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Research paper

OSL dating of mixed coastal sediment (Sylt, German Bight, North Sea)

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ABSTRACT

As part of a study on coastal sedimentary processes this paper presents the OSL dating of mixed coastal sediment samples from the southern North Sea island of Sylt (German Bight). During coring of the swash-bar (beach) sediments, five samples were presumably contaminated by younger overwash and aeolian sediments because of the sampling method employed. To obtain reliable burial ages for these swash-bar sediments, single-grain and small aliquot measurements were used together with the Finite Mixture Model (FMM) proposed by Roberts et al. (2000) to identify the grain population containing the largest doses (from the deepest part of the core). Before the FMM was applied to dating, the parameters and performance of the FMM were first investigated by systematically comparing small aliquot (~20 grains) and single-grain measurements of an undisturbed aeolian and swash-bar sample and a laboratory mixture of both sediments. This test case demonstrates the advantage of selecting the time interval immediately following the initial luminescence signals for background subtraction because unsuitable quartz grains were removed from the dose distribution. It is concluded that the measurement of small aliquots can be regarded as a reliable proxy for single-grain dose distribution if the sediment contains only a small proportion of quartz grains emitting a luminescence signal and that the FMM results are relatively insensitive to changes of the over-dispersion parameter between 5–40% for small aliquots and 10–40% for single-grains.

We show that the burial ages of the contaminated swash-bar samples resulting from the maximum age populations from equivalent dose distributions measured using small aliquots are consistent with the stratigraphy and with ages obtained from uncontaminated samples.

1. Introduction

A better understanding of coastal sedimentary processes and the related controlling factors (e.g. climate, sediment supply, and sea level) is fundamental to developing concepts of improved coastal protection. This task requires, in addition to investigations of sedimentary setting, a reliable estimation of the depositional ages of different sedimentary units. Optically simulated luminescence (OSL) using quartz as a natural dosimeter has proved to be a powerful and reliable dating technique to determine depositional ages of young coastal sediments around the world (e.g. Murray-Wallace et al., 2002; Ballarini et al., 2003; Madsen et al., 2005, 2007, 2009; Nielsen et al., 2006; Buynevich et al., 2007; Lopez and Rink, 2007; Alappat et al., 2011; Reimann et al., 2011b). Nevertheless, there are sources of scatter which can contribute to complex equivalent dose (D_e) distributions; these may lead to inaccurate OSL ages. Recently, several studies have addressed the problem of (i) heterogeneous bleaching of sedimentary grains prior to deposition and (ii) post-depositional mixing of the sediment units, as the most common sources of complex and broad D_e distributions (e.g. Roberts et al., 1998; Galbraith et al., 1999; Olley et al., 1999, 2004; Bailey and Arnold, 2006; Pietsch, 2009; Thomsen et al., 2007). Most of these studies made use of small aliquot (containing less than 100 grains) or single-grain measurements and then employed various statistical models to identify the equivalent dose (D_e) of the smallest dose population to obtain appropriate burial ages (e.g. Olley et al., 2004; Rodnight et al., 2006).

Here we present OSL ages of eight beach sediment samples, five of which appear to have been contaminated during sampling by overlying younger over-wash and aeolian sediments. Dating such samples is not a straightforward task since it requires detailed analyses of complex D_e distributions. The mean or weighted mean

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of D_e distribution made up of more than one component is unlikely to be an appropriate estimate of the true burial dose (Db) (e.g. Rodnight et al., 2006). In this study, we apply the Finite Mixture Model (FMM, Roberts et al., 2000) to identify the population representing the largest D_e i.e. the population derived from the time since burial of the uncontaminated beach sediments. The FMM can be applied to identify discrete D_e populations within a dose distribution containing multiple D_e components. It has been applied to sediment mixtures in a number of single-grain OSL studies (e.g. Roberts et al., 2000, 2001; Jacobs et al., 2006, 2008b; Bateman et al., 2007), and Rodnight et al. (2006) applied the FMM to small aliquot (~30 grains) D_e distributions and obtained burial ages for partial bleached fluvial sediments that were in agreement with independent age control. Arnold and Roberts (2009) more recently suggested that the FMM should only be applied to single-grain D_e distributions to avoid the averaging effect of multi-grain D_e measurements. Their recommendations are based on a stochastic model that simulated multi-grain aliquots and it shows that grain-to-grain averaging effects in multi-grain aliquots should be avoided when using the FMM. Their model assumed one to ten luminescent grains per aliquot and uses a simple weighting factor to define the relative contribution that each luminescent grain will have on the combined multi-grain D_e value of the aliquot. However, this weighting factor and thus the significance of the averaging effects in multi-grain aliquots depend on the contribution of individual grains to the total light sum (i.e. the difference in grain brightness), which can differ between both regional and sedimentary settings (e.g. Duller et al., 2000).

