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Thesis Abstracts

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Thesis Title: The late Quaternary history of aridity in the Strzelecki and Tirari Desert dunefields, South Australia
Grade: PhD
Date: October 2007
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Linear dunes occupy more than one third of the Australian continent, but the timing of their formation and their reliability as proxies for arid conditions is poorly understood. This thesis investigates the late Quaternary history of aridity of the Strzelecki and Tirari Desert dunefields, a region in the driest part of Australia. This was achieved using a threefold approach. Firstly, the morphologic variability of linear dunefields was investigated, in order to understand dunefield formation over regional scales, and to assess the degree to which local geomorphologic context influences dune response to arid conditions. Secondly, the sedimentological and stratigraphic characteristics of linear dunes were used to interpret the degree to which dune activity can be used as a proxy for aridity. The reliability of dune records, based on evidence for reworking and the extent to which stratigraphy is preserved, was also assessed using this evidence. Finally, the timing of dune activity, interpreted using an OSL chronology, was used to provide a proxy history of late Quaternary aridity within the driest part of the arid zone.

The morphological variability of linear dunes in the Strzelecki and Tirari Deserts of Australia was assessed using a dune classification scheme, based on quantifiable variables of substrate, spacing and junction frequency. The use of high spatial resolution ASTER satellite imagery enabled detailed analysis, including spectral characterisation of substrate, at both local and regional scales. The classification of the linear dunes revealed close relationships between substrate type and dune spacing, reflecting local sediment availability. Both downwind evolution and sediment nourishment from local sources play a role in linear dune formation, although the latter dominates. Maps illustrating the spatial distribution of planimetric variables provide a useful tool for investigating linear dune characteristics, although additional variables such as height, width and dunefield age add to the complexity of dune formation and must also be considered.

The extent to which dunes act as proxies for aridity, and their reliability as palaeoenvironmental archives, was examined by characterising dune sediments, stratigraphy, and evidence for reworking. In the Strzelecki and Tirari Deserts, linear dune activity took place in response to intensified aridity. Clay pellets, which form by the efflorescence of salts on seasonally exposed clay flats with high evaporation rates, were found at several sites, and indicate incipient aridity and periodic inundation of adjacent swales. Their presence and inherent fragility suggests that linear dune sediments are mostly derived from local sources. The similarity of dune and underlying substrate characteristics supports the local windrift model for dune formation.

The reworking of underlying palaeosols within dunes, indicated by abrasion and partial preservation of grain cutans, is ubiquitous across the dunefields. Although not all dunes preserve every identified episode of activity due to local reworking, the widespread sampling strategy adopted in this study reduces bias towards more recently reworked periods. In this study, 82 samples from 26 sites across the Strzelecki and Tirari Deserts were collected to provide an optically stimulated luminescence chronology for the dunefields. Standard tests for the luminescence behaviour of aeolian quartz, including dose recovery and the measurement of recycling ratios and thermal transfer, showed that the linear dune sediments are well suited to the OSL SAR protocol. The dunes each preserve up to four stratigraphic horizons, bounded by palaeosols, which represent evidence for multiple periods of reactivation interspersed by episodes of increased environmental stability. The OSL chronology was shown using standard statistical tests to contain five distinct age populations, interpreted to correspond to aeolian events, at 73.3-65.8 ka, 34.7-28.7 ka, 22.1-17.8 ka, 14.1-12.1 ka and 11.7-10.0 ka. A cluster of ages from approximately 3.5 ka to the present suggests that dune activity also took place during the late Holocene, but does not form a statistically significant population by the same tests. Stratigraphic evidence suggests that dunes may have been partially active over long periods of time, resulting in slow net accumulation punctuated by short-lived, substantial sand-shifting events. Dune activity coincided with cold, arid conditions during early marine oxygen-isotope stage (MIS) 4, mid-MIS 3 and the Last

Glacial Maximum (LGM), and warm, dry climates during the Pleistocene-Holocene transition and late Holocene. The timing of widespread dune reactivation coincided with dune activity in other dunefields within Australia, although aeolian activity prior to MIS 5, recorded elsewhere, does not appear to be preserved in the Strzelecki and Tirari Deserts. Aeolian events during early MIS 4 and the LGM correlate with increased dust flux to the Tasman Sea and Antarctic ice cap, glaciation in southeastern Australia, cooler regional sea-surface temperatures, and increased ice volumes in the southern hemisphere and Antarctica.

