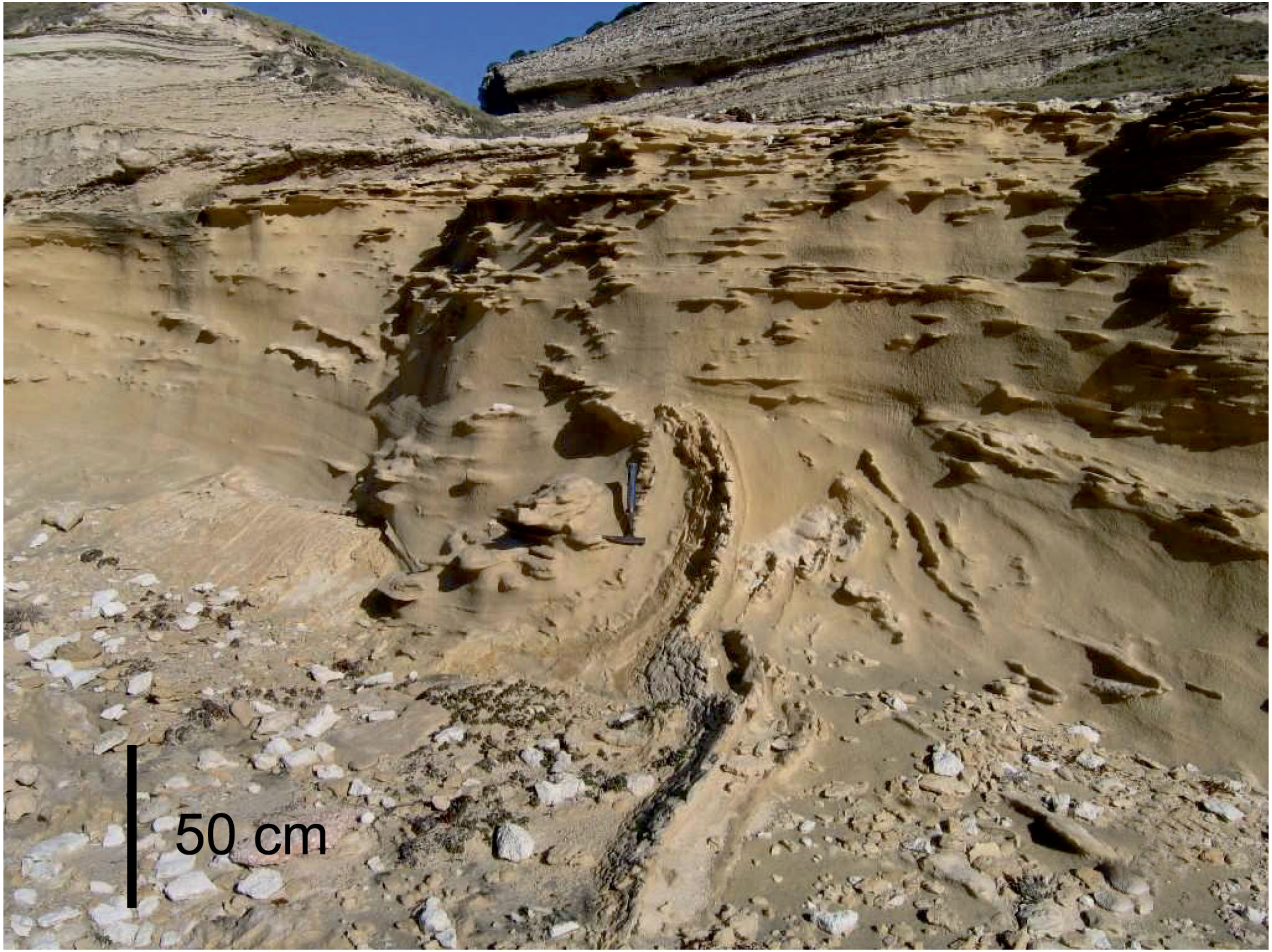

Fig. 13 - Syn-sedimentary soft-deformation in the middle part of Pertusato Member at stop T2.1.3 (modified from André et al., 2011). In the simplified description of the Pertusato Member by Reynaud et al. (2012a), this facies is included to the lower unit P1 (Fig. 7).

Fig. 14 – Silty reddish clay layer in coastal litharenites at stop T2.1.3. This layer can be followed from Cape Pertusato to Anciennes Batteries.

Fig. 15 – Sigmoidal accretion in the upper part of the Pertusato Member (P2 in Fig. 7), with, at stop T2.1.3. Jean Ferrandini on the photo.

Day 2

Stop T2.2.1 – Anciennes Batteries
Coordinates: 41°22'36''N, 9°10'25''E

Topic: From siliciclastic nearshore- to carbonate clastic offshore, tide-dominated deposits

This term refers to canon batteries that were built to defend the fortress and harbor of Bonifacio (late nineteenth century and until the Second World War). From the parking place (41°22'39''N, 9°10'41''E), there is a track along a main gully through the cliff down to the shore (Fig. 11). At this location, the cliff is about 80 m high. On the rocky shore terrace the Pertusato Member crops out (Fig. 16), and the reddish clayey-silty marker layer is present. This allows us to resume the section up to the cliff. The next units above the litharenites of the Pertusato Member form the Bonifacio Member, over 50 m in thickness at this place. A sharp but apparently conformable surface separates the two members. From base to top, this section of the Bonifacio Member shows three units (Fig. 16).

