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Giorgia RATTO (*), Francesca MONTIS (*), Anna DEPALMAS (**),
Marco RENDELI (**) & Rita T. MELIS (*)

PALEOENVIRONMENTAL RECONSTRUCTION OF THE SANT'IMBENIA AREA DURING THE MIDDLE HOLOCENE (SARDINIA, ITALY)

Abstract: Ratto G., Montis F., Depalmas A., Rendeli M. & Melis R.T., *Paleoenvironmental reconstruction of the Sant'Imbenia area during the Middle Holocene (Sardinia, Italy).* (IT ISSN 0391-9839, 2016)

The area of Sant'Imbenia is located on the northwestern coast of Sardinia in the Porto Conte bay delimited by the calcareous promontories of Capo Caccia to the west and Punta Giglio to the east. Pleistocene slope deposits with interbedded beach sediments (Tyrrhenian, MIS 5.5), fill karst cavities developed in the carbonatic Mesozoic substratum. Given this geomorphic setting, Porto Conte Bay has always represented a safe landing place since Middle Holocene, as showed by numerous prehistoric and historic settlements next to the coast. In particular, the Nuragic village (Bronze Age) of Sant'Imbenia attested a midpoint of cultural and commercial exchanges from Middle Bronze Age to Early Iron Age when it was abandoned for unknown reasons. In this paper, we present the preliminary results of a multidisciplinary research aimed to outline the paleoenvironmental evolution of the area around Sant'Imbenia site and to identify the causes that determined its abandonment. Geomorphological analysis coupled with stratigraphic and paleontological studies of three cores and ^{14}C datings allowed to underline that during Holocene this area represented transitional coastal environments, characterized by wetlands and brackish lagoons evolved into marshland during the Roman Period.

Key Words: Paleoenvironmental reconstruction, Bronze Age, Holocene, Sardinia, Italy

Riassunto: Ratto G., Montis F., Depalmas A., Rendeli M. & Melis R. T., *Ricostruzione paleoambientale dell'area di Sant'Imbenia durante l'Olocene Medio (Sardegna, Italia).* (IT ISSN 0391-9839, 2016)

L'area di Sant'Imbenia è localizzata nella Baia di Porto Conte, lungo la costa Nord Occidentale della Sardegna. La baia, delimitata dai promontori calcarei di Capo Caccia a Ovest e Punta Giglio a Est, ha sempre rappresentato un luogo sicuro per gli approdi fin dall'Olocene medio, come testimoniato dai numerosi insediamenti preistorici e storici presenti in prossimità della costa. In particolare il villaggio nuragico di Sant'Imbenia ha rappresentato un punto d'incontro di scambi commerciali e culturali dal Bronzo Medio fino alla prima età del Ferro, quando è stato abbandonato. In questo lavoro sono riportati i risultati preliminari di uno studio multidisciplinare finalizzato alla ricostruzione dell'evoluzione ambientale dell'area intorno al sito di Sant'Imbenia, in riferimento alle potenziali cause dell'abbandono dello stesso sito dopo l'Età del Ferro. Lo studio litostratigrafico di 3 carotaggi, le analisi sedimentologiche, micromorfologiche, della malacofauna e la datazione al radiocarbonio hanno permesso di individuare la presenza di uno stagno che occupava l'attuale area retrolitorale della baia di Porto Conte, tra la linea di costa attuale e il villaggio.

Termini Chiave: Ricostruzione paleoambientale, Età del Bronzo, Olocene, Sardegna, Italia

INTRODUCTION

During Holocene the sea level changes and the resulting evolution of coastal morphology has directly influenced the choice of the settlements. In particular, since Bronze Age the Mediterranean basin has been an area of great cultural exchange between civilizations. Sardinia, given its location in the center of the Mediterranean, played a key role as a crossroads of the Mediterranean routes and as a meeting place of different cultures from the Near East, from the Aegean world and Etruscan, Greece, North Africa, Spain and Sicily (Bartoloni 2000, 2005; Rendeli, 2005; Zucca, 2004; Campus & *alii*, 2006). In Sardinia, some of the most important prehistoric and historic settlements are located along the west coast near the bays. Especially, the deep bay of Porto

(*) *Dipartimento di Scienze Chimiche e Geologiche, Università degli Studi di Cagliari, Italy. Corresponding author: Giorgia Ratto, E-mail: giorgia.ratto@gmail.com.*

(**) *Dipartimento di Storia, Scienze Umane e Formazione, Università di Sassari, Italy.*

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Conte represented since prehistory a safe place for landing.

Bronze and Roman age settlements are present mostly around the bay. In this context the nuragic village of Sant'Imbenia (Late Bronze-Early Iron Age) takes on a particular role as an important center of commercial and cultural exchange until the 7th century BC when it was abandoned for unknown reasons (Garau & Rendeli, 2009). The goal of the present paper is to identify if natural causes have influenced the abandonment of the village through the paleoenvironmental reconstruction of the area around the site.

GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

The Sant' Imbenia site is located in the inner part of the Porto Conte bay, in the northwestern coast of Sardinia (fig. 1a). The bedrock area is mainly constituted by Cretaceous (Bajociano - Bathoniano) limestone affected by a system of normal faults most of which follow a W-SW trend (Carmignani & *alii*, 2001). Permian sandstones outcrop in the hills behind the bay. Quaternary deposits of continental and marine facies are mainly present in the area between the promontories. The continental deposits are characterized by Pleistocene sand and aeolian sandstones with interbedded paleosols. Tyrrhenian (MIS 5.5) bioclastic calcarenites outcrop next to the coastline. Holocene is characterized by aeolian backshore sands, littoral sands, marsh and alluvio-colluvial deposits. The bay, dominated by the cliff of Capo Caccia promontory in the southwest and by the smaller promontory of Punta Giglio in the southeast, represents a *ria* progressively submerged by the sea during the Quaternary (Federici & *alii*, 1999). High cliffs, affected by karst and marine processes, characterize the promontories. The level of tidal notches from about 5.5 m a.s.l (Punta Giglio) to 3.8 m a.s.l. (Capo Caccia) formed during MIS 5.5 (Antonioli & *alii*, 1998, 2006, 2007; Tuccimei & *alii*, 2003) indicate a substantial tectonic stability of the Capo Caccia area at least from the beginning of the Late Pleistocene (Antonioli & *alii*, 1996).

Karstic processes, favoured by the presence of joints and fractures, gave origin to several caves in the promontories (Grotta Verde, Grotta dei Cervi, Grotta Dragonara).

The submerged Neolithic burials at 8.5 m below the sea level, dated to about 7300 years BP in "Grotta Verde" opening in the Capo Caccia cliff, provide the recent sea level rising (Antonioli & *alii*, 1996). Given the complex morphology of the northwestern coastal landscape, dominated by more or less high limestone cliffs that surround narrow inlets, it is easy to understand because the bay of Porto Conte, a low-lying sandy coast, was a safe landing for the people.

In this morphological context, the Sant'Imbenia village rises in a sub-flat area gently sloping toward the sea, characterized by aeolian and eluvial-colluvial quaternary deposits. The Sant'Imbenia site had been excavated, for the first time, from 1982 to 1997. It consists of a village (Bronze -Early Iron Age) characterised by complex structures with several premises, cobbled streets, squares and wells (Rendeli, 2014), next to a Nuraghe with single-tower built with blocks of Tyrrhenian conglomerate (MIS 5.5). A stratigraphic section carried out near the Nuraghe, below the base level of the structures, showed dark grey clay deposits probably of lagoon origin, dated 4155 ± 230 BP (Federici & *alii*, 1999).

MATERIALS AND METHODS

Three cores were drilled at a maximum depth of 5 meters in the back coastal area of Porto Conte bay, at a maximum distance of 500 m from the present day shoreline (fig. 1b), in order to provide stratigraphic information on the paleoenvironmental conditions. Moreover, an innervillage stratigraphic section was analysed. During drilling operations, sediment samples were collected to define colour, texture, grains size and fossil content. The detailed description of the grains size analysis and fauna

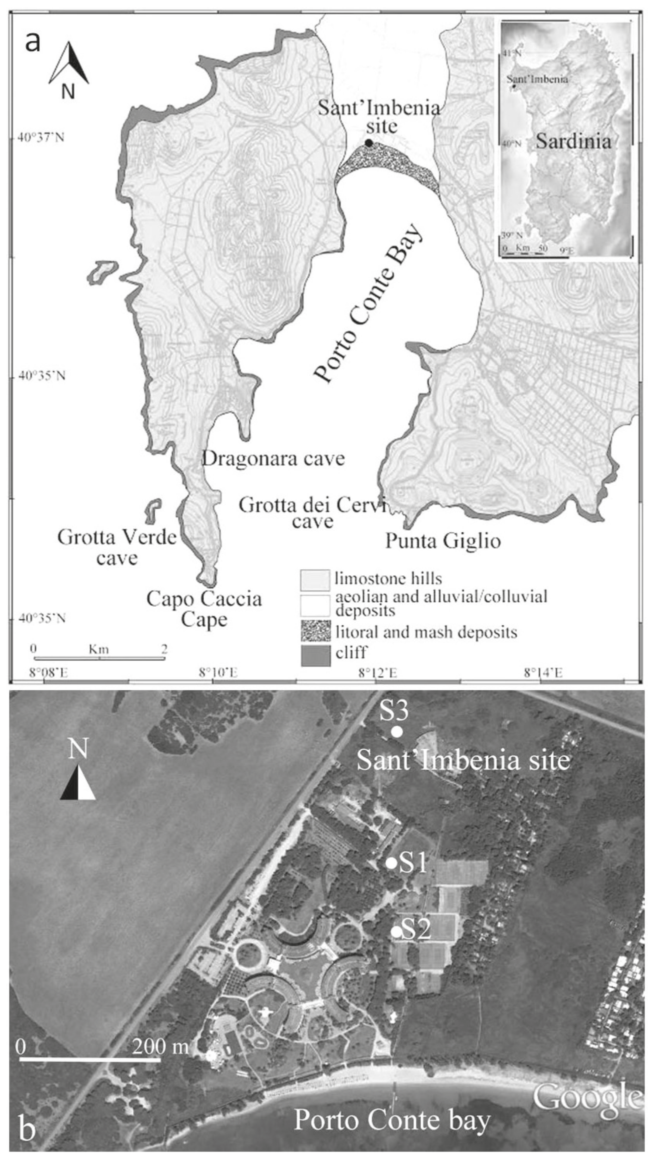

FIG. 1 - a) Location of the Porto Conte bay and the Sant'Imbenia site on the north west coast of Sardinian; b) location of the cores in the Sant'Imbenia area.

assemblage allowed to subdivide the stratigraphic records into units. For the micromorphological study, thin sections of undisturbed samples were analysed and the features were described according to Bullock & *alii* (1985).

