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THESIS ABSTRACT

Comparison of dating methods for paleoglacial reconstruction in Central Asia

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Reconstruction of former extent and timing of Central Asian glaciers can provide valuable information about past atmospheric circulation variations. Further understanding of paleoenvironmental conditions in this area is of particular interest because several studies indicate that periods of extent and retreat of Central Asian glaciers were out of phase with global ice volume records and alpine glaciers from most formerly glaciated areas. However, the robustness of paleoglacial reconstructions largely rests on the accuracy of chronological constraints of glacial landforms, most often moraines. Glacial chronologies derived from moraines and glacio-fluvial deposits are largely based on cosmogenic nuclide exposure (CNE) and optically stimulated luminescence (OSL) dating methods. Large scattering of CNE moraine boulders ages, due to geomorphological processes (e.g. inheritance and post-exposure), often complicates the assignment of a glacial timing associated with moraine formation. Low sensitivity quartz commonly observed in high mountain environment and partially bleached sediments due to short light exposure during glacial or glaciofluvial transport most often hamper the dating of glacio-fluvial deposits using OSL techniques. This thesis focuses on the methodological aspects of directly dating glacial landforms using CNE and OSL techniques, with an emphasis on OSL, in order to improve our understanding of glaciation pattern in Central Asia.

In order to deal with partially bleached sediments, it is essential to measure the luminescence signal at the single grain scale. In line with this need, this thesis contributes to the development of a new Electron Multiplying Charges Coupled Device (EMCCD)-based imaging system for single grain luminescence dating. Such a system would offer a larger flexibility in term of stimulation source, grain fraction and mineral type compared to the current and well-established laser-based single grain attachment scanning system. However, three main issues hamper accurate single grain measurements when using an EMCCD-based imaging system. These issues relate to the sample carrier mo-

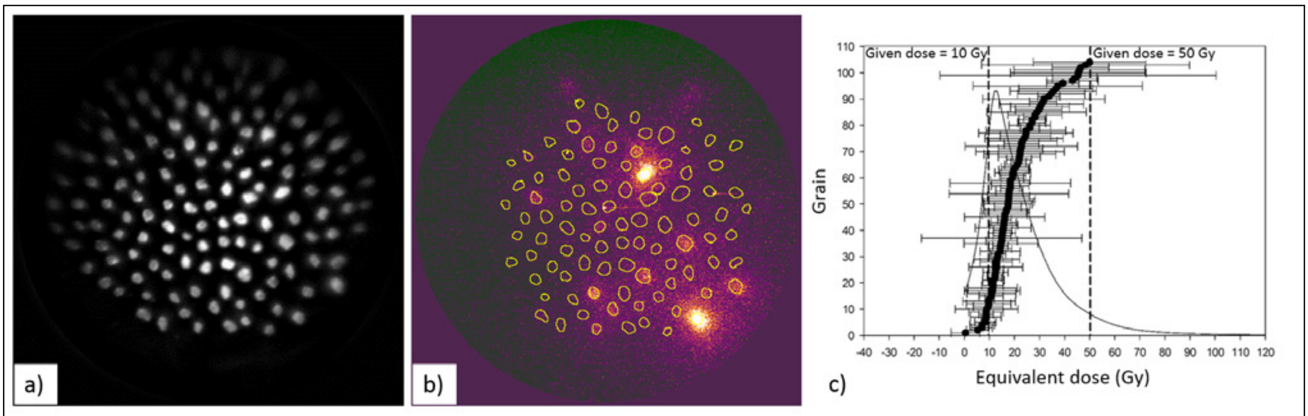
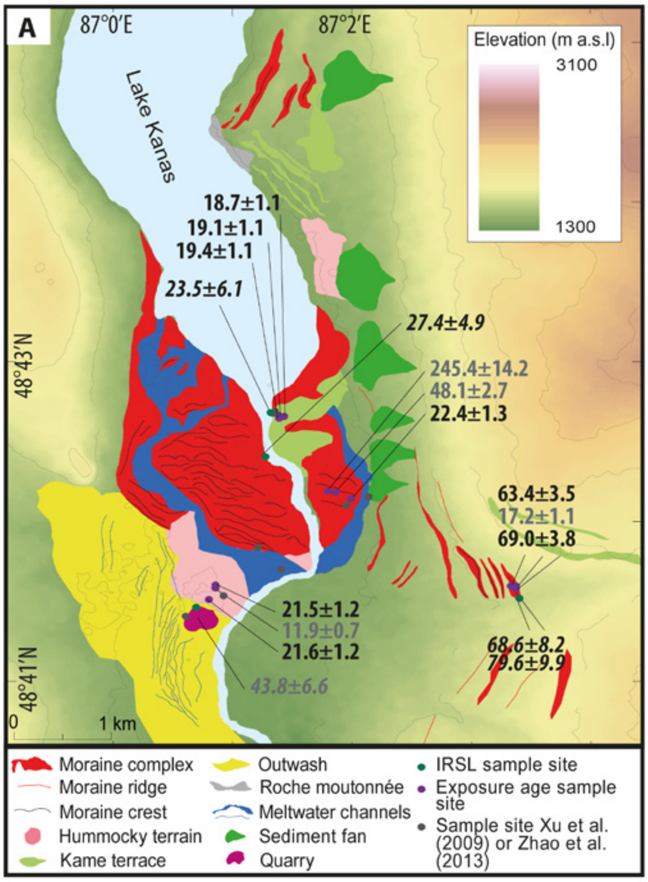