A first unit, about 30 m thick, is formed by medium-grained feldspar-rich sandstone. It is organized in oblique arcuate, sigmoidal or trough cross-beds, or in nodular, flat-bedded levels intensely bioturbated with various fossil debris (bivalves and echinoids). Upwards within the unit, the facies grades to tabular bedding with an increased carbonate content. The unit is bounded at the top by a slightly oxidized, coarser-grained sandy calcarenite encrusted by bryozoan colonies. This unit corresponds to B1 in Reynaud et al. (2012a). It is interpreted as a subtidal complex of dunes and bars, intersected by channels that are well exposed around the harbor of Bonifacio.

The second unit, about 20 m thick, is abruptly more carbonate-rich, although a sandy fraction is still present. It has a flat master-bedding of arcuate to trough cross-beds up to 2 m thick and 20 m in lateral extent. The beds are thickening up the unit (Fig. 17). Intense bioturbation might be responsible for the locally nodular aspect of some beds (an aspect that continues to the top of the Bonifacio Formation). The carbonate grains are composed of numerous red (coralline) algae fragments, bryozoan colonies and echinoid spines. This unit, also well exposed on the "*piale*" (RT10 road turn at Aqua Peruta), has delivered entire echinoids (*Peribrissus*) and a rich fauna of foraminifers pointing to an early Langhian age (*Miogypsinodella pillaria*, *Miogypsina antillea* and *M. digitata*, *Globigérinoides sicanus, Praeorbulina glomerosa* and *Globorotalia peripheroronda*). It corresponds to B2 in Reynaud et al. (2012a), who interpret it as an offshore tidal sand sheet.

Fig. 16 – View of the northern cliff at Anciennes Batteries (Stop T2.2.1). Unit labels refer to the numbering in the text. The trail up the cliff across the gully allows to see unit 3, not visible here. Conversely, the unit labelled B4 on this picture (accordingly to Reynaud et al., 2012a) cannot be seen on the trail. Fabrizio Berra and Flavio Jadoul in the photo.

Fig. 17 – Architecture of unit 2 at Anciennes Batteries (Stop T2.2.1). The master-bedding composes an overall tabular architecture (cf. unit B2 in Fig. 7), which is the most visible feature while looking at the cliffs at distance (e.g. from a boat). The internal cross-bedding, which is impressive at the outcrop scale, is more obvious upward the unit and toward the transition with unit 3, as the beds become thicker (as in this photograph). The main section in this photograph is along the dip of the foresets (toward the West). Note the nodular, flat-bedded intervals interstratified. The two bedding geometries are not observed to pass to each other at the outcrop scale (angular cross-bedding). No formsets of the dunes are preserved anywhere. In the foreground group, Fabrizio Berra and Valentina Rossi.

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The third unit rests on a prominent but irregular coarse lag of oyster fragments, encrusting red algae and bryozoan colonies, and echinoid spines. Above, and up to the section, it is composed of coarse-grained calcarenites dominated by coralline algae, organized in up to 10 m-thick trough cross-beds dipping towards the W. This unit is exposed in many other outcrops in cliff or road-side, and in the wall basement of the citadel of Bonifacio (see Stop T2.2.2). It corresponds to B3 in Reynaud et al. (2012a), who interpreted it as an offshore tidal sand sheet with very-large 3D dunes.
Similar sections can be logged across the cliffs from Pertusato Cape to Fazzio Island, with remarkable continuity. In the Anciennes Batteries section, the scours and large trough crossbedding starts lower in B2 than in other ones. A possible cause is the interplay of a syn-sedimentary flexure in the Anciennes Batteries area (observable during the boat trip), that would have deepened this part of the strait and finally caused in turn incision of B4. This latter unit forms the upper part of the cliff north of the gully (Fig. 16).

Stop T2.2.2 – Bonifacio
***Coordinates*: 41°23’13.30’’N, 9°09’38.30’’E**

Topic: The largest-scale subtidal carbonate dunes, scenic views on the cliffs

The second day of the trip is mostly devoted to the observation of the large-scale geometry of deposits observed at the outcrop scale during the first day. In order to do this, the best is to step back from the cliffs and make observations from the sea during a boat trip. Regular ferries can be one way to get pictures from the cliffs, but the best is to rent a boat to go along the cliffs. In Bonifacio Strait, strong winds can raise and go suddenly. Depending on the weather, the boat trip can be organized in the morning or afternoon, the other half of the day being the occasion to visit the town of Bonifacio. The best way to do this and still looking at geology is to follow the guide published by Orsini et al. (2015).
The following parts of the itinerary suggested in Orsini et al. (2015) are recommended. Starting from *col Saint-Roch* (saint-Roch pass, corresponding to the coordinates in the section heading), 32 m above sea-level, a beautiful landscape offers views of the famous *Diu Grossu* or *Grain de Sable* (Sand Grain) to the left and Bonifacio Citadel to the right. On the way up to Saint-Roch, the rock basement of the citadel provides numerous cuts to observe the crossbedding of the unit B3 of Bonifacio Formation, accordingly to Reynaud et al. (2012a). The very large trough cross-sets are composed by bed packages where internal oblique to up-climbing lamination can be observed (Fig. 18). This compound cross-bedding was interpreted by André et al. (2011) and