The sand fraction was mechanically sieved using a column of sieves descending in size from 5.6 mm to 0.063 mm, spaced at 1/4 phi (ø) per unit. The particle size fraction smaller than 63 micron were determined by the Andreasen Pipette method. Statistical analyses were subsequently performed using the free software "Gradistat v8.0" (Blott, 2008), in order to establish various grain size parameters (mean, sorting, kurtosis, skewness) calculated arithmetically and logarithmically (in phi units) using moment and Folk and Ward graphical methods (1966).

For the macro and microfauna analysis a total of 10 samples were considered (Tab. 1), collected in the most significant lithostrathigrafical levels, from S2 core (from 1 to 3 m core depth) and S1 core (from 0.50 to 1.20 m core depth). The fraction greater than 500 µm was used for molluscan analyses, while the fraction between 63 and 500 µm were observed under a stereo light microscope for ostracods analyses. Biostratigraphic analysis was performed qualitatively, because the samples containing malacofauna and microfauna were insufficient to allow quantitative analysis, although the total abundance and the dominant species of molluscs were counted and expressed as a percentage. For the classification of various identified species, the recourse was the consultation of various atlases and scientific articles of various authors such as Pérés & Picard, (1965), Sohn, (1987), Feist & Grambast - Fessard, (1991), Szarowska, (2006), Angelov, (2000), Georgiev (2012); Delicado & Ramos (2012). In addition, the IT catalog Worms (http://www.marinespecies.org) was used in order to verify species and to recognize their specific name by which they are accepted today. Two samples of the S2 core were collected for radiocarbon dating. Of these, only one has provided a date (DSH5791-1934±46 BP) calibrated by the CALIB 7.0.2 program (Stuiver & Reimer, 1993), using IntCal09 as calibration datasets (Reimer & *alii*, 2013).

CORES STRATIGRAPHY

A detailed description of lithostratigraphic cores drilling performed in the area of Porto Conte bay near of the Sant'Imbenia site, allowed to distinguish six units, indicated by letters. The characterization of the units relies upon sedimentological data of the S1, S2, S3 cores. The stratigraphic record of cores subdivided into units, are described from bottom to top (fig. 2).

Lithostratigrafic units of S1, S2, S3 cores

The S1, S2, S3 cores were performed along the transect from backshore area to the Sant'Imbenia village, respectively at a distance of 270 (S2 core) and 140 meters (S1 core) further southwest of the site. S3 core, instead, was located at 40 meters further northwest near the site (fig. 1b). The stratigraphic sequence is divided in 6 lithostratigraphic units indicated with letters from A to F:

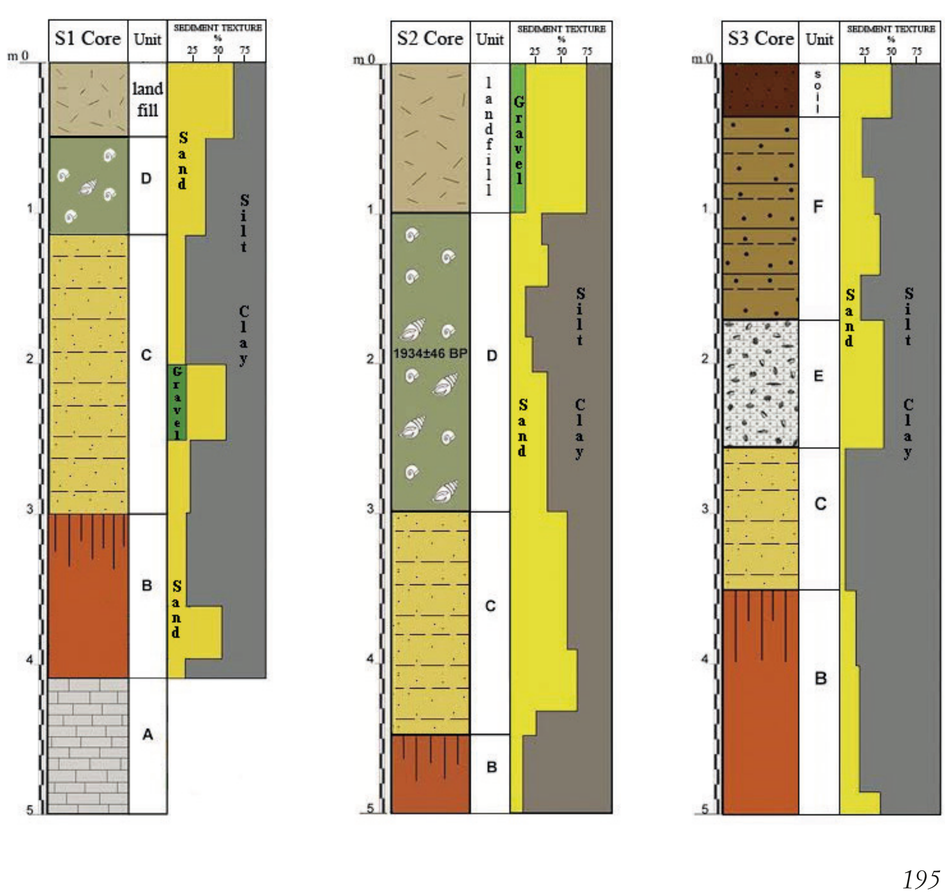

FIG. 2 - Lithostratigraphy of the cores and grain size analyses

TABLE 1 - Distibution of Gasteropods, Bivalves and Ostracods classes (abundant: >30; common: 10-30; scarce: 3-10; rare: 1-3)

