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Post-IR IRSL$_{290}$ dating of K-feldspar in a wind-dominated system on Sardinia

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ABSTRACT

The reliability of a post-IR elevated temperature IRSL (290°C; pIRIR290) is tested on wind-blown, sand-sized (180-250 µm) K-rich feldspar grains. The pIRIR$_{290}$ dates were compared with quartz SAR-OSL data, other independent age controls and historical information.
Three study areas along the coast of Sardinia (Italy) were selected: The Bue Marino cave (NE Sardinia), south Alghero coast and the Alghero bay (NW Sardinia).
The sedimentary succession at Bue Marino cave includes a sandy wind-blown unit sandwiched between two calcareous crusts. U-series dates of these crusts constrain the aeolianite formation between ~125 and ~65 ka. Quartz SAR-OSL samples were saturated (> 2xD$_0$) instead, fading-uncorrected pIRIR$_{290}$ ages on K-feldspar extracts point to a formation between ~100 and ~80 ka, in good agreement with the U-series data.
Along the south Alghero coast a thick dunefield system is widely recognised in the literature to represent the beginning of the last glacial phase (*post* 80 ka). From a single block sand-sized grains for quartz SAR-OSL and K-feldspars post-IR IRSL-OSL purposes were collected. Quartz SAR-OSL sample lies below the saturation limit (< 2xD$_0$) giving a reliable age of 76 ± 6 ka. The fading-uncorrected post-IR IRSL$_{290}$ age of 73 ± 5 ka is in good agreement with the quartz result.
Samples from a modern coastal cordon system backing Alghero bay was collected for quartz SAR-OSL and K-feldspars post-IR IRSL-OSL purposes. This dunefield was stabilized by plantation during the 1950s. The quartz SAR-OSL ages span from 2500±150 years to 60±20 years ago, consistent with the known cordon stabilization. The pIRIR$_{290}$ ages indicate an age offset of ~1500 years.
We can conclude that the pIRIR$_{290}$ method on sand-sized K-feldspar grains shows great promise for samples at or beyond the quartz OSL age limit but should not be applied to Late Holocene or modern deposits.

Key words: late Quaternary, Aeolian deposits, OSL

1. INTRODUCTION

Since the discovery of optical dating on quartz ((Huntley et al., 1985) and feldspar (Hutt et al., 1988) there have been many methodological developments. Especially the development of the Single Aliquot Regenerative-dose (SAR) protocol for quartz (Murray & Wintle, 2000), has improved the reliability of quartz optical dating and since then it has been extensively used to established chronological framework for Quaternary sedimentary successions of both shallow-marine and continental

environments (e.g. Spencer and Robinson, 2008; Jacobs, 2008; Lancaster, 2008; Galli et al., 2009; Andreucci et al., 2010; Thiel et al., 2011; Pascucci et al., 2014; Lamothe 2016).
The range of quartz OSL dating is usually limited to by the saturation of the quartz OSL dose response curve which typically occurs at ~200 Gy Wintle and Murray (2006) suggested an upper dating limit for the quartz OSL (fast component dominated samples) to ~2D0 (i.e. 86% of the saturation level of the dose response curve). For samples with doses beyond 2D0 the reliability is not yet proven and results should be interpreted with caution. There are published examples that quartz SAR-OSL dating method underestimates the age of older deposits (e.g. Buylaert et al., 2007; Lowick et al., 2010).
Feldspar signals are attractive because their dose response curves saturate at much higher dose than quartz OSL- However, feldspar infrared stimulated luminescence (IRSL) signals measured at ambient temperatures are affected by anomalous fading (Spooner, 1994) which causes age underestimations unless an adequate correction is made (Huntley and Lamothe, 2001). However, it is claimed in Huntley and Lamothe (2001) that it should not be applied to samples older than 20-50 ka. Furthermore, fading corrections are based on untestable assumptions (Morthekai et al., 2008). Recently, research effort was made to identify a feldspar signal which shows less fading (Thomsen et al., 2008) and to develop a feldspar dating protocol with a reduced or negligible fading correction. (e.g. post-IR IRSL protocols in Buylaert et al., 2009, 2012; Thiel et al., 2011). In this paper we adopt the post-IR IR_{290} protocol put forward by Thiel et al. (2011) and tested extensively in Buylaert et al. (2012) to further test this method on samples from Sardinia with aeolian and thus well-bleached sediment. The post-IR IR290 results are compared with independent age control (U-Th ages), quartz SAR-OSL ages and historical information.

2. REGIONAL SETTING AND STRATIGRAPHY

The Island of Sardinia is located in the north-western Mediterranean Sea (Fig. 1), emplaced by eastward rotation of the European plate during the Oligocene-early Miocene (Carmignani et al., 2001). In association with this rotation normal and transcurrent faults dissected Sardinian pre-Miocene deposits and allowed the formation of a series of half graben that were filled with Miocene continental and marine deposits and calc-alkaline volcanic bodies (Casula et al., 2001). During the early Pliocene widespread volcanism and basin uplift occurred, but north-west Sardinia is considered to have remained tectonically stable since the Late Pliocene (Lambeck et al., 2004; Ferranti et al., 2006).
The Quaternary deposits crops out quasi-continuously along the study areas and are characterized by an alternation of shallow marine and aeolian/colluvial strata spanning in time from Marine Isotopic Stage (MIS 8; ca 275 ka) to MIS 1 (ca 5 ka; Andreucci et al., 2010; 2011; Pascucci et al., 2014).