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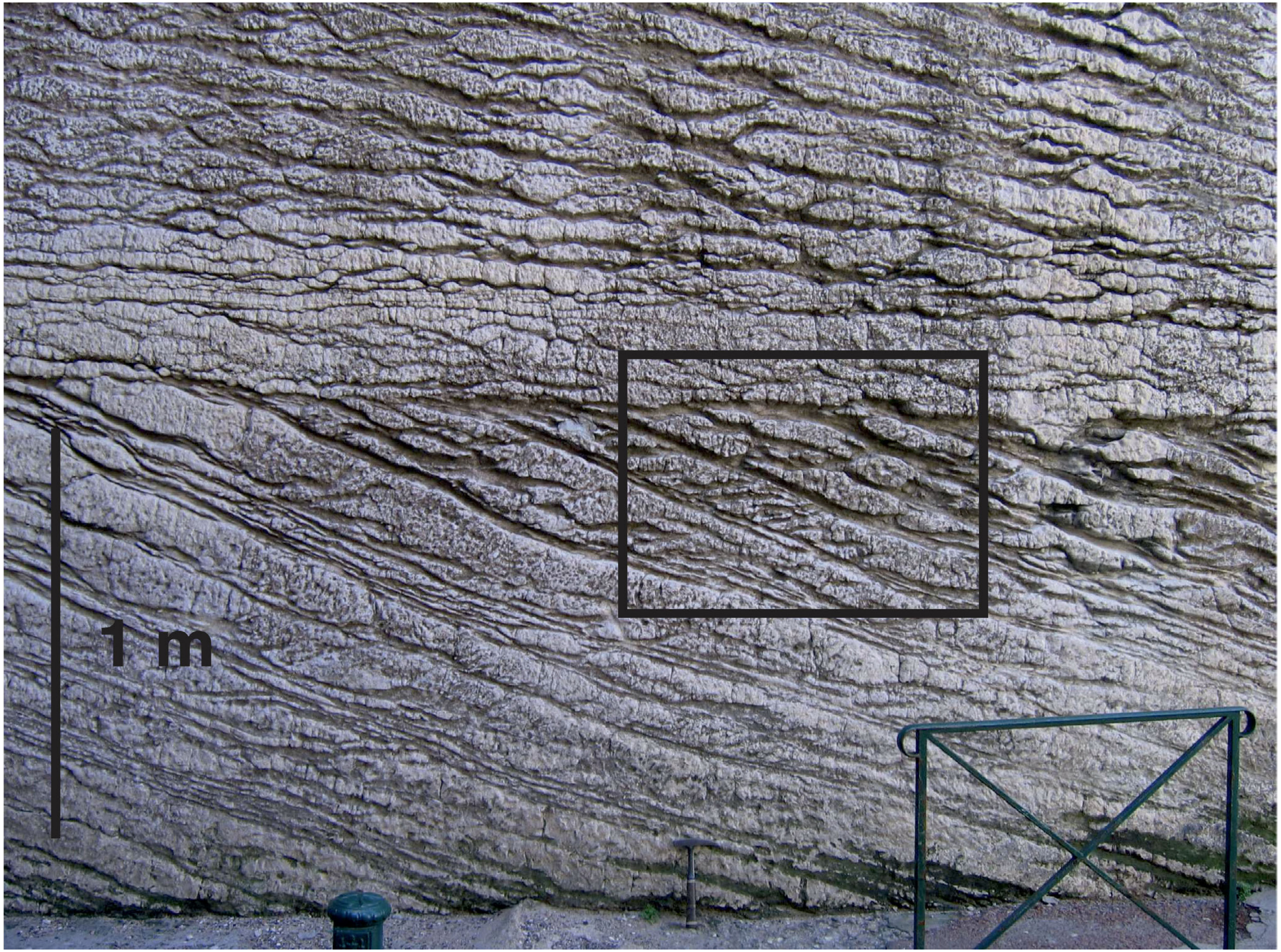

Fig. 18 – Typical facies of the unit 3 of the Bonifacio Member (B3 in Fig. 7) in the citadel of Bonifacio (Stop T2.2.2). The upper part of the picture corresponds to the toesets and bottomsets of the dunes. The nodular aspect in the flat bedded facies might be partly due to bioturbation by echinoids. In the lower part (black frame), the large dune foresets show a rhythmic pattern of accretion, with alternating thin- and thick beds, the latter showing internal upclimbing cross-lamination, that is created by superimposed dunes. These dunes are likely too high in the foreset to correspond to backflow bedforms. In the tidal interpretation, this might rather be the record of the subordinate tidal current. Modified from André et al. (2011).

Reynaud et al. (2012a) as the effect of superimposition of small, subordinate dunes. Some outcrops can also be considered to discuss the dune morphodynamics (Fig. 19). Another good vantage point is at the *Cimetière Marin* (cemetery at the western end of the town). Besides the topic of the Tidalites 2021 field trip, the upper town access through *Porte de Gênes* (Genova Door) allows you to see the rocks used for the building of this

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purtun (portal), or the pavements of the *Rue des Deux Empereurs* (Charles V and Napoleon Bonaparte). The oldest house dates back to the XIVth century.

Fig. 19 – Large dune cross-bedding in the unit 3 of the Bonifacio Member (B3 in Fig. 7) in the old town of Bonifacio (Stop T2.2.2). The recessive interbeds correspond to muddier facies deposited during weaker current stages (but not mud drapes). Planar foresets with angular downlaps (such as those in Fig. 17) pass within the same compound cross-set to sigmoidal foresets with tangential downlaps. Such features, where repeated within cross-sets, are interpreted as the change of dune morphology through neap-spring tidal cycles (e.g. Chiarella, 2016). Given the large size of the dunes in the unit 3 of the Bonifacio Member, however, these bundles more likely represent longer (annual?) cycles, in which other (seasonal?) hydrodynamic and biotic processes could also interplay. In that case, the individual bed/muddy interbed packages would likely correspond to neap-spring cycles.