Author: Li Bo
Thesis Title: Development and application of optical dating using quartz and potassium-feldspar from Quaternary sediments
Grade: PhD
Date: June 2007
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New methods were presented for the dating of Quaternary sediments using luminescence signals from quartz and potassium-feldspar (K-feldspar) grains. These are based on fundamental studies carried out on separated quartz and feldspar grains.

Estimation of the equivalent dose using the fast component and the medium component of optically stimulated luminescence (OSL) from quartz grains was investigated using both linear-modulated OSL (LM-OSL) and continuous-wave OSL (CW-OSL) techniques. By mathematical fitting of the LM-OSL curves, the fast component of the quartz OSL signal can be separated from the signals observed for mixed mineral grains in order to determine the equivalent dose (D_e). The medium component underestimates the D_e for old samples, and this is attributed to its thermal instability. A method was proposed to evaluate the D_e values for the fast component and medium component by analyzing the D_e as a function of stimulation time.

Three kinds of source traps (i.e. shallow, medium and deep sources) for thermal transfer in quartz were identified. The shallow source is thermally unstable below 260°C and is mainly related to the main OSL trap. The medium source is the primary charge source (peak ~300°C). The deep source is dominant at higher temperatures. Two kinds of OSL traps were identified as accepting the charges from the medium and deep sources. These OSL traps have different thermal stabilities and associated sensitization processes from those of the main OSL traps. A method was proposed to correct for thermal transfer effects for young samples based on the linear relationship between the initial and final parts of the thermally transferred OSL signals in repeated heat/OSL measurement cycles.

A new isochron method involving measurement of the IRSL signals from K-feldspar grains of different size was proposed. It is based on the observation that the IRSL signal due to the internal dose does not appear to fade. The consistency between the isochron ages and quartz ages for 12 sediment samples from different geological settings suggests that the isochron method can be used to overcome anomalous fading. It can also be used to avoid problematic effects from changes in environmental dose rate. It was successfully applied to a lacustrine section showing significant changes in environmental dose rate due to a recent uptake of radioisotopes. The validity of the method is also tested using single grain IRSL measurements on K-feldspar grains.

Optical dating using quartz was applied to the Holocene lacustrine and fluvial sediments at the Dagouwan section in the Sala Us River bank, Mu Us Desert. The results indicate that the Holocene Optimum occurred between ~8.3 and ~5.0 ka ago. After ~5.0 ka ago, the Holocene Optimum terminated and the climate became dry again. The Sala Us River began to cut through the underlying Quaternary sediments after ~2 ka ago with a down-cutting rate of ~3-4 cm/year. The drainage of the Sala Us River accelerated the disappearance of the lake water and the deterioration of the local environment. However, impacts from human activities also play an important role during the last 2 ka.

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Thesis Title: Post-glacial history of sea-level and environmental change in the southern Baltic Sea
Grade: PhD
Date: March 2007
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A new palaeoenvironmental record of the post-glacial history of the southern Baltic Sea (~14 ka to present) is presented. During this period, large water level and salinity changes occurred in the Baltic Basin due to opening and closing of connections to the North Atlantic. Previous attempts to establish a detailed chronology for these palaeoenvironmental

changes have been conducted mainly in coastal settings, where organic material for ^{14}C dating is abundant. Many of these records are, however, discontinuous due to large water level fluctuations. In the relatively deep water of the Arkona Basin (45 m deep) in the southern Baltic Sea the sediment record is expected to be more or less continuous, but lack of organic material for ^{14}C dating has impeded previous studies.

