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LUMINESCENCE DATING OF A MIDDLE LATE HOLOCENE LOWER SHOREFACE, SW SARDINIA (ITALY)

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ABSTRACT: Geochronological framework of Middle-Late Holocene coastal succession are usually based on radiocarbon dating method. Homolithic sandy bodies characterize lower shoreface deposits and shells are often the only readily available biogenic materials for radiocarbon dating. However, multiple processes of erosion and deposition frequently affect sediment-grains and biological materials. As a consequence, ^{14}C dating performed on shells often may under or overestimate the true age of the hosting deposits. This study highlights that luminescence dating is better suited to investigate sedimentary body formed in high energetic environments because directly dates the age of the final burial event. Moreover, combining the quartz and k-feldspar derived ages a more robust dataset and internal independent age controls can be provided.

KEYWORDS: SAR-OSL, pIRIR$_{150}$, geochronology, radiocarbon dating, “old shell” problem

1. INTRODUCTION

In the last decade Luminescence has become one of the most used method for dating siliciclastic-rich Quaternary deposits (Pascucci et al., 2014). Nevertheless, its application is usually limited to the Pleistocene while Radiocarbon method is chosen for dating Holocene successions (Pascucci et al., 2014; 2018). In particular, ^{14}C method is widely applied in shallow marine-coastal studies throughout the world but precise dating of lower shoreface deposits remains a major task. Shoreface deposits of wave-dominated system are characterized by homolithic sandy bodies transported basinward from the coastline by return flows induced by major storms. In this highly energetic environment, shells are usually the only readily available biogenic materials for radiocarbon dating. However, shells may suffer of multiple reworking processes prior the final burial event and thus ^{14}C may overestimates the ages of storm beds producing stratigraphic discrepancies. To overcome this problem an alternative or independent geochronological approach is needed.

Luminescence methods date the time elapsed since siliciclastic minerals (quartz and feldspar) were last exposed to day-light and thus directly provide the age of the final burial event (Madsen & Murray, 2009).

Aim of this work is therefore to provide a luminescence-based chronological framework for a Middle-Late Holocene shoreface succession and compare with published radiocarbon ages provided by Romano et al. (2017). Moreover, luminescence ages will be provided using three different protocols such as SAR-OSL on quartz mineral along with IR$_{50}$ and pIRIR$_{150}$ on k-feldspar grains (Madsen & Murray, 2009; Reimann T. & Tsukamoto 2012). Although these protocols share some common features, they also have their own specific traits and can be considered independent from each-other and thus used for age comparisons.

2. MATERIAL AND METHODS

Cala Domestica (SW Sardinia, Italy; Fig. 1) is a narrow 100 m wide and 450 m long bay carved in the Lower Cambrian Meta sandstone and dolostones. It is characterized by a well-developed sandy pocket beach backed by an active dunefield system (Fig. 1). The sediments nourishing the system are mainly bioclastic materials transported onshore from sea grass meadows during storms and minor siliciclastic grains carried by NW/SE longshore current and/or by the seasonal Riu Guttu stream (Fig.1). Samples for luminescence and shells for ^{14}C were collected from a 3-m long sediment core drilled in the shoreface (-13m below the present-day sea level). The sediment core was taken throughout opaque cylindrical plastic tube in order to avoid exposition of sediments to day-light and then opened under red subdued light. From the studied core two marine shells S1 and S5 were collected and the derived calibrated before present (BP) radiocarbon ages are already published by Romano et al. (2017).

A total of six luminescence samples were collected on the same core (Fig.2). In particular ISO0 at the very top, ISO1 and ISO5 at the same position of the shells collected for ^{14}C and the remnant samples (ISO2, ISO3, ISO4) every ~50 cm. All samples underwent chemical treatment at the Sassari Luminescence laboratory to isolate the 180-90 φm pure fraction of quartz and k-feldspar grains. Single Aliquot Regenerative protocol (SAR) for quartz and Infra-red stimulation at 50 °C (IR$_{50}$) along with post Infra-red, Infra-red stimulation at low