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Stop T2.2.3 – Boat trip
Coordinates: 41°43'20''N, 9°09'54''E

Topic: Summary and scenic views of large-scale stratal architecture of the Bonifacio Basin units

A good camera with telephoto-lens is worth using during this trip. The authors of this guide have done a photo paneling of the cliffs from Cala di Paraguano to Cala di Labra, several times and under various light conditions. Some of the photomosaics used for the preparation of the article of Reynaud et al. (2012a) are provided herein as supplementary materials.
Depending on time and weather, the trip may put emphasis on various topics related to the Bonifacio Formation: (1) Around Pertusato Cape, the soft-deformation structures and the westward dip of shoreface strata of the Pertusato Member; (2) in front of Anciennes Batteries, the flexure and dip change of strata at the Pertusato/Bonifacio boundary, and the incision of B4; (3) in front of Grain de Sable, some of the largest trough cross-beds of B3 can be observed; (4) in front of Bonifacio town and westwards until Fazzio bay, the remarkable continuity of bedding of units B2 and B3, with details of the organization of the bedsets in B3 along the foreset dip of the dunes; (5) at Cala di Paraguano, the R2 reef of Cala di Labra Formation above the granitic basement, covered in turn by unit B2 of the Bonifacio Member; (6) on the way back to the harbour, around the promontory of Bonifacio, the very-large trough cross-beds of unit B3, with a nodular aspect produced by bioturbation, enhanced in some levels, and the scour pits of the dunes. Also, at this place, a large scale oblique planar surface crosscuts the large trough cross-bed sets (Fig. 20). This structure has not been studied in detail yet and may reflect the largest-scale bedform migration. This could be one element for discussing whether unit B3 is a tidal sand sheet or an offshore tidal ridge system. Last but not least, the boat may enter a large cave accessible from the sea, the roof of which has a shaft cutting up the shape of Corsica island on the sky! This highlights the importance of karstic processes, which are also responsible for the shape of the ria of Bonifacio (deep valley but no river entering at its head), similar to the valleys dissecting the submarine plateau (Fig. 4).

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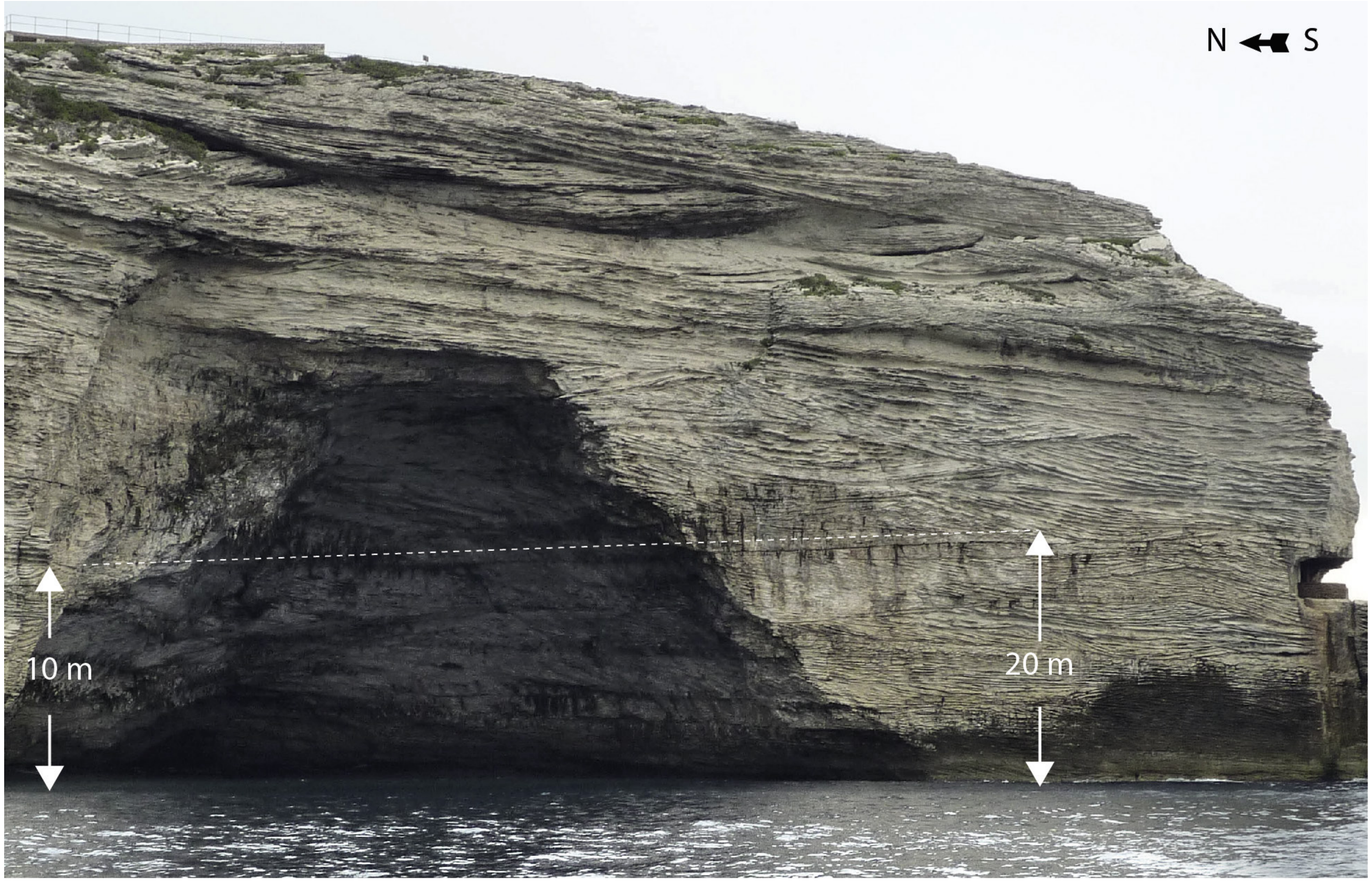

Fig. 20 – Large-scale architecture of the unit 3 of the Bonifacio Member at the entrance of the ria of Bonifacio (Stop T2.2.3). This spectacular outcrop, with a karstic cave in the middle, shows well the overall aggradation of the large dunes, with a flat, horizontal master-bedding, well expressed at the top of the cliff. The picture shows a discrete planar surface (dotted white line, placed above the real surface, to keep the latter visible), slightly oblique to the master-bedding, that separates packages of dune cross-sets. This surface suggests the presence of bedforms (bars?) of larger amplitude than the large dunes (larger than 10 m, which is the difference in elevation noted along the surface on this outcrop).

