Quaternary Geochronology 5 (2010) 125–130

Contents lists available at ScienceDirect

Quaternary Geochronology

journal homepage: www.elsevier.com/locate/quageo

Research Paper

Testing the use of feldspars for optical dating of hurricane overwash deposits

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ARTICLE INFO

Article history:
Received 20 October 2008
Received in revised form
27 February 2009
Accepted 3 March 2009
Available online 13 March 2009

Keywords:
Optical dating
Quartz
Feldspar
Thermal transfer
Hurricane
Subtraction dating

ABSTRACT

The geological record preserved in coastal salt marshes provides an opportunity to determine past hurricane activity during the Late Holocene in New England, USA. High precision dating is important to correlate overwash sand layers associated with hurricane strikes between different sites along the coastline. Three different optical dating methods have been tested and compared with independent age control; i) optically stimulated luminescence from quartz, ii) infrared stimulated luminescence from K-feldspar, and iii) a subtraction method.

Quartz and K-feldspar dating results for three samples in a core from Round Hill Beach Marsh are in stratigraphic order and they are consistent within errors with radiocarbon ages and with each other. Subtraction dating results agreed with the quartz and K-feldspar ages for two of the three samples, but the subtraction age of the youngest sample gave an age underestimate. Replicate equivalent dose values from quartz showed a larger variation than those from feldspars, and this resulted in larger errors for the quartz and subtraction ages than those based on feldspars. K-feldspar yields the most precise optical ages, but is complicated by the need to correct for anomalous fading. Both quartz and K-feldspar are suitable for optical dating of hurricane overwash deposits in New England.

1. Introduction

In coastal marshes on the southern coastline of New England, USA, overwash sand layers associated with hurricane strikes give a record of hurricane activity through the late Holocene (e.g. Donnelly et al., 2001). However, at any one site the overwash sand layers vary in thickness and lateral extent depending for example on the intensity of the hurricane, where it struck the mainland, its direction of travel relative to the coastline, the height of the storm surge and the height of the beach barrier (Donnelly and Webb, 2004). Thus, to obtain a comprehensive record of hurricane activity it is necessary to collate records from different sites along the coastline. Obtaining accurate chronological control using radiocarbon has sometimes proved difficult because of plateaus in the radiocarbon calibration curve resulting in multiple intersections, and because radiocarbon can only bracket deposition of the sands (e.g. Donnelly and Webb, 2004). Optical dating directly dates the sands, is not beset by calibration difficulties, and is applicable over the whole time of interest (decades to millennia).

The only application of luminescence to sediments of this type to date is that of Madsen et al. (in press) who used the optically stimulated luminescence (OSL) signal from quartz to provide a chronology for a core from Little Sippewissett Marsh in Massachusetts covering the last 450 years. Their OSL ages were in stratigraphic order, and in general they agreed with other geochronological data. Three major problems were identified in that study. First, the dosimetry is complex because the stratigraphy is an alternation of sand and peat layers of varying thicknesses, which both have large variations in water and organic content. Second, deposition occurs as a rapid overwash event and Madsen et al. (in press) found that some samples contained material that had not been bleached at deposition. Third, in such young samples the quartz OSL signal is dim, producing broad equivalent dose (D_e) distributions even for those samples where incomplete bleaching was not thought to have occurred.

This paper assesses whether using potassium (K) feldspars instead of quartz provides a means of addressing some of these problems. Li et al. (2007a) have demonstrated that for their desert dune samples K-feldspars give more reproducible and precise D_e values than quartz. They suggested that this is because a greater proportion of K-feldspar grains in an aliquot contributes to the luminescence signal than do quartz grains, and because the internal potassium content of the K-feldspars reduces the impact of variations in the external dose. Li et al. (2007b, 2008) have gone further and suggested that the signal from the internal dose does not suffer from anomalous fading. However, this approach cannot be tested here because it requires a broad range in grain size, which is not

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1871-1014/$ – see front matter
doi:10.1016/j.quageo.2009.03.001

available for these sediments. An alternative approach is to use the difference in D_e between K-feldspar and quartz to determine a subtraction age (Vogel et al., 1999). This subtraction D_e arises principally from the internal dose in the feldspar, and is therefore independent of the external dose rate (Vogel et al., 1999). The subtraction approach will also be tested here.

2. Samples and equipment

2.1. Sample preparation

A 3 inch diameter vibracore (RHB 10a) was taken from Round Hill Beach Marsh, New England (41°32′ N, 70°56′ E), approximately 100 m behind the current beach. The coastline is open to hurricanes tracking from the south. Three sand layers in the split core were sampled for luminescence (120-9, 120-3A and 120-1A, Fig. 1a) under subdued red light conditions. Additionally, a sample was collected from Round Hill Beach as a modern analogue of the source material for overwash sediments (123-RHB). Carbonates and organics were removed from samples using 10% hydrochloric acid (HCl) and 20 Vols. hydrogen peroxide (H_2O_2). After sieving to obtain grains 180–212 μm or 212–250 μm in diameter, quartz and K-feldspar grains were separated using sodium polytungstate (quartz: $2.62 < \rho < 2.70$ g cm^{-3}; K-feldspar: $2.53 < \rho < 2.58$ g cm^{-3}). Quartz grains were etched using 40% hydrofluoric acid (HF) for 45 min, washed in conc. (37%) HCl, and re-sieved to remove any partially etched feldspar grains.