Here, palaeoenvironmental change in the Arkona Basin is reconstructed on the basis of geochemical, sedimentological, mineral magnetic and palaeontological investigations. Additionally, independent physically based chronological control is, for the first time, obtained using Optically Stimulated Luminescence (OSL) dating on fine quartz sand from a ~10.86 m long sediment core. Tests of luminescence characteristics confirmed the suitability of the material for OSL dating and the ages agree well with the available AMS ^{14}C ages on shells; in contrast, bulk sediment ^{14}C ages are generally ~1000 years too old. Stratigraphic marker horizons in this deep basin are now absolutely dated, allowing comparison and testing of existing models of post-glacial Baltic Sea regional development.

Glacial varved clay was deposited during the Baltic Ice Lake stage and a sand layer representing the Baltic Ice Lake drainage to the North Atlantic is dated to ~11.6 ka. This event is followed by a period of low water level and enhanced influence from the Oder River. A period of very rapid sedimentation occurs between ~10.9 and ~10.4 ka and is attributed to the Ancylus Lake transgression. A first anomalous slightly brackish water inflow is recorded at ~9.8 ka, but there is no clear evidence for fully brackish conditions until ~6.5 ka. At that time, the lithologic change to clay gyttja represents a distinct shift in the circulation mode, with the onset of a high-productivity, brackish circulation system in the southern Baltic. Post-depositional diffusion of sulphur from the clay gyttja most likely explains the presence of greigite (Fe_3S_4) concretions in the underlying silty clay unit.

With this new chronology an anomaly appears between the classical model of the Littorina transgressions with brackish conditions starting ~8.5 ka, supported by studies in coastal lagoons, and our first clear brackish/marine influence occurring as late as ~6.5 ka based on studies performed in the deeper basins. This implies that the circulation system of the present Baltic Sea, with fully brackish conditions and the Danish-German Straits as the dominant inflow areas, only started from ~6.5 ka onwards.

Author: Jennifer Ting Lee
Thesis Title: Holocene evolution of hypersaline lake: Lagkor Tso, Western Tibet
Grade: MPhil
Date: August 2007
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Tibet contains numerous saline lakes, the history of which records the effects of global climatic change. One such lake, Lagkor Tso, was chosen for a pilot study. This study demonstrates that the OSL dating technique is suitable for dating regressive paleoshoreline terraces using an appropriate sampling strategy to collect representative backwash deposits. Lake retreat preserves the inter-tidal to supra-tidal beach facies undisturbed since their deposition, matching and fulfilling the fundamental principle of optical dating to determine when the paleoshoreline sediments were last exposed to sunlight.

Luminescence signal characteristics are diagnostic to OSL age accuracy and precision and should be studied site by site. Analysis of the preheat tests, SAR internal checks, dose recovery tests and $D_e(t)$ plots allows qualitative differentiation between well-dated results and unreliable data. $D_e(t)$ plots are also shown to be an effective and convenient tool to check sediment sample bleaching conditions such that routine application on OSL age analysis will be less time-consuming but more precise.

Dating of evaporitic salt bed sediments is, however, problematic. Enriched Sr content in the salt results in significant uncertainties in dose rate estimations because this element is radioactive but its contribution to radiation dose is not detectable using the facilities available. The limited thickness of datable sandy layers within the salt beds further complicates the dose rate estimations with the spatially heterogeneous radiation field problem.