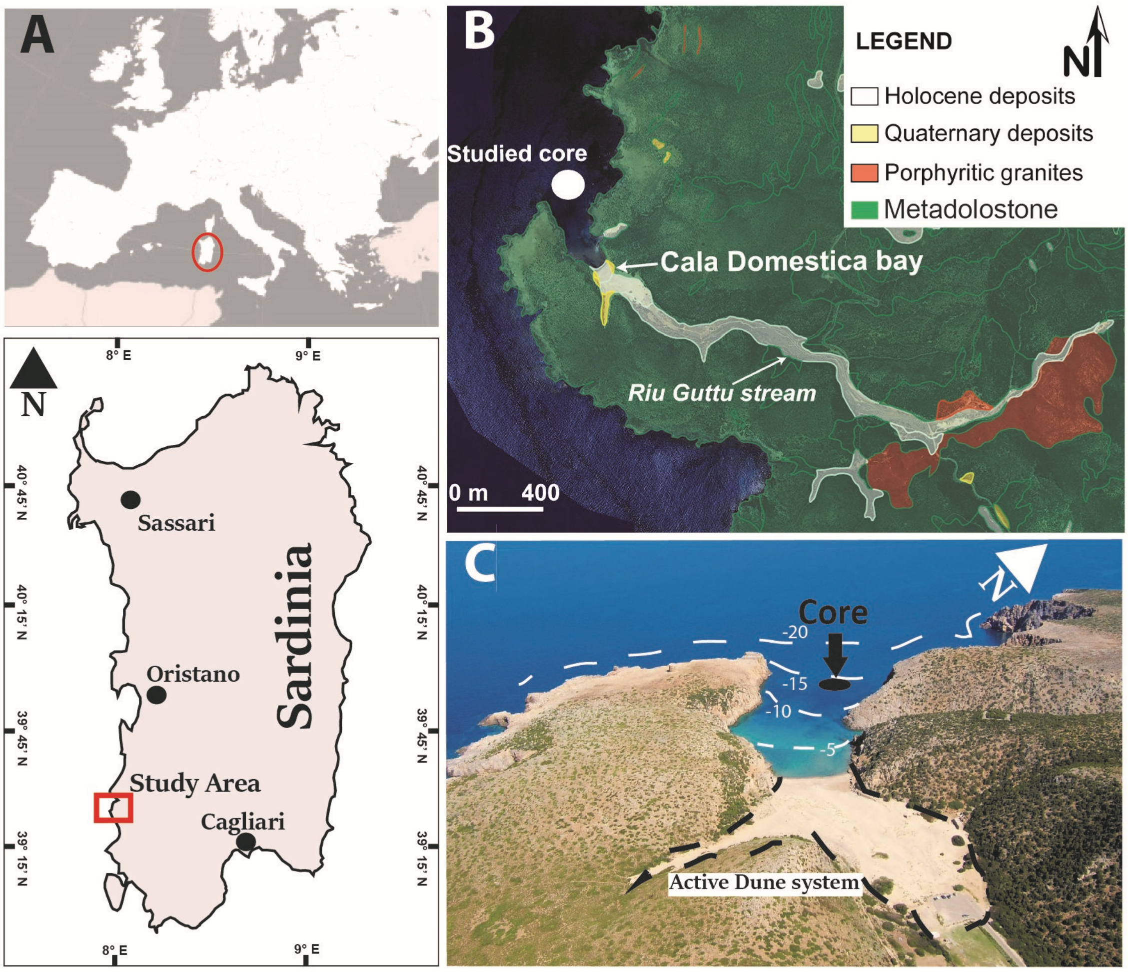

Fig.1 - A) The studied area. A) Location of Sardinia Island in the Mediterranean region where it occupies a central position. The map of Sardinia, reported the main cities (black circles). The red square highlight the position of studied area in the SW of island. B) Main bed-rock lithologies outcropping around the study area. C) Satellite view of Cala Domestica bay with drilling station.

		Quartz		Feldspar					Age		
		SAR		IR$_{50}$		pIRIR$_{150}$			SAR	IR$_{50}$	pIRIR$_{150}$
Sample Code	Depth (cm)*	De (Gy)	Dr tot (Gy/ka)	De (Gy)	g_{2days} (%/dec)	De (Gy)	g_{2days} (%/dec)	Dr tot (Gy/ka)	(a)	(a)	(a)
ISO0	0	0.00	-		4.01	0.25±0.1	0.74	-	-	-	
ISO1	43	1.09±0.04	2.03±0.07	0.8±0.03	3.98	1.17±0.1	0.74	2.55±0.08	540±50	403±12	433±41
ISO2	115	4.37±0.12	2.13±0.08	3.58±0.1	3.82	4.95±0.1	1.03	2.64±0.08	2050±70	1910±61	2005±63
ISO3	155	5.47±0.2	1.90±0.07	4.25±0.1	3.8	5.92±0.1	1.00	2.42±0.07	2880±150	2462±61	2600±84
ISO4	195	6.94±0.13	1.81±0.07	5.37±0.1	3.8	7.56±0.1	1.03	2.32±0.07	3840±160	3247±74	3496±106
ISO5	245	7.47±0.29	1.56±0.06	6.11±0.1	3.8	8.58±0.1	0.78	2.08±0.06	4800±300	4217±87	4347±133

