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Intertidal Upper Pleistocene algal build-ups (Trottoir) of NW Sardinia (Italy): a tool for past sea level reconstruction

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ABSTRACT - Biological sea level indicators such as intertidal coralline red algal build-ups (Lithohyllum rim or Trottoir) are a powerful tool for precise sea level reconstruction.

Several patches of relict intertidal Lithophyllum Trottoir crop out along the north-west Sardinia coasts (Mediterranean Sea, Italy). Based on the strathigraphic correlations and preliminary luminescence ages (avg 120±8 ka) these algal bindstones are associated with the Marine Isotope Stage 5e (MIS 5e, 135-115 ka). A Sedimentological/stratigraphic approach performed on relict Mediterranean Algae Trottoir led us to developed an evolution model and precisely estimate the relative sea level elevation during MIS 5e along the NW coast of Sardinia. Moreover, coastal feature plays a vital role for "Lithophyllum incipient Trottoir" development which under a stable sea condition may growth up to the mature tabular Trottoir aspect. The mean elevation of the studied MIS 5e Lithophyllum bioconstructions is 4.9±0.5 m above the present sea level, which is in good agreement with both the global and the regional data.

Keywords: Mediterranean Sea; Sea level marker; Coralline algal build-up; MIS 5e; Lithophyllum Trottoir.

1. INTRODUCTION

The sea level elevations are multidisciplinary investigated and among the others the intertidal living biological associations are considered a powerful tool for such studies. The coralline rhodophyte Lithophyllum rock-builder species are able to develop different reef-like forms just above the biological mean sea-level (intertidal zone). Therefore, these biological structures mark precisely the sea level position (±10 cm) (Laborel and Laborel-Deguen, 1994; Laborel, et al., 1994).

Presently intertidal Lithophyllum build-ups may appear as a calcareous protrusion that growth up attached to the steep rocky cliff (termed as rim or corniche) and in rare case this forms a tabular bodies developed over wave cut platforms better known as Trottoir.

Modern intertidal Lithophyllum bioconstructions are well documented and used to evaluate the Holocene sea level variations (Laborel et al., 1994; Faivre et al., 2013).

However, few fossil examples of Lithophyllum Trottoir have been described in the literature and similarly used as past sea level indicators (Faivre et al., 2013; Pascucci et al., 2014).

Several well-preserved patches of interpreted MIS 5e Lithophyllum Trottoir crop-out along the north-west Sardinian coast (Pascucci et al., 2014). Such bioconstruction showed different depositional features related to different levels of growth maturity. Thus, this represents an ideal opportunity to:

(i) investigate and interpret the sedimentary processes responsible of Lithophyllum Trottoir formation in a very shallow/intertidal marine mixed siliciclastic-carbonate environment

(ii) use fossil Trottoir as precise fossil biological chronostratigraphic marker of past sea-level.

2. GEOLOGICAL SETTING

Sardinia Island reached its present position, at the centre of Mediterranean Sea, after an anticlockwise rotation due to the opening of Liguro-Provençal basin during the Oligocene-early Miocene (Carmignani et al., 1995) (Fig. 1A). The related tectonic and volcanic activities slowed down and ended at the beginning of Pleistocene. Hence, the Island is considered tectonically stable at least since the last 1 Ma of years, just only affected by a mean -0.01 mm/yr subsidence) and therefore, it is used as a key area for studying present and past sea level fluctuations (Ferranti et al., 2006).