2.1 STUDY AREA

Three study areas have been selected along the Sardinian coasts: The Bue Marino cave (Orosei Gulf; NE Sardinia), south Alghero coast and the Alghero bay (NW Sardinia; Fig. 1A).
The area of Bue Marino cave is characterized by relatively high (50–400 m) and steep carbonate sea-cliffs variable affected by karst phenomena (Fig. 1B). The Bue Marino is coastal cave carved on Jurassic limestone and almost completely filled by wind-blown sediment. The sedimentary succession is sandwiched between calcareous crusts (Carobene and Pasini, 1980).
The south Alghero coast is characterized by small low-cliff-bounded embayments with basal marine terraces backed by 40 m high hills oriented almost parallel to the present-day coastline (Fig. 1C). The sedimentary succession which rests on the bedrock, is characterized by an alternation of thin (3 m-thick) shallow-marine strata and thick (20 m-thick) aeolianites. The bedrock is composed of mainly

Triassic limestone, Oligo-Miocene andesitic pyroclastic deposits and minor Permian, red, sandy to gravelly bodies (Pascucci et al., 2014).

The Alghero Gulf is sea-ward open on the West and laterally bordered by Mesozoic cliffs. The embayment is dominated by 5 km long sandy beach-ridge system backing a N-S oriented lagoon system named Calick (Fig. 1D; Ginesu et al 2001; Zucca et al., 2014). The dune cordon cropping out on the study area has a maximum thickness of 10 metres and was human stabilized by plantation during the 1950s.

3. METHODS

A total of nine samples from the three study areas have been collected for luminescence analyses (Tables 1). Moreover, two samples from the calcareous crusts cropping out at the Bue Marine cave were collected for U-series measurements.

3.1 LUMINESCENCE ANALYSES

Samples were prepared under red light conditions at the University of Sassari (Italy) to extract quartz and K-rich feldspar grains in the size range between 180-250 µm, following the standard procedure (Stokes, 1992), and were analysed at the Nordic Laboratory for Luminescence Dating (Institute for Geoscience, Aarhus University, Risø DTU, Denmark).

All OSL measurements were conducted on an automated Risø TL/OSL model DA-20 (Bøtter-Jensen et al., 20. Quartz was stimulated using blue LEDs (470 nm) and the luminescence detected through a U-340 filter. Feldspar IRSL was stimulated using IR LEDS (875 nm) and detection was through the standard blue filter pack (Schott BG-39 + Corning 7-59). For the quartz measurements large (8mm) aliquots were used. Because of the bright luminescence signals, feldspar measurements were made on small (2 mm) aliquots. OSL signal from quartz in this region is known to be dominated by a fast component (Andreucci et al., 2010; Thiel et al. 2010).

Initial checks using infra-red stimulated luminescence were conducted on quartz materials to test for residual feldspar contamination (Smith et al., 1990). These checks proved negative, so a blue-light stimulation simple SAR protocol was used for quartz equivalent dose (D_e) measurements (Murray & Wintle, 2000). OSL measurements (80 s) were made at 125°C, after pre-heating aliquots for 10 s at 260°C for samples from the Bue Marino cave and South Alghero coast. The pre-heat value was experimentally derived on the basis of the results of a dose recovery pre-heat plateau test. A cut-heat of 220°C was applied to each aliquot before the test dose measurement and a high temperature blue-light clean-out for 40 at 280°C after every SAR cycle. Samples from the modern dune of Alghero bay underwent, instead, to a lower pre-heat (180°C) and cut-heat (160°C) temperatures for the same amount of time to avoid a thermal transfer (Madsen and Murray, 2009). Five regeneration points were measured during the SAR procedure, including a recycling point, which was used to determine the effectiveness of the sensitivity corrections. A dose recovery was carried out for some samples of the different study areas. The initial ~2 s of the luminescence signal, less a background derived from the 4 – 8 s, was used for all calculations.

SAR post infrared stimulation (post-IR IRSL) at elevate temperature (290°C) protocol (Thiel et al., 2011; Buylaert et al., 2012) was applied to K-rich feldspar grains in order to evaluate the D_e of the same sample measured with quartz SAR-OSL method. After a preheat at 320°C for 60 sec, the samples were bleached with IR diodes at first at 50°C for 200 s and then again at 290°C for 200 s to measure the post-IR IR_{290} signal. The same preheat conditions were used for natural, regenerative and test dose measurements. An IR illumination at 325°C for 200 s was inserted at the end of each SAR measurement cycle. Fading measurements (*g* value, Aitken, 1985) were carried out using the same SAR protocol used for D_e determinations. The g values were normalised to a tc = 2 days (Huntley and Lamothe, 2001).The initial ~2 s of the luminescence signal, less a background derived from the last ~10 s, was used for all calculations. A dose recovery test was also undertaken by adding a dose on top of a very young sample.

For each sample, approx. 200 gr of sediment were collected to estimate the water content and to calculate the natural radioactivity (dose rate, Dr, Table 1A).
Dose rate calculations are based on high-resolution gamma spectrometry following the methodology described by Murray et al. (1987) to give natural radionuclide concentrations, and knowledge of burial depth to give cosmic ray contribution (Prescott and Hutton, 1994). The required corrections on the Dr value for cementation (lithified samples) were taken into account and calculated following Andreucci et al. (2009). The lifetime average water content since deposition is assumed to lay between present-day and saturated values and has been estimated for each sample based on sedimentological and hydrogeological conditions. K-feldspar grains have an internal radioactivity due to the presence of structural ^{40}K in the crystal structure. Hence, for the K-feldspars dose rates a contribution to the final dose rate from ^{40}K was incorporated based on the assumption that the internal K content is 12.5±0.5 % (Huntley and Baril, 1997).