Tab.1 - Summary of quartz luminescence dating results. Table reports sample code and depth of sampling. For each mineral dosimeter chosen for luminescence dating, the luminescence protocol/signal used are reported with the estimated burial Palaeodose (De, Gy), environmental Dose Rate (Dr, Gy/ka) and calculated final burial ages expressed in years (a) from present (AD 2017).

temperature 150 °C protocols (pIRIR$_{150}$) on k-feldspars were applied for luminescence burial palaeodose (De) measurements (Madsen & Murray, 2009; Reimann T. & Tsukamoto, 2012). Enviromental Dose rate (Dr) calculations corrected for cosmic rays and water content contributions are based on high resolution gamma spectrometer.

3. RESULTS

Table 1 reports luminescence dataset for the collected samples (Fig. 2). Quartz and k-feldspar signals pass all laboratory tests. These provide very good results for the three main reliability check-criteria: recycling, recuperation and dose recovery. Quartz (OSL-SAR) and feldspar (IR$_{50}$, pIRIR$_{150}$) signals gave in average recycling ratios within the 10 % of unity and recuperation less than 5% of natural De. Dose recovery ratios are all close unity, 1 ±0.02 (SAR-OSL), 1.00±0.01 (IR$_{50}$) and 0.96 ±0.02 (pIRIR$_{150}$). These data confirm the suitability of protocols and dosimeters chosen for dating the sediment of Cala Domestica. Given that k-feldspar suffers of fading (partial loss of signal recovered throughout the time) the g-value (% of loss per decade) was tested. The IR$_{50}$ and pIRIR$_{150}$ show an average fading ratio respectively of 3.86 and 0.89 %/dec. and thus used for correcting final feldspar ages. Quartz SAR -OSL yield ages ranging from the bottom up of 4800±300 to 540±50 a. Feldspar IR$_{50}$ and pIRIR$_{150}$ show ages respectively from 4217±87 and 4347±133 a to 403±12 and 433±41 a (Tab.1).

3. DISCUSSION AND CONCLUSION

Three meters of Holocene core collected on shallow marine (lower shoreface) deposits, far off Cala Domestica bay, is dated using Luminescence and ^{14}C methods. This study sheds a light on strenghths and weaknesses of these two approaches.

Figure 2 compares the three sets of luminescence dating (SAR, IR$_{50}$ and pIRIR$_{150}$) with the radiocarbon ages. Estimated Luminescence ages using the two mineral dosimeter (quartz and feldspar) and different luminescence signals are in stratigraphic order downward the core. The reliability of estimated palaeodose and ages is supported by the pretest results. The uppermost sample (ISO0) yield null or small residual palaeodose for the three protocols applied. This suggests that all different luminescence signals are being well zeroed by day-light at depth of 13 m. Moreover, consistency and increasing of the ages downward confirm that mineral dosimeters well recover the palaeodose (burial time) elapsed from the last exposition and allow to exclude the presence of partial bleached inherit signal issue (incomplete zeroing). Although, SAR-OSL ages slightly overestimate the IR$_{50}$ and pIRIR$_{150}$ ones, these agree each-other within 1 sigma uncertainties. In particular, k-feldspar-derived ages obtained for ISO5 (bottom of core) confirm the ^{14}C age of 4435-4290 Cal BP (Romano et al., 2017). The fading rates obtained for pIRIR$_{150}$ are significantly lower than those form IR$_{50}$ (Tab.1) suggesting the better stability of pIRIR$_{150}$ signal over time and the potential of the protocol for dating