SAMPLES	CLASS	FAMILY	SPECIE/GENRE	HABITAT	DISTRIBUTION
C12 (-4.0 m)	Sterile sample				
C13 (-2.40m)	Gasteropoda	*Hydrobiidae*	*Hydrobia sp. (Hartmann, 1821)*	Brackish water, fresh water	Scarce
			Psaudamnicola sp. (Paulucci, 1878)	Fresh water	Rare
C14 (-2.10m)	Gasteropoda	*Hydrobiidae*	*Hydrobia sp. (Hartmann, 1821)*	Brackish water, fresh water	Rare
			Psaudamnicola sp. (Paulucci, 1878)	Fresh water	Commmon
C15 (-2.0 m)	Gasteropoda	*Planorbidae*	*Planorbis Corneus (Linnaeus, 1758)*	Fresh water (stagnant)	Common
		Hydrobiidae	*Hydrobia sp. (Hartmann, 1821)*	Brackish water, fresh water	Common
			Psaudamnicola sp. (Paulucci, 1878)	Fresh water	Common
	Bivalvia	*Semelidae*	*Abra Alba (Wood, 1802)*	Brackish marine water	Common
	Ostracoda	*Darwinulidae*	*Darwinula stevensoni* (*Brady & Robertson, 1870)*	Brackish fresh water	Common
C16 (-1.80m)	Gasteropoda	*Hydrobiidae*	*Hydrobia sp. (Hartmann, 1821)*	Brackish water, fresh water	Scarce
			Psaudamnicola sp. (Paulucci, 1878)	Fresh water	Common
		Planorbidae	*Planorbis Corneus (Linnaeus, 1758)*	Fresh water (stagnant)	Common
	Bivalvia	*Semelidae*	*Abra Alba (Wood, 1802)*	Brackish marine water	Scarce
	Ostracoda	*Darwinulidae*	*Darwinula stevensoni* (*Brady & Robertson, 1870)*	Brackish fresh water	Abundant
C17 (-1.65m)	Gasteropoda	*Hydrobiidae*	*Hydrobia sp. (Hartmann, 1821)*	Brackish water, fresh water	Rare
			Psaudamnicola sp. (Paulucci, 1878)	Fresh water	Scarce
		Lepetidae	*Propilidium Exiguum (Thompson, 1844)*	Marine water	Scarce
		Planorbidae	*Planorbis Corneus (Linnaeus, 1758)*	Fresh water (stagnant)	Abundant
	Ostracoda	*Darwinulidae*	*Darwinula stevensoni* (*Brady & Robertson, 1870)*	Brackish fresh water	Scarce
C18 (-1.55m)	Gasteropoda	*Hydrobiidae*	*Psaudamnicola sp. (Paulucci, 1878)*	Fresh water	Common
		Lepetidae	*Propilidium Exiguum (Thompson, 1844)*	Marine water	Scarce
		Phasianellidae	*Tricolia sp. (Risso, 1826)*	Marine water	Scarce
		Planorbidae	*Planorbis Corneus (Linnaeus, 1758)*	Fresh water (stagnant)	Abundant
	Bivalvia	*Semelidae*	*Abra Alba (Wood, 1802)*	Brackish marine water	Scarce
	Ostracoda	*Darwinulidae*	*Darwinula stevensoni* (*Brady & Robertson, 1870)*	Brackish fresh water	Scarce
C19 (-1.40m)	Gasteropoda	*Hydrobiidae*	*Peringia ulvae (Pennant, 1777)*	Brackish water, fresh water	Rare
			Psaudamnicola sp. (Paulucci, 1878)	Fresh water	Abundant
		Lepetidae	*Propilidium Exiguum (Thompson, 1844)*	Marine water	Common
		Planorbidae	*Planorbis Corneus (Linnaeus, 1758)*	Fresh water (stagnant)	Abundant
		Trochidae	*Gibbula sp. (Risso, 1826)*	Marine water	Rare
	Bivalvia	*Semelidae*	*Abra Alba (Wood, 1802)*	Brackish marine water	Common
C20 (-1.30m)	Gasteropoda	*Hydrobiidae*	*Mercuria Zopissa (Paulucci, 1882)*	Fresh water	Scarce
			Psaudamnicola sp. (Paulucci, 1878)	Fresh water	Common
		Lepetidae	*Propilidium Exiguum (Thompson, 1844)*	Marine water	Rare
		Planorbidae	*Planorbis Corneus (Linnaeus, 1758)*	Fresh water (stagnant)	Scarce
	Bivalvia	*Semelidae*	*Abra Alba (Wood, 1802)*	Marine water	Scarce
C21 (-1.10m)	Gasteropoda	*Hydrobiidae*	*Mercuria Zopissa (Paulucci, 1882)*	Fresh water	Scarce
			Psaudamnicola sp. (Paulucci, 1878)	Fresh water	Common
		Planorbidae	*Planorbis Corneus (Linnaeus, 1758)*	Fresh water (stagnant)	Common

– **Unit A:** present only in the S1 core. It is represented by Jurassic limestone, took over at 4.10m depth;