Fig. 1: Single grain measurements using an EMCCD-based imaging system. Light reflected pictures (a) allow delineating the regions of signal integration along the grain borders, which are then used to segment the luminescence images (b). c): Example of single grain equivalent dose distribution obtained from a mixed doses sample (10 and 50 Gy). Cross talk effects hamper the recovery of two dose populations centred on 10 and 50 Gy.

tion over repeated measurements, the absence of an automatic and reproducible method to assign pixels per grain for individual signal integration, and the contamination of individual signals by signal emission from neighbouring grains (cross talk). An automated image processing procedure has been developed to compensate for sample carrier displacement and to attribute pixels cluster for each grain to allow automatic signal integration (Greilich et al. 2015). While laboratory measurements and simulations demonstrate that significant cross talk effects prevent the use of this system to perform routine single grain measurements, preliminary experiments using a basic image processing algorithm suggests good potential for a software correction solution (Gribenski et al. 2015), encouraging further work in this direction.

Palaeoglacial reconstructions studies were conducted in the Altai Mountains in Central Asia (Russia and China; Gribenski et al. 2016, *in review*) to investigate uncertainties related to CNE and OSL dating techniques and their effects on the reliability of glacial chronologies. Resulting chronological data demonstrate the importance of conducting luminescence measurements at the single grain scale for sediments deposited in glacial environments. Measurements carried out with multi-grain aliquots were shown to yield large age overestimates of glacial landform age, due to partial bleaching effects. However, determining accurate glacial landform age from single grain luminescence measurements remains challenging. The ages inferred from