The present-day coast between the cities of Alghero and Bosa (north-west Sardinia) is characterized by high sea-facing cliffs dominated at the base by large wave cut

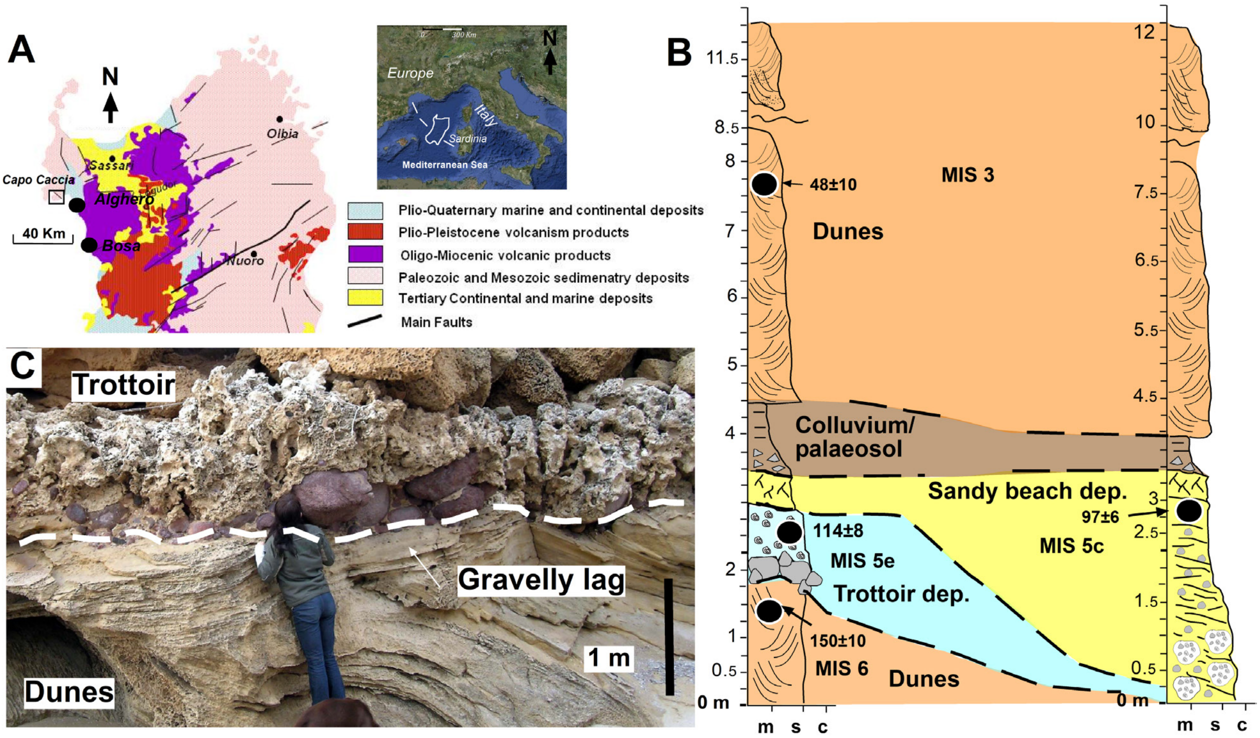

Fig. 1 - A) Geological setting of Sardinia Island and its location at center of the Mediterranean Sea. Performed work cover an area of 100 km along the North-west coast from the city of Alghero to Bosa. B) Representative stratigraphic sketch of Upper Pleistocene succession cropping out along the Sardinia NW coast, succession start with a basal Dune deposits (MIS 6, 150 ka) or bedrock on which rest unconformable the MIS 5e (114±8 ka) marine deposits, these range from well-developed sandy beach deposits to Trottoir bodies. The second marine event occurred during MIS 5c (97±6 ka) is characterized by well-developed prograding beaches systems. The succession ends with several meters of capping dune system alternate to colluvial/paleosol deposits related to the last glacial stage. C) Field example of outcropping patch of mature Trottoir deposit.

platforms, some relatively small sandy to gravel pocket beaches and very few wide embayment occur (Fig. 1A).

Bedrock lithology range from Permo-Triassic continental quartz-rich sandstones to conglomerates; Mesozoic limestones/dolostones and Oligo-Miocene volcanic and continental to marine Pleistocene deposits.