3.2 U-SERIES METHOD

U/Th extraction from two calcareous crusts (flowstone) were carried out at the U-series Laboratory of the University of Bergen (Norway) using a actinide-specific, phosphate/phosphine based (Eichrom TRU) liquid ion exchanger mini-columns, supported on an inert substrate (Amberlite XAD-7) (Hellstrom, 2003; Peterson et al., 2007; Yang, 2009). Isotopic measurements were performed on a Nu Plasma HR multicollector ICP-MS with a U-Pb collector block at the Department of Geology, University of Oslo. Analyses were done in dry plasma using a DSN-100 desolvating nebuliser with a sample uptake rate of 0.1 mL/min. The mixed U and Th solution was analysed in two separate procedures. First, uranium isotopes with mass 236, 235 and 234 were determined in ion counters and thorium with mass 232 in a Faraday cup. The second procedure measures thorium mass 229 and 230 in an ion counter. Tailing from 238 and 232 was corrected by measuring half masses and using an exponential interpolation. Fractionation of the instrument has been determined on a daily basis by analysing mass 235 and 238 of a natural uranium solution in Faraday cups using 238/235 = 137.88. The reproducibility of each measured was 0.11% (2σ). Repeated analyses of BR5 (a high uranium speleothem powder standard) gave an age of 125.862 ± 1.546 kyr (n = 12), with a reproducibility of measured 234U/238U ratio of 0.59% (2σ). Age determinations were based on measured atomic mass ratios of 235U/236U, 235U/234U, 236U/234U, 232Th/229Th; and 229Th/230Th. Data reduction, error optimization and propagation were done using tailored software (Lauritzen and Lundberg, 1997) which has been rewritten for the Windows environment. The presence of the non-authigenic 230Th in the carbonate samples as indicated by the low 230Th/232Th < 20, requires a correction for detrital 230Th contamination. This correction was performed directly by the software, using initial 234U/238U calculated from 2230Th/234U ratio (Table 3).

4. RESULTS

4.1 Study area 1: Bue Marino cave

At Bue Marino, one opaque PVC tube (D = 8 cm; L = 40 cm) of freshly exposed reddish colluvial strata (BUE1) and three sample blocks (ca 50 x 50 x 40 cm) of aeolianites (BUE2, BUE4, BUE5) were collected (Figs 2; Table 1). Samples were collected along a an artificial scarp composed of a basal sandy unit (8.5 m-thick) capped by a 50 cm-thick reddish colluvial strata (Figs 2). The succession is bounded at the base and at the top by 50 cm-thick calcareous crusts.

Aeolianites are characterized by medium to coarse-grained carbonate-rich sandstone made up of: 70-82% $CaCO_3$, 16-28% siliciclastics, 1% fines and 1% organics. Instead, colluvial strata is composed of a matrix-supported sandy to pebbly deposit made up of: 31% $CaCO_3$, 13% siliciclastics, 55% fines and 1% organics.

Quartz equivalent dose (D_e) values lay between 165 and 141 Gy without any significant decrease from the base to the top of the succession. A dose recovery test on sample BUE4 gives a satisfactory dose ratio of 0.99±0.05 (n=12).The quartz dose rates range from 2.21 to 3.05 Gy/ka which is consistent with the dose rates of palaeosols in the area but relatively high for Sardinian aeolinites (Andreucci et al., 2011). The quartz OSL signals for all samples are close to saturation (D_e>2D_0) so the dates between 70 and 50 ka probably give only minimum ages (Table 1).

Post-IR IR290 K-feldspar D_e values range between 281±10 and 320±9 Gy and the K-feldspar dose rates vary between 3.02 to 3.86 Gy/ka. A dose response curve of sample (BUE2, De = 315±6 Gy, n=6) shows that the natural feldspar signal lies far below the saturation level of the curve (Fig. 2D). The dose recovery tests for K-feldspar pIRIR290 dating was carried out by adding a large beta dose (49 Gy) on top of a modern K-feldspar sample (MP7; study area 3, see following section) and subtracting the natural De (2.3±0.2 Gy) from the measured dose. The dose recovery ratio is 0.97±0.08 (n=16) confirming the suitability of this protocol for measuring dose. Fading measurements were carried out on three aliquots from each sample after measuring the D_e values. The mean pIRIR290 g_{2days} value is 1.50±0.10 %/decade (n=12). Buylaert et al. (2012) suggest that these fading rates may be artefacts of our measurement procedure and that the evidence that these apparent fading rates reflect loss of charge during storage is not convincing. Therefore, the ages have not been corrected for fading.

The uncorrected $pIRIR_{290}$ ages range from the base to the top: 104 ± 12 ka, 81 ± 9 ka, 83 ± 9 ka and 83 ± 9 ka. U-series dates of the floatstone that are bounding the sedimentary succession give ages of 100 ka at the base and 80 ka at the top which is in good agreement with the pIRIR290 ages.

4.2 Study area 2: South Alghero coast

One sample block (ca 50 x 50 x 40 cm) of aeolianite (AHO16) was collected (Figs 3; Table 2). Sample was collected at the base of a 20 m-thick lithified transgressive dune body. Sampled block is characterized by medium to coarse-grained carbonate-rich sandstone made up of: 90% $CaCO_3$, 8% siliciclastics, 1% fines and 1% organics.