References

André J.-P., Barthet Y., Ferrandini M., Ferrandini J., Reynaud J.-Y., Tessier B. (2011) - The Bonifacio formation (Miocene of Corsica): transition from a wave- to tide-dominated coastal system in mixed carbonate-siliciclastic setting. Bull. Soc. Geol. Fr., 182, 221-230.

Andreucci S., Pistis M., Funedda A., Loi A. (2017) - Semi-isolated, flat-topped carbonate platform (Oligo-Miocene, Sardinia, Italy): sedimentary architecture and processes. Sediment. Geol., 361, 64-81.

Barthet Y. (2006) - Architecture et faciès des corps sédimentaires de la formation de Bonifacio (Miocène de Corse). Mémoire de Master 2 [MSc Memoir], University of Angers, 36 pp.

Barthet Y., Ferrandini J., Ferrandini M., Reynaud J.-Y., Tessier B., André J.-P. (2009) - Transition tempête-tidal dans un système côtier mixte clastique: l'exemple de la Formation miocène de Bonifacio (Corse du Sud). Poster. 12th French Congress of Sedimentology, Pub. n°64 ASF, abstracts.

Bellon H. (1976) - Séries magmatiques néogènes et quaternaires du pourtour de la Méditerranée occidentale, comparées dans leur cadre géochronométrique. Implications géodynamiques. Thèse de doctorat d'Etat [PhD thesis], Univ. Paris XI, Orsay, 367 p.

Berra F., Stucchi E.M., Moretti S. (2019) - New information from "old" seismic lines: an updated geological interpretation from the re-processing of the CROP line M-2A/I (Bonifacio Straits) at shallow depths. Ital. J. Geosci., 138, 1-12.

Besson D., Parize O., Rubino J.L., Aguilar J.-P., Aubry M.-P., Beaudoin B., Berggren W.A., Clauzon G., Crumeyrolle P., Dexcoté Y., Fiet N., Iaccarino S., Jiménez-Moreno G., Laporte-Galaa C., Michaux J., Salis K. von, Suc J.-P., Reynaud J.-Y., Wernli R. (2005) - Un réseau fluviatile d'âge Burdigalien terminal dans le Sud-Est de la France : remplissage, extension, âge, implications. C. R. Geosci., 337, 1045-1054.

Bieg U. (2005) - Palaeooceanographic modeling in global and regional scale: an example from the Burdigalian Seaway, Upper Marine Molasse (Early Miocene). PhD thesis, University of Tübingen, Tübingen, 108 pp..

Brandano M. and Policicchio G. (2012) - Strontium stratigraphy of the Burdigalian transgression in the Western Mediterranean. Lethaia, 45, 315-328

Brandano M. and Ronca S. (2014) - Depositional processes of the mixed carbonate-siliciclastic rhodolith beds of the Miocene Saint-Florent Basin, northern Corsica. Facies, 60, 73-9.

Brandano M., Jadoul F., Berra F., Lanfranchi A., Petrizzo M.R. (2008) - Mixed carbonate-siliciclastic sedimentation of Bonifacio Basin (early-middle Miocene, South Corsica). Rend. Online Soc. Geol. It., 3, 130-131.

Brandano M., Jadoul F., Lanfranchi A., Tomassetti L., Berra F., Ferrandini M., Ferrandini J. (2009) - Field Trip 13: Stratigraphic architecture of mixed carbonate-siliciclastic system in the Bonifacio Basin (early-middle Miocene, South Corsica). 27th IAS Meeting, Alghero. Field trip volume, pp. 1-14.

Brandano M., Tomassetti L., Bosellini F., Mazzucchi A. (2010) - Depositional model and paleodepth reconstruction of a coral-rich, mixed siliciclastic-carbonate system: the Burdigalian of Capo Testa (northern Sardinia, Italy). Facies, 56, 433-444.

Brandano M., Bosellini F.B., Mazzuchchi A., Tomassetti L. (2016) - Coral assemblages and bioconstructions adapted to the depositional dynamics of a mixed-carbonate-siliciclastic setting: the case study of the Burdigalian Bonifacio Basin (South Corsica). Riv. It. Paleont. Strat., 122, 37-52.

Candela J. (1991) - The Gibraltar Strait and its role in the dynamics of the Mediterranean Sea. Dynam. Atmos. Oceans, 15, 267-299.

Casula G., Cherchi A., Montadert L., Murru M., Sarria E. (2001) - The Cenozoic graben system of Sardinia, Italy: geodynamic evolution from new seismic and field data. Mar. Pet. Geol., 18, 863-888.

Cavazza W., Zattin M., Ventura B., Zuffa G.G. (2001) - Apatite fission-track analysis of Neogene exhumation in northern Corsica (France). Terra Nova, 13, 51-57.

Cavazza W., De Celles P.G., Fellin M.G., Paganelli L. (2007) - The Miocene Saint-Florent Basin in northern Corsica: stratigraphy, sedimentology, and tectonic implications. Basin Res., 19, 507-527.