Optically stimulated luminescence (OSL) dating on quartz using the single-aliquot regenerative-dose (SAR) protocol from seven regressive paleoshoreline deposits shows that the lake level was ~130 m higher than present at 5.5 ± 0.2 ka. Lake paleoenvironment reconstruction using Landsat 7 satellite images and GIS tools (MacDEM, ENVI and MapInfo) reveals a pan-lake (~3272 km^2) connecting Lagkor Tso, Zabuye Caka and Taro Tso were established at that time. Wetter periods should have been persisted prior to ~5.5 ka as higher lake levels are present above the highest terrace dated in this study. Lake regression took place thereafter in two phases: gradual lake level

drop of ~25 m between 5.5 ± 0.2 ka and 3.7 ± 0.2 ka, followed by a rapid level descent of ~31 m between 3.7 ± 0.2 ka and 3.3 ± 0.1 ka. This abrupt climate change from wet to very dry conditions that occurred at ~ 5 - 3 ka is comparable to similar climate change events observed elsewhere in Tibet, China and other parts of the world.

Author: Zhixiong Shen
Thesis Title: Improving the chronologies of British Holocene lake sediments using a combined geomagnetic and optically-stimulated luminescence dating approach: a case study from Crummock Water
Grade: PhD
Date: July 2007
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This research investigated lake sediments from the Crummock Water of the British Isles in order to reconstruct late Glacial to Holocene environmental change. For dating the lake sediments optically-stimulated luminescence (OSL) and the palaeomagnetic secular variation (PSV) records were used. The magnetic properties of the lake sediments and the associated catchment soils were also investigated to reconstruct the source area of the lake sediments at different time intervals.

The fine silt quartz fraction of the lake sediments was used for optical dating. A standard SAR protocol was applied to measure equivalent doses. High resolution low level gamma spectrometry was used to determine radionuclide activity from which annual dose rates were derived. The optical ages of the three samples from the late Glacial silty clay are in agreement with their stratigraphic positions. Ten optical ages were obtained for the Holocene organic mud. Two of them are overestimated due to insufficient OSL resetting. The insufficient OSL resetting was caused by increased water turbidity due to human activity for one sample and rapid sediment reworking without being exposed to light for the other. The other eight optical ages are in agreement with radiocarbon ages. Based on the chronology reconstructed from the optical ages and radiocarbon ages, the timing of three well-known Holocene events was obtained. These events are the start of the Holocene, the 'Elm Decline' and the late Holocene human activity imprint. The results suggest that the OSL signal of the majority of the lake sediments was sufficiently reset prior to deposition. However, the PSV record recovered from the Crummock Water sediments was unreliable due to sediment disturbance caused by coring.

The comparisons of magnetic properties of the lake sediments and the catchment soils suggest that the dominant source area of the lake sediments changed several times during the Holocene. At the beginning of the Holocene the sediment input from bedrock and late Glacial till rapidly deceased, most probably in response to catchment stabilization due to vegetation recovery and soil formation. The catchment remained relatively stable during the Holocene until ca. 1,100 a when human activity induced significant surface erosion and down-cutting erosion. Alongside with the two processes, pedogenic ferrimagnetic minerals and the parent material were massively transported into the lake.

Author: Jan-Pieter Buylaert
Thesis Title: Luminescence dating of aeolian sands and silts: a performance study of different techniques and protocols
Grade: PhD
Date: June 2007
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The overall aim of this thesis was to investigate the usefulness of luminescence dating as a tool to establish reliable absolute chronologies for those sediments which provide a record of the earth's climate, especially during cold and dry periods. This research focused on the sandy infill of frost wedge structures in Flanders and on loess from China. In the first part of this thesis quartz-based optical dating was used to establish an absolute chronology for these two sediment types. The second part of this thesis focused on testing the ability of two alternative luminescence techniques to date loess samples beyond the quartz optical dating range.

The potential of applying quartz SAR OSL dating to the sandy infills of relict sand wedges and composite-wedge pseudomorphs in Flanders (Belgium) was first investigated. Only those wedges that showed

evidence of having been, either exclusively or to a very large degree, filled with sand (primary aeolian infill) were selected for optical dating. Based on the luminescence chronology it was concluded that thermal contraction cracking and infilling with aeolian sediment appears to have been commonplace in Flanders during the Late Pleniglacial (MIS 2); more specifically during the Last Glacial Maximum (LGM, ~23-18 ka) and the transition period between the LGM and the start of the Late Glacial (~14 ka). This study also revealed the presence of two significantly older wedge levels, with a younger (MIS 3) wedge inset into an older (MIS 6) wedge; this clearly illustrates the often complex lithostratigraphy of periglacial sediments in the Belgium lowland and highlights the risks of misinterpretations of past periglacial processes in the absence of an absolute chronology.