– **Unit B:** this unit present in all three cores, is charectherized by yellowish red (5YR 4/6) paleosol, above limestone bedrock. The texture is mainly silty clay to silty clay loam. The grain size analysis of two samples shows polimodal distribution and poorly sorted sediments, with mean corresponding very coarse sand. The micromorphological analysis of 4 thin sections obtained from undisturbed samples collected from S1, S2, S3 cores, showed the following characteristics: massive structure with no fully separated aggregates, few planar voids and voids of irregular shape randomly distributed and the c/f related distribution is open porphyric (cf. Bullock & *alii*, 1985). The coarse fraction is by sand-sized mineral grains, and few rock fragments (Paleozoic metamorphic rocks) (fig 3c), with moderately alteration at the surface of mineral grains, according pellicular type. The mineralogical composition of coarse fraction is mainly constituted by quartz and polycrystalline quartz (about 80%), rock fragments (11%), rare feldspars (5%), and opaque minerals (4%). The fine material of the groundmass has a reddish brown color, due to finely dispersed Fe-oxides (probably hematite randomly distributed in association with goethite) (fig 3b), some amorphous Fe-gels with uneven distribution and particles clay. The groundmass has stipple-speckled or striated b-fabric (both granostriated and parallel) due to the birefringent patches of oriented particles clay, sometimes randomly distributed. The pedofeatures are composed of amorphous and cryptocrystalline mineral material typically ferrouginous nodules (fig 3d) of matt red-brown and dark red color, with a degree of impregnation from moderate to strong, heterogenous nodules and diffuse ferrouginous mottles (fig 3a) characterized by an absence of definite external shape. Typical clay coatings are made of external hypo-coatings of grains and voids (cf. Bullock & *alii*, 1985), impure infillings containing contrasted particles of silt-size and compound layered coatings, including microlaminated clay and poorly laminated clayey silt. These clay textural and ferrouginous pedofeatures, respectively indicate clay illuviation and rubefaction, typical soil-forming processes of red soils in Mediterranean area, developed on limestone bedrocks (cf. Bullock & *alii*, 1985; Fedoroff & Courty, 2013). This paleosol, according micromorphological investigation (base material of the soil and pedofeatures) can be regarded as "*Red Earth*", closely associated with the Mediterranean regions under warm climate conditions, with alternances of wet and dry seasons (cf. Schwertmann & Taylor, 1977; Cornell & Schwertmann, 2003);

– **Unit C:** this unit is above the paleosol (unit B). It consists of poorly sorted and no-laminated sediments (10YR 5/3), characterized by clayey-sandy silts with scarce fine gravels. They are no organic remains (wood and other plant fragments), mollusk fragments or other fossils. The micromorphological analysis shows a groundmass composed of sand-sized mineral grains (25%) and small amounts of clay. The degree of sorting of components is poor and c/f related distribution is open porphyric. The mineralogical composition of the coarse fraction is represented by detrital mineral grains of quartz, sub-rounded and polyhedral shape, k-feldspar, some mafic and opaque minerals. Rock fragments consisted of mainly metamorphic and few calcareous rocks. The arrangement of the materials shows a complex microstructure due to no fully separated aggregates, with interconnection of planar voids and other occasional voids. The groundmass in polarized light presented a variable color from gray-brown to yellow-brown due to fine matrix consisting of carbonate (probably microcrystalline calcite) mixed with clay particles and finely dispersed iron and manganese hydroxides and oxides. Detrital grains are scattered randomly in the fine material, showing both stripple-speckled and striated b-fabric, locally masked by amorphous material. Cryptocristalline pedofeatures composed of mineral material and clay coatings are distinguished. Clay accumulation is shown by few external hypo-coatings of grains, speckled coatings with discontinuous orientation and impure coatings containing contrasted particles of fine silt-sized, with weak striated b-fabric. The other pedofeatures are irregular impregnative nodules of different colour (various shades of brown and black) of Fe/Mn compounds, typic nodules of rounded and irregular shape with diffuse boundaries and fe-oxihydrates mottles from weak to medium impregnation of clay and carbonate particles. There are also discoloured areas of grey colour next to yellowish-brown speckled areas probably due to the ferrous compounds. The main micromorphological features, indicative of a moderate presence of illuvial clay, temporary hydromorphic conditions and lack weathering and carbonate leaching, suggest the presence of a soil developed on eluvial-colluvial sediments, overlying the paleosol (unit B);

– **Unità D:** it is characterized by grey (10YR 5/1) or dark grey (Gley2 4/5BG) fine silty-clayey sediments with mollusks. The few species of mollusks are represented by scarce gastropods and bivalves, both as genre and as number of individuals. The presence of some ostracods valves, observed through the optical microscope, is discontinuous and it is limited between 2.10m and 1.50m. In addition, calcareous algae belong to *Porochara Sardiniae* species (Feist & Grambast – Fessard, 1991) (fig. 4b) have been identified, but their habitat is unknown. The most representative gasteropods taxa (*Hydrobidae* and *Planorbidae*) are characterized by some common species: *Psaudamnicola sp.* (Paulucci, 1878) (Fig. 4f), *Planorbis corneus* (Linnaeus, 1758) (fig. 4d) and *Hydrobia sp.* (Hartmann, 1821) (fig. 4c). The species *Gibbula sp.* (Risso, 1826), *Mercuria zopissa* (Paulucci, 1882), *Tricolia sp.* (Risso, 1826), *Peringia ulvae* (Pennant, 1777) *and Propilidium exiguum* (Thompson, 1844) (fig. 4a) are scarce or rare. Amongst bivalves, only the specie *Abra alba* (Wood, 1802) was identified (from common to scarce). The genre *Psaudamnicola sp.* was not clearly defined at the species level, because it belongs to one of the biggest group of the *Hydrobidae* family, hosting different cryptic species (Szarowska, 2006; Delicado & Ramos, 2012). The identified ostracods belong to a singular species, *Darwinula stevensoni*(Brady & Robertson, 1870) (fig. 4e), which is widely distributed in both freshwater and brackish water environments (Sohn, 1987). The common presence of the species *Psaudamnicola sp., Planorbis corneus* and *Hydrobia sp.*, shows that it consists in a transitional coastal environment, characterized by fresh water and brackish water (Delicado