Chiarella D. (2016) - Angular and tangential toeset geometry in tidal cross-strata; an additional feature of current-modulated deposits. Spec. Pub. Int. Ass. Sediment., 47, 191-201.

Colella A. (1990) - Active tidal sand waves at bathyal depths observed from submersible and bathysphere (Messina Strait, southern Italy). 13th IAS Congress, Nottingham, UK. Abstracts, pp. 98-99.

Colella A. and D'Alessandro A. (1988) - Sand waves, Echinocardium traces and their bathyal depositional setting (Monte Torre Palaeostrait, Plio-Pleistocene, southern Italy). Sedimentology, 35, 219-237.

Cornamusini G. and Pascucci V. (2014) - Sedimentation in the Northern Apennines-Corsica tectonic knot (Northern Tyrrhenian Sea, Central Mediterranean): offshore drilling data from the Elba-Pianosa Ridge. Int. J. Earth Sci., 103, 821-842.

De Falco G., De Muro S., Batzella T., Cucco A. (2011) - Carbonate sedimentation and hydrodynamic pattern on a modern temperate shelf: the strait of Bonifacio (western Mediterranean). Estuar. Coast. Shelf S., 93, 14-26.

Dercourt J., Gaetani M., Vrielynck B., Barrier E., Biju-Duval B., Brunet M.-F., Cadet J.-P., Crasquin S., Sandulescu M. (2000) - Peri-Tethys palaeogeographic atlas. One volume and 24 maps at 1:10 000 000 scale. Publ. CCGM/CGMW, Paris.

Dörfliger N., Ferrandini J., Ferrandini M., Mathieu F. (2002) - Caractérisation géométrique et hydrodynamique du Causse de Bonifacio à partir d'une synthèse des connaissances géologiques et hydrogéologiques et par méthodes géophysiques (Corse). Report BRGM/RP-51183-FR. 128 pp.

Ferrandini M., Ferrandini J., Loÿe-Pilot M.-D., Butterlin J., Cravatte J., Janin M.-C. (1998) - Le Miocène du bassin de Saint-Florent (Corse): modalités de la transgression du Burdigalien supérieur et mise en évidence du Serravalien. Geobios, 31, 125-137.

Ferrandini M., Galloni F., Babinot J.-F., Margerel, J.-P. (2002) - La plate-forme burdigalienne de Bonifacio (Corse du Sud) : microfaune (foraminifères, ostracodes) et paléoenvironnements. Rev. Micropal., 45, 57-68.

Ferrandini J., Gattacceca J., Ferrandini M., Deino A., Janin M.-C. (2003) - Chronostratigraphie et paléomagnétisme des dépôts oligo-miocènes de Corse: implications géodynamiques pour l'ouverture du bassin liguro-provençal. Bull. Soc. Geol. Fr., 174, 357-371.

Ferrandini M., Bou Dagher-Fadel M.K., Ferrandini J., Oudet J., André J.-P. (2010) - Nouvelles observations sur les Miogypsinidés du Miocène inférieur et moyen de Provence et de Corse (France) et de Sardaigne septentrionale (Italie). Ann. Paleontol., 96, 67-94.

Finetti I.R., Ben A.D., Fais S., Forlin E., Klingelé E., Lecca L., Pipan M., Prizzon A. (2005) - Crustal tectono-stratigraphic setting and geodynamics of the Corso-Sardinian Block from new CROP seismic data. In: I.R. Finetti (Ed.), CROP PROJECT - Deep Seismic Exploration of the Central Mediterranean and Italy. Elsevier, pp. 413-446.

Galloni F. (2003) - Organisation sédimentaire et anatomies récifales des systèmes carbonatés à siliciclastiques oligo-miocènes inférieurs de Provence et du bloc corso-sarde. Thèse de doctorat [PhD Thesis], Université de Provence, Aix-Marseille I, Marseille, France, 255 pp.

Galloni F. and Cornée J.-J. (2014) - Les constructions coralliennes du Burdigalien supérieur de Bonifacio (Corse-du-Sud). Geol. de la France, 1, 47-66.

Galloni F., Cornée J.-J., Rebelle M., Maurel-Ferrandini M. (2001) - Sedimentary anatomies of Early Miocene coral reefs in South Corsica (France) and South Sardinia (Italy). Geol. Mediterr., 28, 73-77.

Gattacceca J. (2001) - Cinématique du bassin liguro-provençal entre 30 et 12 Ma. Implications géodynamiques. Thèse de doctorat [PhD Thesis], Ecole Nationale des Mines de Paris, 335 pp.

Gattacceca J., Deino A., Rizzo R., Jones D.S., Henry B., Beaudoin B., Vadeboin F. (2007) - Miocene rotation of Sardinia: new paleomagnetic and geochronological constraints and geodynamic implications. Earth Planet. Sc. Lett., 258, 359-377.

Gerigny O., Martino B.D., Romano J.C. (2011) - The current dynamics inside the Strait of Bonifacio: impact of the wind effect in a little coastal strait. Cont. Shelf Res., 31, 1-8.

Guennoc P., Ferrandini J., Callec Y., Réhault J.-P., Thinon I. (2005) - Evolution néogène du détroit corso-sarde, paléotalus messinien et replissage plio-quaternaire. 10ème Congrès Français De Sédimentologie. Presqu'île De Giens. Publ. n°51 ASF (abstracts).

Homewood P., Allen P.A. (1981) - Wave-, tide- and current-controlled sandbodies of Miocene Molasse, western Switzerland. AAPG Bull., 65, 2534-2545.