Additional samples were collected for dosimetry measurements (Figs. 1a and 2). These were dried, milled, and ashed for 24 h at 450 °C. They were then measured using thick source alpha counting and beta counting. Following the method in Madsen et al. (in press) the gamma dose was modelled using a multi layer gamma model (Bailiff and Barnett pers. comm.) based on Appendix H in Aitken (1985) and using the conversion factors of Adamiec and Aitken (1998). This model calculates the gamma dose to a sample

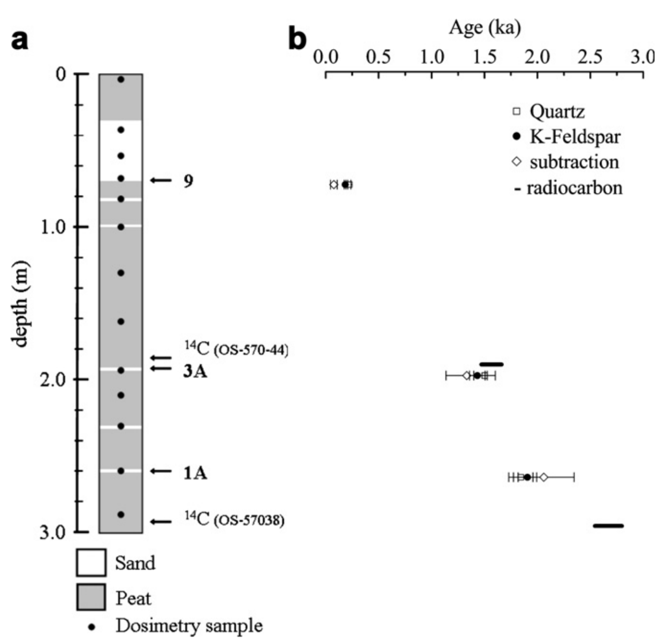

Fig. 1. a) Overview of core RHB 10a. b) The optical ages as a function of depth for samples 120-9, 120-3A and 120-1A. Radiocarbon ages are also shown. Note: The ^{14}C ages were obtained by AMS on macrofossils, calibrated using INTCAL04, Calib 5.0.1, and then 57 years were added so that they were comparable with the optical ages. The uncalibrated ^{14}C results for OS-57044 and OS-57038 are 1630 ± 35 and 2520 ± 35 years B.P. respectively.

surrounded by sedimentary units with varying water content and dose rate, as occurs in these cores (Fig. 2). The alpha, beta, and gamma dose rates were corrected for organic content (measured by loss on ignition) following the calculations of Divigalpitiya (1982) and using the reduction factor for the gamma dose suggested by Lian et al. (1995). The cosmic dose was calculated based on sediment density, depth of the sample, altitude and location. For the K-feldspars the internal dose rate was calculated assuming a potassium concentration of 12.5% (Huntley and Baril, 1997) (Table 1).

2.2. Equipment

Luminescence measurements were made on Risø TL/OSL DA 15 readers (Bøtter-Jensen et al., 2003) equipped with 1.48 GBq $^{90}Sr/^{90}Y$ beta sources. Grains were mounted in a monolayer on aluminium discs 9.7 mm in diameter using silicone oil. All quartz measurements were made with large aliquots (covering an area 8 mm in diameter; ~1000 grains, Duller (2008)), whereas all K-feldspar measurements were on medium aliquots (5 mm diameter area; ~200 grains). Quartz OSL was stimulated using blue (470 Δ 20 nm) light emitting diodes (LEDs) and IRSL from K-feldspars using infrared (875 nm) LEDs. For quartz measurements 7.5 mm of Hoya U340 filter was placed in front of the photomultiplier, while for K-feldspars a combination of Schott BG-39, Corning 7-59 and GG-400 filters were used to isolate emissions ~410 nm. For both OSL and IRSL, luminescence signals were integrated over the first second of optical stimulation and a background integrated over the last five seconds of the decay curve was subtracted.

3. Optical dating methods

3.1. Quartz OSL

The single-aliquot regenerative-dose (SAR) protocol was applied to the quartz samples (Murray and Wintle, 2003; Wintle and Murray, 2006), holding the aliquot at 125 °C while stimulating with blue LEDs for 40 s. The SAR dose response curve for the OSL signal from quartz shows little curvature up to ~20 Gy. In this core the largest D_e value is ca. 3 Gy so all of the natural luminescence signals are in the linear part of the growth curve (Fig. 3a). Aliquots were accepted if their recycling ratio was within 10% of unity and if recuperation was less than 10% of the natural signal. For young samples, aliquots with a $D_e < 1$ Gy were rejected if their recuperated signal in response to a zero laboratory dose was equivalent to an apparent dose of 0.1 Gy or larger. Approximately 20% of the quartz aliquots had to be rejected because of poor recycling or recuperation.

D_e as a function of preheat for 120-9 and the modern sample (123-RHB) is shown in Fig. 3b and c. In both samples some aliquots contain incompletely bleached grains giving rise to larger D_e values. Excluding such outliers, sample 120-9 gives a preheat plateau from 160 to 280 °C (Fig. 3b), and the modern sample shows a preheat plateau from 160 to 200 °C (Fig. 3c). At preheat temperatures of 220 °C or above, the D_e from the modern sample increases due to thermal transfer. Therefore a preheat of 200 °C and a cut heat of 160 °C were used to date the three samples. Table 1 gives the weighted mean D_e for each sample. The distribution of D_e values for samples 120-1A and 120-3A are normal. The distribution of sample 120-9 contained two outliers that were more than 3σ above the mean value; these outliers were therefore excluded from the weighted mean.

A dose recovery experiment was undertaken on sample 120-9. The mean ratio of recovered dose divided by delivered dose for the 10 accepted aliquots using a preheat of 200 °C is 0.96 ± 0.14,