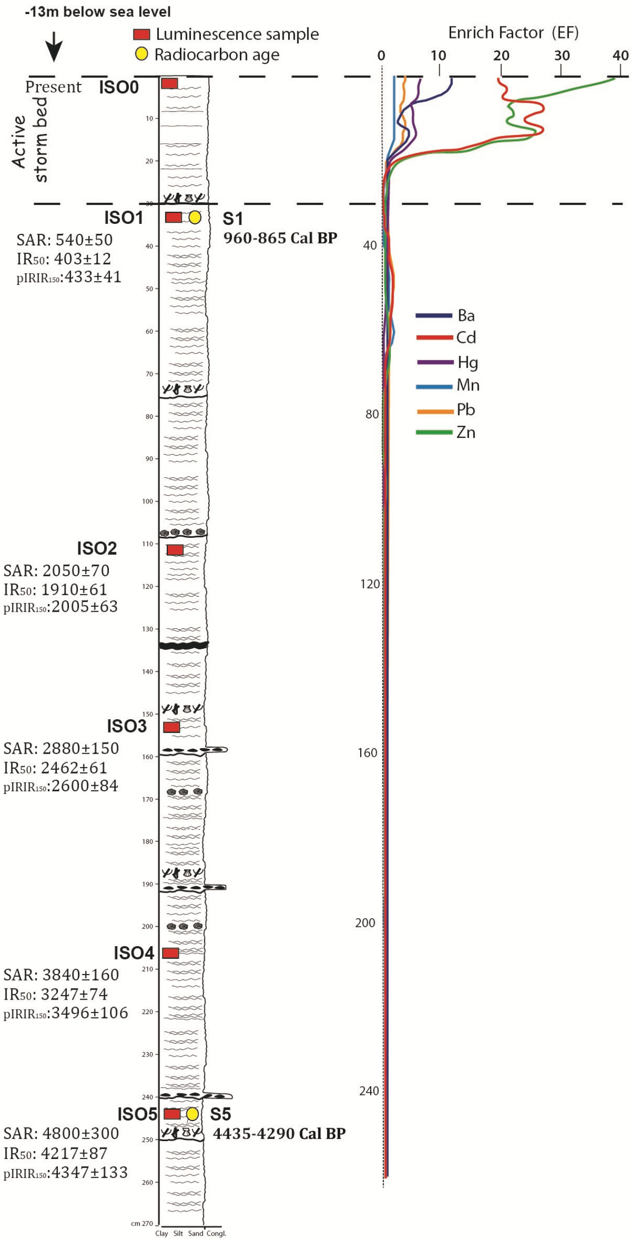

Fig. 2 - On the right the stratigraphic reconstruction of drilled core and position of radiocarbon and luminescence samples collected. The radiocarbon ages (Romano et al., 2017) are reported against the estimated SAR, IR50 pIRIR150 luminescence ages. On the left, the plot of geochemical Enrichment Factor (EF) along the core depth published by Romano (2017). Only element anthropogenically enriched (EF>1.5) are reported.

recent to very recent sedimentary bodies.

The ISO1 sample shows luminescence ages consistently younger than 960-860 Cal BP ^{14}C (Fig. 2). This ca. 500 a discrepancy between luminescence and ^{14}C ages most likely is due to the multiple reworking processes that shells and sediment-grains suffering in the shoreface environment. In particular, shells may be temporarily stored in the foreshore part of the beach system prior to be finally buried in the lower shoreface as a consequence of major storms.

The anthropogenically enriched elements (Hg, Pb and Zn) measured along the studied core by Romano et al. (2017) show a strong enrichment in the first 20 cm of the core clearly referable to the recent mine activity (Fig. 2). Whereas based on the ^{14}C available age a small peak observed at ca. 60 cm were associated as well with ore exploitations in pre-industrial times but with no possibility to refer this activity to the Phoenician, Romans, Pisans or Middle Ages. However, luminescence ages point the first peak to a post-Romans ore exploitations better constraining the mining activity at the study area.

The carried out study highlights that in highly energetic environments such as lower shoreface multiple reworking processes frequently affect sediment-grains and biological materials. As a consequence of this, ^{14}C dating performed on shells might under or overestimate the final burial age of the host deposits. Therefore, luminescence dating is better suited to investigate homolithic sedimentary body because it directly dates the mineral grains sun-exposition, transport and accumulation history. Moreover, using different luminescence signals and dosimeters allow to have a better knowledgement of sedimentary depositional history and internal independent age controls.

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