The Upper Pleistocene stratigraphy of NW Sardinia, based on Pascucci et al. (2014), is characterized by an alternation of shallow marine and colluvial/aeolian deposits formed during major climatic and sea-level variations (Fig. 1B).

In particular, marine deposits range from well-developed fossiliferous sandy-rich Lithophylllum bindstones to sandy pocket beaches (Fig. 1C). Based on the strathigraphic correlations and on preliminary published ages (avg 120±8 ka), algal build-ups are related to the Marine Isotope Stage 5e when sea level was 6±3 m above the present (MIS 5e 135-115 ka; Ferranti et al., 2006; Tuccimei et al., 2007; Andreucci et al., 2010; Sechi et al., 2013; Pascucci et al., 2014) (Fig. 1B).

3. METHOD

Five algal bindstone bodies cropping out along the coast comprised between Alghero and Bosa towns were studied in order to define depositional forms, stratigraphic position and elevation above the present sea level (a.s.l.).

4. DISCUSSION

Studied red algal build-ups rest directly over the bedrock or drape a basal conglomerate lag forming bodies up to 1 m-thick (average 50 cm-thick (Fig. 1C). Depositional body is mainly dominated by coralline red algal built up of genus Lithophyllum in association with intertidal invertebrate fauna such as Serpulides sp. and Barnacles sp. often in life position.

Build-ups are generally highly fossiliferous with dispersed well-rounded pebbles to boulders clasts. Trapped marine fossils comprise: Acanthocardia tuberculata, Patella ferruginea, Glycymeris glycemeris, Conus testudinarius and Thais haemastoma spp.. Occasionally, bioconstructions are gravelly dominated and show a crude alternation of conglomerate strata and poorly developed algal bindstone layers. These are interpreted as the fossil analogue of the present-day forming Lithophyllum rim or the most mature form of Trottoir (Laborel and Laborel-Deguen, 1994; Laborel et al., 1994) (Fig. 2).

The morphology of the coast and bedrock characteristics play an important role in determining the incipient development of Lithophyllum encrusting. Under ideal and stable environment (stable sea level and climate condition), they may growth in dimension up to the final aspect of mature Trottoir (Fig. 2).