Jadoul F., Berra F., Brandano,M., Ferrandini J., Ferrandini M., Lanfranchi A., Petrizzo M.R., Tomasetti L. (2009) - Depositional architecture of a mixed succession: the early Miocene succession of Bonifacio (southern Corsica). 27th IAS Meeting. Algero, Sardinia. Abstracts.

Jakni B., Poupeau G., Sosson M., Rossi P., Ferrandini J., Guennoc P. (2000) - Dénudations cénozoïques en Corse: une analyse thermochronologique par traces de fission sur apatites. C. R. Acad. Sci. IIa, 331, 775-782.

James N. P., Seibel M.J., Dalrymple R.W., Besson D., Parize O. (2013) - Warm-temperate, marine, carbonate sedimentation in an Early Miocene, tide-influenced, incised valley; Provence, south-east France. Sedimentology, 61, 497-534.

Kalifi A., Sorrel P., Leloup P., Spina V., Huet B., Galy A., Rubino J., Pittet B. (2020) - Changes in hydrodynamic process dominance (wave, tide or river) in foreland sequences: the subalpine Miocene Molasse revisited (France). Sedimentology, 67, 2455-2501.

Lesueur J.-L., Rubino J.-L., Giraudmaillet M. (1990) - Organisation et structures internes des dépôts tidaux du Miocène rhodanien. Bull. Soc. Geol. Fr., 6, 49-65.

Longhitano S.G. (2011) - The record of tidal cycles in mixed silici-bioclastic deposits: examples from small Plio-Pleistocene peripheral basins of the microtidal Central Mediterranean Sea. Sedimentology, 58, 691-719.
Longhitano S.G. (2018) - Between Scylla and Charybdis (part 1): the sedimentary dynamics of the modern Messina Strait (central Mediterranean) as analogue to interpret the past. Earth Sci. Rev., 185, 259-287.
Longhitano S.G., Telesca D., Pistis M. (2017) - Tidal sedimentation preserved in volcaniclastic deposits filling a peripheral seaway embayment (early Miocene, Sardinian Graben). Mar. Pet. Geol., 87, 31-46.
Longhitano S.G. and Chiarella D. (2020) - Chapter 15 - Tidal straits: basic criteria for recognizing ancient systems from the rock record. In: Scarselli N., Adam J., Chiarella D., Roberts D., Bally A.W. (Eds.) Regional Geology and Tectonics (Second Edition), Elsevier, pp. 365-415.
Massari F., Grandesso P., Stefani C., Jobstraibizer P.G. (1986) - A Small Polyhistory Foreland Basin Evolving in a Context of Oblique Convergence: The Venetian Basin (Chattian to Recent, Southern Alps, Italy). In: Allen P.A., Homewood P. (Eds.), Foreland Basin. Int. Ass. Sedimentol. Spec. Pub., 8, 141-168.
Miller K.G., Browning J.V., Schmelz W.J., Kopp R.E., Mountain G.S., Wright J.D. (2020) - Cenozoic sea-level and cryospheric evolution from deep-sea geochemical and continental margin records. Sci. Adv., 6, eaaz1346.
Moissette P. (1996) - The cheilostomate bryozoan *Batopora rosula* (Reuss, 1848): a paleobathymetric indicator in the Mediterranean Neogene. In: Gordon D.P., Smith A.M., Grant-Mackie J.A. (Eds.), Bryozoans in space and time. Proceedings of the 10th International Bryozoology Conference, Wellington, New Zealand, 1995. National Institute of Water & Atmospheric Research Ltd, Wellington. pp. 193-198.
Molli G. (2008) - Northern Apennine-Corsica orogenic system: an updated overview. In: Siegesmund S., Fügenschuh B., Froitzheim N. (Eds.), Tectonic aspects of the Alpine-Dinaride-Carpathian System. Geol. Soc. Spec. Pub., 298, 413-442.
Monleau C., Arnaud M., Magné J., Négretti B., Rossi F. (1996) - Précisions stratigraphiques et paléoécologiques sur le Miocène inférieur et moyen du Sud de la Corse et du Nord de la Sardaigne. Geol. Mediterr., 23, 235-241.
Museur T. (2014) - Interprétation sismique à très haute résolution du bassin de Bonifacio. Mémoire de M1 [MSc Memoir], Université de Lille 1, 28 p.
Orsini J.-B., Capdevilla M., Ferrandini J., Ferrandini M., Loÿe D., Guennoc P., Pluquet F., Thinon I., Santiago M., Oggiano G., Cherchi A., Orru P., Puliga G., Pintus M., Ulzega A., Gamisans J., Tramoni P., André J.-P., Galloni F., Münch P., Saint-Martin J.-P., Alamy Z., Reynaud J.-Y., Tessier B. (2011) - Notice explicative, Carte géol. France (1/50 000), feuille Sotta - Bonifacio - Santa Teresa di Gallura (1127). Carte géologique [Geological Map] par Orsini J.-B., Ferrandini J., Ferrandini M., Loÿe M.-D., Guennoc P., Pluquet F., Oggiano G., Cherchi G., Gattacceca J., Orrù P., Puliga G., Pintus M., Ulzega A. Orléans, BRGM, 360 pp.
Orsini J.-B., Ferrandini M., Di Meglio A., Ferrandini J. (2015) - Promenade géologique à Bonifacio. Collection Balades géologiques. Biotope Editions. 34 pp.
Orszag-Sperber F. and Pilot M.-D. (1976) - Grands traits du Néogène de Corse. Bull. Soc. Geol. Fr., 18, 1183-1187.
Ottaviani-Spella M.-M., Girard M., Cheilletz A. (1996) - Les ignimbrites burdigaliennes du sud de la Corse: pétrologie et datations K-Ar. C. R. Acad. Sci. IIa, 323, 771-778.

https://doi.org/10.3301/GFT.2021.01

Ottaviani-Spella M.-M., Girard M., Rochette P., Cheilletz A., Thinon M. (2001) - Le volcanisme acide burdigalien du Sud de la Corse: pétrologie, datation K-Ar, paléomagnétisme. C. R. Acad. Sci. IIa, 333, 113-120.