Quartz D_e value is 67 ± 4 Gy and the quartz dose rate is 0.88 ± 0.04 Gy/ka; both values are typical for Sardinian aeolianites (Andreucci et al., 2009, 2011). The studied sample shows good OSL characteristics (fast component, recycling values close to unity (1.12 ± 0.14 n = 12; dose recovery (1.02±0.04, n =18). Because of the low dose rate the quartz OSL signal lays below the saturation limit (69 % of saturation) and AHO16 has a reliable age of 76±6 ka.

K-feldspars D_e value is of 124± 4 Gy and the Dr of 1.69 ± 0.07 Gy/ka. The K-feldspar sample has a fading-uncorrected age of 73 ± 5 ka.

4.3 Study area 3: Alghero bay

Four opaque PVC tubes (D = 8 cm; L = 40 cm) of freshly exposed modern coastal deposits (MP4, MP5, MP6, MP7) were collected (Figs 4; Table 3).
Three samples (MP5, MP6, MP7) were collected on a natural 5 m-thick scarp along the stabilized coastal cordon, one (MP4), instead on the modern backshore, in front of an active blow out (Fig. 4A).
Samples are characterized by medium to coarse-grained carbonate-rich sandstone made up of: 55-75% $CaCO_3$, 33-43% siliciclastics, 1% fines and 1% organics.
Quartz D_e values (MP7: 1.69±0.06 Gy, MP6: 1.22±0.07 Gy, MP5: 0.04±0.01 Gy, MP4: 0.006±0.01 Gy) decrease significantly from the base to the top of the succession, as expected. The Dr values of all samples are around 0.07±0.01 Gy/ka as expected for beach-dune deposits (ref?).
The studied sample shows good OSL characteristics such as recycling values within 1.0 ± 0.05 and dose recovery measurements on 9 aliquots were performed with a mean value of 1.03±0.08.
Samples collected on the natural scarp (MP5, MP6, MP7) from the base to the top have ages of 2450±150 yr, 1670±100 yr and 60±20 years respectively. The sample (MP4) from the modern backshore zone shows a zero age (9±14 years). The pIRIR290 age for sample MP7 is 1520±150 years which is clearly too old. The corresponding De value of 2.3±0.2 Gy (n=6) may represent the true unbleachable residual of the pIRIR290 signal or it may be the result of thermal transfer during preheating.

5. DISCUSSION

The results from the study area 1 (Bue Marino cave) clearly indicate that the quartz-OSL signal can be saturated already for a D_e of 141 Gy, corresponding to a minimum age of about 50 ka (Fig. 2C). Instead the pIRIR290 measurements on K-feldspar give uncorrected ages between ~100 and ~80 ka, in good agreement with the U-series data.
Along the south Alghero coast (study area 2) the thick lithified transgressive dune system is widely recognized in the literature to represent the beginning of the last glacial phase (*post* 80 ka; Andreucci et al., 2010; Pascucci et al., 2014 Figs 3). The coupled quartz-OSL and K-feldspar post-IR IRSL protocols on sediments coming from the same sampled block show interesting results. Firstly, the quartz OSL D_e (67±4 Gy) lays below the 2D0 saturation limit giving a reliable age of 76±6 ka, that is in perfect agreement with the previous study (Andreucci et al., 2010; 2011). The fading-uncorrected post-IR IRSL290 age of 73±5 ka confirms the quartz result.
Finally, the third study area (Alghero modern dune system), shows instead some limitations for the pIRIR290 measurements on K-feldspar grains when applied to very young samples. We report a age of 1520±150 a for a sample which is only 60±20 a old based on historical information and quartz OSL; the feldspar pIRIR290 D_e is 2.3±0.2 Gy; this is significant when dating young (Late Holocene, modern) samples but becomes very quickly unimportant for older samples. We suggest that, if possible, modern or very young samples with quartz OSL age control should always be collected during fieldwork to be able to place some lower limit to the residual pIRIR290 doses for investigated sediments.

6. CONCLUSIONS

This study has contributed to the further testing of the post-IR elevate temperature (290°C) IRSL protocol applied to coarse-grained K-feldspar for dating well-bleached sedimentary samples. We conclude that:

1. The dating technique shows great promise for dating coastal deposits in Sardinia that are at or beyond the quartz OSL dating limit (D_e> 85% of $2D_0$) as indicated by the agreement between the uncorrected post-IR IRSL results and the bracketing U-Th ages.
2. The $pIRIR_{290}$ protocol shows a significant age offset for young (Holocene) samples but becomes quickly insignificant as deposits get older.

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Captures to the figures

Fig. 1 – Location map of the studied areas. A) Satellite view of the Sardinia Island and inset map of the west Mediterranean region. B) Detailed view of the Bue Marino cave entrances (studied area 1). C)

Satellite view of the South Alghero rocky coast (Study area 2). D) Satellite view of the SE side of the Alghero bay and the modern coastal cordon (Study area 3), fragmented by several blow out, and stabilized by artificial plantation.

Fig. 2 – Study area 1: Bue Marino cave. A) Detailed view of the basal part of the aeolian deposits. Note that the sedimentary body drapes the cave flank encrusted by a calcareous crust (floatstone). The black square indicates the sample position for U/Th analysis and italic letters the relative age. The black circle the OSL sample position. Scale on the left side is a hammer (40 cm high). B) Detail view of central to top parts of the succession characterized, from bottom up, by aeolianites and thin colluvial strata. The succession is capped by a 50 cm-thick floatstone. The white square indicates the sample position for U/Th analysis and italic letters the age. The black circle the OSL sample positions. Scale on the right side is a sitting woman (1 m high). C) Schematic drawing showing the relationship between samples at the Bue Marino cave. The white square indicates the sample position for U/Th and italic letters the age. The black circle the OSL sample positions D) K-feldspar post-IR IRSL290 growth curve for sample BUE2 showing a recycling point (grey circle) and a recuperation point (white triangol). The insets shows the natural pIRIR290 decay curve. Note that sensitivity corrected natural signal (white circle) is well below the saturation limit.