For instance, along sheltered and partially submerged

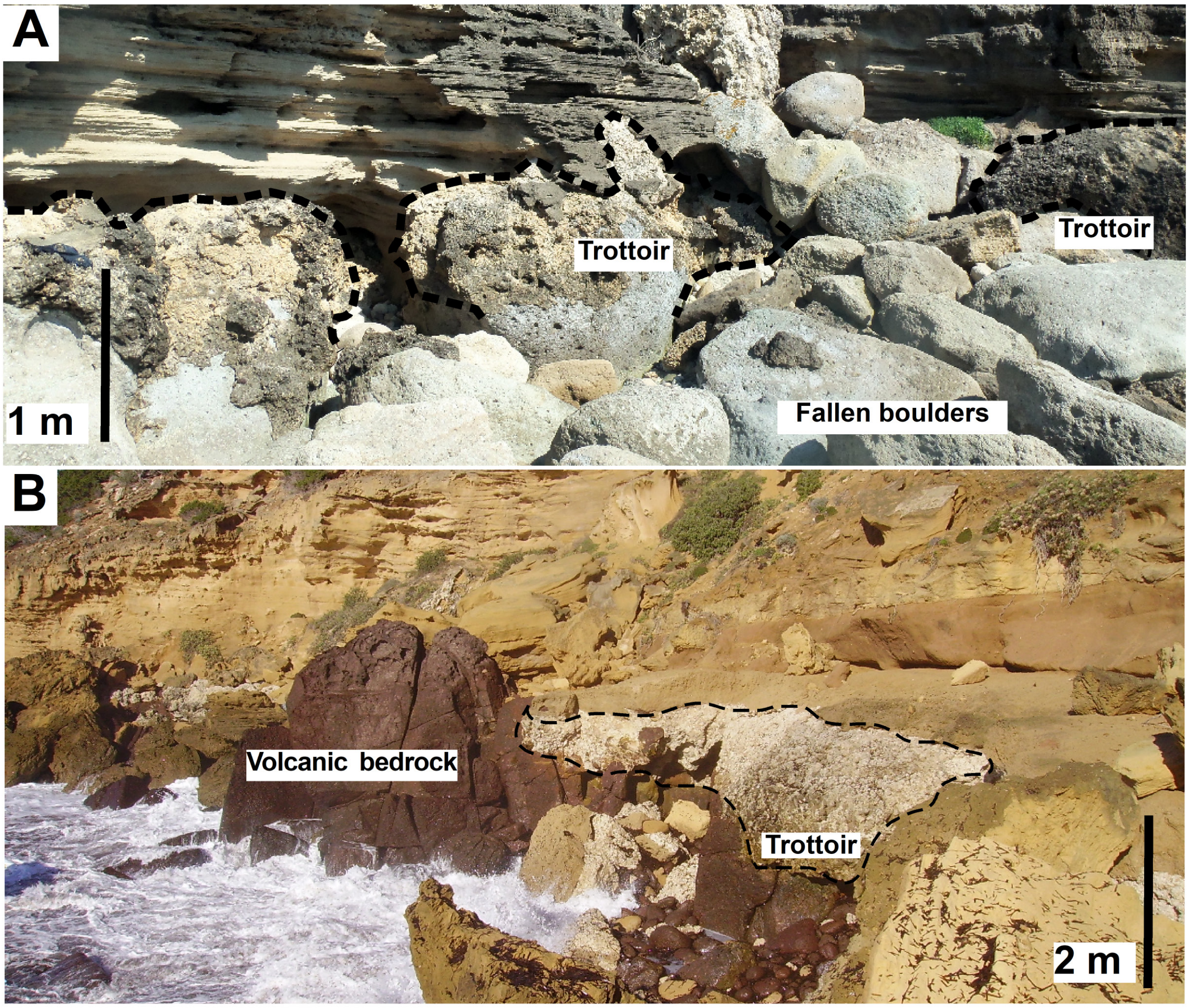

Fig. 2 - Field view of two different fossil Trottoir outcropping along the Alghero coast. A) Trottoir developed above a transgressive gravelly (boulder- cobbly) lag resting non conformable above cross-bedded sandstone interpreted as Dune field system. B) Mature Trottoir developed directly attached to the volcanic bedrock. Bedrock morphology is interpreted as a shore platform carved at the base relict cliff.

rocky bouldery shores, cliff fallen blocks rest on shallow shore platform forming wave-sheltered shady environment. Incipient Lithophyllum encrustations (bindstone) develop undisturbed in such environment, firstly as incipient binding (30-cm thick) layer, then passing to isolated mature algal mounds which, may connect each others to the final Trottoir appearance (Fig. 2). Fundamental conditions for developing a mature Trottoir is a stable or slowly rising sea level through the time (Laborel et al., 1994).

In order to reconstruct the sea-level and coastal shoreline positions during MIS 5e, five different cropping out relict Trottoir bodies along the North western Sardinia coast were identify and measured, in terms of elevation on the present sea level. Estimated field stratigraphic elevations range from a minimum of 3 to a maximum of 4 m above sea level.

The maximum field measured elevations are corrected for the subsidence ratio of 0.01 mm/yr proposed by Ferranti (2006) for the NW Sardinia occurred since the MIS 5e maximum sea level highstand (125 ka). Finally a standard uncertainty value of 0.5 m, corresponding to the average tidal range, has been considered (Tab. 1).

The average corrected elevation is 4.9 m a.s.l. This data well agrees with estimated elevations ranging between 3.5 to 5.5 m a.s.l for directed and undirected dated MIS 5e markers (phreatic overgrowths and notches) measured along the close by Capo Caccia area (Alghero, see Fig. 1 for location) (Ferranti et al., 2006; Tuccimei et al., 2007). The mean of corrected elevations is plotted against to the worldwide and recently published for the Mediterranean Sea accepted sea level curves (Waelbroeck et al., 2002; Dorale et al., 2010) (Fig. 3).