Oudet J., Münch P., Verati C., Ferrandini M., Melinte-Dobrinescu M., Gattacceca J., Cornée J.-J., Oggiano G., Quillévéré F., Borgomano J., Ferrandini J. (2010) - Integrated chronostratigraphy of an intra-arc basin: $^{40}Ar/^{39}Ar$ datings, micropalaeontology and magnetostratigraphy of the early Miocene Castelsardo basin (northern Sardinia, Italy). Palaeogeogr. Palaeocl., 295, 293-306.

Pascucci V., Merlini S., Marrini I. P. (1999) - Seismic stratigraphy of the Miocene-Pleistocene sedimentary basins of the Northern Tyrrhenian Sea and western Tuscany (Italy). Basin Res., 11, 337-356.

Pluquet F. (2006) - Évolution récente et sédimentation des plates-formes continentales de la Corse. Thèse de doctorat [PhD Thesis], Université de Corse, 300 pp.

Reynaud J.-Y. and Dalrymple R.W. (2012) - Shallow-Marine Tidal Deposits. In: R.A. Davis, R.W. Dalrymple (Eds.), Principles of Tidal Sedimentology. Springer, pp. 335-369.

Reynaud J.-Y. and James N.P. (2012) - The Miocene Sommières basin, SE France: bioclastic carbonates in a tide-dominated depositional system. Sediment. Geol., 282, 360-373.

Reynaud J.-Y., Dalrymple R.W., Vennin E., Parize O., Besson D., Rubino J.-L. (2006) - Topographic controls on production and deposition of tidal cool-water carbonates, Uzes Basin, SE France. J. Sediment. Res., 76, 117-130.

Reynaud J.-Y., Ferrandini M., Ferrandini J., Santiago M., Thinon I., André J.-P., Barthet Y., Guennoc P., Tessier B. (2012a) - From non-tidal shelf to tide-dominated strait: the Miocene Bonifacio Basin, Southern Corsica. Sedimentology, 60, 599-623.

Reynaud J.-Y., Vennin E., Parize O., Rubino J.-L., Bourdillon C. (2012b) - Incised valleys and tidal seaways: the example of the Miocene Uzès-Castillon basin, SE France. B. Soc. Geol. Fr., 183, 471-486.

Rögl F. (1998) - Palaeogeographic Considerations for Mediterranean and Paratethys Seaways (Oligocene to Miocene). Ann. Nat. Hist. Mus. Wien, ser. A, 99, 279-310.

Rossi V.M. (2011) - Analisi sedimentologica della successione carbonatico-silicoclastica miocenica del bacino di Bonifacio (Corsica): distribuzione delle facies e processi sedimentari. Corso di Laurea, Elaborato finale [MSc Memoir], Università degli Studi di Milano. 212 pp.

Rossi V.M., Longhitano S.G., Mellere D., Dalrymple R.W., Steel R.J., Chiarella D., Olariu C. (2017) - Interplay of tidal and fluvial processes in an early Pleistocene, delta-fed, strait margin (Calabria, Southern Italy). Mar. Pet. Geol., 87, 14-30.

Santiago M. (2010) - Exploitation de données sismiques haute à très haute résolution pour la cartographie des formations géologiques en domaine côtier (exemple des Bouches de Bonifacio, Corse). [MSc Memoir], Université de Caen. 43 pp.

Séranne M. (1999) - The Gulf of Lion continental margin (NW Mediterranean) revisited by IBS: an overview. In: Durand B., Jolivet L., Horvath F., Séranne M. (Eds.), The Mediterranean Basins Tertiary Extension within the Alpine Orogen. Geol. Soc. Spec. Publ., 156, 15-36.

Speranza A., Villa I.M., Sagnotti L., Florindo F., Consentino D., Cipollari P., Mattei M. (2002) - Age of the Corsica-Sardinia rotation and Liguro-Provencal Basin spreading: new paleomagnetic and Ar/Ar evidence. Tectonophysics, 347, 231-251.

Sztanó O. and De Boer P.L. (1995) - Basin dimensions and morphology as controls on amplification of tidal motions (the Early Miocene North Hungarian Bay). Sedimentology, 42, 665-682.

Telesca D., Longhitano S.G., Pistis M., Pascucci V., Tropeano M., Sabato L. (2020) - Sedimentology of a transgressive middle-upper Miocene succession filling a tectonically confined, current dominated seaway (the Logudoro Basin, northern Sardinia, Italy). Sediment. Geol., 400, 105626.

Thomas B. and Gennesseaux, M. (1986) - A two-stage rifting in the basins of the Corsica-Sardinian Straits. Mar. Geol., 72, 225-239.

Tomassetti L. and Brandano M. (2013) - Sea level changes recorded in mixed siliciclastic-carbonate shallow-water deposits: The Cala di Labra Formation (Burdigalian, Corsica). Sediment. Geol., 294, 58-67.

Tomassetti L., Bosellini F.R., Brandano, M. (2012) - Growth and demise of a Burdigalian coral bioconstruction on a granite rocky substrate (Bonifacio Basin, southeastern Corsica). Facies, 59, 703-716.

Voisin R. (2013) - Architecture stratigraphique des Bouches de Bonifacio. Mémoire de M2 [MSc Memoir], Université de Lille. 43 pp.

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