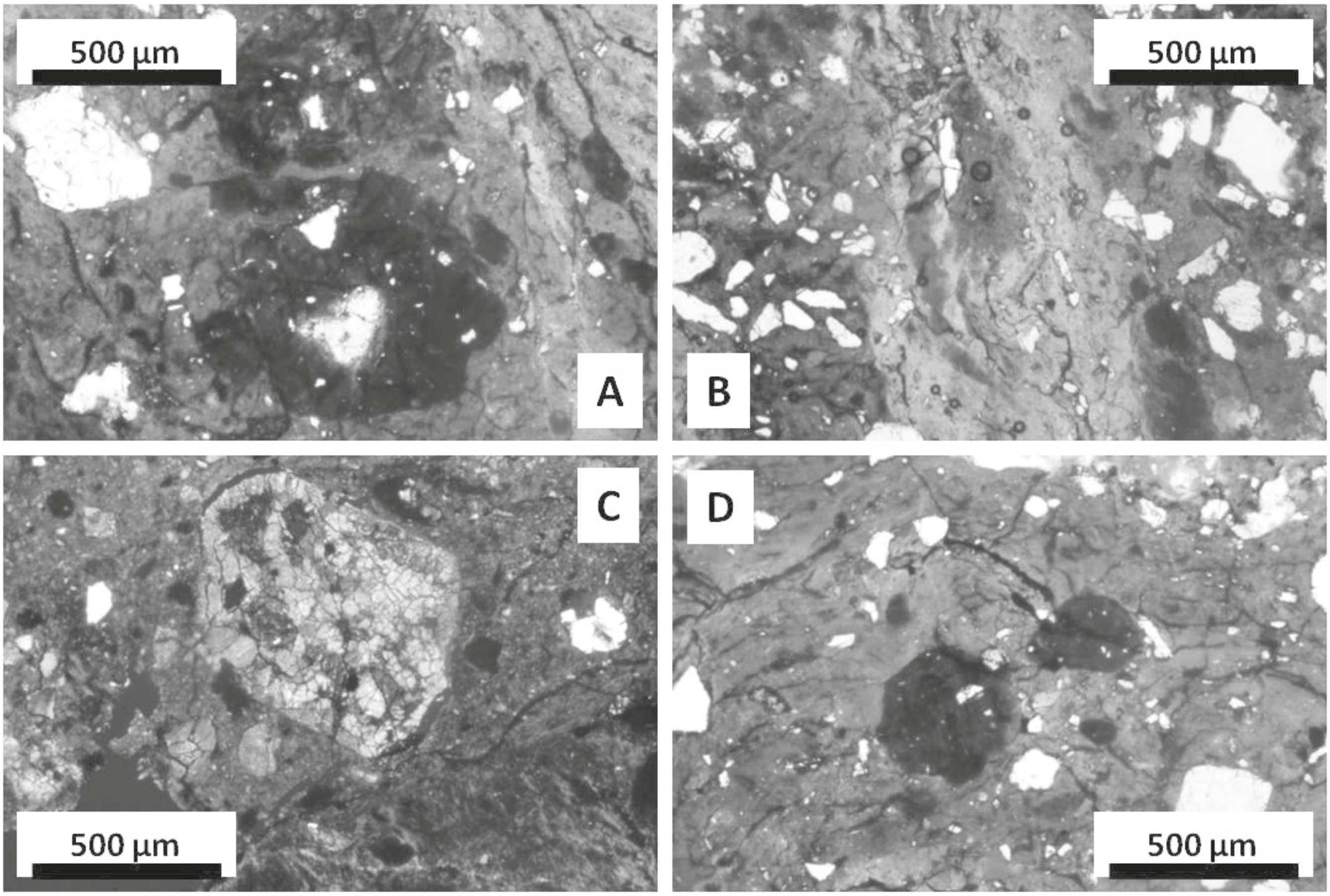

FIG. 3 - Thin section of Unit B (paleosol, S1): A) reddish brown mottles (PPL, x2.5); B) micromass characterised by clay particles with iron oxides and hydroxides (PPL, x2.5); C) lithorelict of metamorphic rock (XPL, x2.5); D) ferruginous rounded nodules (PPL, x2.5)

& Ramos, 2012). A radiocarbon date from the middle-upper portion of this unit (at 2.0 m core depth) yielded an age of 1934±46 cal BP;

– **Unit E:** this unit is represented by carbonate-cemented fossil deposit (10YR 8/2). The fossil content mainly consists of bivalves, gasteropods especially *Cardium edule* (Linnaus, 1758) (fig 5a, b, c, d). The study of thin section shows the presence of microfossils as ostracods valves, foraminifera, red algae surrounded by calcite cement (micrite). The fossiliferous content attributes this calcrete to *Panchina Tirreniana Auct.* (Affricano, 1962); this deposit is also outcropping 150 meters southwest of the Sant'Imbenia village;

– **Unit F:** it represents the top of Holocene stratigraphic record in S3 core, underlying the present soil. This unit, above unit E, is characterized by brown (7.5YR 5/6) massive and poorly sorted sediments with sandy clay loam texture and rare sub-angular pebbles. The sediments (1.30 m of thickness) lack sedimentary structures and do not contain fauna or plant remains. According to the sedimentological features, this unit can be interpreted as a colluvial deposit produced by raindrop impact leading to displacement of material.