Our data matches the global inferred MIS 5e elevation and slightly overestimate elevation measured at Majorca Island by Dorale et al. (2010). This difference in the MIS 5e elevations between the two Islands was already highlights by Tuccimei et al. (2007).

Our results seem to indicate that the MIS 5e was the period of maximum development of the Lithophyllum Trottoir along the NW Sardinia coast when sea level and shoreline stood at least 5 meters above the present.

			Elevation		
Area	Deposit	Age	a.s.l*	C s.l#	Reference
		ka	m	m	
Alghero	Trottoir	114 ± 8	3.5	4.8 ± 0.5	Pascucci (2014)
Alghero	Trottoir		4	5.3 ± 0.5	This work
Alghero	Trottoir		3.5	4.8 ± 0.5	This work
Bosa	Trottoir	125 ± 8	4	5.3 ± 0.5	Pascucci (2014)
Bosa	Trottoir		3	4.3 ± 0.5	This work

Tab. 1 - Field maximum elevations measured above present sea level (*) and the elevation corrected for the subsidence (#) for each Trottoir identified along the study area. Reported Luminescence potassium-rich feldspar ages performed by Pascucci et al. (2014) on Trottoir deposits cropping out along NW Sardinia coast.

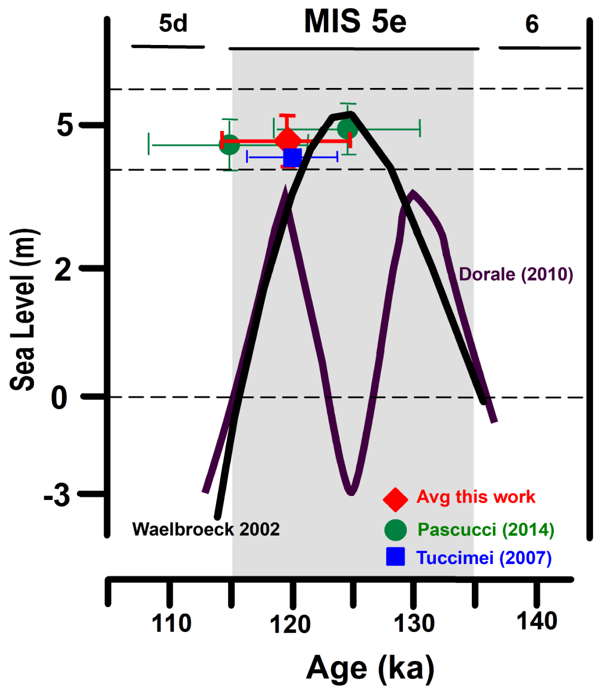

Fig. 3 - Sea level curve established for the Ocean (black line, Waelbroeck et al., 2002) and for the Mediterranean Sea (purple line, Dorale et al., 2010). Corrected elevations were plotted against performed Luminescence ages (Tab.1) as green full circles with error. The red diamond highlights the average of all estimated corrected elevations against the estimated mean age (120±8 ka). Blue square identify the elevation of dated MIS 5e phreatic overgrowths of Capo Caccia (Alghero) published by Tuccimei et al. (2007).

5. CONCLUSION

Sedimentological and chrono-stratigraphic approaches on Sardinian outcropping patches of Lithophyllum Trottoir give the opportunity to understand their development based on shore setting and sea level fluctuation.

Whether coastal feature plays an important role in determining the Lithophyllum initial incipient form, the later evolution and then the final mature form of Trottoir is instead much more prone to the sea level and climate stability. Identify such sedimentary facies and features (incipient or mature) in a stratigraphic succession is a powerful correlation marker strata and a precise paleo-sea level indicator of MIS 5e highstand for the Sardinia Island.

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