High resolution quartz SAR OSL dating was then applied to three sites (Zhongjiacai, Le Du and Tuxiangdao) in the western part of the Chinese Loess Plateau. In total, sixty-two optical dates were obtained ranging from ~12 to ~75 ka. The age-depth patterns at all three sites revealed that loess accumulation in the western part of the CLP had an episodic character and large variations in sedimentation rate within and between sites have occurred. Moreover, a convincing sedimentary hiatus between ~20 and ~30 ka was identified at the Tuxiangdao site; this was undetected in previous proxy-record and dating studies and clearly illustrates the importance of high-resolution absolute dating studies for palaeoclimatic research on Chinese loess. Unfortunately, due to the relatively high dose rates (~3 Gy/ka) of this material, it would appear that the quartz OSL age range is rather limited, probably up to only ~40-50 ka (~120-150 Gy). Another method was thus needed to date older loess successfully.

Two other approaches to luminescence dating, one based on quartz and the other on feldspar, were tested to investigate their potential to extend the age range of the luminescence dating of (Chinese) loess. The reliability of a different single aliquot protocol was tested; this used isothermal thermoluminescence (ITL) signals from quartz. Despite the fact that the shape of the growth curve suggests that much higher doses could be measured than with OSL, it seems that the D_e values obtained with ITL are overestimates. The protocol employed also failed the dose recovery test, overestimating the dose given prior to any heating; this was explained by a sensitivity change which occurred when the first heat treatment was applied to measure the natural signal. It was shown that one way to circumvent this sensitivity change is to use a multiple aliquot approach (the single aliquot regeneration and added (SARA) dose procedure) in which doses are given prior to the measurement of the ITL signal. The origins and the dosimetric characteristics of the ITL signal were also investigated into more detail for quartz extracted from several other sediments and it was concluded that some initial sensitivity change is common in quartz.

The accuracy and precision of IRSL dating using sand-sized K-feldspar grain was tested on an Eemian coastal marine deposit in Denmark, with well-known independent age control (~125-130 ka). The uncorrected feldspar ages severely underestimated (by ~30%) both the quartz ages and the independent age control. Using a site-averaged fading rate (*g* value = 3.66±0.09%/decade) to correct the optical ages of all samples provided good agreement between the average fading-corrected K-feldspar age (120±3 ka random uncertainty; ±6 ka total) and the independent age control (~125-130 ka); Nevertheless, this result is not considered significantly different from the quartz age (114±4 ka; ±7 ka total).

Because of these encouraging results on a known-age site, it was decided to apply IRSL dating with anomalous fading correction to old (> ~70 ka) Chinese loess samples from two sites (Luochuan and Dongchuan) for which quartz OSL was thought to be inappropriate (see above). We showed that anomalous fading of the IRSL signal from polymineral fine-grains extracted from Chinese loess is ubiquitous and an overall average *g* value for these samples of 3.10±0.13%/decade was obtained. At both sites, the quartz OSL ages are always lower than the fading-corrected IRSL ages; the latter are also in better agreement with the pedostratigraphic age control (~75 and ~130 ka). Based on a comparison of the quartz OSL ages with the pedostratigraphic age control and the fading-corrected IRSL ages it is concluded that quartz OSL dating of Chinese loess from these sites should be restricted to samples not exceeding ~40-50 ka (~120-150 Gy). For IRSL dating using polymineral fine-grains with anomalous fading correction comparison with pedostratigraphic age control would suggest an upper dating limit of probably ~100-120 ka (up to ~300 Gy uncorrected dose). Ages older than this should be considered minimum ages.