Fig. 3 – Study area 2: south Alghero coast. A) Panoramic view of the 20-m thick transgressive dune body. Note that the aeolian deposits span in time from the Marine Isotopic Stage (MIS 4) to MIS 3. On the top of the hill a MIS 8 (250 ka) dunes crop out. The black circles indicate previous OSL date and italic letters the relative ages (modified from Andreucci et al., 2010). Scale on the left side is a white line. B) Detail view of the basal part of the dune body. The white square indicates the new OSL ages and italic letters the relative age. The white circles previous OSL samples and italic letters the relative ages. Scale on the left side is a black line.

Fig. 4 – Study area 3: Alghero bay. A) Panoramic view of the Alghero bay, sandy beach system and dune cordon human stabilized during the 50th. The white circle indicates OSL sample and italic letters the relative age B) Detail view of the basal part of the dune body. The white circle indicates the OSL sample position and italic letters the relative age. C) Detail view of the top part of the dune body. The white circles indicate the OSL sample positions and italic letters the relative ages.

Figure
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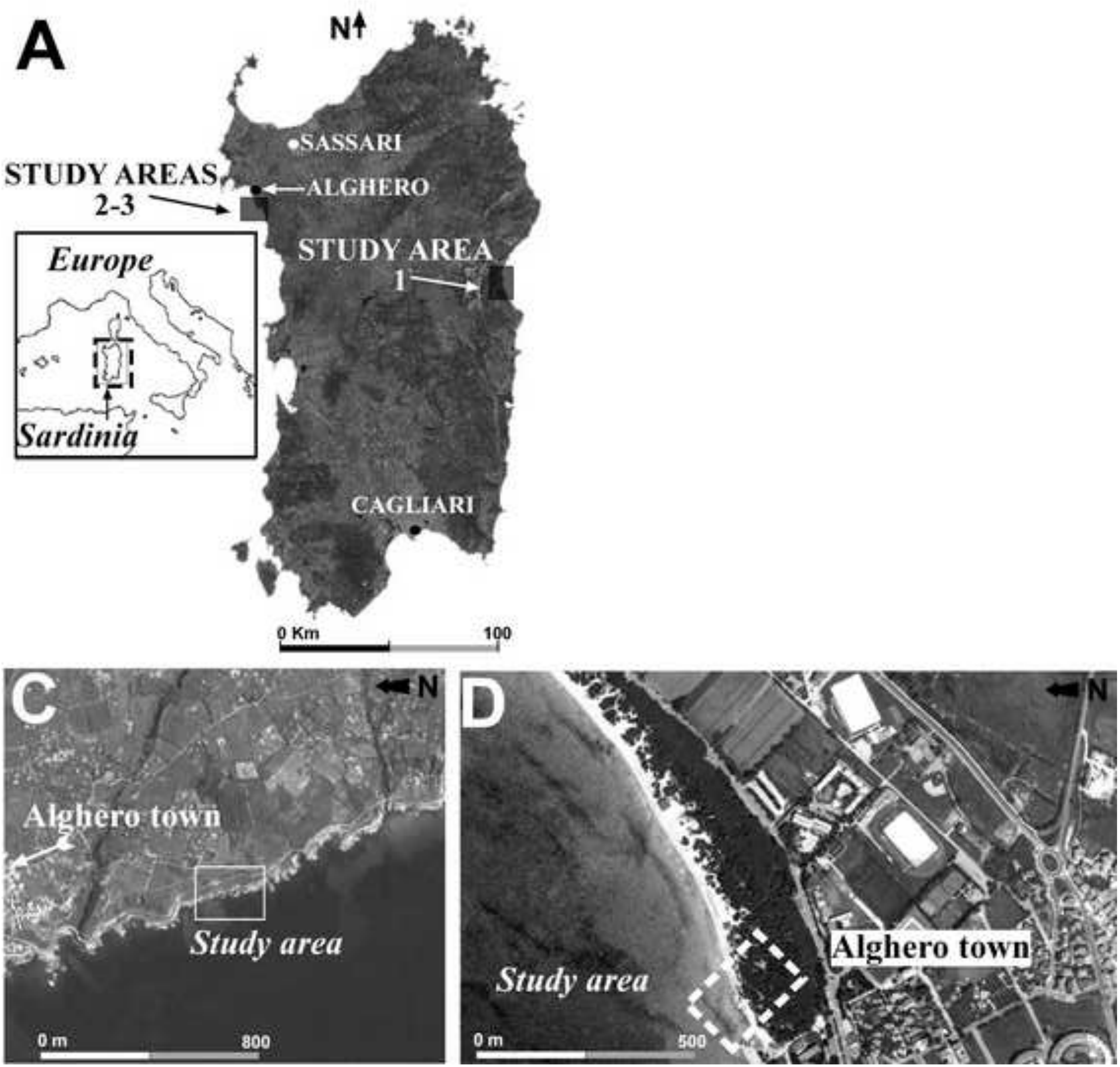