Stratigraphic Section in Sant' Imbenia village

The inner-village stratigraphic section (1.0m depth) is characterized, at the bottom, by a massive level (60 cm thick) of sandy sediments (10YR 5/3) in a silty clay matrix, which does not contain biogenic component. On this level Early Iron Age structures lie. They are covered by massive sandy silty sediments (10YR 7/2), 40 cm thick, with sherd and coal fragments, pottery remains, scarce gastropods fragments (*Planorbis corneous* specie) and rare sponge spicules. The distinctive sedimentological features (colour, grain size composition, the scarce presence of reworked shell fragments) indicate for these levels a fully terrestrial genesis, of colluvial and aeolian nature. These sediments are similar to deposit of Unit F in S3 core.

DISCUSSION

The combined study of sedimentological, bio-stratigraphic data together with the micromorphological analysis obtained from the 3 cores allowed reconstructing the paleoenvironment of the Sant'Imbenia area during Late Holocene. Stratigraphic records showed a weak interplay between littoral and continental processes in controlling

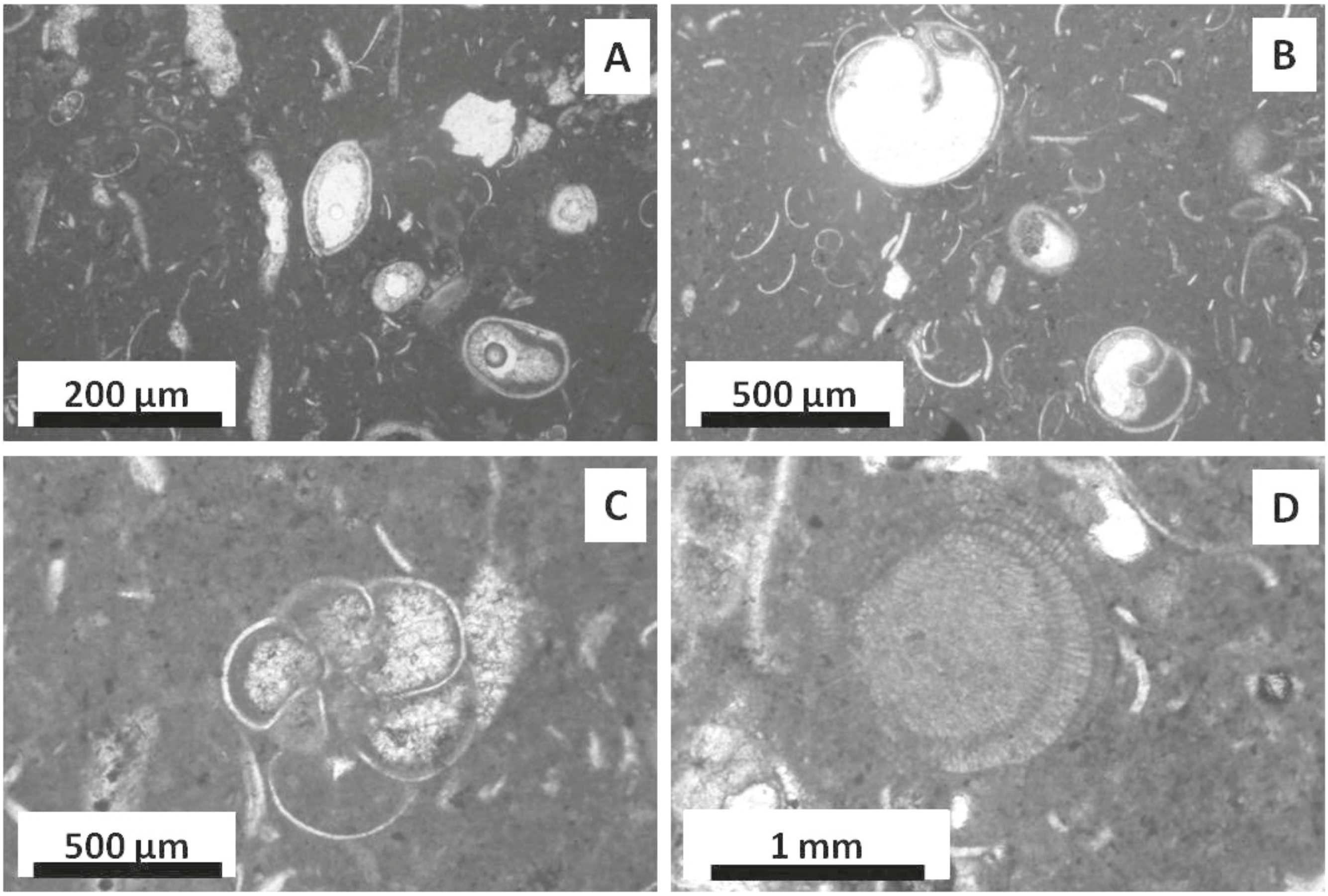

FIG. 5 - Thin section of «Panchina Tirreniana Auct.» (Unit F, S3): a) ostracods (PPL, x2.5); b) gastropods and valves of ostracods (PPL, x2.5); c) foraminifera (PPL, x10); d) red algae (PPL, x10)