The case study presented here systematically compares the performance of the FMM based on single-grain and small aliquot data sets and makes a contribution to the ongoing debate regarding the use of small aliquots as a proxy for the more time-consuming analysis of single-grain D_e distributions. The FMM is then used to identify maximum dose populations in mixed sediment samples that had been accidentally contaminated by younger material during sampling.

First and foremost we investigate whether we can date such contaminated samples and secondly we investigate whether single-grain analysis is required in such an analysis or whether small aliquots (each containing ~20 grains) can be used as a reliable proxy. The performance and the parameters of the FMM are systematically investigated to determine if they can be applied successfully to estimate a maximum D_e population from a laboratory sediment mixture. The resulting procedure is then used to date the contaminated beach samples and the ages are discussed within the stratigraphic context. Finally, the importance of the overdispersion (σ_{OD}) parameter in the FMM and the reliability of small aliquot compared to single-grain analyses are discussed.

2. Study area

2.1. Geology and geomorphology

The study area is located on the northern barrier spit of Sylt, an island on the eastern side of the North Sea 11 km from the coast just south of the border between Germany and Denmark (Fig. 1a). The

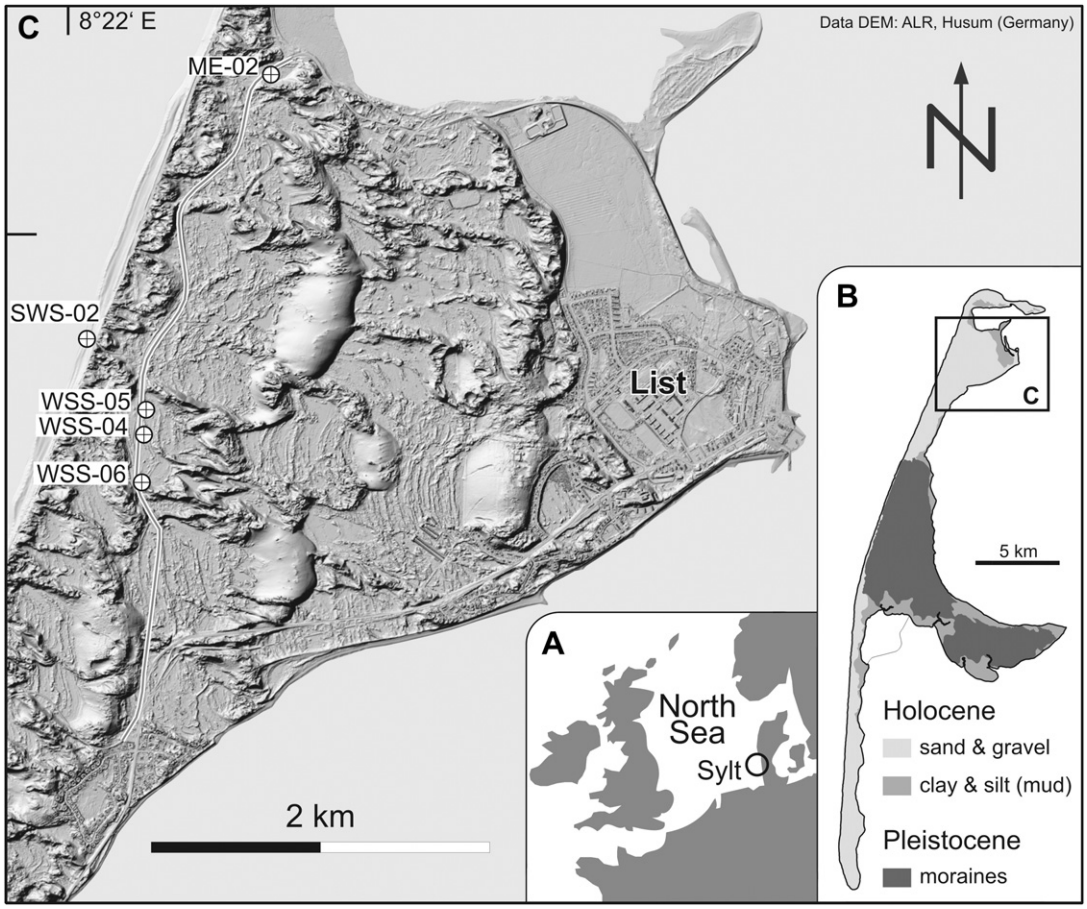

Fig. 1. Map of the study area. The barrier spit system of the island of Sylt is located in the southern North Sea, near the border between Denmark and Germany (a). Sylt consists of a Pleistocene moraine core with two Holocene sandy barrier spits towards the north and the south (b). The geomorphology of the northern barrier spit is characterized by aeolian dunes, which are partly actively migrating (c). The sample locations are situated along the western coast of the spit facing the open sea. Note active swash-bars along the recent coast.