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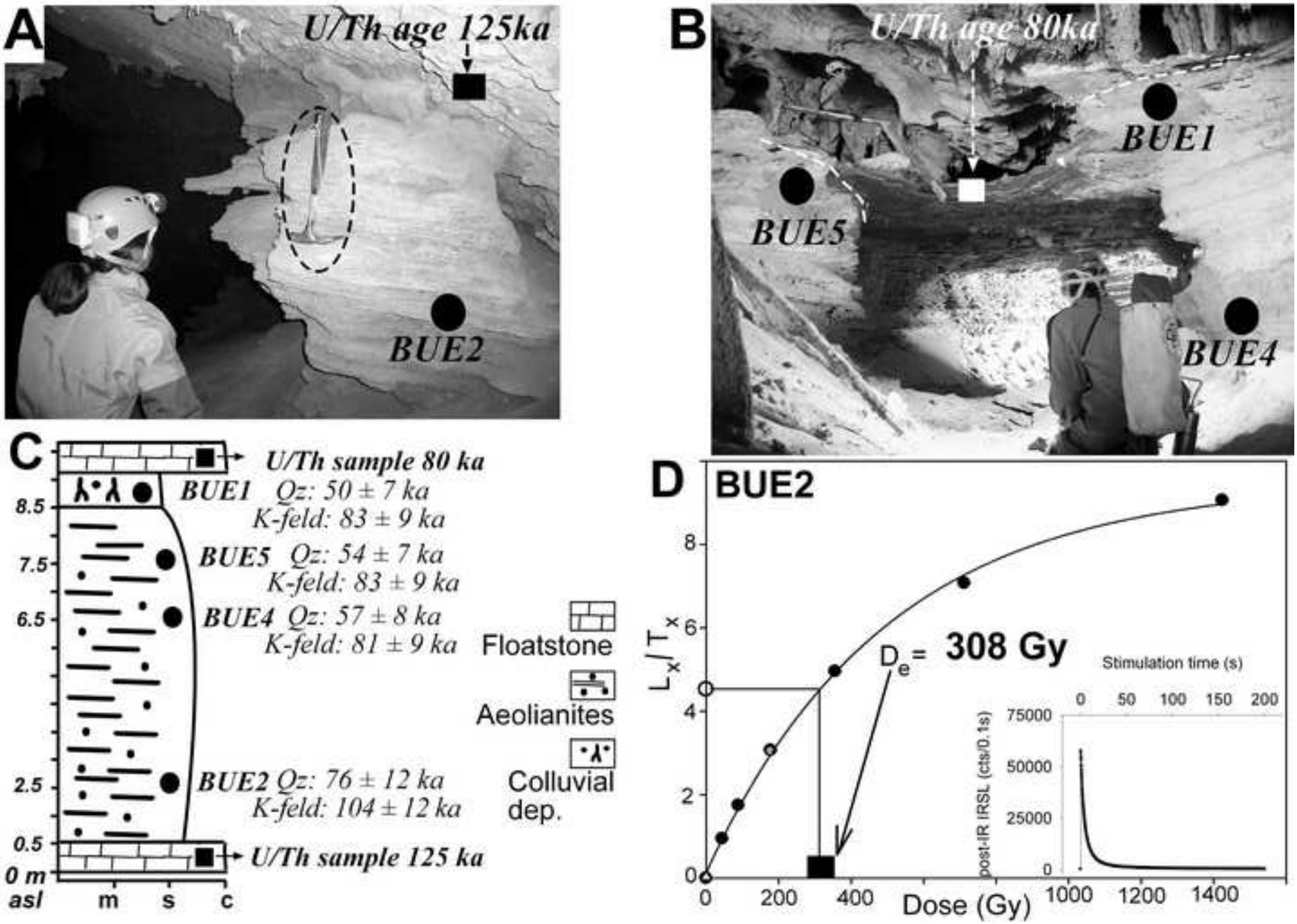

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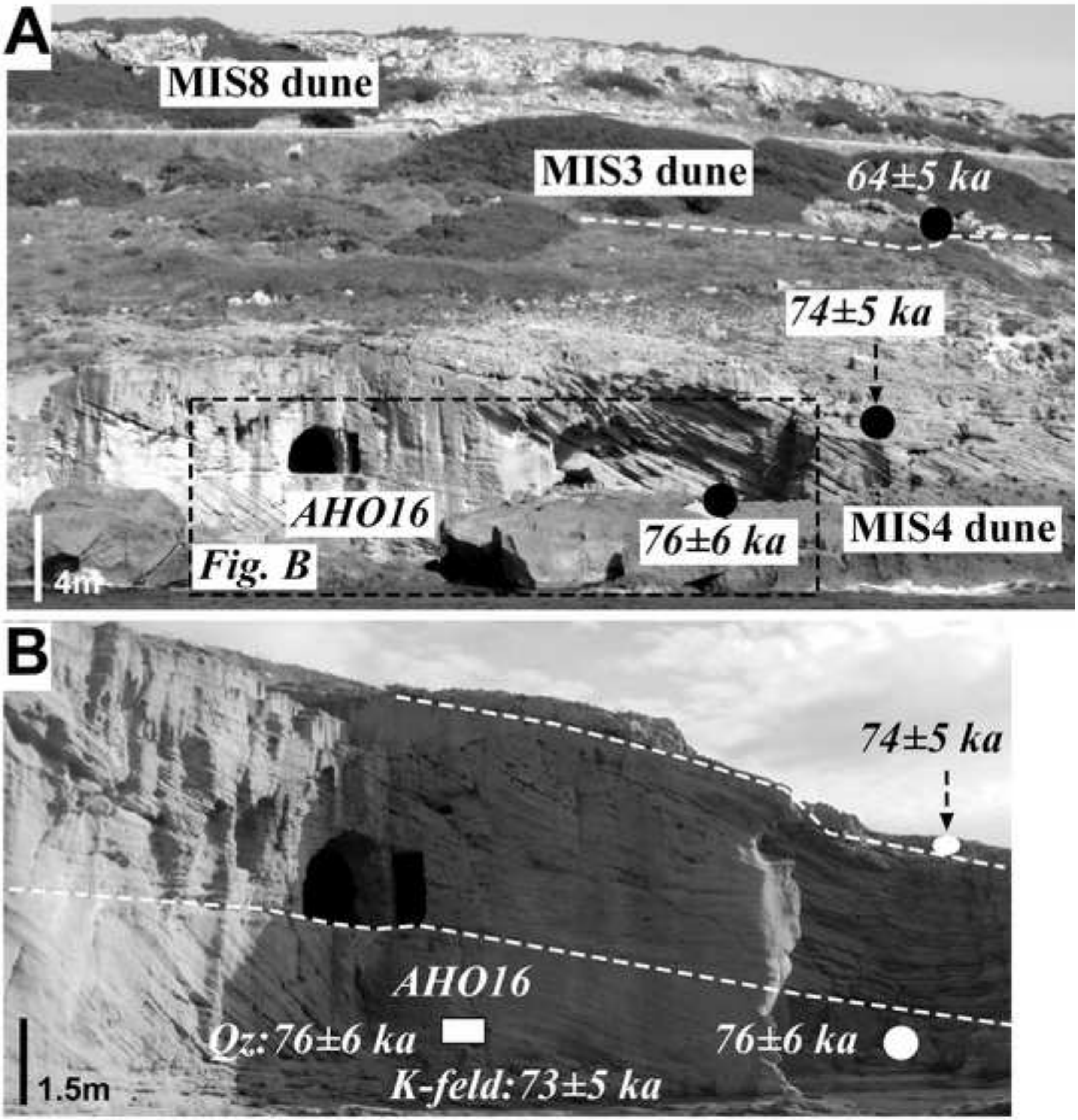