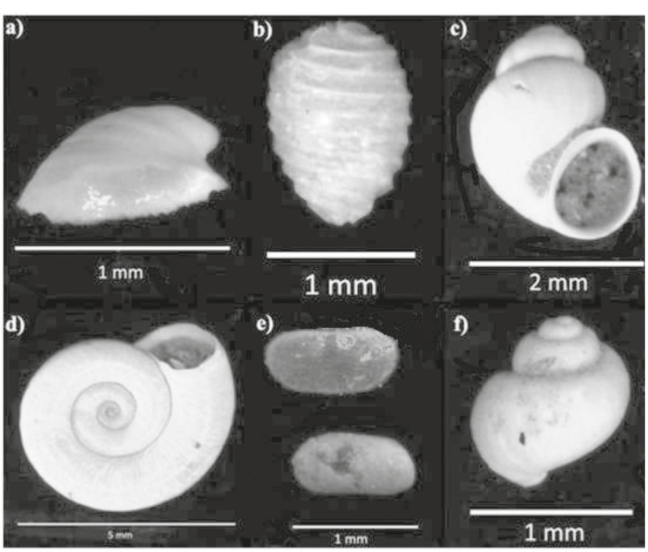

FIG. 4 - Identified species (fossils): a) Propilidium Exiguum, b) Porochara Sardiniae, c) Hydrobia Sp., d) Planorbis Corneus, e) Darwinula Stevensoni, f) Psaudammnicola Sp.

the environmental evolution of the area. Notably, we observed the clear transition from continental facies to coastal transitional facies, highlighted by overlapping of Unit D on Unit C in S1 and S2 cores. The faunal content found in dark grey silty clays of Unit D, characterized by the common presence of brackish (*Hydrobia sp., Abra alba*) and freshwater (*Planorbis corneus* and *Psaudamnicola sp.*) fossils, with scarce species of littoral environment (*Gibbula sp., Tricolia sp., Propilidium exiguum*), testifies a brackish depositional environment. According radiocarbon date, ca. 2.0 cal kyr BP the area next to Sant' Imbenia village (further southwest) was characterized by brackish wetland (lagoon or marsh) of unknown extension. This environment was probably present even during Bronze/Iron Age, as shown by an excavation section carried out in the outer perimeter of the Nuraghe, that highlighted a clayey deposit deep up to 4 meters, dated 4155±130 kyr BP (Federici & *alii*, 1999), underlying the support surface of the building. There are no sedimentological evidences demonstrating that the sea or the nearby brackish wetland have affected somehow the village during the Bronze - Early Iron Age, as evidenced by the sandy silty sediments that cover some of the village structures and constitute its foundation, probably derived by colluvial or aeolic processes. However, the lack of radiocarbon dating of the unit D bottom and further stratigraphic analysis does not allow us to objectively confirm the age and determine the extension of this brackish environment. We can exclude the presence of the brackish lagoon or marsh, about 40 meters away to the northwest of the Sant' Imbenia village, as shown in the stratigraphic record core S3, characterized at the bottom by a red paleosol (unit B), covered by colluvial deposits affected by pedogenic processes (unit C), followed by "*Panchina Tirreniana, Auct.*" (unit E), in turn, underlying deposit of continental environment (unit F). Unit E, measured at an altitude of about 2-3 meters above the current sea level and outcropping 150 meters southwest of the site, indicates that the maximum marine ingression in the area was recorded during MIS 5.5, reaching about 0.5 km inland from the modern shoreline. Moreover, the presence in all the investigated area of a paleosol (unit B) developed on residual deposits overlying limestone bedrock, indicating past climatic conditions related to a long warm period with strong seasonal contrasts (wet and dry), previous to the Tyrrhenian tragression (MIS 5.5), according to the stratigraphic succession recorded in the cores.

CONCLUSIONS

The litho-stratigraphic framework provided by cores combined with stratigraphic section data from Sant'Imbenia site, allowed a first paleoenvironmental reconstruction of the area. The major outcomes of this work can be summarized as follows:

1) Brackish environment conditions were present to southwest of the Sant'Imbenia village, during Roman period. The lack of a chronological constraint of the bottom of Unit D does not allow us to confirm that coastal transitional environment was also present during the Bronze /Iron Age next to the Nuraghe, as results from previous studies;
2) There are no sedimentological evidence confirming that the Sant' Imbenia village has been affected directly by the sea or the nearby lagoon, as proved by the Iron Age structures built on substrate consisting of fine continental deposits, probably colluvial and aeolic nature. However, we cannot presently exclude that the lagoon was in the vicinity of the village during the Bronze Age. Further analyzes are then strongly requested in order to confirm this hypothesis;
3) The presence of "*Panchina Tirreniana*" about 50 meters away to the west of the Sant' Imbenia and the lack of the overlying lagoonal deposits suggest that the maximum marine ingression in the area was recorded during Tyrrhenian, reaching 0.5 km inland.

The results of this study show no natural causes responsible for the abandonment of the site after the Iron Age. Possible reasons should be sought in the strategic choices of the civilizations of the period.

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