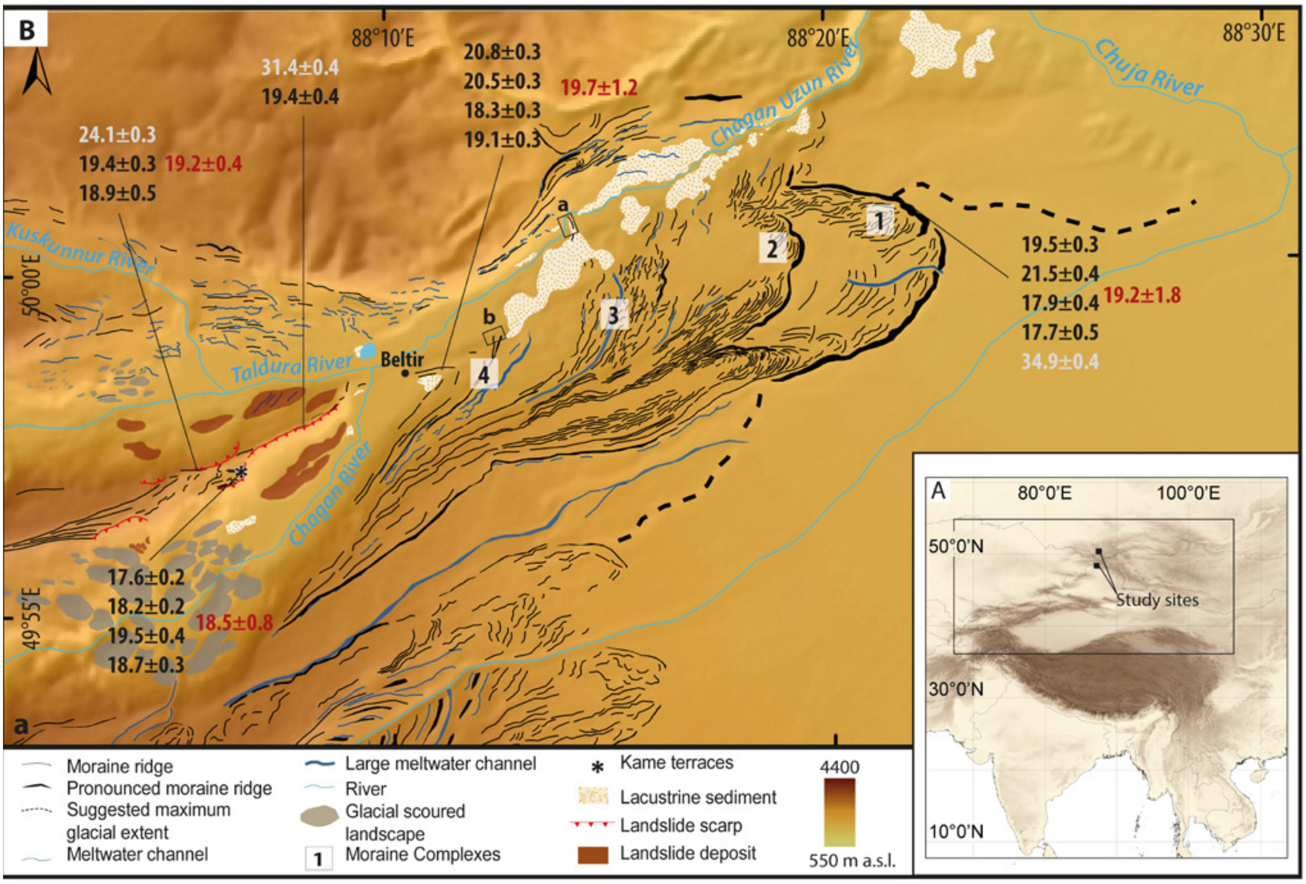


Fig. 2: Geomorphological mapping and cosmogenic as well as OSL (in italic) data obtained from the two palaeoglacial reconstructions conducted in the Chinese (A), and Russian (B) Altai (Central Asia). Ages in grey are discarded for glaciation timing interpretation. Ages in red (in B) represent the average age for each landform sampled.

single grain measurements can vary significantly depending on the statistical sub-sampling technique used for extracting luminescence data associated with well-bleached grains. In addition, fading corrections, associated with the use of the feldspar mineral as a dosimeter, increase the final uncertainty. CNE dates of moraine boulders revealed important inheritance effects, in contrast to previous data-compilation analyses and model-based studies that suggest a pre-dominance of post exposure effects. In general, CNE ages of moraine boulders exhibit significant scattering, however glaciation timing can be extracted from CNE age populations that are composed of a majority of ages concentrated within a few thousand years and a small number of older/younger outliers. Glaciation periods inferred from CNE ages ranging over a few thousand years are considered acceptable, as this time range can reflect still stands oscillations of the ice margin. The presented paleoglacial reconstruction studies show that combining CNE and OSL methods to directly date glacial landforms is a powerful approach for producing reliable glacial chronologies, in particular for pre-LGM glacial deposits for which source of uncertainties are typically larger when dated using a single technique. Consistent CNE and single grain OSL ages strengthens our confidence in the chronologies despite uncertainties related to each dating method individually.

The palaeoglacial reconstructions conducted in the Altai Mountains in this project clearly constrain glacial advances to the MIS 2 and are in line with the glaciation timing indicated by most of the well-constrained glacial chronologies published in Central Asia region. In addition, our study also provides robust evidence for a local maximum extent beyond the MIS 2 glacial extent (Kanas Valley, China; Gribenski et al., *in review*), which occurred somewhere during the MIS 4/late MIS 5 and so predated the global LGM. However, too few palaeoglacial reconstructions have been conducted in the Altai area to attribute a regional character to this pre-LGM glacial event. In general, abundant geomorphological evidence indicates earlier Last Glacial glaciation(s) exceeding the MIS 2 glacial extent in Central Asia. In particular, a period of major glacial advances during MIS 3 in Central Asia has been suggested by several studies, which in addition to be out of phase with global ice volume records, corresponds to a period of relative global warmth. However, detailed analysis of chronological data set associated with major MIS 3 glacial advances in Central Asia indicate that most of the reconstructions are based on few or heavily and evenly scattered CNE ages of moraine boulders, or on OSL or Electron Spin Resonance (ESR) data for which potential partial bleaching of the samples has not been thoroughly investigated. Therefore, at this stage, available chronological data do not present a compelling case for a widespread MIS 3 glaciation in Central Asia. Future detailed geomorphological and chronological studies of former glacial extents in this region are warranted to provide tighter constraints on the pre-LGM glacial activity in Central Asia.

Finally, this thesis highlights the importance of detailed geomorphological and sedimentological investigations to understand former ice dynamics, which is crucial for proper paleoclimate inferences. Indeed, numerous non-climatic factors such as local topography, debris cover, or geological substrate can influence glacier expansion, interfering with the interpretation of climatically induced glacier extent changes. As such, geomorphological and sedimentological data indicate that large outermost moraine belts marking prominent advances of the Chagan Uzun Glacier in the Russian Altai, and dated at ~MIS 2, were formed during fast flowing or surge-like event. Based on these interpretations, it would be inappropriate to reconstruct ELA from the outer moraine belts, as fast flowing/surge-like behaviour reflects a glacier not in equilibrium with climate. Although understanding palaeo ice dynamics might be challenging, detailed geomorphological and sedimentological investigations can help to identify non-climatically driven (or not mainly) paleo glacier expansions, and so prevent inappropriate ELA reconstructions and paleoclimate inferences.

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