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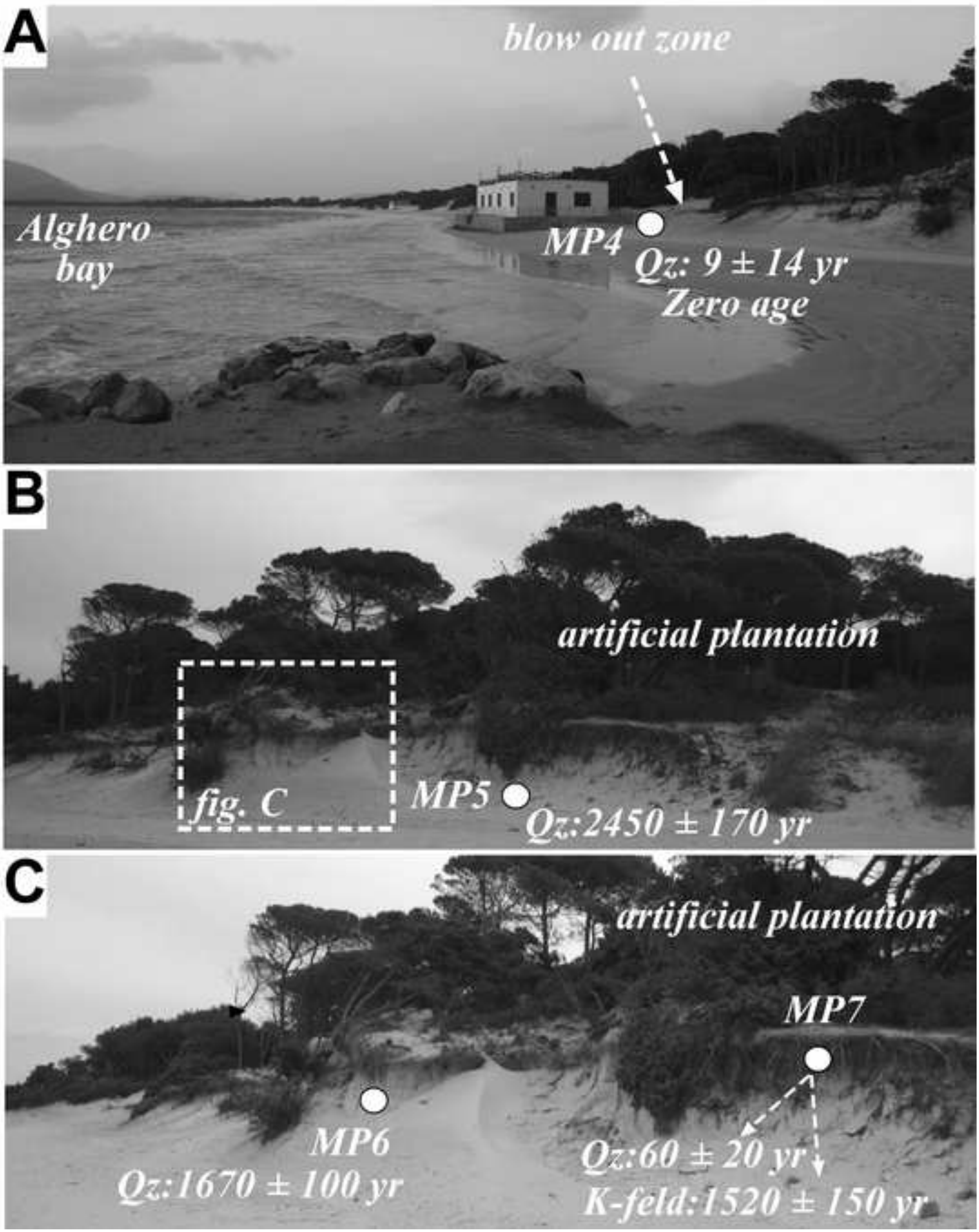

Table 1

Table 1. Summary of principal radionuclides, water contents and total quartz and K-feldspar dose rates for all samples. The quartz and K-feldspar grain size range was 180-250 µm. The conversion factors from activity concentrations to dose rate are taken from Olley et al. (1996). For the K-feldspar dose rates an internal K content of 12.5±0.5% was assumed (Huntley and Baril, 1997).

Site & Location	Sample code	Elevation (1) (m)	^{238}U (Bq kg^{-1})	^{226}Ra (Bq kg^{-1})	^{232}Th (Bq kg^{-1})	^{40}K (Bq kg^{-1})	Moisture (2) %	Quartz Dose rate (Gy ka^{-1})	K-feldspar Dose rate (Gy ka^{-1})
Alghero bay	MP4	1	14 ± 4	5.0±0.3	8.9±0.3	70 ± 3	25	0.65 ± 0.04	1.53±0.07
	MP5	3	14 ± 3	15.3 ± 0.2	5.9 ± 0.2	93 ± 4	25	0.69 ± 0.04	1.57±0.07
	MP6	4	10 ± 3	11.2 ± 0.2	14.3 ± 0.2	126 ± 5	25	0.73 ± 0.04	1.61±0.07
	MP7	4.5	4 ± 3	5.4 ± 0.2	5.9 ± 0.2	226 ± 3	25	0.73 ± 0.04	1.61±0.07
South Alghero	AHO16 (3)	2	-	-	-	-	-	0.88 ± 0.04	1.73±0.08
Bue Marino	BUE1	9	5 ± 5	8.1 ± 0.4	16.2 ± 0.5	642 ± 13	15	2.80 ± 0.13	3.68±0.14
	BUE2	2.5	10 ± 6	6.5 ± 0.4	10.3 ± 0.5	580 ± 13	5	2.20 ± 0.11	3.08±0.12
	BUE4	6.5	10 ± 5	9.5 ± 0.4	19.0 ± 0.6	546 ± 13	5	2.66 ± 0.12	3.54±0.13
	BUE5	7.5	10 ± 5	8.3 ± 0.5	11.9 ± 0.4	815 ± 16	5	2.93 ± 0.14	3.81±0.15

Notes:

(1) Elevation corresponds to the elevation of samples collected above the present sea-level.

(2) Moisture corresponds to water content chosen as life-time average for the site. An absolute error of 4% is assumed. The effect of cementation is incorporated in the final dose rate values following Andreucci et al. (2009).

(3) For this sample only dose rates are given, other information can be found in Buylaert et al. (2012).

Table 2

Table 2. Summary of quartz OSL and K-feldspar $pIRIR_{290}$ D_e values, $pIRIR_{290}$ fading rates (g_{2days}), quartz OSL and uncorrected $pIRIR_{290}$ ages. The number of individual aliquots contributing to D_e is denoted with n. Fading rates are determined on three aliquots previously used for D_e determination. Uncertainties represent one standard error.

Site & Location	Sample code	OSL D_e (Gy)	n	$pIRIR_{290}$ D_e (Gy)	n	g_{2days} (%/decade)	OSL age (ka)	$pIRIR_{290}$ age (ka)
Alghero bay	MP4	0.011±0.006	32	1.65 ± 0.10	3	1.05±0.34	16±10 (3)	1080±80 (3)
	MP5	1.82 ± 0.05	34	4.34 ± 0.10	3	1.54±0.11	2640±180 (3)	2770±150 (3)
	MP6	1.21 ± 0.05	34	3.74 ± 0.12	3	1.42±0.03	1660±120 (3)	2320±130 (3)
	MP7	0.060 ± 0.008	32	1.92 ± 0.16	5	1.58±0.05	83±13 (3)	1200±160 (3)
South Alghero	AHO16 (2)	67±4	30	127±7	9	1.44±0.19	76 ± 6	73 ± 5
Bue Marino	BUE1	>200 (1)	4	317±7	6	1.77±0.13	> 70 (1)	86 ± 4
	BUE2	"	4	332±6	6	1.19±0.20	> 90 (1)	108 ± 5
	BUE4	"	4	296±10	5	1.63±0.26	> 75 (1)	84 ± 4
	BUE5	"	4	338±9	6	1.45±0.09	> 70 (1)	89 ± 4

Notes:

(1) The natural signal lies above the 86% of the saturation level of the dose response curve (see Fig. 2a). The dose corresponding to $2*D_0$ (86% saturation) is given and the quartz age is considered a minimum age.

(2) Data from Buylaert et al. (2012).

(3) Age expressed in years from 2010.

Table 3

Table3. Summary of Uranium concentration, U/Th ratios, row and corrected ages. Uncertainties represent two standard error (2σ).

ID Lab	ID sample	U (ppm)	$^{234}U/^{238}U$	2σ+ (%)	2σ- (%)	$^{230}Th/^{234}U$	2σ+ (%)	2σ- (%)	$^{230}Th/^{232}Th$	2σ+ (%)	2σ- (%)	Age (ka)	Initial $^{234}U/^{238}U$*	Corrected Age (ka)
857	AL3-2	0.0257	1.035	2.79	0.03	0.647028	6.67	0.04	4	6.11	0.27	113,3±14	1.04 ± 0.029	**86,1±13**
855	AL2-stm	0.0280	0.958	3.99	0.04	0.702972	10.94	0.08	21	10.19	2.15	139,5±32	0.93 ± 0.037	**134,2±32**

* = data deriving from $^{230}Th/^{234}U$ ratio.